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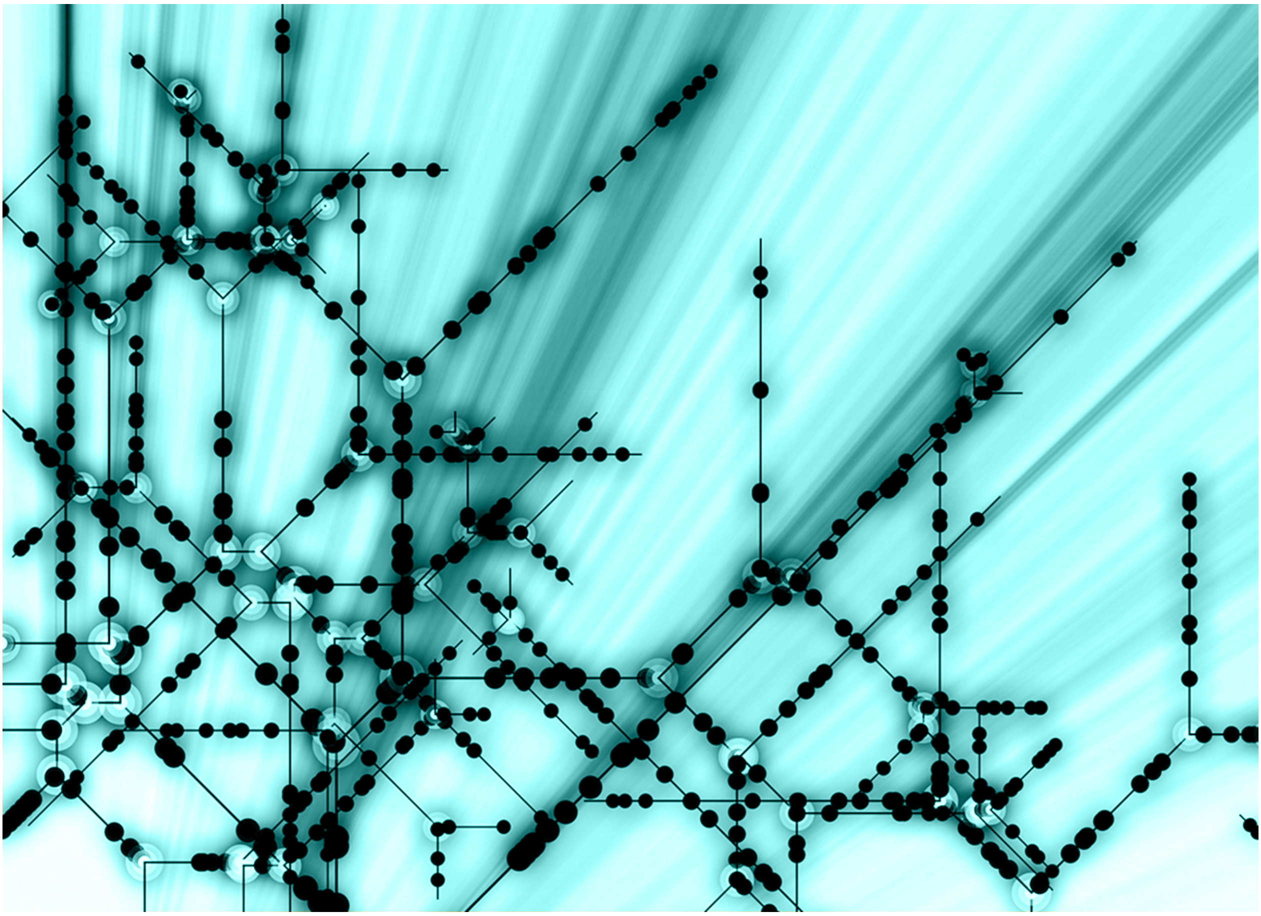
100 ANTICIPATED RADICAL TECHNOLOGIES, 20 REGIMES, CASE FINLAND



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100 ANTICIPATED RADICAL TECHNOLOGIES, 20 REGIMES, CASE FINLAND

Risto Linturi and Osmo Kuusi

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Content

Dear reader

You are holding in your hands perhaps the most important book ever written about radical technologies. In this brief preface, I will state the reasons for this and provide some tips for how you should use this book to support your own deliberations. But before that, we need to go back in time and briefly review why and for whom this book is written. This time, the book is divided into two sections. The first section presents a report and research results by the Committee for the Future, while the latter section introduces the methods, value-producing networks and technologies.

The key role of the Finnish Parliament's Committee for the Future is to evaluate the development of technologies. For this purpose, the Radical Technologies section was launched during the government term of 2011–2015. At the time, the section, under the leadership of Adjunct Professor Osmo Kuusi, conducted a study and evaluation of international organisations that carry out technology foresight work: what type of methods they use in their own evaluations and what type of future scenarios they produce (TUVJ 2/2013). We learned from the best.

Based on the report, we developed our own foresight method, which we refer to as the Radical Technology Inquirer (RTI). This model was first published in the publication Suomen sata uutta mahdollisuutta (TUVJ 6/2013) by the Committee for the Future. An observant reader who has read the report in question will notice immediately that the model has been developed further.

I suppose I should also answer the question why we changed the model despite our model having been utilised in an OECD report as one of the best national technology foresight methods in the world (OECD Science, Technology and Innovation Outlook 2016) and in foresight work by the European Commission, among other things. We wanted to continue developing the model and obtaining answers to any new questions that we ask.

In addition to wanting to identify the 100 most promising technologies as a result of this report, we also wanted to identify 100 legislative objectives with which the adoption of technologies can be streamlined. Furthermore, we wanted to identify 100 new professions of the future in order to be able to prepare for upcoming challenges with the right knowledge and skills. We managed to exceed this goal and identified 200 professions. The legislative objectives and professions are listed under each value-producing network in both the actual research report and the statement prepared by the Committee.

In order to obtain answers with regard to the legislative objectives and professions, we replaced the section on customer knowledge in different export areas and export channels, which was used in the Radical Technology Inquirer in the previous report, with extensive consultation with experts. During the consultation with experts, we heard evaluations of the technologies with regard to the various value-producing networks from trade unions, ministries and research institutes.

This change also, for its part, demonstrates how flexible the application of our Radical Technology Inquirer can be. The basic idea has remained the same. The RTI is basically a tool that can be used to identify rapidly evolving technologies and quickly get involved in the research related to them. However, we noticed that we are also able to compare the rates of change in the various value-producing networks. The results we received are very interesting. These are discussed in the Committee's own section.

An easy way to explain our method could be to describe it as asking questions or creating lists of questions systematically. We often receive the right answers when we ask the right questions. Furthermore, when we systematically pose the right questions to suitable groups of experts, we are better able to receive the right answers. This is the method followed in our report. To my understanding, no report on technology foresight has posed questions regarding value-producing networks and technologies as systematically as we have in our report.

We can consider to some extent that the report has improved on the socio-technical regime model proposed by Professor Frank W. Geels, which is described in the introduction to this report. To our knowledge, our report is the most extensive practical application of the socio-technical regime model in the world. No one else has previously tried to apply the regime model to all societal functions simultaneously.

In Chapter 1, we introduce the twenty value-producing networks. In simple terms, the term "value-producing network" refers to an answer to some relatively succinct social need or problem. We evaluate value-producing networks systematically with the help of seven different factors of change. We describe the regime that challenges the value-producing network in question as well as the methods and values of the dominant regime. We evaluate the benefits, risks and inhibitors of change.

As a new question, we contemplate new professions arising from radical technologies and skills shortages in the new professions. We compare the radical technologies to legislation and propose legislative objectives. We also list other special national characteristics.

In Chapter 2, we introduce the radical technologies. The technologies are discussed with the help of seven stages of development and from the perspective of four factors of change. For each anticipated radical technology (ART), we present the technology's target area, rate of development, resources and motive for its development, in addition to discussing the advancements made in the technology since the previous report.

The book includes two independent conclusion sections. One is included at the end of the technology report as Chapter 3. The statement prepared by the Committee for the Future, which is provided at the start of this publication, forms the other conclusion section. These should be weighed in slightly different ways.

The conclusions drawn at the end of this study are an evaluation by the authors of this report, Risto Linturi and Osmo Kuusi, on the potential consequences, benefits and adverse effects of the transformation enabled by technological advancement. For its part, the Committee for the Future was tasked with evaluating this range of positive and negative effects from a political perspective. The social effects of the radical technologies will also be evaluated in further research projects related to this report. With this, the Committee for the Future wishes to invite discussion on what type of future we want to build for Finland.

In the statement prepared by the Committee for the Future, we introduce the 20 value-producing networks in order of their rate of change. Each value-producing network is presented on a separate page. We describe the current state of things, the pressure for change arising from the technologies, the most important technologies, the fastest developing technologies, new professions and legislative needs.

The statement by the Committee for the Future also includes a list of the fastest developing technologies, which was drawn up by comparing the list of technologies from 2013 to this new study. Additionally, we define the most important generic technologies that are present in many value-producing networks and will have a strong impact on our lives. The full lists can be found in attachments 4 and 5 to this report.

This report was written for every citizen who is interested in the future. I believe that there are a great many of them, as we will spend the rest of our lives in the future. A curious reader will read this report and identify the technologies that will evolve the fastest and advance the most rapidly in terms of their impact on society. On the other hand, a reader who is interested in phenomena and the impact of technologies on society will certainly be interested in the summary of each value-producing network, prepared by the Committee.

This report was written for you who have made it this far in this preface. We hope that you will browse this report, spend time with it and use it as a technology reference book in the future. This is a book that I wish I could have read before beginning my studies. This is a book that I want to read now in order to see into the future and understand the business opportunities offered by the technologies and how professions and the skills required in them will change. If we want to understand the future, we must understand how technologies will change it. This allows us, as a society, to do our part in making the world a better place.

I would like to take this time to thank Risto Linturi and Osmo Kuusi for their exceptionally meritorious work and for writing this report. Linturi has also moderated the Radical Technologies Facebook group of the Committee for the Future, the members of which also deserve our thanks. See attachment 7 for links to this discussion (in Finnish). Those who participated in gathering the links listed under the sections of the 100 anticipated radical technologies are mentioned by name at the beginning of Chapter 2. With regard to the Committee's own section, I want to thank Committee Counsellor Olli Hietanen and Committee Senior Advisor Maria Höyssä. Adjunct Professor Osmo Kuusi has contributed to the different phases of the foresight work with his comments and participated in the preparation of numerical evaluations of the impacts of the radical technological solutions on the value-producing networks.

Kuusi has simultaneously worked on the Radical Innovation Breakthrough Inquirer (RIBRI) project commissioned by the European Commission, in which he also utilised the Radical Technology Inquirer of the Committee for the Future. This has allowed these two projects to engage in fruitful cooperation along the way.

Finally, the results of the Radical Technologies project were evaluated and supplemented at expert workshops. The workshops were held by the Ministry of Transport and Communications, the Prime Minister's Office, the Academy of Finland, Sitra, the Ministry of Social Affairs and Health, Academic Engineers and Architects in Finland TEK, the Finnish Funding Agency for Technology and Innovation, the Ministry of Economic Affairs and Employment of Finland and VTT. The participants of the workshops are mentioned at the beginning of Chapter 1. Thank you to all organisers and participants of the workshops. Cooperation is power.

I believe that all of us who are mentioned above want to extend a humble thank you to the science community and parties engaging in technology foresight work for everything that they have taught us. We hope that we are able to give back some of what we have received through this report.

"Run."

Helsinki, 18 April 2018

Ville Vähämäki
Chairman of the steering group of the Radical Technologies project

Statement by the Committee for the Future: Radical technology will change our society

1. Background and aims of technology foresight by the Committee for the Future

Assessing the impacts of technologies in a future-oriented manner is one of the core tasks of the Committee for the Future. For this purpose, the Committee has developed a method for technology foresight, the so-called Radical Technology Inquirer (RTI). Since 2013, the following studies related to this have been carried out:

- TUVJ 2/2013 Tulevaisuuden radikaalit teknologiset ratkaisut
- TUVJ 6/2013 Suomen sata uutta mahdollisuutta: radikaalit teknologiset ratkaisut
- TUVJ 11/2014 100 Opportunities for Finland and the World [English translation of TUVJ 6/2013]
- TUVJ 1/2016 Teknologiamurros 2013-2016: Esiselvitys radikaalien teknologioiden kehityksestä 2013 katsauksen jälkeen
- TUVJ 2/2016 Technological change 2013-2016 [English translation of TUVJ 1/2016]
- TUVJ 1/2018 Suomen sata uutta mahdollisuutta 2018–2037 - Yhteiskunnan toimintamallit uudistava radikaali teknologia [Finnish original version of this translated English report]

The technology foresight was begun with a pre-study (TuVJ 2/2013) that compared the methods and results of several existing technology foresight approaches. Subsequently, the Committee for the Future developed, as a commissioned study, its own foresight method that produced the first radical technology foresight report in this series (TuVJ 6/2013). This report defined 100 radical technologies that will change the world. The method anticipated the radical impacts that these technologies will make, and a respective ranking of the most important technologies was created (TuVJ 1/2016). Based on the 2016 evaluation, the first round of foresight seemed to have been on the right track. All the technologies identified in the first round of foresight had advanced, and the rate of advancement matched with the initial ranking: the TOP 1 - 25 technologies had advanced the fastest, the TOP 26 – 50 technologies the second fastest, and so forth.

This report updates and improves upon the original radical technologies report (TUVJ 6/2013). It includes more than 1,600 links to background. We dare to claim that this is one of the broadest and most detailed insights into the future of technological development. Over 2,500 people (of which 300 more actively) have participated in the project in the Radical Technologies Facebook group[1] as well as in various workshops. This foresight process has been characterized in the introduction of the report.

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[1] https://www.facebook.com/groups/TuVRadikaalit/

While reading the report, it is important to remember that the foresight approach has been created to anticipate the potential societal impact of technologies. The report is not a description of the technologies that at the moment are the most important, in the sense of being the most dominant ones in our society. Instead, the report aims to identify the fields from which the challengers to dominant technologies are now rising. The time span of the foresight is 20 years (the reference year for anticipated effectiveness is 2037). This overview draws the most important conclusions based on the report.

2. Taking into account the social nature of technological change

The foresight approach of the Committee for the Future considers technologies from both the "technology-push" and "demand-pull" perspectives. The technology-push approach has been used in identifying and grouping radical technologies: First, 1,600 of the most important technological advancements were identified through crowdsourcing. These were subsequently grouped into 100 anticipated radical technologies (ARTs). The demand-pull approach has been used in evaluating the ARTs in relation to societal and individual needs. Societal and individual values have been condensed into 20 value-producing networks. The ARTs have been scored based on how well they produce each of these values – i.e., how well they satisfy societal/individual needs. The definition of value-producing networks, i.e., needs, has been improved in relation to the 2016 evaluation. The aim was to cover more comprehensively the various nexuses of technology and good life. Included are now, for example, the value producing network of existential meaning and that of producing experiences.

Value-producing network	Dominant regime	Challenger regime
Passenger transport	Private cars operated by a driver, public transport	Autonomous transport as a service
Logistics	Transport operated by a driver, repetitive automated loading	Autonomous transport, smart loading robotics
Manufacturing of goods	Industrial, centralized, repetitive manufacturing	Robotized, decentralized, discrete manufacturing
Sustenance	Agriculture, food industry, distribution channels	Urban agriculture, discrete and local robotic food preparation
Energy supply	Centralized and fossil energy sources, peaking power plants	Renewable, decentralized energy sources and energy storage
Materials	Mining based products, energy-heavy process industry	The circular economy, renewable materials
Built environment	Traditional construction and maintenance	Robotized construction and maintenance
Exchange	Brands, physical retail locations, hierarchies, B2B2C	The reputation economy, e-commerce, P2P, C2B2C
Remote impact	Telephone, television, internet, social media	VR/AR, avatars and other remote control

Value-producing network	Dominant regime	Challenger regime
Automation of work	Centralized automation and human-steered machines	Decentralized robotics based on AI and crowdsourcing
Work and income	Salaried employment related to specialization and exchange	Cooperation, self-sufficiency, micro-entrepreneurs
Healthcare	Healthcare system, general health recommendations	Self-diagnostics, gamification, individual nutrition
Redressing disabilities	Institutional, outpatient and family care, cheap assistive devices	Robotics, AI, avatars, artificial organs, crowdsourcing
Acquiring information	Certified research, reports, news	AI, crowdsourcing, personal instruments and applications
Proficiency and its proof	Educational institutions and qualifications, on-the-job learning	Flipped learning and independent learning, AI, proficiency demonstrations
Producing experiences	Focus on producers and consumers, mass entertainment, tourism	Games, shared VR, AR, interaction, AI
Safety and security	Material safety in society, social security	Decentralized, individual and crowdsourced safety and security
Collaboration and trust	Guaranteed by authorities, brands and hierarchies	Peer-to-peer trust through platforms and transparency
Existential meaning	Work, position, social network	Achievements, likes, participation, communities
Power structures	Regional power structure, opaque power	Subject-matter subsidiarity, location independence

Table I. Value-producing networks with their most potential transformations.

In the 2016 evaluation of the original 2013 foresight report, a need to better understand societal change and impediments to transformation was recognized. Therefore, this updated report utilizes Geels' model of socio-technological transition[2].

One of the main results of this report is the holistic mapping of dominant and challenger regimes across modern society (Table I). The dominant regime characterizes the present situation, while the challenger regime pictures a situation where the satisfying of needs is structured around radically novel technologies.

The fundamental message stemming from the report's distinction between dominant and challenger regimes is that transformation is not only about technological change. Instead, technological and societal development are co-dependent: parallel to technological change, there is change in societal and social structures, business models, knowledge, skills and professions, cultures of use and ways of life. Radical change—i.e., transformation toward a

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[2] F. W. Geels (2011), The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environmental Innovation and Societal Transitions Vol. 1, No. 1, 24-40.

challenger regime—means a change in the way we fulfil our basic needs: how we eat, move and live, and how we access and produce the energy, materials, goods, experiences and safety that we need and want. At the end of this section, the reader can find a page for each of the above-listed potential transformations, including a listing of related technologies, occupations and regulatory needs.

3. Observations of technological change

The present update enables comparisons with the report published in 2013. The original aim of the Committee for the Future was the ability to make such comparisons and to recognize radical and transformative technologies at an early developmental stage. In its Future Submission (TuVM 1/2014 vp), the Committee concluded the necessity to act early; if we spring to action only when new technologies have matured, we will be helplessly late.

Which technologies, that yet lack societal impact, could then be at the technological forefront in 20 – 30 years? Perhaps these can be found among the group of technologies that were ranked in places 80 – 100 in the Committee's first foresight report (TUVJ 2/2013). From those, the attention should specifically be on the technologies that seem to have developed faster than others.

A reader comparing the reports can notice several changes in the list of the 100 most important radical technologies. Direct comparison between the two reports is challenged, however, by the fact that the method has been developed. Some new technologies have risen to the list due to accelerating development (such as VR-glasses) or dropped out due to development slowing down (spray-on textiles). Some changes are due to slightly adjusted principles in the scoring of ARTs.[3] Another complication stems from the nonlinear nature of technological change. In many cases, a certain core ART, such as Big Data technologies, has evolved into numerous new applications, forming several novel ARTs. This is why some ARTs of the original report cannot be found from the update and why the update includes some entirely new ARTs.[4]

Based on this foresight, it becomes possible to identify development in the level of value-producing networks as well as in the level of individual ARTs.

Table II below ranks the 20 value-producing networks based on their technological development speed (based on the rate with which the anticipated effectiveness of technological development has grown). The value-producing network where technological change is the fastest (Passenger transport) has gained first place, and the last one (Redressing disabilities) features the slowest technological progress. Thus, the value-producing network of passenger transport can be interpreted as being under the strongest transformation pressure.

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[3] The scoring method is explained in Attachment 2.
[4] Examples of such changes can be found in Attachment 3.

Ranking	Value-producing network	The rate with which the anticipated effectiveness has grown
1	Passenger transport	6,7
2	Logistics	6,3
3	Work and income	5,9
4	Automation of work	5,8
5	Sustenance	5,3
6	Manufacturing of goods	5,2
7	Built environment	5,0
8	Exchange	4,6
9	Acquiring information	4,1
10	Safety and security	4,1
11	Remote impact	4,0
12	Existential meaning	3,7
13	Power structures	3,1
14	Producing experiences	2,7
15	Healthcare	2,6
16	Materials	2,4
17	Energy supply	2,3
18	Collaboration and trust	2,3
19	Proficiency and its proof	1,0
20	Redressing disabilities	0,8

Table II. Value-producing network ranking based on technological development speed. The measuring of development speed is based on growth-of-estimated-impact-in-20-years from 2013 to 2018.[5]

The nature of Table II can be illustrated with the value-producing network of healthcare that is ranked as low as 15th. How is this compatible with the news of health technology breakthroughs that we get to read almost on a daily basis? In fact, most of these breakthroughs are supporting the current dominant regime, that being centralized healthcare. The anticipated effectiveness of de-centralized healthcare models was already high in the 2013 report. Despite progress in this field, the expectations concerning transformative technologies have grown faster in some other networks between 2013 and 2018.

At the level of individual ARTs, it is possible to study which technologies have a central position in multiple value-producing networks (Table III). These radical individual ARTs

[5] Formulas I and II in Attachment 1.

are generic technologies that have the greatest potential to already change the world, now and in the near future:

Ranking	Anticipated radical technology	Genericity score
1	Neural networks and deep learning	3820
2	AI performing local work on global basis	3021
3	Autonomous cars and trucks	2010
4	Material scanner - hyperspectral camera	1854
5	Radical growth in computing power	1760
6	Ubiquitous environment and Internet of Things	1666
7	Facial and emotion recognition and projection	1598
8	Speech recognition/synthesis and interpreting	1581
9	Memristors and neural processors	1455
10	Commercial platforms for sharing economy	1455
11	Reading and editing thoughts from the brain	1445
12	Verbot/chatbot, talking/corresponding robots	1328
13	VR-glasses, MR-glasses and virtual reality	1326
14	M2M trade and other online commerce	1296
15	Rapid development of photovoltaics	1260
16	Personal health diagnostics systems	1260
17	Robotized physical remote work, AI as superior	1245
18	Environment 3D scanning & positioning	1209
19	Real time 3D-modelling of environment	1170
20	Pattern recognition and other AI platforms	1095
21	Global wireless broadband	1080
22	3D-printing of things	1072
23	Smart glasses, AR-glasses and augmented reality	1050
24	New robotized services	1050

Table III. TOP 24 ARTs ranked by their extent of anticipated generic influence.

One can also identify important radical technologies by comparing the current updated report with the original one, as well as identify ARTs whose rate of advancement stands out in relation to most other ones. This analysis also highlights some ARTs that are not yet at the top of the genericity list but which presently change the most (Table IV).

Ranking	Anticipated radical technology	Rate of development
1	P2P trust solutions, blockchain	13,8
2	MyData & GDPR	13,0
3	Biotechnical meat and meat imitations	12,1
4	AI performing local work on global basis	12,0
5	Small particle accelerators, femto and nanolasers	12,0
6	Neural networks and deep learning	11,4
7	LED farming, robotic farming	10,8
8	Verbot/chatbot, talking/corresponding robots	10,0
9	AR & VR platforms and content standards	10,0
10	New separation techniques & circular economy	10,0
11	Cheap small fuel cell and microturbine CHP	10,0
12	Radical water-borne traffic	10,0
13	Hyperloop and other tunnel technology	9,6
14	Microbiome, metabolism and genetics of cells	9,0
15	Quantum computers and quantum communication	8,2
16	New power sources for vehicles	7,8
17	Self organizing and swarm intelligence	7,8
18	New methods to manipulating materials/substances	7,8
19	Global wireless broadband	7,2
20	Genetic editing techniques, CRISPR/Cas9	7,0
21	Cheap efficient storage of hydrogen	6,6
22	3D-printing of organs and biomaterials	6,5
23	Fast and dense memory materials	6,5
24	Speech recognition/synthesis and interpreting	6,4

Table IV. TOP 24 ARTs by rate of development.

In conclusion, it can be noted that ongoing broad technological changes seem to particularly relate to solar energy, autonomous robots, virtual reality, pattern recognition, sharing economy, LED farming, DNA technology, nanomaterials, quantum computing and robotized manufacturing.

4. Twenty socio-technical transformations

Being at the technological forefront requires a courageous and visionary mentality. The Committee for the Future has strived to bring this forth with its technology foresight model.

The Committee for the Future states that Finland should be active in regard to those technologies that solve grand societal challenges, as these technologies create global business opportunities while bringing forth utility for the people and society. Additionally, though the perspective of the presently large sectors and respective export is important, if multiple anticipated transformations are indeed realized in the future, it will be necessary to have knowledge, competences and regulation in place for a society where the use and even the development of technology may disperse and the economies of scale dissolve to an unforeseen extent.

Knowledge and competence are important in all future scenarios. The Finnish education system should invest early on in those technological fields that are estimated to become significant in 20—30 years. In its futures report (TuVM 1/2014 vp; TUVJ 10/2014 in English), the Committee for the Future has previously noted that *"[f]*or *example, a professorial chair in theoretical electronics was created at the Helsinki University of Technology already in the 1950s, followed by the first chair in telecommunications in the following decade. The same period saw the creation of chairs in data processing science at the University of Tampere (1965) and the University of Helsinki (1967), and the electrical technology department at the University of Oulu (1965). It was from these investments in information technology (including radio technology) and telecommunications that Finnish competence in information technology grew. Electrical technology and electronics accounted for 2% of Finnish exports in 1970, 4% in 1980, 11% in 1990, 31% in 2000, and 15% in 2010. Thus, the results of academic and applied research form into business operations and industry in parallel with related changes in our ways of life, but the time lags can be very long."*

In what follows, the reader can find a summary page for each of the 20 value-producing networks. The fastest developing network is presented first, with the slowest as the last.

Each page mentions the main need that the network serves and characterizes the related dominant regime as well as the challenger regime that is structured around radical technological solutions. Under these, the reader can find two different top lists of radical technologies that are interesting for this value-producing network.

The first list in each page features those ARTs that are crucial for the respective socio-technological transformation to occur. For example, the radical transformation of passenger transport changes mobility into service and reduces the private ownership of cars. The respective challenger regime is structured around electric robotized vehicles and technologies necessitated by automatized public transport: technologies of positioning and real-time 3D modelling of the environment are a necessary requirement for autonomous traffic. Efficient and rapidly charging batteries is a requirement for the electrification of traffic.

The key ARTs for each value-producing network have been identified by scoring all ARTs from two perspectives: the centrality of the ART for reaching the goal of each value-producing network and maturity of the ART (functionality and advancement along the commercialization path). The passenger transport value-producing network develops most rapidly because the radical technologies that are central for realizing its goals have matured the most. This is reflected in the fact that the effectiveness index values of the four ARTs that are central for passenger transport (140, 140, 120, 100) are significantly higher than those of the slowest-developing value-producing network, redressing disabilities (60, 60, 50, 50). It should be noted, however, that the technologies in this slowest value-producing network have also clearly advanced between the foresights of 2013 and 2018. The formula for calculating the effectiveness index is in attachment 1 (formula VI).

In each page, there is also another list, which is formed by analyzing all ARTs and listing those where anticipated effectiveness has increased the most between the foresights of 2013 and 2018. The formulas for calculating the anticipated effectiveness are in attachment 1 (formulas VII and VIII). One should note that if the expectations were already high at the time of the first foresight, and if the technological development has occurred according to these expectations but has not exceeded them, the ART does not show at the list of fast developers. This is the case with e.g., the development of driverless, autonomous cars. Thus, autonomous cars show in the listing of key technologies of the challenger regime (the first list of the passenger transport summary page) but not on the list of fast developers (the second list of the passenger transport summary page).

The lists of rapid developers take into account all ARTs that are somehow relevant for the goal of the value-producing network, without emphasizing the centrality of the technologies for the goal. The rate of development of a given ART is the same in each value-producing network, meaning that it is not adjusted for ART-specific applications. For example, the rate of development of MyData solutions has not been assessed separately for applications relating to positioning in passenger traffic and applications relating to personal health data.

Most of the fastest developing ARTs are at least somewhat relevant for most value-producing networks. Therefore, the same rapid advancers are featured in multiple summary pages. For example, quickly maturing LED-farming technologies appear not only in the value-producing network of sustenance, but also in rapidly developing networks of built environment, logistics, and existential meaning. This is because LED-based farming, as it becomes more commonplace, will change where the production of food and related transport and logistics take place. The ART of "P2P trust solutions and blockchain", in turn, has been assessed as belonging to the second-lowest effectiveness category within the value-producing networks of energy and acquiring information. Nevertheless, it appears as the first in the top list of fast developers, because expectations concerning these technologies have grown so rapidly during the past couple of years.

In each summary page, the table of rapid developers includes brief explanations of how the most rapidly advancing technologies help in reaching the goal of the value-producing network. These explanations illuminate the systemic nature of technological change. It can be seen that advances in a single ART, such as robot car, LED-farming or blockchain, may be reflected in several value-producing networks. Connections to multiple value-producing networks most likely also reflects back on the development of a single ART. The development presumably is faster the more there are application areas that can provide funding and markets for the novel solutions of the ART.

Each summary page also displays a number of new occupations and competence needs that are expected to emerge and become more commonplace as the challenger regime strengthens. The occupations have been formed by grouping together tasks that would be necessary for the functioning of the challenger regime.

Finally, each of the summary pages also features a list of policy objectives to consider should one choose to support and control the respective transformation. In this context, the Committee for the Future reminds the reader that even though the technologies and probably also the transformations characterized in the report will advance on a global level regardless of our will, it is possible to influence the pace, direction and consequences of change with regulation. A transformation is never beneficial for all stakeholders; there are always losers in all renewal processes. We often hear of disappearing professions, but holdings, investments and infrastructures may equally lose their value. Therefore, many of those who benefit economically from the present situation have good reasons to resist change. There are also those for whom change signifies a change in their way of life, for better or worse. Moreover, the impacts of transformation on the natural environment are always complex. For example, there is no certainty that the increasing use of renewable energy and energy-efficient innovations will necessarily lead to a future where less fossil energy is used.

The results and ranking lists of the report should not simply be interpreted that Finland should only invest in the top technologies. It is equally important to look at the bottom of the lists and consider whether there are technologies that we would like to see develop faster, such as better technologies for the disabled.

Based on this study, it also seems that the value-producing network of proficiency and its proof is not at the forefront of transformation, despite the shared understanding of the importance of education and learning and investments into educational technologies. How should this be interpreted, and how should the situation be addressed? The regulatory needs of technological change do not only relate to technology policy. For example, the technologies of proficiency and its proof are in fact relatively advanced, but aligning them with the education system has been slow. This is also why the expectations have grown slowly and there is little faith in the rapid development of this value-producing network. The policy objectives relating to proficiency and proof in the face of transformation pressure concern the ability of the education system to implement novel technologies and organization models enabled and necessitated by them, rather than the development of actual new technologies.

The policy recommendations and policy objectives in the following pages outline what we should do to speed up and ease the transformation. It is equally important to consider, however, whether we want to support or slow down the transformation, i.e., what are the opportunities and threats involved. We should also consider whether it is possible to influence the consequences of the transformation with regulation and polices at the societal and individual level. The importance of such ethical and value discussion is one of the key conclusions from the results of this foresight report. The Committee for the Future will continue the analysis of these value issues in its follow-up projects. The results will become available during 2018.

Helsinki 18 April 2018

The Committee for the Future

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PASSENGER TRANSPORT Transporting people from one place to another comfortably, safely, cost-effectively and by offering freedom of choice.	
Dominant regime: Private cars operated by a driver, public transport	**Challenger regime**: Autonomous transport as a service
Key ARTs of the challenger regime	**Effectiveness index**
Environment scanning & positioning	140
Transportable batteries and supercondensators	140
Real time 3D-modelling of environment	120
Autonomous cars and trucks	100
Commercial platforms for sharing economy	60
New power sources for vehicles	60
Neural networks and deep learning	50
AI performing local work on global basis	40
Radical growth in computing power	40
Light person & cargo transport vehicles	40
Hyperloop and other tunnel technology	40

The most rapidly advancing technologies of the challenger regime		
ART	**Applications of the ART**	**Developm. rate**
MyData & GDPR	The transfer of MyData from one operator to another can essentially facilitate services.	13,0
AI performing local work on global basis	It is possible that all sales, management, remote control and manufacturing required by robot taxis would be done abroad and only the infrastructure and maintenance would be done locally.	12,0
Small particle accelerators, femto and nanolasers	Lidar systems used in robot transportation are based on small lasers. The laser is also suitable for headlights and identifying materials.	12,0
Neural networks and deep learning	The development of artificial intelligence is an essential cost factor for autonomous robot transportation and the technology is essential in self-driving cars, at least at the level already achieved.	11,4
Verbot/chatbot, talking/corresponding robots	The possibility to discuss the destination and sights with the car promotes robot transportation. The car can also suggest connections and accommodation services as needed or entertain.	10,0
AR & VR platforms and content standards	Traffic signs and routes are visible in AR glasses or on the windscreen. Things that are notable on the route will be explained. VR glasses will entertain on the road if the content is compatible with one's own glasses.	10,0
Cheap small fuel cell and micro-turbine CHP	An inexpensive fuel cell makes a fuel cell car possible.	10,0
Radical water-borne traffic	Foiling speeds up water-borne traffic. Robotisation makes water taxis less expensive. Ships with lightweight hulls allow new routes to be introduced.	10,0
Hyperloop and other tunnel technology	The travel speed and lack of schedules between city centres makes commuting and using services of neighboring cities easy. Reduces motoring.	9,6

Growing professions and skills shortages
Transition to autonomous transport organised as service creates many new professions. A transport coordinator is responsible for ensuring that the means of transport are waiting for new rides where they are needed next. A traffic information analyst produces information, creates new driving instructions for robots and plans adjustment of the transport system. A remote controller monitors driving, investigates problem situations and guides an autonomous vehicle when it is not able to proceed as needed. A remote assistant talks with passengers and guides them and the car by choosing the destination and route and makes a decision on actions in case of personal injury. A vehicle cleaner is responsible for the cleanliness of the vehicles and, if necessary, provides passengers with feedback on unwanted behavior. A city air traffic controller takes care of the flight routes, landing field conditions and availability of air taxis. Robot police and an inspector of autonomous transport monitor autonomous transport, its service level and security threats related to it. A traffic ethicist consults on ethical and legal liability issues related to transport. An insurance auditor of robot transport investigates accidents..
Policy objectives of the change
The transport sector has already significantly promoted the introduction of new vehicles and robotisation—for example, by enabling the use of electronic light traffic devices, promoting traffic as a service through Transport Code and promoting experimental culture. The following actions should be further promoted: The disturbance of robot transportation should be criminalised. All traffic sign data, signal data and roadway information should be collected automatically and in real-time in a shared cloud service as open data. Information could be obtained in real time from selected vehicles in traffic—for example from Posti vehicles. As for city air traffic, airspace monitoring should be automated for the needs of self-piloting passenger aircraft. Especially the definition of routes and access credentials from the point of view of enabling transport would be important. The service interface related to the Transport Code should be implemented quickly. The need for compatibility of the interface between transport providers and passenger applications with the interface of international actors such as Lyft's alliance should be taken into account. The obligation to monitor self-driving cars and passing the responsibility for damage on to the vehicle manufacturer should be regulated before the wide launch of robot transportation. The role of statutory insurance between vehicle users, victims and responsible parties should be preserved, but in a way that the low accident rate of a self-driving car reduces the manufacturer's costs. Training related to robot transportation, including the organisation of activities, technical maintenance and control, should be implemented quickly and widely. The regulation of a robot transport service should be regulated in a way that simultaneously enables models of sharing economy, car rental and robot taxi operations and, to a sufficient extent, integrates with Mobility-as-a-Service thinking (MaaS).

LOGISTICS

The transfer of goods, equipment, animals, raw materials and waste from one place to another through convenient, accurate, cost-effective and common means.

Dominant regime:	**Challenger regime:**
Based on repeated automation and human labour. Characteristic: transport operated by a driver, repetitive automated loading.	Smart robotisation enables cost-efficient sorting and autonomous transportation of goods. Characteristic: autonomous transport, smart loading robotics.

Key ARTs and effectiveness index of the challenger regime

Environment scanning & positioning	140
Quadcopters and other flying drones	140
Real time 3D-modelling of environment	120
Autonomous cars and trucks	100
Transportable batteries and supercondensators	70
New power sources for vehicles	60
Neural networks and deep learning	50
Material scanner – hyperspectral camera	50
IR, THz and GHz, transmitters and receivers	50

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	The decentralisation of waybills and logistics forwarding becomes possible.	13,8
MyData & GDPR	The transfer of logistics history information (MyData/GDPR) from one operator to another can facilitate logistics.	13,0
AI performing local work on global basis	It is possible that most of the sales, forwarding, transportation, loading and manufacturing work of the logistics would be done abroad. Only the infrastructure and maintenance would be done locally.	12,0
Small particle accelerators, femto and nanolasers	Lidar systems used in robot transportation are based on small lasers. The laser is also suitable for headlights and identifying materials.	12,0
Neural networks and deep learning	The development of artificial intelligence is necessary for the development of an autonomous robot transportation.	11,4
LED-farming, robotic farming	The needs of food logistics are going to completely transform when cultivation shifts from cyclical and agriculture-dominated cultivation to continuous urban and factory cultivation.	10,8

Growing professions and skills shortages

When goods are transported robotically from the manufacturer to the customer, the need for transporting vehicles will be reduced or no longer exist. As cost-effectiveness improves, a significant part of the collection and transportation presently carried out as self-service will be realised as a service. There will be more jobs for small freight forwarders and unloaders, such as dispatchers and freight traffic controllers. Freight forwarders or transportation companies will be responsible for the role of controlling and organising the fill rate. “Fleet manager” jobs will be formed for guiding and controlling robot transportation. A crowdsourced transportation will require its platform and controllers and the defective goods robots and the goods left by them will need robotic transportation rescuers.

There will be more jobs for remote loaders and unloaders of goods. The mapping of transportation routes, especially in retail distribution, will create new jobs. In addition to mappers, accessibility inspectors of the robot transportation will be needed. Food delivery designer and carbon footprint analyst of freight traffic can be new professions. Also the installation, cleaning and control of the distribution boxes will create new jobs if a uniform and widely available infrastructure can be accomplished. The skills shortage is particularly high when it comes to drone transportations and decentralised sorting of heterogeneous goods.

Policy objectives of the change
Open distribution boxes located within walking distance and in traffic nodes should be organised as part of the transportation infrastructure in a way that an open transportation chain of the crowdsourced distribution connecting different parties will be made possible. This should be taken into account in the reform of the Land Use and Building Act. A clear and fast target schedule should be set for allowing autonomous drone distribution of goods. Disturbing the drones and other robot transportation should be criminalised and the disturbance-related control with robots should be allowed. Reception kiosks of the drone distribution should be determined in the city plan as part of the distribution boxes. The address and owner information of the goods to be distributed should be digitised in such a way that the product itself contains a unique identity that allows other information to be found in the cloud if the access rights have been granted. This information should be available in the cloud regardless of the manufacturer to the extent and in the form needed by the logistics robots. The main policy objective needed for this is that the state, municipalities and state institutions begin to use a new practice with regard to addresses. Logistics training should be updated to match the expected robot era. This applies to both seasonal and day-to-day tasks of planning, management and operational levels.

WORK AND INCOME Securing own well-being and the well-being of loved ones by deeds that fit one's own skills and are personally relevant.	
Dominant regime: Salaried employment related to specialisation and exchange	**Challenger regime:** Cooperation, self-sufficiency, micro-entrepreneurs

Key ARTs and effectiveness index of the challenger regime

Neural networks and deep learning	100
Speech recognition, speech synthesis and interpreting	60
Commercial platforms for sharing economy	60
VR-glasses, MR-glasses and virtual reality	60
Flipped learning and proficiency demonstrations	50
3D printing of things	35
Memristors and neural processors	30

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
AI performing local work on global basis	Transition of work can be regionally very fast due to globalisation.	12,0
Neural networks and deep learning	Artificial intelligence can teach and assist people whose inadequate skills and knowledge would otherwise prevent working. This kind of supportive intelligence facilitates the completion of several jobs.	11,4
LED-farming, robotic farming	The increase in small-scale food production expands the share of subsistence economy.	10,8
Verbot/chatbot, talking/corresponding robots	Work efficiency improves by the use of communicative machines.	10,0
AR & VR platforms and content standards	Remote control, remote guidance and remote entertainment become meaningful jobs with VR/AR glasses. Platforms ensure the compatibility between glasses and content.	10,0
Radical water-borne traffic	Robotisation of water-borne traffic increases remote control and remote monitoring jobs.	10,0
Hyperloop and other tunnel technology	As the commuting and services areas expand, specialisation and opportunities for earning income increase.	9,6
Self-organising and swarm intelligence	Work carried out by people will be gamified and, in its own way, work will become more independent and self organizing.	7,8
Global wireless broadband	A global high-speed network promotes the opportunities for global remote work.	7,2
3D printing of organs and biomaterials	Cell cultivation, indoor farming, and 3D food printing promote the subsistence economy.	6,5
Speech recognition, speech synthesis and interpreting	Machine simultaneous interpretation introduces the possibility for both local and remote work regardless of one's own language skills.	6,4

Growing professions and skills shortages

The biggest change in doing work is generated by growth in platform economy. Growth in subsistence economy and voluntary work also play a major role in the change and future professions will emerge related to them. Examples of new professions include, for example, platform auditor, platform police officer, online work (predictor, freelancer, reputation vendor), platform manager, authority facilitator, local service dealer, micro-insurer, self-sufficiency consultant and community manager.

Policy objectives of the change
The most important regulatory objective of the change is to facilitate micro-entrepreneurship and platform work. Simplified rules should be developed for the income and cost calculation of shared resources. The obstacles of cooperative-type activities and subordination to market economy should be dismantled and the development of platform cooperatives should be supported. Employment legislation should be made independent of the place, on the one hand, so that remote work could be controlled and, on the other hand, so that working would not necessarily require physical presence. Transactions of sharing economy should be standardised and the research on modern subsistence economy should be increased.

AUTOMATION OF WORK Acceptable and cost-effective replacement of human work with machines that are easy to use and reliable and that create high-quality results.	
Dominant regime: Centralised automation and human steered machines	**Challenger regime:** Decentralised robotics based on AI and crowdsourcing

Key ARTs and effectiveness index of the challenger regime

Neural networks and deep learning	100
Environment scanning & positioning	70
Verbot/chatbot, talking/corresponding robots	50
Autonomous cars and trucks	50
Pattern recognition and other AI platforms	50
Facial and emotion recognition and projection	40
Radical growth in computing power	40
Sensitive robotic fingers and arms	40

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Blockchain-based transactions are easier to automate than services of public authorities.	13,8
MyData & GDPR	GDPR in its present form prevents the intelligent use of artificial intelligence in personal customer services.	13,0
Biotechnical meat and meat imitations	It is easier to robotise cell cultivations than cattle farming and slaughtering.	12,1
AI performing local work on global basis	Global AI learns from extremely comprehensive materials and is able to share the learning cost with a very large user base.	12,0
Small particle accelerators, femto and nanolasers	Automated machines such as a robot vacuum cleaner and weeding robot can explore their surroundings with laser techniques and perform operations by using a laser or a particle accelerator.	12,0
Neural networks and deep learning	Versatile tasks or tasks that vary based on situations and needs performed by a machine require either continuous presence of a human being or a learning artificial intelligence.	11,4
LED-farming, robotic farming	LED farming facilitates the robotisation of food production.	10,8
Verbot/chatbot, talking/corresponding robots	Many service tasks can be transferred to machines when machines have a sufficient ability to discuss the matter. The machine asks people to assist if necessary.	10,0
New separation techniques and circular economy	Machines are able to distinguish raw materials in a way that people can not do economically. The work performed by machines gives significant added value.	10,0
Radical water-borne traffic	When oceanography and ocean cleaning tasks as well as transportation tasks of water-borne traffic are automated many tasks can be carried out more efficiently than currently.	10,0
Self-organising and swarm intelligence	Self-organising control structures replace managerial work by coordinating employees to work locations based on their proximity, skills and preferences.	7,8
Global wireless broadband	Machines must have a high-speed telecommunication connection, the latency must be low and the network must be in accordance with the general standard in order the machines to operate smoothly.	7,2

Growing professions and skills shortages
Robots do not only reduce work when they replace old procedures. Development, management and maintenance of the robots provide jobs as well as do marketing, training and organising the services they provide. Many services become so affordable with robots that the amount of work in the price elasticity areas increases in its entirety. Robots also cause harm and danger and preventing those increases people’s work. Fast-growing and new professions will be, for example, robot security inspector, robot insurance appraiser, robot field maintenance technician, robot foreman, robot trainer, robot work planner, robot energy manager and robot transporter. New jobs are mainly related to enabling the work done by robots and minimizing harms caused by it.
Policy objectives of the change
Legislation should aim for providing easy access to work done by robots for as many people as possible. The introduction of robots should be expedited with the help of references offered by innovative procurement of public administration. Responsibility related to the robot mobility and work done by robots should be clarified. At the moment, the limits of the responsibility of manufacturer, teacher, owner and ordered are unclear. The disturbance of robots should be criminalised. Robots should be allowed to monitor their environment and the control of robots should be clarified, especially in the case of robots moving autonomously moving in a public environment. The relation of robots and other artificial intelligence to the General Data Protection Regulation (GDPR) should be resolved quickly. Interpretation should strive for a solution that intervenes as little as possible with the easy usability of robots as the help of individuals. The knowledge base related to and supporting robot mobility should be placed in the same position with physical infrastructure.

SUSTENANCE Getting energy and the necessary nutrients and trace elements in a healthy and enjoyable way, affordably and guaranteed.	
Dominant regime: Agriculture, food industry, distribution	**Challenger regime:** Urban cultivation, robotic local food

Key ARTs and effectiveness index of the challenger regime

DNA reading and writing (full genome)	140
LED-farming, robotic farming	120
Biotechnical meat and meat imitations	100
LiFi networks and other LED technology	60
Neural networks and deep learning	50
Material scanner – hyperspectral camera	50
Smart glasses, AR glasses and augmented reality	50
Personal health diagnostics systems	50
GMO producing substances and organs	40

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, block chain	The food chain from raw materials to consumer products can be registered to blockchain up to the home delivery level of a single product.	13,8
MyData & GDPR	Combining one's own genome, microbiome and nutritional information enables the development of lifestyle recommendations on an individual level and by many actors.	13,0
Biotechnical meat and meat imitations	Raising beef cattle causes significant disadvantages and is ineffective. Replacing it with a biotechnical or cultivated protein of a good quality would be a great achievement.	12,1
AI performing local work on global basis	The AI of the robot cook can be global and so can the platform from which the food will be ordered.	12,0
Small particle accelerators, femto and nanolasers	The irradiation of food is a means for preservation.	12,0
Neural networks and deep learning	Guidance and learning of the robot cook, planning of individual nutrition and optimisation of growth conditions.	11,4
LED-farming, robotic farming	The potential transformation of the food industry from cyclical agriculture to continuous and need-based, decentralised urban and factory cultivation.	10,8
Verbot/chatbot, talking/corresponding robots	Discussing food with a robot kitchen is easier than using the menus.	10,0
AR & VR platforms and content standards	A remote cook can participate in demanding work phases with VR glasses assuming that the remote cook and robot kitchen work on the same platform.	10,0
New separation techniques and circular economy	The separation technique affects the raw materials needed for plant and meat cultivation and it may affect the preparation of food. The circular economy affects the nutrient intake.	10,0
Microbiome, metabolism and genetics of cells	The understanding of cell metabolism and knowledge of microbiome help with the planning of individual nutrition. Hereditary tendencies can also be considered.	9,0

Growing professions and skills shortages
The most significant aspect affecting professions is the personalisation of nutrition and urban farming. Growing new professions in the new operating model include bioproduct factory designer, urban farmer, cultivar and nutrition optimizer, bio-raw material logistics officer, traceability officer, food insurance agent, indoor cultivation supply vendor and mechanic, nutrigenomics consultant, metabolism analyst, food designer, robot cook technician, robot restaurateur, virtual restaurateur, food service platform specialist, remote cook, maturation scheduler, artificial meat farmer and food freight forwarder. These new jobs essentially differ from the current jobs of nutritionist, farmer, market vendor and restaurateur and the number of jobs will increase compared to these but respectively the jobs in the current food chain will decrease.
Policy objectives of the change
The research and teaching of LED farming, biotechnical farming and nutrigenomics should be significantly expanded. Official instructions for ensuring the conditions of the buildings used for indoor farming and the quality of food are needed. The artificial, cultured meat must be defined as vegetable. GMO food should be allowed more easily than currently especially in indoor farming. LED farming should be regulated as support neutral with all other cultivation and it should be favoured for quality assurance reasons due to the decrease in the need for storage. Obstacles and burdens to small-scale production should be cut off by the means of the platform economy by generating, for example, digital marketplaces that use public robotised logistics and by making small-scale production more proportional to a household's own food production. The experimental activities of robot community kitchens should be started. Roles and responsibilities should be created for the operations and plan provisions prepared for robot community kitchens.

MANUFACTURING OF GOODS

The availability and manufacturing of physical goods and equipment with available raw materials in a functional, easy, cost-effective and high-quality way.

Dominant regime:	**Challenger regime**:
Industrial, centralised, repetitive manufacturing	Robotised, decentralised, discrete manufacturing

Key ARTs and effectiveness index of the challenger regime

3D printing of things	140
Rapid development of photovoltaics	70
Real-time 3D modelling of environment	60
Ubiquitous environment and Internet of Things	40
Cloud computing and storage services	35
P2P trust solutions, blockchain	30
Modular interfaces for robot ecosystems	30
VR-glasses, MR-glasses and virtual reality	30
Robotic tailor	30

The most rapidly advancing technologies of the challenger regime

ART	**Applications of the ART**	**Developm. rate**
P2P trust solutions, blockchain	Manufacturing methods, materials, sales, service history and other life cycle of individual goods can be recorded decentralised in the blockchain and controlling counterfeit goods will be increasingly easier.	13,8
MyData & GDPR	Receiving own dimensions and information about own goods from the service provider reduces the need for repeated measuring and errors related to it.	13,0
AI performing local work on global basis	Global models of goods and the online sales platform can be generated globally. If a customer visits a printing service the service robot can be guided by a global AI.	12,0
Small particle accelerators, femto and nanolasers	Some 3D printers use laser to attach materials by sintering. Even low-power lasers are used for cutting and welding materials.	12,0
Neural networks and deep learning	Artificial intelligence is needed especially for the handling of fabrics, individual production and production maintenance related to cloths made by robots.	11,4
AR & VR platforms and content standards	A remote expert can use VR-glasses to participate in the most difficult work phases that require manual work by a maintenance worker who uses AR-glasses. Standardisation of interfaces makes the practice more common.	10,0
New separation techniques and circular economy	The idea of circular economy affects the raw materials of goods. Recycled materials are a more and more essential part of the raw materials of goods.	10,0
Self-organising and swarm intelligence	Goods can grow into their shape or microbots can make them. The growth and restorability can be controlled with DNA and epigenetics.	7,8
New methods for manipulating materials/substances	New methods for manipulating goods and materials enable an assembly of miniaturised machines and many other new flexible manufacturing processes without an assembly line.	7,8
3D printing of organs and biomaterials	Organs that resemble their natural counterparts can be manufactured from a cultured cell with 3D printing of biomaterials.	6,5

Growing professions and skills shortages
As the local manufacturing increases, many industries that have almost disappeared in Finland will make a come back. This can especially apply to the textiles sector. In other sectors, the emphasis of professions will change. Digitalisation creates professions, in which application expertise is important. A digital designer creates, designs and produces individual personal items and home or consumer goods according to the needs and wishes of customers, for example, tools for the elderly or disabled, professional tools produced according to the size of the user and personalised tableware for young couples. Also specialty niche professions will emerge, such as 3D measurer, 3D modeller, model selection consultant, 3D printer, local manufacturer, printing post-processor, goods stylist, raw material consultant, goods programmer and inspector of goods made by robots. Skills associated with the change in industrial regime are particularly inadequate because each profession and sector evaluates their own tasks within the well-established structure at the moment and there are no business skills for the opportunities introduced by new technologies. Digital product integrator will emerge as a new important profession in the industry and its task in industrial companies include combining design and production into a well-functioning entity, for example, with model-based definition.
Policy objectives of the change
To speed up change, tens of thousands of public, free models of the most common everyday goods should be created and made available for free use for local printing services. Educational institutions could produce and review these as student works. This should be considered as an intangible infrastructure, such as public service broadcasting or public education and health care. Reasonable requirements that do not complicate operations should be set for the product descriptions of local manufacturing. Public administration should manufacture a growing part of the goods they need themselves. Manufacturing of the least difficult goods should be considered as equivalent to using copying machines.

BUILT ENVIRONMENT Designing, constructing, maintaining and demolishing spaces and routes with demand controlled location and conditions for the activities and mobility of people, animals, equipment and plants and providing technical equipment for them cost-efficiently and respecting regulations.	
Dominant regime: Traditional construction and maintenance	**Challenger regime:** Robotised construction and maintenance

Key ARTs and effectiveness index of the challenger regime

Rapid development of photovoltaics	70
LiFi networks and other LED technology	60
Walking robot and walking assists	50
Autonomous cars and trucks	50
Smart glasses, AR glasses and augmented reality	50
Global wireless broadband	50
Structural materials replacing concrete	40
Light and strong or insulating materials	40
Ubiquitous environment and internet of things	40
3D printing of buildings and constructs	40
New robotised services	40
Hyperloop and other tunnel technology	40

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Transactions related to properties and maintenance can be recorded in blockchain.	13,8
MyData & GDPR	Usage pattern information on buildings helps to optimise maintenance and energy consumption.	13,0
Biotechnical meat and meat imitations	Replacing meat with cell culture or plant proteins would have a significant impact on agricultural buildings as well as food industry and commercial premises.	12,1
AI performing local work on global basis	Some of the building and maintenance robots can be guided and managed by the global AI.	12,0
Neural networks and deep learning	Maintenance needs control, maintenance guidance, designing of lightweight, aesthetic structures and route guidance.	11,4
LED-farming, robotic farming	Indoor farming changes the need for space. The need for arable land and greenhouses decreases and the use of indoor spaces in cultivation increases. The need for moisture resistant indoor spaces increases.	10,8

Growing professions and skills shortages

Growing new professions include, for example, community designer, social architect, car park re-designer, living environment analyst, controller of the use of space, property control room supervisor, builder robot mechanic and instructor, robot building material regulator, construction foreman, controller and architect, remote maintenance supervisor and maintenance robot trainer.

Policy objectives of the change
Unique identifiers should be provided for structures and spaces that make it possible to find their location, composition and other information on a cloud service. The interface should be open and maintained throughout the lifecycle from designing to demolition and additional activities after the demolition. The information should be in a universal robot-readable format behind a standard software interface. Accessibility regulations should be renewed in preparation for robot-assisted mobility and maintenance performed by robots. Maintenance robots moving autonomously on public routes and working on properties should be enabled. Regulations related to windows should be amended so that natural windows can be replaced with display surfaces. The use of solar panels as surface materials should be allowed and the regulation restricting it should be prevented. Effects of indoor cultivation on buildings should be studied. The planning should take into account driverless transportation as a service and its reducing impact on the fleet as well as the opportunity to increase the use and routes of light traffic devices as car dependency decreases.

EXCHANGE Transfer of ownership and access rights reliably, locally and flexibly with the lowest possible search, agreement and delivery costs.	
Dominant regime: Brands, physical retail locations, hierarchies, B2B2C	**Challenger regime:** The reputation economy, e-commerce, P2P, C2B2C

Key ARTs and effectiveness index of the challenger regime

Encrypted and anonymous telecommunication	120
M2M trade and other online commerce	100
Cloud computing and storage services	70
Commercial platforms for sharing economy	60
P2P trust solutions, blockchain	60
Speech recognition, speech synthesis and interpreting	60
Autonomous cars and trucks	50
Neural networks and deep learning	50
Pattern recognition and other AI platforms	50
MyData & GDPR	50
Ubiquitous environment and Internet of Things	40
Radical growth in computing power	40
AI performing local work on global basis	40

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	All rights, agreements and transactions can be recorded in the blockchain. Separate registrars are not needed if the blockchain can not be broken.	13,8
MyData & GDPR	MyData data can be merchandise. MyData provides the seller an opportunity to offer something suitable for needs. Data portability provides added value.	13,0
AI performing local work on global basis	Exchange platforms can all be controlled by global AI. Exchange AI assistants and lenders, accounting and auditing AI can all work globally.	12,0
Neural networks and deep learning	Optimising stock and product selection, searching for the best products and target groups, stock exchange, identifying problem situations will all benefit from artificial intelligence.	11,4
LED-farming, robotic farming	Food trade changes radically as production decentralises into cities.	10,8
Verbot/chatbot, talking/corresponding robots	User's personal agent can discuss the needs of his/her owner and search for goods and services online. Verbots/chatbots can handle a significant part of trading.	10,0
AR & VR platforms and content standards	Objects being exchanged can be seen from different angles with VR/AR glasses. Glasses also make it possible to sit next to another person and have a conversation. Platform compatibility is required.	10,0
New separation techniques and circular economy	Industrial symbiosis means that one organisation's waste is a raw material for another organisation. The exchange becomes more efficient and matures into circular economy as the separation technology evolves.	10,0
Cheap small fuel cell and micro-turbine CHP	Enables easy private load following plants and staying outside the electricity trading.	10,0
Radical water-borne traffic	Many small deliveries by waterway will be facilitated. For example, smuggling will become easier.	10,0
Hyperloop and other tunnel technology	The significant geographical expansion of an easy physical service and work area affects the exchange.	9,6

Growing professions and skills shortages
Platform economy creates a significant number of new jobs. Growing or new professions include, for example, platform selection consultant, artificial intelligence assistant trainer, artificial intelligence personaliser, local exchange catalyst, identity inspector of goods, identity manager, reputation economy manager, professional praiser, platform lobbyist, artificial intelligence optimiser, artificial intelligence lobbyist and self-service kiosk manager.
Policy objectives of the change
The portability of the data of customers collected and stored by platforms should be ensured. In the case of responsibilities of P2P exchange, it must be ensured that responsibilities of the platform and seller remain separate and the responsibility for clarification in the exchange between small operators shifts more to the customer and, from the part of conveying feedback, to the platform. The P2P exchange platform must be responsible for transactions and realisation of the paid service. Reputation economy marketing responsibilities should be regulated so that cheating becomes more difficult. For example, trusted reviewers are needed. The taxation of P2P exchange and its platforms should be reviewed and it should strive for the utilisation of the strengths of crowdsourcing as the promoter of small operators. Settings for the local distribution infrastructure should be regulated so that operators have sufficient incentives to create lockers in walking distance from residential areas that can be digitally opened for exchanging goods without meeting the other party. This requires city planning measures.

ACQUIRING INFORMATION Information perceived as trustworthy and credible about people and things of personal interest.	
Dominant regime: Certified research, reports, news	**Challenger regime:** AI, crowdsourcing, personal instruments and applications

Key ARTs and effectiveness index of the challenger regime

DNA reading and writing (full genome)	140
Neural networks and deep learning	100
Environment scanning & positioning	70
Fast and dense memory materials	70
Material scanner – hyperspectral camera	50
AR & VR platforms and content standards	50
Lab on a chip	40
Ubiquitous environment and Internet of Things	40
Light continuously (24/7) flying aircaft	40
Transportable batteries and supercondensators	35
Quadcopters and other flying drones	35
Speech recognition, speech synthesis and interpreting	30
New nanomaterials in electronics	30
Real-time 3D modelling of environment	30
Reading and editing thoughts from the brain	30
Memristors and neural processors	30
Quantum computers and quantum communication	30

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Blockchains are more reliable globally than local registry authorities.	13,8
MyData & GDPR	The GDPR drastically limits the individual's ability to know something about other people.	13,0
AI performing local work on global basis	Sensors that collect information are always local but the interpretation and learning of their data can be done globally.	12,0
Small particle accelerators, femto and nanolasers	Femto lasers, DIAL lasers, laser distance measurements and particle accelerators are used to obtain a wide range of information.	12,0
Neural networks and deep learning	Artificial intelligence helps a lot with perception. Artificial intelligence reaches an expert level in many tasks and is of great help to a layperson.	11,4
Verbot/chatbot, talking/corresponding robots	Artificial intelligence assistants are extremely useful when they are familiar with the needs and situations of their users and constantly perceive the environment and point out important considerations.	10,0
AR & VR platforms and content standards	VR/AR glasses bring to our vision all information and book knowledge of all simulations, IoT devices, artificial intelligence and material scanners in their exact locations. Platforms standardise the content.	10,0
New separation techniques and circular economy	Separation techniques provide information about the environment.	10,0
Radical water-borne traffic	Autonomous water-borne traffic increases especially the information obtained from seas.	10,0

Microbiome, metabolism and genetics of cells	Increasing the understanding of cell metabolism and microbiome helps to get more information about the living environment.	9,0
Growing professions and skills shortages		
The biggest phenomena changing the work scene are the fact that measuring instruments become common, crowdsourcing of information and artificial intelligence. As a result of the change, more popular and new growing professions include, for example, Big Data analyst, data modelling analyst, information architect, controversial information investigator, data acquisition crowdsourcer, source analyst, context modeller, measuring instrument inspector, artificial intelligence educator, virtual guide, mushroom and berry picking remote guide, super skill trainer, digital material producer, lie detector expert and fact inspector.		
Policy objectives of the change		
Capacities of consumers to independently identify dangers should be increased as well as their capacities to control food, condition of their own body and environment. Activities of the authorities should be steered so that they support this kind of observation instead of regulating and controlling only centralised processes. Properties, municipalities and farms should produce information with IoT devices for the needs of Big Data analytics and citizen and corporate GIS applications. As for the Big Data, the obligation to collect and disclose should be viewed from the point of view of the benefits gained by the citizens and in relation to global crowdsourcing. Passing the responsibility to platforms of crowdsourced information in order to ensure the quality of the information presented should be clarified. Intentional misleading by clearly distorting facts for political, economic, military and religious purposes should be sanctioned. AI assistants should be equated with prostheses and their use should not be prevented by invoking privacy or other intangible rights.		

SAFETY AND SECURITY Freedom from an external threat and the opportunity to promote one's own goals within known and predictable rules that support caution and justice.	
Dominant regime: Material safety in society, social security	**Challenger regime:** Decentralised, individual and crowdsourced safety and security

Key ARTs and effectiveness index of the challenger regime

Autonomous cars and trucks	100
Quadcopters and other flying drones	70
DNA reading and writing (full genome)	70
Quantum computers and quantum communication	60
Material scanner – hyperspectral camera	50
Environment scanning & positioning	35
Rapid development of photovoltaics	35
Speech recognition, speech synthesis and interpreting	30
Real time 3D modelling of environment	30
LiFi networks and other LED technology	30
P2P trust solutions, blockchain	30
Encrypted and anonymous telecommunications	30

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Blockchain is relatively safe at the moment but, as quantum computing develops, existing chains can be corrupted and a decentralised system is difficult to fix.	13,8
MyData & GDPR	The GDPR hampers the organisation of security on an individual level but protects the data of an individual.	13,0
Biotechnical meat and meat imitations	Animal diseases will be reduced in cell culture and quality control will increase as production is decentralised.	12,1
AI performing local work on global basis	A global artificial intelligence is a threat to national security but, in some respects, it may increase the security of an individual citizen.	12,0
Small particle accelerators, femto and nanolasers	The information provided by laser scanners increases security and devices that operate with lasers can both threaten and protect people. Particle accelerators can kill unknowingly.	12,0
Neural networks and deep learning	Artificial intelligence can detect security problems and guide safe practices on a case-by-case basis.	11,4
LED-farming, robotic farming	Individual cultivation both increases and reduces safety. Maintenance assurance increases.	10,8
Verbot/chatbot, talking/corresponding robots	Security related interviews can be automated and anomalies may become easier to find using verbots.	10,0
AR & VR platforms and content standards	VR content can be dangerously intense emotionally or cause other problems.	10,0
Cheap small fuel cell and micro-turbine CHP	Monitoring equipment and base stations can operate on a fuel cell and fuel tank.	10,0
Radical water-borne traffic	Robot ships eliminate the insecurity and mistakes of the crew. Lightweight hulls make the ships unsinkable.	10,0

Growing professions and skills shortages
The decentralisation of threats and their becoming more complex generates many new types of jobs and skills requirements. Growing new professions related to safety and security include, for example, cloud security service consultant, cyber security consultant, home security technician, security janitor, self-sufficiency planner, personal security remote controller, cyber security police, manipulation detective and fake news prevention officer. Assessors of the impact of international crises and risk analysts will also be needed more in the future.
Policy objectives of the change
The change can be promoted by many measures. Peer to peer security information platforms should be catalysed and a framework created for them. The authority should help with generating operations. Capacities should be developed for cyber security operations and the authority should support households in cybercrime and fake news prevention. Personal security cameras should be allowed and the artificial intelligence related to them should be clearly outlined outside the EU Privacy Policy (GDPR). The role of super sense platforms should be investigated and shifting the emphasis to monitoring performed by the consumer should be explored. Threats and harassment in the virtual world should be inspected and the possibility of people to move safely in public virtual market places should be ensured.

REMOTE IMPACT Easy and safe impact on things and events in places where the impacter itself is not physically present.	
Dominant regime: Telephone, television, internet, social media	**Challenger regime:** VR/AR, avatars [robots and devices enabling telepresence] and other remote control

Key ARTs and effectiveness index of the challenger regime	
Commercial platforms for sharing economy	120
AI performing local work on global basis	80
Verbot/chatbot, talking/corresponding robots	50
Walking robot and walking assists	50
New robotised services	40
Facial and emotion recognition and projection	40
Environment scanning & positioning	35
Encrypted and anonymous telecommunications	30
P2P trust solutions, blockchain	30
Speech recognition, speech synthesis and interpreting	30
Quantum computers and quantum communication	30
Easier access to space	30
VR-glasses, MR-glasses and virtual reality	30
Robotised physical remote work, AI as superior	30

The most rapidly advancing technologies of the challenger regime

ART	**Applications of the ART**	**Developm. rate**
P2P trust solutions, blockchain	Remote impact will be easier if a blockchain is used for certifying a contract or transaction instead of a registration authority or pledgor in compliance with the local legislation.	13,8
MyData & GDPR	GDPR moderates remote effects but, at the same time, creates practices for data portability that enable even more extensive remote impact.	13,0
Biotechnical meat and meat imitations	The use of cultured meat as nutrition increases the possibilities of remote impact in food production with 3D printing and bio-design of meat.	12,1
AI performing local work on global basis	Any kind of remote impact can basically be carried out by a global AI.	12,0
Small particle accelerators, femto and nanolasers	Remote-controlled devices can explore their surroundings with laser techniques.	12,0
Neural networks and deep learning	Artificial intelligence is a useful help in avatars, as well as in other types of remote impact.	11,4
LED-farming, robotic farming	Farming can be controlled remotely and the overall functionality of robot farming can be delivered globally.	10,8
Verbot/chatbot, talking/corresponding robots	Verbots/chatbots can be given tasks and they can participate in countless online discussions and learn and copy the most influential arguments.	10,0
AR & VR platforms and content standards	VR glasses are used for remote control. A person using AR glasses can be impacted by placing holograms in his/her visual field. The platform ensures compatibility.	10,0
Radical water-borne traffic	Remote-controlled and robotic water vessels provide a clear opportunity for remote impacting things and events.	10,0

Quantum computers and quantum communication	Breaking public key encryption opens up great impact opportunities. Quantum communication provides reliable channels encrypted from all operators.	8,2
Global wireless broadband	Remote impact requires telecommunication standards. Impacting through robots requires low latency, high speed and general ICT interfaces.	7,2
Growing professions and skills shortages		
The possibility to do physical work without commuting increases the demand for services, in which an expert performs the task requested with an avatar. There will be more jobs related to the organisation of services that enable telepresence. Jobs related to the prevention of risks of remote impact will increase substantially. Growing professions include, for example, avatar cook, avatar musician, avatar doctor and avatar maintenance officer. Cyber security guard, VRAR counselor, trainer of robotised remote work, avatar guide customiser, avatar prevention officer, artificial intelligence controller, data analyst and IoT risk analyst will also become necessary professions.		
Policy objectives of the change		
Using an avatar to access public services should be enabled. Maintenance and monitoring should be carried out with avatars wherever appropriate and experiments should be initiated quickly. Legislation related to these practices should be reviewed. Passing the responsibility to an autonomous robot and a partly autonomous or completely controlled avatar and remote controller should be reviewed and clarified. Avatar telepresence should be equated with physical presence in as many cases as possible. This principle has an impact on numerous legislations and their implementation. One example is the copyright, where the concept of a private event should be extended to a private type telepresence. Individualised mass communication carried out through artificial intelligence and social media should be regulated in a way that prevents a deliberate and extensive manipulation with incorrect information.		

EXISTENTIAL MEANING Experiencing own existence and functions as meaningful, typically through self-realisation, serving others or joining a greater story or mission.	
Dominant regime: Work, position, social network	**Challenger regime:** Achievements, likes, participation, communities

Key ARTs and effectiveness index of the challenger regime

VR-glasses, MR-glasses and virtual reality	60
Biotechnical meat and meat imitations	50
Facial and emotion recognition and projection	40
DNA reading and writing (full genome)	35
Fast and dense memory materials	35
Speech recognition, speech synthesis and interpreting	30
Commercial platforms for sharing economy	30
Memristors and neural processors	30
Curing and preventing dementia	30
LiFi networks and other LED technology	30
LED-farming, robotic farming	30
Radical longevity	30
Neural networks and deep learning	25
Global wireless broadband	25
Flipped learning and proficiency demonstrations	25
Personal health diagnostics systems	25
Walking robot and walking assists	25

The most rapidly advancing technologies of the challenger regime

ART	**Applications of the ART**	**Developm. rate**
Biotechnical meat and meat imitations	Animal welfare is a very important and meaningful objective for many people.	12,1
AI performing local work on global basis	A global artificial intelligence can affect the existential meaning in many unpredictable ways.	12,0
Neural networks and deep learning	Teaching AI's can be one of the meanings of life and represent the continuity of one's own thoughts or development of memes instead of helping fellow men and animals.	11,4
LED-farming, robotic farming	Nothing is as important as gardening – this idea will gain followers.	10,8
Verbot/chatbot, talking/corresponding robots	A human being experiences a conversation as meaningful and as having an existential meaning. A talking machine is a more intense conversational partner than a book and can strengthen the sense of existential meaning.	10,0
New separation techniques and circular economy	Sustainable development is an important pursuit and continuity is one of the cornerstones of meaningful life.	10,0
Hyperloop and other tunnel technology	As the commuting and services areas expand, opportunities for creating meaningful communities and being part of them increase.	9,6
Quantum computers and quantum communication	Due to many turbulences associated with trust, many people's belief in the existential meaning of life shakes. The multiverse idea makes choices unnecessary on the philosophical level.	8,2
Global wireless broadband	A high-quality presence of the VR/AR world can increase the sense of existential meaning.	7,2

Genetic editing techniques, CRISPR/Cas9	Adult human genome editing makes a man become his own creator and those for whom life is a performance will have access to new tools.	7,0
Growing professions and skills shortages		
New and growing professions include, for example, value consultant, meaning designer, gamification officer, self-sufficiency consultant, self-sufficiency supply vendor, life management guide, virtual living environment developer, cohesion manager, needs hunter, logo therapist, gestalt therapist, tribal manager, AI friend shepherd, e-sport manager, noise cancellation technician and AI awareness mechanic.		
Policy objectives of the change		
The removal of obstacles for economy of smallness promotes the increase of existential meaning. In practice, this means reducing the burden of bureaucracy especially among small operators. New community of purpose contributions should be generally recognised when only traditional forms of action are currently publicly emphasised. The decision-making power should be delegated from the physical local level and state to societies. Subsistence economy should be enabled on the community level at least in terms of production, energy, education and food. Obstacles to development and experimentation should be dismantled. Regulatory needs that prevent or moderate the emerge of harmful isms or destructive ideologies should be clarified.		

POWER STRUCTURES Productive and equal decision-making in collaboration, in public activities.	
Dominant regime: Regional power structure, opaque power	**Challenger regime:** Subject-matter subsidiarity, place independence

Key ARTs and effectiveness index of the challenger regime

Neural networks and deep learning	100
AI performing local work on global basis	80
Crowdfunding and microfinancing	60
Flipped learning and proficiency demonstrations	50
Radical growth in computing power	40
Cloud computing and storage services	35
VR-glasses, MR-glasses and virtual reality	30
Commercial platforms for sharing economy	30
Memristors and neural processors	30
P2P trust solutions, blockchain	30
Robotised physical remote work, AI as superior	30

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Structures of trust shift outside national operators and to ownerless structures. Exercising the power by the state may be insufficient in conflict situations.	13,8
MyData & GDPR	People are more in charge of the information collected of them and can use information as a means of payment. This reduces the power of platforms and increases the potential of collaboration.	13,0
AI performing local work on global basis	Decision-making can become very challenging if a multitude of artificial intelligence services optimise the whole and master the details. Many decisions will be made on the global level.	12,0
Neural networks and deep learning	Artificial intelligence can be used for raising issues affecting decisions and decision backgrounds, evaluating the quality of decisions and showing the best choices in relation to goals.	11,4
Verbot/chatbot, talking/corresponding robots	A personal artificial intelligence agent can help decision-makers to find and remember the issues needed for decision-making and negotiations and promote smooth administration.	10,0
New separation techniques and circular economy	Understanding the circular economy is one of the key decision-making issues. Becoming more common increases understanding. Systematic modeling helps decision-makers.	10,0
Hyperloop and other tunnel technology	As the commuting and services areas expand substantially differing from regional limits, tensions increase and making of good decisions becomes more difficult.	9,6
Quantum computers and quantum communication	The changes will be great and “surprising” because decision-makers have not anticipated them and the impact on the competency of decisions is clearly negative.	8,2
Self-organising and swarm intelligence	The idea of self-organising processes and their modelling develops social modelling as a self-organising process at the same time.	7,8
Global wireless broadband	Decision-making on network infrastructure has shifted on the global level.	7,2

Growing professions and skills shortages
Decision-making information systems will substantially change due to IT skills of citizens, digitalisation and artificial intelligence. This also affects the regional distribution of power. As a result of the change, new and growing professions include, for example, simulation expert, crowdsourcing coordinator, data reliability analyst, happiness operator, career operator, ecosystem developer, metadata coordinator, artificial intelligence reliability supervisor, administrative gamification officer, caller for administration tender, artificial intelligence administration moderator, artificial intelligence administration inspector, prioritisation effect simulator, administration platform developer and administration platform moderator.
Policy objectives of the change
Resource balance-based calculation should be used instead of gross domestic product. Observation of externalities should be developed. Reviewing issues that are suitable and unsuitable for market operators should be systematically performed based on the transaction cost theory created for the purpose instead of sphere of influence thinking. Greater transparency and social responsibility should be required from organisations operating based on privileges granted by the society. The subject-matter of administrative subsidiarity principle should be clarified and the responsibilities of municipalities should be further reduced in matters in which distances are not that important. Responsibility for the development of administration platforms should be passed to someone and a framework should be created for an artificial intelligence administration. Democracy for alternative administrations should be prepared. The management system of large administration offices should be reviewed and a politically elected administration board or an elected management should be considered as alternatives. Decision criteria and their simulation must be made transparent and citizens must be provided with public simulation models.

PRODUCING EXPERIENCES

Emotional experiences, the joy of insight and shared experiences generated intentionally in different contexts.

Dominant regime:
Focus on producers and consumers, mass entertainments, tourism

Challenger regime:
Games, shared VR, AR, interaction, AI

Key ARTs and effectiveness index of the challenger regime

Transportable batteries and supercondensators	70
VR-glasses, MR-glasses and virtual reality	60
Reading and editing thoughts from the brain	60
Neural networks and deep learning	50
Verbot/chatbot, talking/corresponding robots	50
Smart glasses, AR glasses and augmented reality	50
IR, THz and GHz transmitters and receivers	50
Facial and emotion recognition and projection	40
Digital art and experience platforms	40
Radical growth in computing power	40
New robotised services	40

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
MyData & GDPR	Preferences are saved on experience platforms, from where they can be transferred to other platforms based on conditions defined by the GDPR.	13.0
Biotechnical meat and meat imitations	Cultured meat can be very exotic, both genetically and in texture.	12.1
AI performing local work on global basis	A global artificial intelligence will be able to embroider experiences culturally and locally. Experience industry will rely on artificial intelligence on global basis to a significant extent.	12.0
Small particle accelerators, femto and nanolasers	Femto lasers can be used for creating 3D images in the air. Lasers can produce light art.	12.0
Neural networks and deep learning	Artificial intelligence can be used for producing art experiences, companion computers, role characters, natural and emotional landscapes and for assisting in the production of entertainment.	11.4
LED-farming, robotic farming	An private garden and possible GMO production can provide experiences.	10.8
Verbot/chatbot, talking/corresponding robots	A communicative and learning AI-toy is an experience. A game that individually responds to the player is an experience. In future network games, it will be impossible to tell which players are humans.	10.0
AR & VR platforms and content standards	A standardised AR/VR platform is important for content production so that the market will be sufficiently large and the development work profitable. Platform development enables content of good quality.	10.0
Radical water-borne traffic	Foiling is an exciting way to move on water in all of its forms. Robotisation facilitates and diversifies water-borne traffic in many ways.	10.0
Hyperloop and other tunnel technology	A fast transition from one place to another increases leisure travelling and is in itself an experience.	9.6
Self-organising and swarm intelligence	Monitoring activities that are self-organising and lead to emergence is an experience.	7.8

Growing professions and skills shortages
It is obvious that new technology opens up enormous opportunities for experiences. Growing new professions include, for example, location information expert, virtual service manager, virtual remote guide, virtual decorator, parlor game assistant, e-sports coach, e-athlete, experience guide, real VR star, VR event coordinator, VR therapist, online game coach, AR/VR haptic costumier and haptic supporter. Concierge services will be extended to everyday hedonism and there will inevitably be also sex robot pimps. Virtual travel officer, substitute traveller, experience stimulator and experience developer will emerge as new professions. Experience producers are needed for developing working in companies and customer experiences. With robotisation, craftsmen will again be a major profession group as they guide machines for individual production and finalise these "handicrafts" produced by tools.
Policy objectives of the change
The phenomena of virtual reality and expanded reality should be regulated as a private and public space and taken into account in the Copyright Act. The police's right to access VR facilities should also be clarified and defined on the basis of this allocation. In order to pass responsibility to the artificial intelligence, a framework and practices should be created that will make it possible to record the actions of the artificial intelligence that essentially affect an individual. Individually generated intense experiences could have serious consequences for a person and the potential disadvantages of this area should be explored extensively, both on the part of deliberate influence and drug-like use. The distinguishability of AR signs and advertising should be considered, as well as subconscious and manipulative influence as part of the experiences.

HEALTH CARE A person living his/her life healthily while the body and mind remain functioning and staying well-being and beautiful as long as possible.	
Dominant regime: Healthcare system, general health recommendations	**Challenger regime:** Self-diagnostics, gamification, individual nutrition

Key ARTs and effectiveness index of the challenger regime

Personal health diagnostics systems	100
Microbiome, metabolism and genetics of cells	80
DNA reading and writing (full genome)	70
Radical longevity	60
Curing and preventing dementia	60
Neural networks and deep learning	50
Material scanner – hyperspectral camera	50
Genetic editing techniques, CRISPR/Cas9	50
AI performing local work on global basis	40
Nanoparticles and microbots in mammal body	40
Cyborgs uniting biology and mechatronics	30
New nanomaterials in electronics	30
Repair of organs, cultivating cells	25
Biotechnical meat and meat imitations	25

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
MyData & GDPR	Transfer of health-related data enables use of alternative services.	13.0
Biotechnical meat and meat imitations	Cell cultivations can be programmed to produce individual nutrition as needed.	12.1
AI performing local work on global basis	A human being is the same everywhere and diagnosis can be the same as well as major part of the lifestyle coaching.	12.0
Small particle accelerators, femto and nanolasers	Small particle accelerators, THz-waveband femto lasers etc. enable the examination of a body and early detection of possible problems.	12.0
Neural networks and deep learning	Artificial intelligence is able to monitor early symptoms, diagnose illnesses, advise on healthy lifestyles and encourage to adapt them.	11.4
LED-farming, robotic farming	Increasing individual needs-based production and improving freshness by utilising local manufacturing enhance the health effects of food.	10.8
Verbot/chatbot, talking/corresponding robots	A communicative (emotional) machine can have a positive effect on health.	10.0
New separation techniques and circular economy	Separation techniques can make it possible to filter out unhealthy substances from food and also from blood circulation.	10.0
Microbiome, metabolism and genetics of cells	Understanding cell metabolism, microbiome and genome is necessary when avoiding individually unhealthy lifestyles and planning individual nutrition.	9.0
New power sources for vehicles	Internal combustion engines increase unhealthy fine particle concentrations of breathing air.	7.8
Genetic editing techniques, CRISPR/Cas9	Adult human genome can be corrected. GMO food can be made more healthy than natural food on an individual level.	7.0

Growing professions and skills shortages
Health is a vital thing for people and individuals can use more of their resources on it if the effectiveness is clear to them. Numerous new jobs will emerge from individual health care. Examples of growing professions include DNA analyst, microbiome counsellor, biomarker interpreter, charlatan teaching how to use self-diagnosis tools, self-diagnostic tool maintenance technician, biosecurity jurist (judge, council member, attorney), bioconsultant, medication printer, DNA modifier, amino acid cook, well-being coach, diagnostic coach, self-diagnosis inspector, digital therapist, implant installer, digital tattooist, biodetective and biorisk mapper.
Policy objectives of the change
Publicly funded information sources of doctors should be made public information. Self-diagnosis guidelines should be developed and equipment used for self-diagnosis should be tested and inspected. DNA testing of the population should be developed and favoured. Nutritional recommendations should be tied to the information about human genome and equipment enabling gamification should be developed by the society for this purpose. Responsibility limits of the doctor, patient and pharmacy should be revised taking into account the development of self-diagnosis. Responsibilities of equipment manufacturers should be defined in relation to self-diagnosis. The control and certification of self-diagnosis equipment and lifestyle applets should be organised. The prioritisation of the public funding of expensive individual treatments should be carried out.

MATERIALS Cost-effective supply of raw materials and materials used in production of goods, chemical industry and construction with minimal negative impacts and sufficient quality.	
Dominant regime: Mining based products, energy-heavy process industry	**Challenger regime:** The circular economy, renewable materials

Key ARTs and effectiveness index of the challenger regime

DNA reading and writing (full genome)	70
Nanomaterials as fibres, fabrics and reinforcement	60
Lab on a chip	40
Plant and animal fibres, nanocellulose	40
Structural materials replacing concrete	40
Rapid development of photovoltaics	35
Carbon capture and CO2 usage as raw material	30
Simulating living cells, artificial cell	30
Easier access to space	30
Production of nanomaterials	25
New separation techniques and circular economy	25
Material scanner – hyperspectral camera	25
Repair of organs, cultivating cells	25
DNA reading and writing (full genome)	70
Nanomaterials as fibres, fabrics and reinforcement	60
Lab on a chip	40
Plant and animal fibres, nanocellulose	40

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Materials can be recorded by material batches in the blockchain for recycling in a way that links them to products and remains until scrapping.	13,8
AI performing local work on global basis	Designing of new tailored materials can be a global AI service.	12,0
Neural networks and deep learning	Designing of new materials and their production with artificial intelligence.	11,4
LED-farming, robotic farming	Raw material efficiency improves in a closed cycle.	10,8
New separation techniques and circular economy	The use of waste and byproducts as raw materials will be easier with new separation techniques.	10,0
Radical water-borne traffic	The plastic waste in oceans can be collected with robot vessels to be used as raw materials.	10,0
New power sources for vehicles	The extensive growth in demand for batteries affects the demand for rare metals.	7,8
Self-organising and swarm intelligence	Materials grown by GMO bacteria.	7,8
New methods to manipulate substances	The development of new raw materials, especially meta materials, is likely to benefit from new types of manipulation methods of subtances.	7,8
Genetic editing techniques, CRISPR/Cas9	GMO techniques have become easy and accurate. They contribute to the development of GMO-based material production.	7,0

Growing professions and skills shortages
The change will result in the following new professions, for example: Biomaterial tutor teaches bacteria and yeasts with genetic modification to produce new materials and structures. Nanosurface engineer and nanofibre engineer design new materials and their manufacturing methods and applications. Nanocarbon structure designer and MOF designer are material structure designers for special needs. Material modeller is a common term for these and other professionals who design materials by using computer techniques. The number of separation technicians and recycling technicians will significantly grow and their expertise differs from the current one and shifts into a more technical direction. Recycling strategy planner will be an important decision-maker along with industrial designer. Raw material needs analyst will find out which raw materials should be used at a given time and, as the raw material selection and manufacturing methods multiply and the individual production increases, this need will grow rapidly.
Policy objectives of the change
The need to regulate GMO material production needs to be reviewed. The replacement of concrete and iron with new structural materials should be made easier by developing common recommendations and approval procedures. The utilisation of mineral products should be perceived as a burden to the natural resources balance sheet in the same way that using stocked raw materials affects the balance sheet. Therefore, in the national economy calculations, decrease in existing resources, externality and unsecured liabilities should be registered alongside with income as a reducing entry. Material requirements should be made functional in their entirety instead of mentioning the actual materials in the regulations. Users of recycled materials should be appointed the recipients of environmental protection charges.

ENERGY SUPPLY Need-based, acceptable and reliable energy for buildings, transportation, machines and processes in a cost-efficient way.	
Dominant regime: Centralised and fossil energy sources, peaking power plants	**Challenger regime:** Renewable, decentralised energy sources and energy storage

Key ARTs and effectiveness index of the challenger regime

Rapid development of photovoltaics	140
Grid level energy storage	100
Cheap small fuel cell and micro-turbine CHP	50
Transportable batteries and supercondensators	35
LED-farming, robotic farming	30
Small fusion and fission plants	30
New power sources for vehicles	30
Cheap efficient storage of hydrogen	30
Artificial leaf and synthetic fuels	30
Plasmonics and photonics	30

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Electricity trading of the peer-to-peer network can be registered to the blockchain.	13.8
Neural networks and deep learning	Optimisation of the storage capacity, energy production and maintenance of the grid.	11.4
LED-farming, robotic farming	LED farming will be a major consumer of energy and a reducer of the need for load following plants.	10.8
New separation techniques and circular economy	Bioenergy is produced from waste that cannot be recycled. The development of the separation technique improves the quality grade.	10.0
Cheap small fuel cell and micro-turbine CHP	The use of renewable synthesized fuel in fuel cells enables carbon neutral driving, heating and seasonal/reserve power with low storage costs.	10.0
Radical water-borne traffic	An electric, lightweight inland barge affects the form in which energy is distributed and consumed.	10.0
New power sources for vehicles	Vehicle electrification significantly affects the ratio of energy forms, increases the use of electricity and acts as an electricity storage most likely smoothing fluctuations of demand.	7.8
Cheap efficient storage of hydrogen	Hydrogen can efficiently and effectively be separated from water with electricity and light and be recombined with oxygen into water if hydrogen storage can be easily carried out.	6.6
New robotised services	Robotised cleaning services are needed for solar panels.	6.0
New nanomaterials in electronics	Energy storage with new electronics materials and more energy efficient electronics.	6.0
Smart materials and their simulation techniques	Smart materials are related, for example, to batteries, other energy storages, solar energy, its transformation to fuels and fuel cells. Simulation is an important development technique.	6.0
Off-Grid and Micro-Grid solutions	Decentralised energy and strive to break away from the grid will become more common and affect the profitability of centralised solutions and the grid.	6.0

Growing professions and skills shortages
New professions emerging from the change or growing due to it include, for example, local energy mechanic, local energy storer, energy storage predictor, fuel cell vendor, wind turbine maintenance technician, fuel distributor, off-grid maintenance inspector, solar panel cleaner and energy scrap recycler. The number of energy cooperative officers and energy advisers should also be growing and the need for energy sector know-how should completely change from its current status.
Policy objectives of the change
Selling of electricity should be allowed regardless of the national grid by utilising the internal networks of small communities. An experimental law should be stipulated for this kind of electricity cooperatives that are based on microgrid thinking. The shared use and exchange of electricity should be enabled in these as a peer-to-peer activity in sharing economy-like structures separated from the obligations related to the national grid. Kite energy should be allowed first in an experimental mode and distinguished from the handling of other aircraft. Energy storages should be allowed as part of the operations of a transmission network operator. This can be done, for example, so that the user rents storage space if needed when electricity is inexpensive and uses the electricity storage when electricity is expensive or the capacity limit is about to exceed.

COLLABORATION AND TRUST Increasing collaboration on issues that produce synergistic benefits by supporting transparency, risk management and trust.	
Dominant regime: Guaranteed by authorities, brands and hierarchies	**Challenger regime:** Peer-to-peer trust through platforms and transparency

Key ARTs and effectiveness index of the challenger regime

Speech recognition, speech synthesis and interpreting	60
AI performing local work on global basis	40
Gamification of collaboration and society	40
Cloud computing and storage services	35
Commercial platforms for sharing economy	30
Crowdfunding and microfinancing	30
Material scanner – hyperspectral camera	25
Neural networks and deep learning	25
Global wireless broadband	25
M2M trade and other online commerce	25
Pattern recognition and other AI platforms	25
Flipped learning and proficiency demonstrations	25

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	The blockchain facilitates collaboration and increases trust.	13.8
MyData & GDPR	The forced customer data portability obligation increases collaboration.	13.0
AI performing local work on global basis	A global artificial intelligence can identify needs of exchange and optimise them effectively. It can be learned to be trusted and collaboration can significantly increase.	12.0
Neural networks and deep learning	Artificial intelligence identifies frauds, which increases trust and collaboration. Artificial intelligence also helps to perceive needs and solutions which adds its positive effects.	11.4
Verbot/chatbot, talking/corresponding robots	Verbots as a part of platform economy improve collaboration between people.	10.0
AR & VR platforms and content standards	Exchange is possible if the platform is shared.	10.0
Hyperloop and other tunnel technology	As the commuting and services areas expand, collaboration improves.	9.6
Quantum computers and quantum communication	Trust in existing public key encryption crashes. Trust in the total encryption of quantum communication grows.	8.2
Global wireless broadband	Improving communication connections to the level of shared virtual reality improves collaboration.	7.2
Speech recognition, speech synthesis and interpreting	Interpretation enhances collaboration between people speaking different languages.	6.4

Growing professions and skills shortages
Currently, a large number of legal practitioners, software designers, and economists negotiating on agreements are employed by structures of trust. Transition of structures of trust significantly affects the content of their job. New and growing professions include trust leader, trust consultant, voluntary work lobbyist, crowdsourcing recruiter, P2P work moderator, motivation planner and predictor and crowdfunding manager.
Policy objectives of the change
The most important objectives should include clarifying sanctioning and control activities related to P2P trust structures, defining certification levels for different levels of P2P trust, moderating network effects in order to avoid dominance, clarifying the ownership of volunteer work content and blockchains, formalising P2P trust on the same kind of level as regulatory approval and degrees and increasing competition in record keeping as well as transferring it, where appropriate, to P2P networks both on the private sector and public registers. The possibility of standardising metadata and interfaces related to trust should be clarified.

PROFICIENCY AND ITS PROOF Demand controlled proficiency and proficiency demonstrations – emphasising the recognisability of proficiency, sensemaking and procedural and methodological skills.	
Dominant regime: Educational institutions and qualifications, on-the-job learning	**Challenger regime:** Flipped learning and independent learning, AI, proficiency demonstrations

Key ARTs and effectiveness index of the challenger regime

Flipped learning and proficiency demonstrations	100
AI performing local work on global basis	80
Neural networks and deep learning	50
Facial and emotion recognition and projection	40
Smart materials and their simulation techniques	40
Gamification of collaboration and society	40
3D printing of things	35
Speech recognition, speech synthesis and interpreting	30
VR-glasses, MR-glasses and virtual reality	30
Commercial platforms for sharing economy	30

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
P2P trust solutions, blockchain	Theses etc. can be registered in the blockchain in an indisputable way.	13.8
AI performing local work on global basis	In principle, a global artificial intelligence can learn and teach the basics for virtually all kind of proficiencies. A global artificial intelligence can also efficiently evaluate the proficiency of a person.	12.0
Neural networks and deep learning	Artificial intelligence can evaluate the proficiency of a person. Demonstrating proficiency will become easier for a layperson and be separated from the institution that provided the education. Artificial intelligence is also important as a teacher.	11.4
Verbot/chatbot, talking/corresponding robots	AI can have conversations with the student and help to understand necessary things or ensure they were understood. Verbot/chatbot can also evaluate the proficiency.	10.0
Global wireless broadband	Wireless networks significantly facilitate on demand learning.	7.2
Speech recognition, speech synthesis and interpreting	Speech technology helps to learn and understand foreign languages. It also helps to show own proficiency to another verbal person.	6.4
VR-glasses, MR-glasses and virtual reality	With VR glasses, simulated environments help to understand cause-effect relationships of things and also show when they have been understood and when not.	6.0
Digital art and digital experience platforms	Proficiency on the platform is indicated by likes.	6.0
Smart materials and their simulation techniques	Simulation techniques provide a very good tool for demonstrating proficiency. The behavior of materials can be understood more easily than before with simulation.	6.0
Radical longevity	More and more formal proficiencies are outdated and the need for demonstrating proficiency regardless of studies increases.	5.3

Growing professions and skills shortages
As a result of the change, growing and new professions include, for example, organisation physician, multiple intelligences organiser, artificial intelligence examiner, AI psychologist, AI-assisted cyborg, gamification officer, context analyst, meta analyst, simulation producer, simulation developer, proficiency inspector, remote trainer, proficiency network officer, proficiency path counsellor, remote learning mentor, certification manager and social media reputation improver.
Policy objectives of the change
In order to promote change, proficiency demonstrations required by the decrees should be removed from the education and entrance exams of educational institutions. Qualification requirements for public appointments should be changed to contextual. Customer evaluations on the capability of public services should be made public. All public education should be produced on information networks on the MOOC platform. All basic education should be transformed into flipped learning and, in this context, job descriptions of teachers, lesson hour quota and principles of compiling study materials should be changed. Methods of simulation and gamification should be increased in teaching, contents of teaching should be reformed and contents should be regularly evaluated by actors other than teachers. Study materials of public education should be freed by crowdsourcing or public funding and exercises should be carried out with artificial intelligence so that the feedback is immediate.

REDRESSING DISABILITIES

Compensating functional deficiencies and optimising the functional ability of a person in everyday life with assistive devices and by facilitating the operating environment, taking into account the social costs and benefits.

Dominant regime:	**Challenger regime:**
Institutional, outpatient and family care, cheap assistive devices	Robotics, AI, avatars [robots and devices enabling telepresence], artificial organs, crowdsourcing

Key ARTs and effectiveness index of the challenger regime

Cyborgs uniting biology and mechatronics	60
Speech recognition, speech synthesis and interpreting	60
Personal health diagnostics systems	50
Autonomous cars and trucks	50
Walking robot and walking assists	50
Microbiome, metabolism and genetics of cells	40
DNA reading and writing (full genome)	35
Transportable batteries and supercondensators	35

The most rapidly advancing technologies of the challenger regime

ART	Applications of the ART	Developm. rate
AI performing local work on global basis	The contribution of a global artificial intelligence in restoring functional ability is limited.	12.0
Neural networks and deep learning	Artificial intelligence can assist in deficiencies of functional ability, such as sensory impairment, as part of various prostheses and as a general counsellor, for example, for a person with a memory disorder.	11.4
Microbiome, metabolism and genetics of cells	Deficiencies of functional ability of the body can be compensated artificially when the functional mechanisms are understood well enough.	9.0
Global wireless broadband	Securing functional ability may require the help of a cloud service and a high-speed connection to it.	7.2
Genetic editing techniques, CRISPR/Cas9	Growing of GMO artificial organs contributes to the restoration of functional ability.	7.0
Speech recognition, speech synthesis and interpreting	Speech technology is an important aid to deaf, dumb and visually impaired for various reasons.	6.4
VR-glasses, MR-glasses and virtual reality	In a virtual world, a person is able to experience and do many things with the help of avatars that would not be possible in the real world.	6.0
New robotised services	Avatar services for people with limited functional ability make it easier to cope with everyday life.	6.0
New nanomaterials in electronics	Electronics that are permanently placed within body as part of it will be enabled.	6.0
Cryogenics of biomaterials	Organ transplantations become easier to carry out when longer transportation times are allowed as cryogenics improves.	6.0

Growing professions and skills shortages

Nousevia ja uusia ammatteja ovat mm. proteesinsäätäjä, proteesitulostaja, AI-avustajan ja AI-valvojan ohjaaja, etiäislähiavustaja, etiäiskauko-ohjaaja, escort-seuranpitäjä, keinoelinkasvattaja, keinoelintarkastaja ja aivoimplanttien konfiguroija. Uudet ammatit liittyvät apuvälineiden säätämiseen, konfigurointiin ja sovittamiseen, automaation luomaan sosiaaliseen tyhjiöön sekä etiäisavustustyöhön ja keinoelimiin.

Policy objectives of the change
Tärkeimpiä säädöstavoitteita ovat yleinen apuvälineiden aseman kohentaminen suhteessa mm. esteettömään rakentamiseen ja erityisesti robottiraajojen edistäminen, varhaisen vaiheen dementikkojen avustaminen tekoälyn keinoin, kuntoutuksen digitalisointi ja pelillistäminen, joukkoistusavun alustojen tukeminen, etiäisapuvälineiden sisällyttäminen tuen piiriin sekä näkövammaisten tekoälyyn ja laajennettuun todellisuuteen liittyvien avustimien edistäminen.

SOCIETAL TRANSFORMATION 2018–2037

100 ANTICIPATED RADICAL TECHNOLOGIES, 20 REGIMES, CASE FINLAND

Risto Linturi and Osmo Kuusi

Summary

This report describes a hundred rapidly evolving technologies that have a radical impact. The analysis covers all significant areas of organised activity and the most essential goals of individual activity. Impacts are anticipated with the help of twenty value-producing networks. Each of these networks is described through their main purpose, key values and potential transformation.

The impacts of several of the introduced technologies alone are expected to exceed the impact of the Internet and smartphones on the activities of organisations and the everyday lives of individuals by 2037, the chosen year of evaluation. The new operating models presented in the report that will challenge the current basic structures of society are maturing quickly. We should also consider the possibility of the start of a new Kondratiev cycle and a potential crisis arising from the rapid transformation of socioeconomic structures.

This report leans on thousands of sources compiled by hundreds of experts, with roughly 1,600 of the links included in this report. The sources explain the detailed development background of the highlighted technologies. In addition to the technologies, this report also lists 2,000 areas of application or social impacts, 250 new professions and 100 legislative objectives or areas of development in administration that are enabled by these technologies.

This is a completely updated edition of the report "Suomen sata uutta mahdollisuutta" that was published in 2013 (English translation, "100 opportunities for Finland and the world," published in 2014). All sources, as well as the value-producing networks and descriptions of technologies, are new. Technology evolves rapidly. The method has been refined, but the foundations remain the same. In addition to Finland, the original report drew widespread attention within the EU and OECD, and it has been utilised in development work by companies, authorities and regional developers.

Anticipating the social transformation caused by radical technologies will be increasingly important as the pace of development accelerates, and this report does so in a more extensive and systematic way than any of its predecessors. New opportunities have been evaluated as open-mindedly and openly as possible, as new observations often make even improbable development paths possible. All the sources, conclusions and evaluation criteria of the systematic evaluation can be found in this report and its sources.

We want to challenge decision-makers and all Finns to join us in developing these technologies in order to provide Finland with new strengths. Being at the forefront of technological development depends on good cooperation between political decision-makers and companies, the methods of the attention economy, the boldness of the government as a market-leading client, and relaxing the legislation for the best practices of the new technologies.

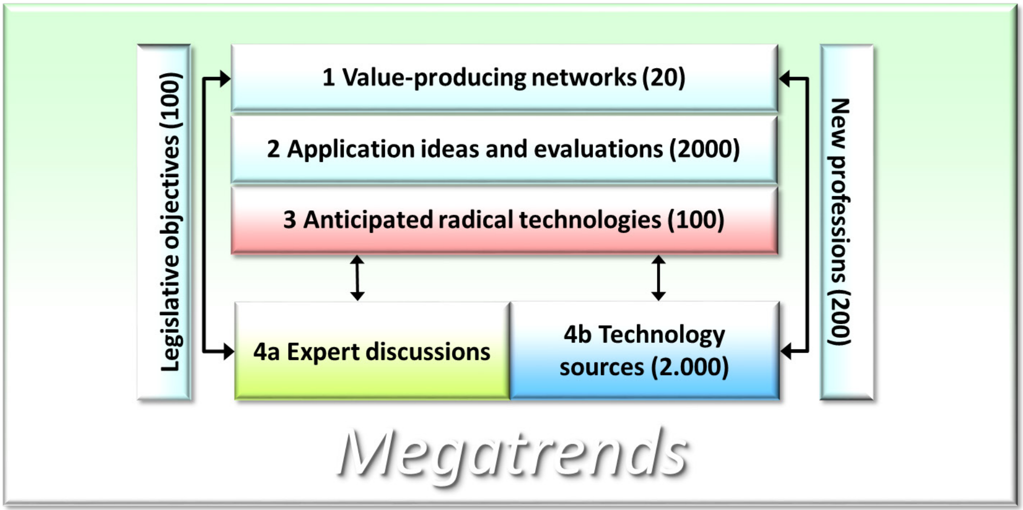


Figure 1. Radical Technology Inquirer (RTI). The original Finnish name of the model is Nelitasomalli (lit. four-level model).

Background – megatrends

The model stems from megatrends and the level of general changes. As the name implies, megatrends are large-scale development trends, often even consequences of the combined effects of conflicting development trends. In this report, megatrends form a general frame of reference that we will come back to in the summary.

Level 1 – value-producing networks

The most extensive concrete description is provided at the level of value-producing networks. According to the definition formed in this report series, value-producing networks seek to cover all areas of life and society, human needs and social problems in the broadest sense. In each value-producing network, the report highlights the areas of the greatest visible change, i.e. volatility. This is done by describing the current state of things and the systemic operating model that may potentially challenge it as each other's opposites in a pointed way.

Value-producing networks are global, but their descriptions are proportioned to the scale of Finland by utilising figures of the Finnish national economy. This is necessary when evaluating the significance of development with regard to the expenditure of the Finnish national economy. In terms of their export potential, every value-producing network offers opportunities that are substantially greater than the scale of Finland's export industry. When evaluating the year 2037, the most important factor anticipating Finland's export potential is the nature of demand in Finland. Because of this, the report does not particularly emphasise the current export industries.

In identifying value-producing networks, we have sought to identify major value propositions that are as mutually independent and orthogonal as possible. Of course, the value-producing networks are dependent of each other, but the main added value of each deviates from the others. In this context, value-producing networks are not exactly the same as "the market." We are talking about "clusters of needs" arising from individual and collective motives. As a result, fields of individual and collective, as well as public or market-based, activity arise to meet these needs. These either increase or undermine the well-being of the citizens.

Level 2 – Application ideas and evaluations

Level 2 links the value-producing networks and radical technologies to each other. Application ideas are short-term future scenarios in which individual technologies are expected to develop rapidly, and the potential consequences of this development are evaluated for each value-producing network in the form of application ideas. Each of the 100 anticipated radical technologies is examined separately in relation to each value-producing network. There are 2,000 pairs for us to examine: not all of them yield application ideas worth mentioning, while some yield several.

Level 3 – Anticipated radical technologies (ARTs)

Level 3 includes the actual substance of the Radical Technology Inquirer to be evaluated, referred to as anticipated radical technologies (ARTs) in this report. The ARTs are divided into four effectiveness groups based on a systematic evaluation of the application ideas and their maturation probability. The technologies have been identified from various sources through the collaboration of hundreds of people over the course of several years, but development continues to introduce new opportunities, which is why important innovations that this report has not been able to anticipate may even arise from the lowest levels of the list or from outside it.

For the list of 100 ARTs, we have chosen promising social and technological innovations or scientific breakthroughs that may reach market maturity during the 2020s and are anticipated to have a wide impact by 2037. In order to be included on the list, the theoretical potential of the described technology must have been proven in a scientific publication or through a practical prototype. Many of the listed solutions have already started spreading commercially, but their impact is expected to grow.

One criterion for an ART to be listed is its anticipated potential ability to concretely deliver significant instrumental added value to existing practices, either by saving costs, facilitating people's everyday lives, increasing comfort or by strengthening or weakening structures of power. The ARTs have been formed based on their functionality or the phenomenon that they utilise. Each ART typically includes several methods of technical implementation and lists benefits of applications. Thus, an ART should be understood as a cluster of technological solutions serving the same need. As an ART matures, some of the solutions typically become more dominant while the development of others stalls or ceases altogether.

The maturation probability of an ART is the most important individual factor in the evaluation of its effectiveness. This probability is determined based on the current maturity of the technology, its recent rate of development as well as the theoretical and financial conditions for its further development.

Level 4 – technology sources and discussions with experts

Level 4 includes the sources used. The material describing scientific and technological breakthroughs that underlies this report has been collected since 2013 by a group that, at the moment this report was written, comprised 2,452 members.
https://www.facebook.com/groups/TuVRadikaalit/

The collection efforts have been in the form of daily, goal-oriented voluntary work. Numerous experts in their own fields have participated in the examination of their own areas of interest and the search for better sources. Roughly 1,600 of the most representative sources were chosen for the final report. Each source was categorised and scored in the database relating to the report, which includes links to source-specific discussions that also feature several other sources related to the topic which were not selected for the report or database.

Each of the value-producing networks was discussed at a workshop attended by invited experts in the subject matter in question, in addition to which a large number of individual experts have read and commented on the draft texts. The challenger regimes described by the value-producing networks have been outlined by the authors of this report over many years in almost a hundred separate events held for experts and several more concise reports.

New professions and legislative objectives

The description of the value-producing networks involves an operating model enabled by technological advancement that challenges and offers an alternative to the current operating model. When describing a value-producing network, we also list the professions arising from this new operating model in order to illustrate new forms of human cooperation and the impact of the change on human labour and skill requirements. In connection with the descriptions of the value-producing networks, we have also compiled legislative objectives and other government actions that are required to enable and hasten development or moderate adverse effects because of the new operating model.

Introduction

Traditionally, Finland has been a land of pioneers and quick learners. A book called Suuret keksinnöt (Great Inventions, translated from the work Die denkwürdigsten Erfindungen im neunzehnten Jahrhundert by Louis Thomas) was published in 1885, adapted and expanded on by lecturer Samuli Suomalainen for the Finnish conditions. In the preface, Suomalainen states: "And now it is ready, with all its shortcomings. It is my ardent wish that the public not have excessive expectations of this first Finnish book of inventions, on which at least no time or effort has been spared." The book was astonishing in its comprehensiveness and attention to detail. It covered the latest technological solutions, ranging from the telephone to industrial processes.

In the late 19th century, technology spread quickly around Finland. A telephone network was built, industrial activities were launched, planes were developed and even author Zachris Topelius contemplated the nature of space in his columns after reading about conflicting tests that sought to measure the speed of light. Though Topelius did not invent the theory of relativity, Finland continued its slow, inventive progress towards the top of the world.

Finland is now remembered as a leading country in telecommunication. Finland was well-equipped for this achievement in the 1990s, having been the promised land of telephones for a hundred years. Broad university education in information technology and telecommunication was launched in the 1960s. The first commercial microcomputer in the world was built by Digelius Elektroniikka in 1973. Teleoperators began to prepare for digital telephone exchanges at the end of the same decade. On television talk shows, politicians and industrial leaders discussed how Finland should approach the coming transformation in the industrial structure that would occur as a result of information technology.

In the 1990s, Finland was a showcase to the world, having embraced the early use of the Internet and mobile technology quicker than others. In his speeches, Finnish President Martti Ahtisaari addressed the potential of the Internet and promoted the establishment of the European GSM standard. Numerous ministers set up groups, and the potential of information technology was known to everyone interested in the subject.

In the early 21st century, Finland has basked in the glory of the past. Export companies have developed technology, but Finnish society on a wider scale appears to not have believed in technology or, at least, not have been particularly interested in it. Intoxicated by its success, Finland's perspective on technology grew narrower. Many failed to notice how quickly technological advancement continues to progress in different parts of the world. President Sauli Niinistö recently drew attention to this change in his New Year's address.

The narrowing of the perspective can be prevented by using systematic methods. In these efforts, a systemic frame of reference and criteria, commissioned by the Committee for the Future, have been created for evaluating the potential of radical technologies. This method allows comprehensive evaluation of the various benefits of each technology and identification of any problems related to them. Relying on these criteria, we have described and evaluated a hundred radical technological solutions that we consider to be the most important. This set of criteria allows the list to be updated in a systematic manner. The quality of the list can also be improved by discussing the perspectives used in the evaluation.

This work is a continuation of a report written on the same topic in 2013 by Risto Linturi, Osmo Kuusi and Toni Ahlqvist, which established the foundation for the foresight model used here, in addition to being a continuation to a follow-up report written by Risto Linturi based on said report. Through a data network, the work was contributed to by a great number of experts in various fields and citizens interested in technological advancement. The active contributors to this report with regard to the value-producing networks and technological content are named separately in the relevant chapters.

This type of work is never finished. Technology is advancing increasingly rapidly, and there are news about new breakthroughs every week. As the world changes and skills evolve, so does the evaluation of technologies. For this reason, this second report that utilises the RTI method must continue to be considered as a start to the development work. We hope that the opportunities described here will inspire Finnish society to renew itself and its developers to find seeds of ideas.

In this work, we deviate from the normal format of a technology report. The future is most commonly built with the help of general directions of change. However, on a concrete level the world is changing as a consequence of technological breakthroughs and the social innovations interwoven with them. Technological advancement opens up opportunities that are selectively adopted by society and individuals according to their own sets of values. The purpose of the method developed here is to help people identify combinations of technological solutions and social innovations. The greatest innovations that challenge the structures of society arise from combinations that cut across several industries and areas of life.

In other words, this work is not structured through megatrends, though the authors kept them in mind as background variables. The most important structural factor chosen for this work are the twenty value-producing networks. Value production, as referred to in this context, deviates from economic activity, which is commonly used in statistics. The increasing of national income in the form of increased wages for doctors does not necessarily lead to better health. Similarly, food is not necessarily worse if it costs less or is grown to meet our own needs.

The value-producing networks are described in Chapter 1. Each value-producing network is an answer to some deliberately narrow need or problem in society. Each network is defined with the help of its primary purpose and related values. The twenty primary purposes and the moderating values related to them cover the majority of all needs satisfied instrumentally by society in an organised manner. The most important thing offered by the description, in addition to describing the scope and nature of value production, is to demonstrate the greatest possible systemic change in each value-producing network and the related means, benefits, threats, and values with a renewing or inhibiting effect.

Chapter 1 also lists the new professions arising from change for each value-producing network as well as areas requiring government actions or a legislative change. The potential applications of the new technologies are also listed for each value-producing network. The ART specific evaluations of potential effectiveness are provided together with the applications, with the assumption that the technology will reach market maturity in the 2020s.

The actual technology section of the report is provided in Chapter 2. The 100 ARTs evaluated to be the most important are described and divided into four priority groups according to their maturation probability and effectiveness. The technological solutions are evaluated by using three key criteria in anticipation of the effectiveness in 2037:

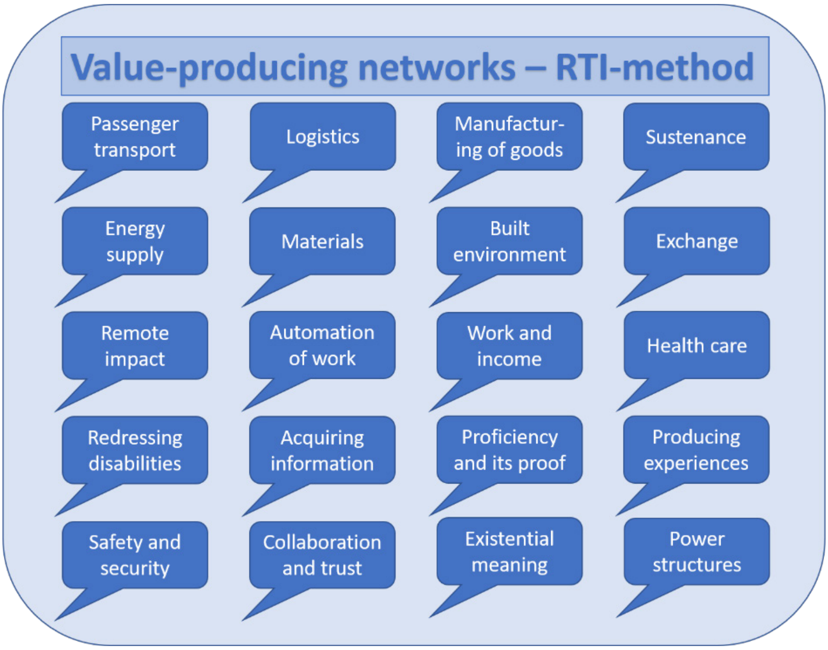
1. The technology enables significant added value in the value-producing networks that are important for human activity, as described in Chapter 1.

2. In a scientific sense, the technology is located in an area in which research is progressing rapidly or is related to other extensive and well-funded development work.

3. The technology's rate of development and theoretical potential strengthen the notion of its potential to rise to the next level of maturity.

Chapter 3 sets out the conclusions and compares the observations made in the report to the megatrends considered to be the most important and states the known needs for development that are associated with this evaluation of radical technological solutions.

1 Level of value-producing networks



Technological advancement does not constitute straightforward economic development. Scientific, social and technical innovations may open up a very wide range of opportunities and threats relating to added value. For example, the Internet has become greatly significant in streamlining almost all human activity. Due to this permeability, it has also reorganised society in a new way. Many technologies are similarly revolutionary. For example, the link between the invention of iron and the birth of democracy is well-documented. Alvin Toffler, Jeremy Rifkin, Manuel Castells, Jakob Bronowski, Michael Mann and numerous other futurologists and historians have each demonstrated the radical impact of various inventions on social structures and forms of human activity.

No individual perspective alone is enough in the evaluation of technological advancement. In order to identify the most promising technological solutions, they must be examined from a variety of perspectives. For this purpose, in order for different perspectives to be systematically taken into account, this report describes twenty value-producing networks. Each of them is used in the evaluation of the potential of each technological solution.

In this context, a value-producing network refers to the following: A value-producing network describes an activity that is at least partly organised and contributes to the satisfaction of a clear global need. In other words, a value-producing network is defined by a primary goal or need that must be satisfied. For example, a hospital as a whole is not part of just one value-producing network, as it partly contributes to housing, nourishment, health and safeguarding of functional ability, among other things. However, the value-producing networks are not analysed this closely in this report. The value-producing networks were chosen from a Western perspective, which is familiar to Finns.

In order to understand the scale of potential savings in the Finnish market as well as the potential in the Finnish export market, the scope of the value-producing networks is described using the figures of the Finnish economy. These figures indicate the relative percentage of the potential value in similar developed countries. Because we are talking about a large market, the exact size of the global market is not relevant from the point of view of an export economy the size of Finland. Each value-producing network is large enough that even a niche in the global market would be a significant export area for Finland.

Export is considered to be a lifeline for Finland, and many similar reviews focus on considering the conditions for export. However, we must note that most value production and work in Finland is carried out for the needs of the domestic market, and Finland is more dependent on import than export. Export should be viewed as an enabler of import, and attention should be focused on the comprehensive efficiency of the economy. Increasing export efforts is not particularly helpful in dealing with a leaking balance of trade or budget deficit if the reason for the leakage lies in the inefficient structures of society. In this report, the main attention is focused on value production and its general development. An efficient economy produces the export it requires.

Although the networks described in this chapter resemble a sectoral breakdown in some respects, instead of a sectoral breakdown we are talking about the flows of specialisation and exchange, in which interaction produces a specific indirect or final value. Organisations and individuals are often part of several different value-producing networks, which is why we only group the content of the group organisations' primary activities rather than the group organisations themselves.

If successful, each of the new technological solutions described in Chapter 2 will introduce opportunities for significant added value as well as threats to these value-producing networks. This may involve increased risks or meeting individual needs and wishes in a more efficient, comprehensive or higher quality manner. We should react to opportunities and threats as quickly as possible. The radical innovations are advancing exponentially, and market shares and the orientation of practices are determined early on. Most technologies that challenge current value-producing networks are now at the same stage as the Internet was 20 years ago. At the time, Finland was a significant forerunner in communication equality.

The follow-up report proposed the utilisation of the regime model developed by Professor Frank W. Geels in describing mainstream practices and inertial forces. We have done so in a loose sense. In the spirit of envisioning the future, the operating model following the probable upcoming transformation has also been discussed as a challenger regime.

Geels identifies seven dimensions in a socio-technical regime. These are technology itself, user practices and application domains (markets), the symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge. A socio-technical regime must often change materially, particularly in the face of radical technological changes, in order for the market mechanism to be able to promote these changes.

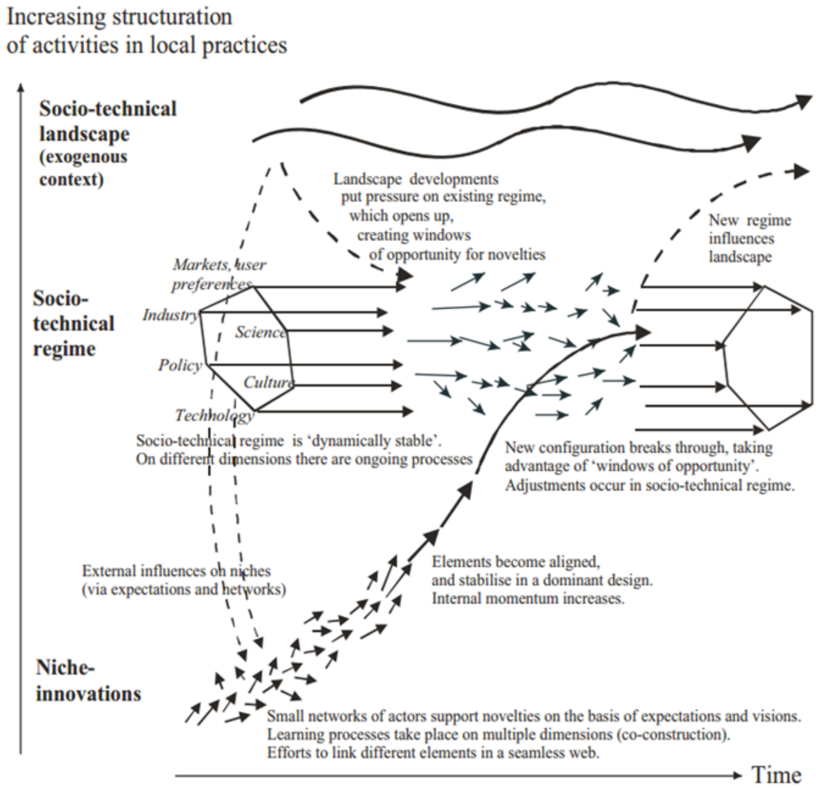


Figure 2: The impact of a socio-technical regime on the breakthrough of innovations. Source: F. W. Geels (2011) The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions* Vol. 1, No. 1, 24–40.

In many areas, particularly in oligopoly situations, major companies want to maintain the prevailing situation for as long as possible. When economies of scale prevail, the customer understanding of major companies often allows them to keep small newcomers to the market away despite the latter's better technology.

Change can be expedited in many ways. For example, the government can utilise means of attention economy. New technology can be favoured in public procurement. Regulations restricting or preventing its use can be dismantled. Regulatory obstacles hindering small operators can be removed by opening up public procurement through open interfaces, for example. Training in new technology and other services related to it can be increased. Practices relating to new technology, platforms that catalyse ecosystems, and functional roles can be established.

The value-producing networks presented in this chapter are based on the aforementioned report and proposals for development that arose in conjunction with the follow-up report and other evaluation of results carried out in relation to the report. In order to develop these value-producing networks, online discussions and 12 separate workshops were also held after the draft phase. The individuals who participated in the development of the value-producing networks are listed below. (The individuals who contributed sources for the ARTs are mentioned in the next chapter):

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Description of the value-producing networks

The goal described under the section *Scope of the value-producing network* may be indirect or final, and the qualitative values are related to the way in which the goal is met. This section is the most important with regard to the method, as the technologies are only assigned points for a value-producing network if upon maturing and spreading they will influence the actual goal of the value-producing network or the realisation of the qualitative values related to it.

The section *The means and values of transformation* describes the potential transformation of the value-producing network and the key technologies that enable the new operating model. The key motives promoting the change are described at the same time.

The section *The means and values of the dominant regime* describes the current primary operating model of the value-producing network as well as its grounds, scope, the power structure maintaining it and the values maintaining the current structure. The majority of the figures provided in the descriptions of the value-producing networks are based on data of Statistics Finland, while any other data is mentioned either in the chapter introductions or in the source links below the descriptions.

The section *The benefits, risks and inhibitors of change* evaluates the most important benefits and risks of the transformation that should be taken into account when preparing for the change. The inhibitors examined comprise obstacles to the change as described above in relation to the socio-technical regime.

Growing professions and skills shortages is a lighter section of the text that illustrates the change in human labour and skills needs with the help of descriptive professional titles. In principle, anticipating professions is more useful than anticipating skills needs, as work duties require combinations of skills. The operating models described by the challenger regime allow the bodies of work to be outlined, but this section should not be taken at face value. Disappearing professions and skills are easier to identify than new ones. The reason for this is not that the range of new professions arising would be more diverse than the range of old ones disappearing, but that there are less controllable variables.

The section *Policy objectives of the change* identifies actions by the government and legislators that are required to expedite the desirable parts of the transformation and moderate any adverse effects. If these actions are taken proactively, Finland can potentially achieve benefits as a quick learner and forerunner while avoiding any adverse effects of the new technologies and practices. A forerunner can also influence global operating models.

Special national characteristics are mentioned when something special is involved.

Descriptions of applications relating to the technologies is a description in the form of a list. Each of the 100 ARTs was evaluated against each value-producing network and its goals and values. The material benefits or adverse effects caused to a value-producing network by each ART as it matures are listed separately for each ART. From the perspective of the evaluation, a value-producing network is like a jury member with blinders who performs his/her own duty with a narrow field of vision, assigning points to a technology if it promotes his/her own narrow goals or values related to them.

Points for effectiveness are assigned with the assumption that the primary capability described in the ART will reach market maturity in the 2020s. Effectiveness is evaluated at the level of the year 2037. The scoring is heavily logarithmic, and each value-producing network assigns points only through the effect of its own limited perspective. An effect may be useful or harmful for the whole, but in order for a technology to be effective, an operator must have a motive for promoting it. To understand the evaluation, it is important to note that the scoring reflects any type of effectiveness and not collective benefit.

The primary role of the Radical Technology Inquirer (hereinafter RTI) described in this report is to identify any social impacts of the new technologies in advance in order for us to prepare for both their potential benefits and harmful effects.

This foresight is carried out by multiplying the realisation probability of each technology with its potential social impact. The scoring related to the evaluation of the technological probabilities is described at the beginning of the next chapter together with the technologies. We first describe the potential effectiveness evaluations of the technologies, with the evaluations provided separately for each value-producing network in this chapter. The impacts may be economic or non-economic, relating to the everyday practices of individuals.

The points from 1 to 20 are assigned loosely according to the following criteria (Finnish scale):

1 point is assigned if the development of the ART delivers concrete benefits that make it worthwhile to apply the technology to this use.

3 points are assigned if the development of the ART delivers material benefits with regard to a value related to the value-producing network's goal or is part of a whole that materially promotes the actual goal. In this context, a material benefit would be an economic impact at the level of €10–100 million per year or, on an individual level, an impact of 5–50 million person-hours on everyday life per year.

5 points are assigned if the development of the ART delivers significant benefits with regard to a value related to the value-producing network's goal or is an important part of a whole that promotes the actual goal in a transformative way. In this context, a significant benefit would be an economic impact at the level of €100–1,000 million per year or, on an individual level, an impact of 50–500 million person-hours on everyday life per year.

10 points are assigned if the development of the ART results in a transformative impact, within the meaning of the description of the value-producing network, on the way the value-producing network's goal is realised. On an annual level, the potential impact must exceed €1 billion or impact the weekly everyday life of hundreds of thousands of people.

20 points are assigned if the development of the ART is a necessary part of the most important transformative impact on the value-producing network's operating model. On an annual level, the potential impact must exceed €1 billion or impact the weekly everyday life of hundreds of thousands of people.

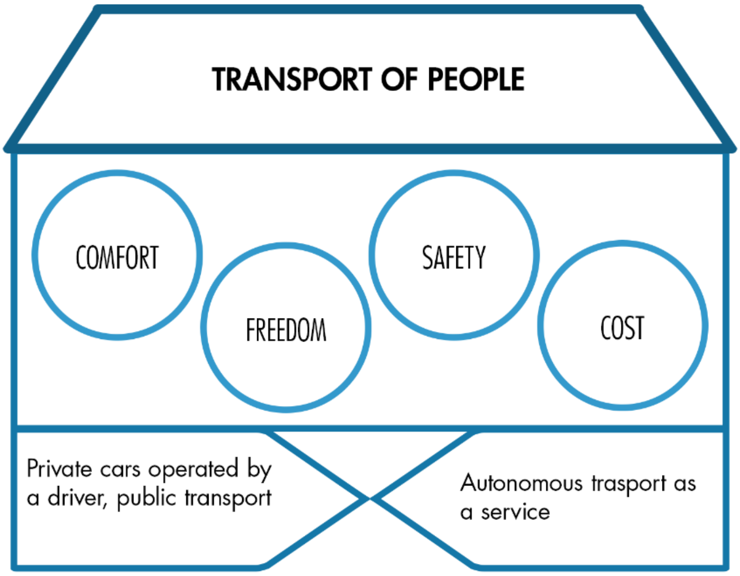
The breakdown into twenty value-producing networks for scoring purposes was carried out so that very few organised production and government structures or economic goals of society are left outside the breakdown. Another goal in the breakdown was to ensure that each value-producing network has a primary goal and related moderating values that materially deviate from those of the others. It must be noted that these values comprise values of citizens and decision-makers that are realised in practice, and they may even be opportunistic. They do not comprise collective overall benefits. The goal is to establish a foresight model and situation awareness.

The value-producing networks are divided so that each network involves a change to a key operating model that is made possible by technology. This is described in the table 1 below with the help of a dominant regime and a challenger regime. The purpose of this division is to establish twenty relevant and representative perspectives that clearly deviate from each other for the evaluation of the technologies' maximum potential for change. The foresight method is robust, which is why even considerable changes to individual value-producing networks will not materially influence the ranking of the ARTs.

Table 1. The value-producing networks according to which the anticipated radical technologies are valued.

Value-producing networks with their most potential transformations			
VPN-ID	**Value-producing network**	**Dominant regime**	**Challenger regime**
1	Passenger transport	Private cars operated by a driver, public transport	Autonomous transport as a service
2	Logistics	Transport operated by a driver, repetitive automated loading	Autonomous transport, smart loading robotics
3	Manufacturing of goods	Industrial, centralised, repetitive manufacturing	Robotised, decentralised, discrete manufacturing
4	Sustenance	Agriculture, food industry, distribution channels	Urban cultivation, robotic local food preparation
5	Energy supply	Centralised and fossil energy sources, peaking power plants	Renewable, decentralised energy sources and energy storage
6	Materials	Mining-based products, energy-heavy process industry	The circular economy, renewable materials
7	Built environment	Traditional construction and maintenance	Robotised construction and maintenance
8	Exchange	Brands, physical retail locations, hierarchies, B2B2C	The reputation economy, e-commerce, P2P, C2B2C
9	Remote impact	Telephone, television, Internet, social media	VR/AR, avatars and other remote control
10	Automation of work	Centralised automation and human-steered machines	Decentralised robotics based on AI and crowdsourcing
11	Work and income	Salaried employment related to specialisation and exchange	Cooperation, self-sufficiency, micro-entrepreneurs
12	Health care	Health care system, general health recommendations	Self-diagnostics, gamification, individual nutrition
13	Redressing disabilities	Institutional, outpatient and family care, cheap assistive devices	Robotics, AI, avatars, artificial organs, crowdsourcing
14	Acquiring information	Certified research, reports, news	AI, crowdsourcing, personal instruments and applications
15	Proficiency and its proof	Educational institutions and qualifications, on-the-job learning	Flipped learning and independent learning, AI, proficiency demonstrations
16	Producing experiences	Focus on producers and consumers, mass entertainment, tourism	Games, shared VR, AR, interaction, AI
17	Safety and security	Material safety in society, social security	Decentralised, individual and crowdsourced safety and security
18	Collaboration and trust	Guaranteed by authorities, brands and hierarchies	Peer-to-peer trust through platforms and transparency
19	Existential meaning	Work, position, social network	Achievements, likes, participation, communities
20	Power structures	Regional power structure, opaque power	Subject-matter subsidiarity, location independence

1.1 Passenger transport



Scope of the value-producing network: The purpose of passenger transport is to transport people from one place to another. The most important values are comfort, freedom, safety and cost. Comfort involves the smoothness, punctuality and physical ease of the journey. Freedom involves both the freedom to choose the time and destination of travel and the freedom to do other things of one's choice while travelling. Safety applies to both the passenger and bystanders and extends to continuity and the environmental impact of modes of transport. The cost arising from the solution to the need to travel from place to place is divided into fixed and variable costs paid by the passenger and society.

The means and values of transformation: The robotisation of transport frees the driver. Modes of public transport can be reduced in size, departures can be made more frequent, and individual mobility can be offered as a service at an advantageous price. The use of shared resources will become simpler than before when you can call a mode of transport to come when you need it and leave it to continue its way to the next person when you no longer have any need for it. This also makes it possible to use an increasing variety of modes of transport to implement a travel chain. A good example of this is the rapidly expanding shared use of bicycles in cities. Autonomous transport also enables the easy and affordable individual mobility of people without a driver's licence.

The robotisation of transport pertains to road, rail, air and waterborne transport. It pertains to both modes of public transport and other modes of passenger transport. The main attention is focused on self-driving cars, and their capabilities are evolving rapidly. In the first phase, robotics has assisted the driver. In ongoing pilots, cars can travel a certain route or in a certain area autonomously. These types of solutions are already having a major economic impact.

According to experts in the field, the technological capacity for perfect, human-like, autonomous driving is within arm's reach. NVidia has announced that its new processor will be capable of the highest human-like level 5 autonomy once the necessary software is completed. GM has announced that it has completed a production line that is able to manufacture hundreds of thousands of self-driving cars intended for autonomous driving per year. Google has launched a fully automated self-driving taxi service in downtown Phoenix.

The automotive industry and electronics industry have reported numerous investments worth billions to promote autonomous transport. Based on this information, we can estimate the most rapid market growth of self-driving cars to start in the early 2020s and continue to the 2030s. The diversification of applications and strong growth of the service market will likely take place in the 2030s.

Self-flying air taxis have been developed for air transport. Several noteworthy organisations are in the process of performing test flights with devices that transport the passenger from one heliport to another without a pilot. Most of the devices are electric and intended for short journeys in congested urban areas. The development of batteries and electric motors is likely to make this mode of transport significantly more common than existing small aircraft and helicopters over the course of the 2020s.

In rail transport, the most significant innovation enabled by robotisation is the Hyperloop, in which pods travel on a magnetic track in a vacuum tube, free of friction, at a speed of nearly a thousand kilometres per hour. This technology allows the travel times between city centres to be reduced, for example from two hours to ten minutes, and waiting times between departures to be reduced from hours to minutes. The first Hyperloop tracks intended for passenger transport are planned to be opened for traffic in the early 2020s.

The most important values that promote robotisation are related to freedom provided by Mobility as a Service as well as the cost-effectiveness of shared use and the safety and comfort of autonomous transport. Robotisation makes it easier to remove driver's licences from high-risk drivers. Environmental friendliness and forerunner status are contributing factors, as is the elimination of the driver's responsibility.

The means and values of the dominant regime: According to the data of the Finnish Transport Agency, the total yearly domestic distance travelled by passengers in Finland is approximately 74 billion kilometres, of which road transport accounts for 90% and public transport for 20%. Most passenger transport, a little over 70%, comprises travel with a passenger car; short journeys are the most common. Only a small part of public transport is fully market-based. There are roughly 2.7 million passenger cars in operation. The number of registered motor vehicles in Finland is approximately 5 million.

People spend roughly a billion person-hours per year driving a passenger car in Finland. The average distance travelled by each car per year is 17,000 kilometres. The utilisation rate of vehicles is very low while the fixed annual car maintenance costs are considerable. Each car requires more than one parking space near workplaces, services, entertainment or housing. The impact on city structures is considerable.

It is common for the driver of a passenger car to travel alone in the car. Typical journeys take place between home, the workplace and service locations during rush hours. This loads the trunk routes and slows down public transport. The loading of the trunk routes is partly due to a lack of park-and-ride facilities, partly due to a need for onward connections after the trunk routes, and partly due to a desire for comfort.

Public transport can be considered to be well-organised in large cities with regard to the frequency of departures and the coverage of routes, but it is problematic in sparsely populated areas. The development of public transport has not prevented the increase in the number of passenger cars and the resulting congestion. The dominant regime in passenger transport is clearly private cars, which land use planning for the most part caters to with the road networks, streets, parking areas and service placements.

Above all, the current dominant regime is maintained by the existing provisions and urban architecture. For many, driving or owning a car is a pleasure. The freedom of mobility provided by a car is significant in sparsely populated areas compared to the present type of public transport. The relatively high maintenance cost of a car and low variable cost also favour the use of a car if a person has purchased one for some reason.

The benefits, risks and inhibitors of change: Autonomous transport enables an affordable service structure that combines the benefits of a passenger car and public transport. A self-driving vehicle can pick us up from the front door and take us to where we want to go or to a public transport trunk route. As autonomous transport does not include the cost of a driver, and with maintenance costs being distributed over a greater number of kilometres due to the higher utilisation rate, the total cost per kilometre in transport provided as Mobility as a Service (MaaS) is less than that of a privately owned car, even though the variable cost is the same. With an increase in the utilisation rate, even the variable cost of MaaS transport can be reduced while increasing the passenger load factor.

Mobility as a Service is effortless and easy. At the level of the national economy, the savings may amount to as much as €10–20 billion per year on the Finnish scale, and MaaS can be roughly estimated to free up as much as €100 billion in capital as the car parc decreases and urban structures become denser. Additionally, autonomous transport is expected to become significantly safer than transport operated by a driver in the future. Depending on the method of calculation, the cost impact of this in Finland will be €1–2 billion on an annual level.

The risks involved are related to unclear liabilities, systemic vulnerabilities and data protection. The liability for any problems and vulnerabilities should be borne by the party that can bear it and has the capability to reduce the number of problems and vulnerabilities. Many people think that this liable party is the manufacturer of the vehicle. It must be noted that it is practically impossible for a single citizen to claim his/her rights from a vehicle manufacturer, which is why directly assigning legal liability is not sufficient without efficient middlemen.

On a national level, assigning liability for poor driving skills to vehicle manufacturers is a challenge and a major change to the current way of thinking. In addition to poor driving skills, there are other systemic vulnerabilities, such as ones related to the implementation of remote control through telecommunication technology as well as software updates and the use of cars for the purposes of terrorism. Autonomous transport should be organised so that all remote control that would endanger transport safety is prevented with the help of the car's own, local autonomy that cannot be bypassed via telecommunication technology.

There are many factors that slow down the change. The service life of vehicles is long, and the car parc is renewed slowly. The investments are large for households, and the advance of autonomous transport may cause the resale value of old cars to plummet, making it impossible to get rid of cars profitably. For many, a privately owned car is a status symbol and a demonstration of freedom and capability. The physical infrastructure is not an obstacle as such, even though many people talk about the need for smart roads and 5G networks in connection with autonomous transport. Vehicle manufacturers are developing their self-driving cars to be suitable for normal roads. However, the cars require precise digital maps and numerous other services. For example, self-driving cars cannot refuel or recharge themselves, and some type of service structure yet to be created will also be required for cleaning them.

The sector's structure and policy environment serve the current dominant regime. New operators and operating models are required in order for autonomous transport as a service to negate the significance of a private car as something that increases freedom of mobility. Both service providers and the authorities have inadequate technical expertise if the transition from private car ownership to MaaS will be as rapid as anticipated, with robotisation leading to the car parc becoming electric and monitored from control rooms.

Growing professions and skills shortages: The transition to autonomous transport organised as a service will create many new professions. A transport coordinator is responsible for ensuring that the means of transport are waiting for new rides where they are needed next. A traffic information analyst produces information, creates new driving instructions for robots and plans adjustment of the transport system. A remote controller monitors driving, investigates problem situations and guides an autonomous vehicle when it is unable to proceed as needed. A remote assistant talks with passengers and guides them and the car in choosing the destination and route and makes a decision on actions in case of personal injury.

A vehicle cleaner is responsible for the cleanliness of the vehicles and, if necessary, provides passengers with feedback on unwanted behaviour. A city air traffic controller takes care of the flight routes, landing field conditions and availability of air taxis. A robot police officer and inspector of autonomous transport monitor autonomous transport, its service level and security threats related to it. A traffic ethicist consults on ethical and legal liability issues related to transport. An insurance auditor of robot transport investigates accidents.

Policy objectives of the change: The transport sector has already significantly promoted the introduction of new vehicles and robotisation by e.g. enabling the use of electronic light transport devices, promoting transport as a service through the Transport Code and promoting experimental culture.

The following actions should be further promoted: The disturbance of robot transport should be criminalised. All traffic sign data, signal data and roadway information should be collected automatically and in real time in a shared cloud service as open data. Information could be obtained in real time from selected vehicles in traffic – for example from Posti vehicles. As for city air traffic, airspace monitoring should be automated for the needs of self-piloting passenger aircraft. It would be particularly important to define routes and access credentials from the point of view of enabling transport.

The service interface related to the Transport Code should be implemented quickly. The need for compatibility of the interface between transport providers and passenger applications with the interface of international actors, such as Lyft's alliance, should be taken into account. The obligation to monitor self-driving cars and assigning responsibility for damage to the vehicle manufacturer should be regulated before the wide launch of robot transport. The role of statutory insurance between vehicle users, victims and responsible parties should be preserved, but in a way in which the low accident rate of a self-driving car reduces the manufacturer's costs.

Training related to robot transport, including the organisation of activities, technical maintenance and control, should be implemented quickly and widely. Robot transport services should be regulated in a way that simultaneously enables models of sharing economy, car rental and robot taxi operations and, to a sufficient extent, integrates with Mobility-as-a-Service thinking (MaaS).

Special national characteristics: In Finland, winter conditions and long distances lead to a range of special national characteristics. Self-driving cars can handle winter conditions in terms of their technical capabilities, but it is certainly not the highest priority of all vehicle manufacturers, and it is important for Finland to be able to control and promote the matter. The winter maintenance of roads is a considerable single cost, the robotisation of which would be a particularly interesting challenge, taking the Finnish conditions and capabilities into account. In the table below, ART-ID refers to the number of the ART. All 100 ARTs can be found in order of effectiveness in Table 2 in section 3.1.

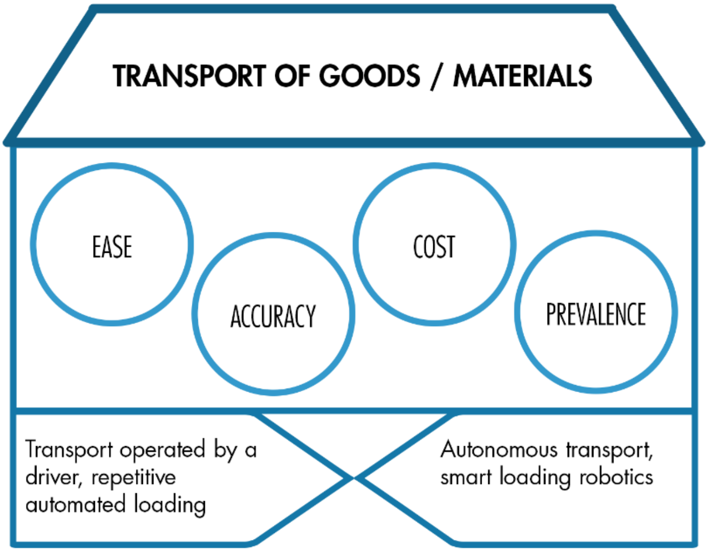
ART-ID	Passenger transport: applications of the ARTs and evaluations of their effectiveness	Weight
1	Adjustment of the route, entertainment and conditions affecting travel comfort	3
2	DNA-based verification of access rights and security checks.	1
3	Recognition of the strain of the journey and bodily needs in order to increase travel comfort.	5
4	Identification of dangerous or harmful substances and residues in autonomous transport. Identification of dangerous environmental conditions.	5
5	The driving safety of a self-driving car improves when the car is able to distinguish between materials on the roadway and identify any dangerous items carried by passengers.	5
6	Environment 3D scanning and positioning in relation to the model or absolute positioning are a necessary requirement for autonomous transport.	20
7	IR, THz and radar bands are all very useful in scanning the environment. The IR/THz band is efficient in interaction with self-driving cars via short-range radio frequencies.	5
10	Lidar systems used in robot transport are based on small lasers. Lasers are also suitable for headlights and identifying materials.	5

ART-ID	Passenger transport: applications of the ARTs and evaluations of their effectiveness	Weight
11	A self-driving taxi can converse with the customers and understand their wishes. Verbots overall require speech synthesis and recognition.	3
12	The development of artificial intelligence is an essential cost factor for autonomous robot transport and the technology is essential in self-driving cars, at least at the level already achieved.	10
13	Through platforms, a great number of mobile device applications are created for a variety of pattern recognition tasks in order to increase travel comfort.	3
14	The recognition of passengers' emotions is helpful in problem situations and in increasing comfort. Facial recognition facilitates transactions and increases security.	3
15	The possibility to discuss the destination and sights with the car promotes robot transport. The car can also entertain or suggest connections and accommodation services as needed.	5
16	A self-driving vehicle absolutely requires a real-time situation picture of its environment and other moving vehicles and people. Detecting and identifying other moving vehicles, people and material is an advantage.	20
17	Imaging baggage is a safety factor and increases service opportunities.	1
20	VR glasses keep passengers entertained in autonomous transport. In problem situations, an assistant can see the car's situation through his/her VR glasses and guide the car or passengers as needed.	3
22	A self-driving car collects an enormous amount of situation data that can be used to teach, optimise and fund autonomous transport.	3
23	Artificial intelligence will become faster, and the computing required for driving will consume less energy.	3
24	Quantum communication can enable theft-proof remote control.	3
26	The computing required for reliable autonomous driving now requires a very expensive processor that needs several kilowatts of power, so it is necessary to improve efficiency.	10
27	Robotic legs allow people with low strength in their legs or reduced mobility to move about in normal traffic and without a wheelchair, assistants or special needs vehicles.	5
28	Today, passenger cars are the main mode of transport. Robotisation enables Mobility as a Service and a radical reduction in the number of privately owned cars.	20
29	Light and portable electric vehicles are an efficient addition to public transport.	10
30	Quadcopters facilitate traffic control.	1
31	Short-distance flights from roof to roof or yard to yard make it quicker to travel in a city, reduce congestion and facilitate traffic in archipelagos, for example.	5
32	Traffic control becomes increasingly efficient with the help of continuously flying devices.	3
33	Foiling speeds up waterborne traffic. Robotisation makes water taxis less expensive. Ships with lightweight hulls allow new routes to be introduced.	3
34	The travel speed and lack of schedules between city centres makes commuting and using services of neighbouring cities easy. Reduces motoring.	10

ART-ID	Passenger transport: applications of the ARTs and evaluations of their effectiveness	Weight
38	Vehicles and their parts can be 3D printed.	1
39	Automation of street and road repairs by 3D printing structures.	3
41	MaaS transport becomes easier when modes of transport, routes and addresses have unique identification and when all of them can be communicated with in a uniform manner.	3
42	The loading, unloading and home delivery of baggage can involve a robotised service.	3
45	In practice, a passive maglev is required for a Hyperloop (1,200 km/h) and transporting cars in a tube (200 km/h) below cities.	5
46	The insulation of the interior of vehicles is a key factor in energy-efficient modes of transport. It allows aircraft and vehicles to be made lightweight.	5
48	Sturdy, lightweight wing structures contribute to light aircraft.	3
49	The affordability of sturdy, lightweight materials and efficient batteries is key for aircraft.	3
51	The cleanliness of shared vehicles and reducing the risk of infection are very important factors in reducing the need for private car ownership.	5
65	More elderly persons retain their driver’s licence. (Not a major issue with autonomous transport becoming more common.)	1
70	The energy used by electric vehicles is almost free of charge if the vehicle has a low utilisation rate and high maximum capacity, as the vehicle can be recharged with its own solar panel.	5
73	Affordable and efficient batteries are necessary for electric cars while light and efficient batteries are necessary for light aircraft and quickly recharged batteries for public transport.	20
74	Synthetic fuels may allow carbon-neutral motoring with current and future vehicles that are equipped with an internal combustion engine.	3
75	An inexpensive fuel cell makes a fuel cell car possible.	3
76	Safe and affordable storage of hydrogen in a dense form allows hydrogen cells to be utilised more easily as a power source for vehicles.	5
77	Depending on local renewable energy in activity increases the meaningfulness of electric cars and directs driving behaviour towards favouring inexpensive energy.	3
78	Synthetic fuel made with renewable energy increases the acceptability of internal combustion engines and influences their fuel costs.	3
80	The recovery and harvesting of kinetic energy improves the energy efficiency of all forms of mobility.	3
82	Charging of electric modes of public transport at stops becomes easier.	3
83	Electrification and similar changes significantly affect the structure, energy need, operating range, harmful effects, travel comfort and manufacture of vehicles, among other things.	10
84	Gamified mobility with the help of MaaS applications, for example, can teach people about less congested and smoother mobility.	3
86	Many local transport service models can arise from crowdfunding.	1
88	Remote controllers and assistants may be needed in passenger transport if self-driving cars are unable to do everything by themselves. Uber and similar platforms are already performing many supervisory duties.	5
89	The reliability and unfalsifiability of traffic data are important.	3

ART-ID	Passenger transport: applications of the ARTs and evaluations of their effectiveness	Weight
91	Passenger transport is suitable as a platform service due to its global homogeneity and the clarity of its structures of trust.	10
93	With e-commerce shifting towards home delivery, transport routes are becoming simpler and we do not have to carry items with us.	5
94	A 5G network improves the smooth operation of autonomous transport and travel comfort. It is not necessary for autonomous transport, but it is useful.	5
95	Cloud computing facilitates the maintenance of a shared real-time 3D model for supporting the vehicle's own modelling and for the purposes of foresight and road maintenance.	3
96	It is possible that all sales, management, remote control and manufacturing required by robot taxis would be done abroad and only the infrastructure and maintenance would be done locally.	10
98	Autonomous transport frees up a billion hours spent holding the steering wheel in Finland alone, a large part of which will be used for global digital entertainment. This increases travel comfort.	3
99	The transfer of MyData from one operator to another can materially facilitate services.	1
100	Traffic signs and routes are visible in AR glasses or on the windscreen. Things that are notable on the route are explained. VR glasses entertain passengers on the road if the content is compatible with their own glasses.	3

1.2 Logistics



Scope of the value-producing network: The transfer of goods, equipment, animals, raw materials and waste from one place to another is the goal of this value-producing network. This includes transfers of functional equipment, which may involve the device running on its own wheels, and procedures in which the transfer is performed by a person or nature. Examples include a combine harvester, log driving and picking up groceries.

The most common target values are the ease, accuracy, cost and prevalence of the transport method. Ease includes the efficiency, suitableness and simplicity of transport. Accuracy covers the security of supply and smooth transport. Costs include all financial sacrifices that must be made for the transfer, modes of transport and routes. Prevalence is a separate goal, as it reduces the risks of investments. Furthermore, it produces significant cost benefits through standardisation.

The means and values of transformation: Freight transport is now based on repeated automation and human labour. Smart robotisation enables cost-efficient sorting and autonomous transport of goods. This allows individual items to be transported cost-effectively from the manufacturer to the consumer and for material flows to be delivered to manufacturers as needed. The goal is to achieve MaaS in logistics, with an open digital platform linked to freight transport. It consists of the identification of goods, crowdsourced participation and a high degree of robotisation in the delivery of goods from the manufacturer to the place of use and from there to recycling.

Unique packaging, loading, unloading and sorting of goods is rapidly becoming robotised. To support this trend, unique labelling and general-purpose robots are being developed. Robots are able to move from place to place and pick up, pack and transfer goods flexibly between production lines, modes of transport and storage facilities or between store shelves. In port logistics, this automation has already been carried out with regard to containers, but it will also be carried out on a smaller scale during the period examined.

The robotisation of passenger transport is in the process of creating technology for self-driving vehicles that can also be applied to transport on a wider scale. Small freight transport vehicles travelling on sidewalks and autonomous delivery vans and trucks are at the pilot stage. The technology can also be applied to rail, waterborne and air transport. Each autonomous mode of transport requires machine vision and the ability to manage a range of surprising situations. The basic technology is common, although each environment features its own special characteristics and needs.

The facilities and equipment required for a crew can be omitted from autonomous ships. This increases the cargo space and reduces costs. With the elimination of personnel costs, ships can also reduce their speed, which makes it possible to save significantly in fuel costs. Autonomous ships are being developed for the needs of both ocean transport and inland waterway transport. Robotised research and waste collection ships are also under development.

Unmanned air transport of goods with quadcopters and other drones is at the deployment stage. In addition to transporting small packages of medicine, there is already talk about transporting loads weighing hundreds of kilos and forming broad commercial distribution networks that would transport goods by quadcopter.

In order to manage a heterogenous transport chain, development is underway on cloud services for unique identification of goods and vehicles, location data and control, in addition to physical interfaces. Through the resulting digital and physical infrastructure, goods can be transferred from one carrier to another, even if they do not have a mutual contractual relationship. Shared smart lockers can open up access to the goods for those that have the right to transport them. These measures make it possible to establish equivalents of MaaS services for goods, in which the transport chain for the goods is created as needed using the available modes of transport at any given time.

The most important values that promote change can be considered to include the need for individuality, people's home-centric nature and cost-effectiveness, but also the ease in purchasing and comparing options that is enabled by globalisation and e-commerce. The heterogeneity, transience and volatility of flows of goods play a significant role in the transition.

The means and values of the dominant regime: The basic solutions used by logistics are currently implemented on the terms of industry and trade. For the most part, freight transport shares the same infrastructure with passenger transport. In short-distance sea transport, Finland relies on RoRo vessels. This reduces the need for reloading and maximises the capacity of pallets used by trade. With the exception of loads of raw material, ocean transport is based on container shipments, with the containers for the most part being packed homogeneously and transported from the industrial manufacturer to a logistics centre for resorting. This transport in sea containers is typically very inexpensive and favours large shopping centres and the logistics chains of major companies involved in trade.

Raw materials are picked up from farms primarily for industrial use, and industry delivers the finished products for export or to wholesalers for further domestic distribution. The bulk of the goods is transported by road in domestic traffic, but train transport accounts for a high proportion of all transport with regard to centrally processed industrial raw material. At present, inland waterway transport accounts for a low percentage of all freight transport in Finland.

In retail, the home delivery of goods is for the most part carried out as a self-service and with consumers transporting goods in their own passenger cars. The resulting need for parking space has influenced the locations of shops and land use planning. In contrast to many other reports, this document considers the pickup of goods to be freight transport and not passenger transport due to its primary goal being the transport of goods.

According to the data of the Finnish Transport Agency, total domestic freight activity in Finland is roughly 20 billion tonne-kilometres for trucks, roughly 10 billion tonne-kilometres for rail transport and roughly 2 billion tonne-kilometres for waterborne transport. Maritime transport accounts for almost 90% of Finland's foreign trade. A total of 87% of all shopping trips and running of errands is carried out by passenger car, and this proportion is not usually included in the statistics on logistics costs.

The most important values maintaining the dominant regime are related to the current norms, the desire to maintain the old sectoral structures and jobs as well as spending habits.

The benefits, risks and inhibitors of change: When goods are delivered more smoothly from manufacturers to customers, it reduces people's need to run errands, the need to store goods and loss relating to expiry and prediction errors. It simultaneously enhances distribution logistics, reduces congestion and allows urban structures and the availability of goods to be improved and diversified. Sparsely populated areas also benefit greatly in the form of better availability of goods and improved delivery capacity. The opening of distribution logistics also leads to more extensive competition, with the manufacturer not being dependent on access to a wholesaler's channel.

The greatest risks are related to employment effects if the old jobs become automated. This change and the development of added value to offset it may progress so slowly that new jobs are not created quickly enough to keep up with successes, or they are created outside national borders or the expertise required for them is lacking.

The automation of logistics can also easily lead to systemic problems and centralised risks through both mechanical failures and intentional cyberattacks that hinder normal operations. It must also be noted that heterogeneous packages make it increasingly easy to deliver forbidden or dangerous substances anonymously. Autonomous logistics must be able to identify the goods transported or verify the senders' responsible conduct.

The change is slowed down by the attitudes of both employer and employee organisations as well as the fact that the population is accustomed to going shopping in person and to the existing product names and marketing channels. The change is further slowed down by the low variable costs of passenger cars, land use planners' desire to favour old practices and an unwillingness to solve the problems in distribution that extends all the way to the consumer. The strong vertical structure of the sector prevents the structural change, and horizontal interfaces have not been established by regulators. Digitalisation has been ignored in this regard.

Growing professions and skills shortages: When goods are transported robotically from the manufacturer to the customer, the need for transporting vehicles will be reduced or eliminated. As cost-effectiveness improves, a significant part of the collection and transport presently carried out as self-service will be realised as a service. There will be more jobs for small freight forwarders and unloaders, such as dispatchers and freight traffic controllers. Freight forwarders or transport companies will be responsible for the role of controlling and organising the fill rate. “Fleet manager” jobs will be formed for guiding and controlling robot transport. Crowdsourced transport will require its platform and controllers, with any defective goods robots and goods left by them needing robotic transport rescuers.

There will be more jobs for remote loaders and unloaders of goods. The mapping of transport routes, especially in retail distribution, will create new jobs. In addition to mappers, accessibility inspectors of robot transport will be needed. Food delivery designer and carbon footprint analyst of freight traffic are potential new professions. Also, the installation, cleaning and control of delivery lockers will create new jobs if a uniform and widely available infrastructure can be accomplished. The skills shortage is particularly high when it comes to drone transport and decentralised sorting of heterogeneous goods.

Policy objectives of the change: Open delivery lockers located within walking distance and in traffic nodes should be organised as part of the transport infrastructure so that an open transport chain of crowdsourced distribution connecting different parties will be made possible. This should be taken into account in the reform of the Land Use and Building Act. A clear and fast target schedule should be set for allowing autonomous drone distribution of goods. Disturbing the drones and other robot transport should be criminalised and disturbance-related surveillance by robots should be allowed.

Reception kiosks for drone distribution should be set out in the city plan as part of the delivery locker system. The address and owner information of the goods to be distributed should be digitised in such a way that the product itself contains a unique identity that allows other information to be found in a cloud if access rights have been granted. This information should be available in the cloud regardless of the manufacturer and to the extent and in the form needed by the logistics robots. The main policy objective needed for this is that the state, municipalities and state institutions begin to use a new practice with regard to addresses. Logistics training should be updated to match the expected robot era. This applies to both seasonal and day-to-day tasks at planning, management and operational levels.

Special national characteristics: Finland transports an exceptionally small proportion of the internal flows of goods in containers, and there is a limited amount of traffic that combines several modes of transport. This is due to the size of the pallets used in trade as well as the limited desire of railways and inland ports to invest in robots that would transfer loads from one mode of transport to another. Strong centralisation of trade has also led to closed logistics structures. Roughly estimated, the costs of logistics are twice as much as the European average.

https://julkaisut.liikennevirasto.fi/pdf8/lts_2014-16_liikkumisen_ohjaus_web.pdf

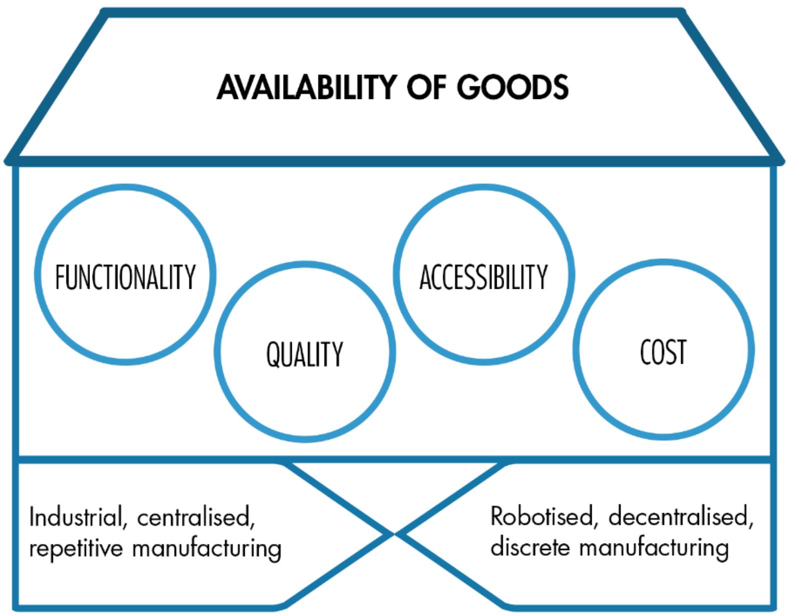
ART-ID	Logistics: applications of the ARTs and evaluations of their effectiveness	Weight
2	Biometric sender data and authentication, acceptance inspection of biomaterial.	3
3	Monitoring of health and conditions as required in animal transport.	3
4	Identification of dangerous substances and residues on the surfaces of packages and in evaporating gases. For example, identification of explosives and drugs. Detection of freshness.	5
5	The identification of dangerous goods in both transport and reception, and the identification of the material of any obstacles on the road in autonomous transport.	10
6	Environment 3D scanning and positioning in relation to the model or absolute positioning are a necessary requirement for autonomous transport.	20
7	IR, THz and radar bands are all very useful in scanning the environment and goods. The IR/THz band is suited for local communication between robots.	10
10	Lidar systems used in robot transport are based on small lasers. Lasers are also suitable for headlights and identifying materials.	5
11	A distribution robot can converse with customers (verbot) and act as a shop, for example.	3
12	The development of artificial intelligence is necessary for the development of autonomous robot transport.	10
13	Platforms make it easy to develop specialised freight transport equipment, also for narrow market segments.	5
14	Facial recognition facilitates transactions and increases security.	1
15	The ability to converse as a verbot with the receivers of goods about delivery times, routes and orders promotes the operation of distribution robots.	5
16	A self-driving vehicle absolutely requires a real-time situation picture of its environment and other moving vehicles and people. Detecting and identifying other moving vehicles, people and material is an advantage.	20
17	The identification, grabbing, loading and unloading of goods becomes easier.	5
19	Packing and unloading becomes easier when VR glasses point out the goods and their designated places.	5
20	VR glasses assist the remote controller of a loading or unloading machine in problem situations.	3
21	When robotised loading and unloading of goods requires subtle remote control, it is easier with haptic interfaces that are based on body movements, and VR glasses.	5
22	A self-driving car collects an enormous amount of situation data that can be used to teach and optimise autonomous transport and cover the operating costs.	3
23	Increasingly small devices have the storage capacity for artificial intelligence that is required for autonomous control, leaving more room for freight. The transport of small packages by quadcopter benefits from this the most.	10
24	Quantum communication can enable theft-proof remote control.	3
25	Increasingly small sensors and more efficient electronics make smaller devices possible.	3
26	The computing required for reliable autonomous driving now requires a very expensive processor that needs several kilowatts of power, so it is necessary to improve efficiency.	10

ART-ID	Logistics: applications of the ARTs and evaluations of their effectiveness	Weight
27	A walking robot is necessary for autonomous distribution of goods to households. An exoskeleton makes “manual” loading easier.	5
28	A self-driving car enables a radical reduction in the costs of distribution transport and efficient delivery of goods to households.	20
29	Lightweight freight transport equipment contributes to logistics and transport of goods and enables cost-efficient local distribution under suitable conditions.	5
30	Quadcopters and other drones can be used to transport goods in short-distance distribution and express deliveries over long distances very energy-efficiently and quickly.	20
32	The renaissance of airships will facilitate freight transport independent from roads and improve energy efficiency in comparison to many other modes of transport.	3
33	Small deliveries by waterborne transport will be made easier by robotisation, similarly to large freights. Ships with lightweight hulls allow larger freights to be transported in inland waters and new waterways to be introduced.	5
34	Ports can be relocated off shore and terminals inland. Goods will be transported more energy-efficiently and quickly. The trade area for fresh goods will expand.	5
37	Remote-controlled or autonomous loading and unloading of sensitive goods by a robot requires touch-sensitive hands.	5
38	Reduced mass production volumes and gradual return to local manufacturing will make freight transport more personalised and heterogenous in nature.	5
39	Automation of street and road repairs by 3D printing structures.	1
40	The swarm intelligence of robots that put together consignments can greatly enhance warehouse logistics. Detection of product defects in the pickup phase will save a great deal of work.	5
41	The unique identity of goods enables crowdsourced freight transport, address changes during transport and right-based key management when goods change hands.	10
43	New methods of transferring goods are being developed for warehouse logistics.	1
45	The Hyperloop and other frictionless transport of goods. Reducing friction in ships and trucks.	3
46	Refrigerated transport or other condition requirements and insulation of packaging. Inland waterway vessels and air transport equipment can be made lighter.	5
48	Sturdy, lightweight wing structures contribute to air transport.	1
49	The affordability of sturdy, lightweight materials and efficient batteries is key for aircraft.	3
50	Waste management is part of freight transport, and new separation techniques affect the methods in which goods are handled as well as the reuse of waste as raw material, thereby also affecting transport routes.	5
51	The cleanliness of containers, transport facilities and transfer equipment is essential in the transport of material.	3
53	Artificial muscles and skin allow the creation of better robots that handle and transfer goods for warehouses, shops, plants and local distribution.	5
66	The logistics of food, animal transport and feedstock will change materially.	5

ART-ID	Logistics: applications of the ARTs and evaluations of their effectiveness	Weight
67	The needs of food logistics are going to completely transform when cultivation shifts from cyclical and agriculture-dominated cultivation to continuous urban and factory cultivation.	5
69	The need for refrigerated transport will increase as refrigeration becomes more efficient and its quality improves.	3
70	Electric transport benefits from inexpensive solar energy. For example, it may have a material effect on small waterborne vessels and rail transport, at least in southern countries.	5
73	Inexpensive and efficient batteries are necessary for electric cars while light and efficient batteries are necessary for helicopters that transport goods, and quickly recharged batteries are necessary for other freight transport.	10
74	Synthetic fuels may enable carbon-neutral motoring with existing vehicles that are equipped with an internal combustion engine.	3
75	Hydrogen cells allow quadcopters to stay in the air longer than batteries do.	3
76	Safe and inexpensive storage of hydrogen in a dense form allows hydrogen cells to be utilised more easily as a power source for aircraft, marine vessels and vehicles.	5
78	Synthetic fuel made with renewable energy increases the acceptability of internal combustion engines and influences their fuel costs.	3
80	Recovery/harvesting of kinetic energy improves energy efficiency.	3
81	Ray guns can efficiently disturb traffic.	1
82	Wireless charging of autonomous delivery vans and quadcopters during loading.	5
83	Electrification and similar changes will significantly affect the structure, energy need, operating range, adverse effects, travel comfort and manufacturing of vehicles, among other things.	10
84	Gamification of logistics impacts may influence choices made by consumers.	1
85	Time banks can increase peer assistance in freight transport in local communities. Extensive use of cryptocurrency will increase deliveries of illegal goods and make it more difficult to control freight transport.	1
86	Many local transport service models can arise from crowdfunding.	1
88	With a self-driving car replacing a human driver, human assistance will be needed for remote controlling loading or unloading and solving problem situations.	10
89	The anonymisation of freight transport data and encryption or authentication of route directions received by modes of transport is an important thing both for criminals and with regard to cyber security.	3
90	Platforms can organise local distribution and material recycling in local manufacture.	5
91	Freight transport as a decentralised platform service may grow considerably, but it requires pick-up and delivery points to be standardised.	5
92	In freight transport, modularity will help with issues relating to remote freight forwarding, warehouse logistics, loading, small-scale distribution and home delivery.	10
93	E-commerce will change freight transport materially in a more heterogeneous direction. A greater proportion of goods will be delivered directly to end customers rather than retailers that function on the pick-up principle.	5

ART-ID	Logistics: applications of the ARTs and evaluations of their effectiveness	Weight
94	A 5G network is essential for logistics, as it allows the loading and unloading of goods and other similar activity to be assisted through remote control as necessary.	5
95	Logistics requires extensive data in as close to real time as possible on both external and internal spaces and routes on land, at sea and in the air. This supports the device's own observations.	5
96	It is possible for most sales, forwarding, transport, loading and manufacturing work related to logistics to be carried out abroad, leaving only the infrastructure and maintenance to be handled locally.	10
97	The decentralisation of waybills and logistics forwarding will become possible.	5
99	The transfer of logistics history information (MyData/GDPR) from one operator to another can facilitate logistics.	3
100	VR glasses are used in remote control related to logistics.	3

1.3 Manufacturing of goods



Scope of the value-producing network: The availability and manufacturing of physical goods and equipment from available raw materials is the objective of this value-producing network. This definition excludes food and the fixed built environment, which are addressed in their own value-producing networks.

The most important values relating to goods and equipment are functionality, perceived quality, ease of purchasing and cost. Functionality involves appropriateness and e.g. aesthetic values if the item is intended to please the eye. Functionality also involves ease of use and other practicalities in maintenance situations, for example. Perceived quality involves expectations about surface materials, physical durability and long service life through compliance with standards or a modular structure and ease of maintenance, for example. Ease of purchasing is reduced by the amount of effort required to seek out, compare, pick up and recycle items as well as long waiting periods. Cost includes the expected operating cost and purchase cost.

The means and values of transformation: With the advancement of robotisation, a production structure that is based on present-day mass production and hierarchic distribution may become decentralised so that an increasing proportion of goods will be manufactured near customers in accordance with their individual needs. Flexible production lines and contract manufacturing are already a step in this direction. Digital manufacturing combines design and manufacturing tasks and increases the subcontractor's responsibility through a model-based definition, making it a part of the seamless production entity. Production and service are drawing closer to each other.

According to the data of the WTO, world trade has been growing more slowly than the global GDP for several yeas. This indicates that the percentage of local manufacturing is already growing. If taken to the extreme, this trend would lead to activity reminiscent of the artisan period, which would mean making goods for the manufacturer's own needs and providing them to customers as a service according to the dimensions and wishes stated by the customers.

Efficient customised production requires digitally controlled and technically flexible machines that are able to effortlessly adjust their operation as needed. 3D printers are a good example of this type of development. There are several techniques for 3D printing, and no single device is suitable for all purposes, but flexibility, versatility, efficiency and quality are improving continuously. These devices are already being used to manufacture aircraft and car parts, glasses, prostheses and medical instruments that comply with demanding industrial norms, in addition to a great variety of long-lasting consumer goods, such as shoes and decorations. Materials in use extend from metals and plastic to ceramics, composite materials and biological materials.

In addition to 3D printing, numerical machining and assembly technology created within traditional automation are constantly evolving, becoming more flexible. In the textile industry, fabrics can become personalised, with robots capable of automatically sewing simple and customised pieces of clothing. Furthermore, robots are increasingly evolving into multi-skilled entities similar to humans. A robot can move to the target object as needed and e.g. grab it with one hand while choosing a suitable tool with the other hand and then perform a measure related to machining or assembly. As a consequence of the adaptability of robots, an actual production line or conveyor belt will no longer be needed when the same robot can perform a great variety of work stages, such as first manufacturing a chair and then a stool.

Artificial intelligence and new measurement and modelling techniques, particularly parameterised modelling, will speed up customised design. New imaging techniques allow the measurement of the user, operation environment and need for goods to be automated, and artificial intelligence can propose drafts conforming to the desired style for approval and subsequently draw up manufacturing instructions for robots.

3D scanning, robotisation and 3D printing link the digital and physical worlds. They form a digital manufacturing chain for goods that reduces the order-to-delivery time and eliminates or combines various phases. The operating structure becomes flexible when one employee can manage the production chain as well as parts of the chain of the customer and subcontractors.

The most important values promoting this change are related to customisation or small production volumes and special needs as well as the significance of a wide variety of products. Competitive flexibility also promotes development.

The means and values of the dominant regime: Today, almost all goods are produced in large industrial facilities with the help of automatic equipment that performs repetitive work tasks. A significant part of labour-intensive industry has been relocated to countries with low labour costs due to the decrease in logistics costs, and the centralisation of industry has continued, with automation increasing economies of scale.

Manufacturing processes seek to mass-produce products with the help of global centralisation, distribution logistics and mass marketing. Design is subordinate to manufacturing, and large brands seek to control consumption habits with the help of images. Subcontractors deliver components to their clients, whose assembly lines manufacture products that are delivered via distribution steps to major customers and retail stores for customers to pick up. E-commerce and the enhancement of logistics that delivers individual packages globally have begun to eat away at this simplified hierarchical model. Design and manufacturing are separate tasks, and it is rarely possible for a subcontractor to directly influence design.

The value of Finnish export and import of goods is roughly €60 billion. Some of this trade is left outside the scope of this value-producing network, as is a part of the industrial workforce of roughly 300,000 people. On the other hand, many other sectors serve the manufacturing of goods and equipment, and everyday life or society in the modern sense would not exist without commodities.

The needs of the manufacturing industry have dictated a significant part of the structures of society. Housing has been built in industrial municipalities and near logistics nodes. The largest groups of goods are related to electronics and machines, vehicles and other transport modes, interior design, clothing and accessories.

The most important values preserving the current dominant regime are related to normative safety, the structures of trade and logistics and an unwillingness to take risks in the development of methods in both the domestic market and the export industry.

The benefits, risks and inhibitors of change: Production that meets individual needs is beneficial in many ways. It reduces the need for storage and logistics with regard to all products made of simple raw materials and components. The need for raw material and packaging material is reduced. Customisation and suitability deliver added value to the customer. Flexible production facilitates maintenance, allowing any broken or worn parts to be manufactured quickly and locally as necessary.

Local manufacturing reduces the need for import and export and increases employment. In small-scale production linked to a service, the relationship between capital and labour is typically more labour-intensive than in repetitive industrial labour and logistics. Local decentralised and flexible production capability also reduces susceptibility to crisis.

Need-based local manufacturing that is based on flexible robots and 3D printers involves significant risks. Product safety and liability issues are unclear, and decentralised need-based manufacturing also leads to a new situation with regard to intangible rights that partly corresponds to the challenge posed by the Internet to the music industry. For example, if a certain protected commodity is manufactured in hundreds of thousands of localities by small local organisations, with each of them only manufacturing a few pieces, the rights are difficult to defend. With the customisation of products and the contribution of artificial intelligence to design increasing, it is also becoming increasingly difficult to say what exactly constitutes a breach of someone's intangible rights.

User habits slow down the change, and no pressure is applied to the development of the supply by the user base. The unwillingness of the trade and service sectors to seize new opportunities and adopt them as part of their own supply is a significant factor slowing down development, together with incomplete technologies. E-commerce is speeding up the change because it bypasses channels that are unwilling to change. One major inhibiting factor is the lack of skill, particularly at the level of new business models.

Growing professions and skills shortages: As local manufacturing increases, many industries that have almost disappeared from Finland will make a comeback. This can especially apply to the textiles sector. In other sectors, the emphasis of professions will change. Digitalisation will create professions in which application expertise is important. A digital designer creates, designs and produces unique personal items and home or consumer goods according to the needs and wishes of customers, such as tools for the elderly or disabled people, professional tools produced according to the size of the user and personalised tableware for young couples. Also, specialty niche professions will emerge, such as 3D measurer, 3D modeller, model selection consultant, 3D printer, local manufacturer, printing post-processor, goods stylist, raw material consultant, goods programmer and inspector of goods made by robots.

The new skills associated with the change in the industrial regime are particularly inadequate because currently each profession and sector evaluates its own tasks within the well-established structure, and there are no business skills for the opportunities introduced by new technologies. Digital product integrator will emerge as an important new profession in the industry, and its role in industrial companies includes combining design and production into a well-functioning entity, for example with the help of model-based definition.

Policy objectives of the change: To speed up change, tens of thousands of public, free models of the most common everyday goods should be created and made available for free use for local printing services. Educational institutions could produce and review these as student works. This should be considered as an intangible infrastructure similar to public service broadcasting or public education and health care. Reasonable requirements that do not complicate operations should be set for the product descriptions of local manufacturing. Public administration should manufacture a growing part of the goods it needs by itself. Manufacturing of the least difficult goods should be considered as equivalent to using copying machines.

Product liabilities should be clarified in situations in which a service company manufactures a model chosen by the customer or a user manufactures products using models produced by other parties. This work combines manufacturing equipment and material in a way that is out of the control of the model's creator. Instead of physical labels, any manufacturer and product data concerning customised products must be established in cloud services through open digital interfaces, and these data must be provided separately for the material, models, printing equipment and manufacturer with the overall responsibility. The aim should be to facilitate the use of 3D printing as part of a customised product manufacturing service. Transitioning from physical labels to digital data will also facilitate recycling.

Special national characteristics: Finland is exceptionally dependent on import, and the domestic market is small, making it difficult to gain industrial economies of scale. The high level of education, high logistics costs and decentralised social structure make Finland an opportune area for being at the forefront of local manufacturing. Finland's industry is widely based on small production volumes, for which 3D printing could be a suitable method.

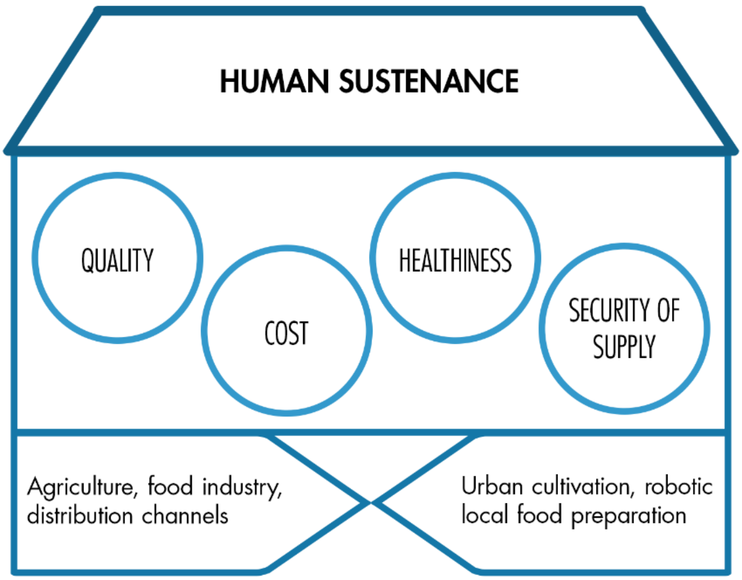
ART-ID	Manufacturing of goods: applications of the ARTs and evaluations of their effectiveness	Weight
1	Quality and preferences are easier to check with a direct link to the brain.	1
4	Adjusting the concentrations in a production process, and monitoring the safety of production facilities.	3
5	Identifying the properties of raw materials, and quality control of the finished product.	5
6	3D scanning is needed to copy goods, and it requires imaging.	3
8	One of the techniques used in 3D printing utilises photocurable resin. The development of LED technology plays a significant role in it.	1
10	Some 3D printers use laser to attach materials by sintering. Even low-power lasers are used for cutting and welding materials.	3
12	Artificial intelligence is needed especially for the handling of fabrics, individual production and production maintenance related to clothes made by robots.	5
13	Platforms enable easy copying of goods by sharing 3D models as well as many individual need-based modelling tasks comprised of narrow segments.	5
16	The ability of an assembly robot to move, grab components, handle an item being assembled and look out for people requires real-time modelling of the environment.	10
17	Easy 3D imaging of objects facilitates copying and modelling an item that is customised to fit the shape of the environment. This also facilitates assembly.	5
19	AR glasses can identify a task and show how assembly must be carried out.	5

ART-ID	Manufacturing of goods: applications of the ARTs and evaluations of their effectiveness	Weight
20	VR glasses can be used to view printing models before they are printed and control assembly robots.	5
21	The remote control of customised robots in miniaturised or heavy manufacture work is natural with haptic user interfaces.	3
25	It is increasingly easy to add electronics and optics to goods.	3
26	The perception required in assembly tasks benefits greatly from growing computing power.	5
27	An exoskeleton provides assistance in heavy assembly work.	1
29	Lightweight transport equipment can partly replace a conveyor belt in manufacturing.	1
30	Quadcopters can perform some industrial assembly tasks and transport tasks relating to manufacturing on a production line, in addition to monitoring production.	3
35	Manufacturing in a vacuum or a weightless space is the easiest way to manufacture some goods and the only way to ensure the high quality of other goods.	1
37	A robot that manufactures versatile, customised products requires touch-sensitive hands.	5
38	3D printing plays a growing role in the manufacturing of goods and their spare parts. Particularly small production batches and customised products should be printed where possible.	20
40	Goods can grow into their shape or microbots can make them. The growth and restorability can be controlled with DNA and epigenetics.	5
41	The unique identity of the manufactured products allows all history information, properties, owner information and future needs to be recorded in cloud services.	10
42	Robotic arms allow certain manual labour phases in the manufacturing or installation of goods to be provided as a service that a machine is not capable of but can learn when controlled.	3
43	New methods for manipulating goods and materials enable the assembly of miniaturised machines and many other new flexible manufacturing processes without an assembly line.	5
44	Autonomous and customised manufacturing of clothing.	10
45	The use of levitation in the assembly of miniaturised equipment.	3
46	The properties and manufacturing methods of goods benefit from new materials.	5
47	New metamaterials and assembly techniques offer significant opportunities for product innovation in the manufacturing of goods.	3
48	Nanomaterials enable new product properties and manufacturing processes, such as bullet-proof clothing lighter than Kevlar and wearable electronics.	5
49	The inexpensiveness of nanomaterials substantially impacts the materials used in the manufacturing of goods as well as the product properties.	5
50	The idea of circular economy affects the raw materials of goods. Recycled materials are an increasingly essential part of the raw materials of goods.	5
51	New coating techniques help in the manufacturing of dirt-repellent clothing, antibacterial food processes and goods that are easier to keep clean.	5

ART-ID	Manufacturing of goods: applications of the ARTs and evaluations of their effectiveness	Weight
53	The development of robots contributes to the automated manufacturing of goods.	3
54	Water is a raw material in the manufacturing of goods, and its quality is essential in many processes.	1
55	New materials enable the development of processes and product properties. Simulation techniques speed up the creation of the required product properties.	5
59	GMO materials increase opportunities in the manufacturing of goods. Genetic modification enables both new raw materials and product parts that are grown into shape.	3
61	Simulation makes it possible to design goods made by microorganisms.	1
63	Cell culture produces raw materials for the manufacturing of goods.	3
64	Organs that resemble their natural counterparts can be manufactured from a cultured cell with 3D printing of biomaterials.	3
68	Many new fibres have a significant impact on the quality of goods.	3
70	Energy-intensive manufacturing can be relocated from industrial countries to countries with inexpensive solar energy.	10
71	Using heat and electricity generated by solar mirror systems in production is energy-efficient. Turning waste heat into electricity improves efficiency.	3
72	Enables continuous production powered by renewable energy.	3
78	The use of nanocarbons mass-produced from carbon dioxide as a raw material in goods may change industrial structures and product properties.	3
79	Small nuclear power plants can make industrial processes independent of the electricity grid.	3
81	High-performance lasers make it possible to cut and otherwise work on materials easily and precisely.	5
82	In swarm manufacturing, ensuring continuous energy supply to the members of the swarm.	3
86	Many new goods are being developed with crowdfunding and produced with flexible production lines and 3D printers.	3
87	The manufacturing of goods can be decentralised more easily if the required skills can be obtained in a decentralised manner.	1
88	In many tasks relating to robotic manufacturing, the robot must be taught and, in rarer cases, controlled. A human can do so through remote control.	3
90	Platforms can organise the material flows, distribution and orders related to local manufacturing as well as the models required for manufacturing and marketing.	5
92	Local manufacturing of a wide range of customised products requires semi-finished goods and multi-skilled robots that cannot be created without a clear, specialised ecosystem.	10
93	Goods are increasingly being bought from machines in the style of Industry 4.0. The buyer may also be a machine, and payment traffic is becoming automated.	3
95	The models for printable goods are increasingly often crowdsourced and available via cloud services.	5
96	Global models of goods and the online sales platform can be generated globally. If a customer visits a printing service, the service robot can be guided by a global AI.	5

ART-ID	Manufacturing of goods: applications of the ARTs and evaluations of their effectiveness	Weight
97	Manufacturing methods, materials, sales, service history and other life cycle data of individual goods can be recorded in a decentralised manner in a blockchain, and counterfeit goods will be increasingly easy to control.	5
98	Some goods are art or entertainment objects, and digitality is increasingly unifying global material culture.	3
99	Receiving one's own dimensions and information about one's own goods from the service provider reduces the need for repeated measuring and errors related to it.	3
100	A remote expert can use VR glasses to participate in the most difficult work phases that require manual work by a maintenance worker who uses AR glasses. Standardisation of interfaces will make the practice more common.	3

1.4 Sustenance



Scope of the value-producing network: The primary objective of this value-producing network is human sustenance, as well as pet sustenance, i.e. the intake of energy and the necessary nutrients and trace elements in a healthy and enjoyable way.

The most important values in people's choices are perceived quality, purchase costs, the notion of healthiness and security of supply. Quality involves taste preferences and sense perceptions as well as the social context. Costs must be considered to include not only the price but also the effort of acquiring or preparing the food, while healthiness involves the amount of energy in the food, its nutrient content and spoilage as well as allergens or similar individual problems. The availability of food from the perspectives of security of supply and sustainability is an important cornerstone of society. Regardless, sustenance must meet individual needs and desires.

The means and values of transformation: At present, food production is primarily based on cultivation of fields, cultivation in greenhouses as well as animal husbandry. These produce, on an industrial scale, raw materials that are processed by the food industry and taken from there to the commercial distribution chain and institutional kitchens.

The challenger regime is based on aquaculture that is primarily carried out under artificial lighting in a closed space in cities and factories as well as insect husbandry, biotechnical food production and robotised, decentralised and customised food orders. By replacing the cultivation of fields and animal husbandry with urban farming, production can be made continuous and need-based, and food production will no longer require a major industrial intermediate phase. Indoor farming and new GMO techniques will make genetically manipulated food safe, efficient, nutritious and tasty.

Indoor farming usually takes place in tight spaces, with the plants growing on shelves. The nutrients are provided to the roots in the form of liquid and the Sun is replaced by LED lights that are set to provide the leaves of the plants with the wavelengths that they need at any given time. Compared to the cultivation of fields, this farming method requires dozens of times less water, and no fertilisers leak into the environment. With farming taking place indoors, the growing season lasts all year and the cultivated area only covers a few hundredths of the space taken by cultivated fields.

If energy were to be generated in arable land with solar panels, a significantly higher amount would be generated compared to a natural growing season. The low efficiency of solar panels and LED lights currently wastes these and other benefits that are gained from precise pointing of light. However, we can estimate from the perspective of the energy economy that the energy generated by solar panels covering all arable land could already be used to cultivate the same amount of food indoors as by cultivating fields, particularly in northern conditions. As the efficiency of solar panels and lighting as well as farming methods evolve, the advantageous position of indoor farming will also improve in this respect.

The need for protein and people's food preferences are difficult to satisfy with vegetables only. The culture of animal cells is being developed by various means, and biotechnological protein is expected to become common towards the end of the period examined in this report. Plant and insect-based proteins that mimic meat will become common before this. In addition to the taste, the amino acid composition can be adjusted so that the products correspond to the nutritional values of meat. In the future, artificial meat can for the most part be produced locally by means of local manufacturing.

The food industry mass-produces processed food with the help of the industrial paradigm. Robot cooks, which are currently in the pilot phase, operate like human cooks, preparing individual meals. They run on rails, and their hands can reach the kitchen cabinets, refrigerator, chopping board, stove and oven. A robot cook can be placed in a restaurant, institutional kitchen or shop, for example. The most advanced product is said to be able to prepare a hundred different dishes and cost €75,000.

It seems to be only a matter of time before a robot cook can prepare food for the residents of an apartment building according to their tastes and needs, at a fraction of the costs of an institutional kitchen. A robot cook could also order any necessary foodstuffs and invoice the residents individually according to the ingredients consumed.

As a somewhat contradictory trend that makes the development of robot cooks partly unpredictable, the methods of preserving processed food may evolve radically. According to some observations, vacuum-packaged food that is irradiated underwater retains its freshness for several months at normal room temperature. If this process truly guarantees the food's tastiness in a way that satisfies consumers, it may radically change the e-commerce of food. For example, consumers could order a month's worth of food from anywhere according to their own tastes. Food would be delivered inexpensively as sea freight, and it could be stored in any room-temperature cabinet.

The most important innovative values are related to individual needs and preferences as well as sustainable development. These are strengthened by a range of ethical values, increasing allergies and increasingly diverse ethnic backgrounds. Development is accelerated by the increase in the number of options as well as awareness of the state of one's own body. The popularity of functional nourishment and our understanding of the impacts of unnecessary or harmful substances on our own bodies will continue to grow thanks to evolving measurement equipment and artificial intelligence.

The means and values of the dominant regime: The cultivation of fields is a cyclic activity that produces a great amount of raw food material at once. Animal husbandry and greenhouse farming also feature obvious economies of scale and even some cyclicality due to seasonal fluctuations in natural light, cattle fodder or consumption needs. The efficiency of large farms far exceeds the amount of food produced if everyone had his/her own cow or goat, a few chickens and a plot of arable land, with enough storage space for a year's worth of food. However, large farms with their intensive farming and animal farming processes create a need to process and store industrial amounts of foodstuffs. This in turn creates a need for distribution channels, grocery stores and institutional kitchens, in addition to a need to control all of this.

Control of the cleanliness of the food supply chain, regulation of the additives in processed foods and control of labelling have become more important than a normal consumer's understanding of what everyone should eat.

Food production relies on subsidies and operates within a frame established by regulation. The subsidies are allocated for the tools and methods used rather than production output. Other regulation and control measures also primarily pertain to operating methods rather than output. The most important value is compliance with the prevailing operating model. The logistics chains of the food industry and retail are closed and controlled by few operators. They benefit from preserving this operating model as is.

The benefits, risks and inhibitors of change: New indoor farming techniques and robot cooks are still in the pilot phase. The technologies will likely mature and become suitable for wide-scale use in the 2020s. The benefits provided by this change are related to public health, quality of life, environmental sustainability, crisis resilience, terms of trade, employment and other factors. Personalised sustenance that satisfies our own preferences and needs and is farmed and prepared nearby is in many ways healthier than standardised, processed and preserved food. The adverse environmental effects of indoor farming are significantly lower than those of cultivated fields.

The current centralised control processes can be considered to pose a risk to the transition to new practices. They hinder and prevent the change by imposing obligations on small local operators that are designed for the needs of major operators and to prevent systemic risks. As food becomes personalised, control must become automated. Instead of processes that are laborious for entrepreneurs, small operators could be controlled with consumer notification procedures, insurance coverage for entrepreneurs and in-house control as suitable for controlling local level risks.

Factors that slow down change include the fact that people are accustomed to going shopping and a lack of an alternative distribution channel. Strong integration of the food supply chain and streamlining implemented within the chain make it more difficult to gradually change the chain's structure. On the other hand, the change can be accelerated by local food and special diets being a part of one's identity and the farming and preparation of food being a part of one's way of life.

Growing professions and skills shortages: The most significant aspect affecting professions is the personalisation of nutrition and urban farming. Growing new professions in the new operating model include bioproduct factory designer, urban farmer, cultivar and nutrition optimiser, bio-raw material logistics officer, traceability officer, food insurance agent, indoor cultivation supply vendor and mechanic, nutrigenomics consultant, metabolism analyst, food designer, robot cook technician, robot restaurateur, virtual restaurateur, food service platform specialist, remote cook, maturation scheduler, artificial meat farmer and food freight forwarder.

These new jobs essentially differ from the current jobs of nutritionist, farmer, market vendor and restaurateur, and the number of jobs will increase compared to these, but the jobs in the current food chain will decrease correspondingly.

Policy objectives of the change: The research and teaching of LED farming, biotechnical farming and nutrigenomics should be significantly expanded. Official instructions for ensuring the conditions of the buildings used for indoor farming and the quality of food are needed. Artificial, cultured meat must be defined as a vegetable. GMO food should be allowed more easily than currently, especially in indoor farming. LED farming should be regulated as support neutral with all other cultivation, and it should be favoured for reasons related to the security of supply due to the decrease in the need for storage. Obstacles and burdens to small-scale production should be removed by means of the platform economy by e.g. generating digital marketplaces that use public robotised logistics and by making small-scale production more proportional to a household's own food production. The experimental activities of robot community kitchens should be started. Roles and responsibilities should be created for the operations and plan provisions prepared for robot community kitchens.

Special national characteristics: The growing season is short in Finland, retail is centralised and food control is highly normative. The technical skills and proactivity of the population are at a high level.

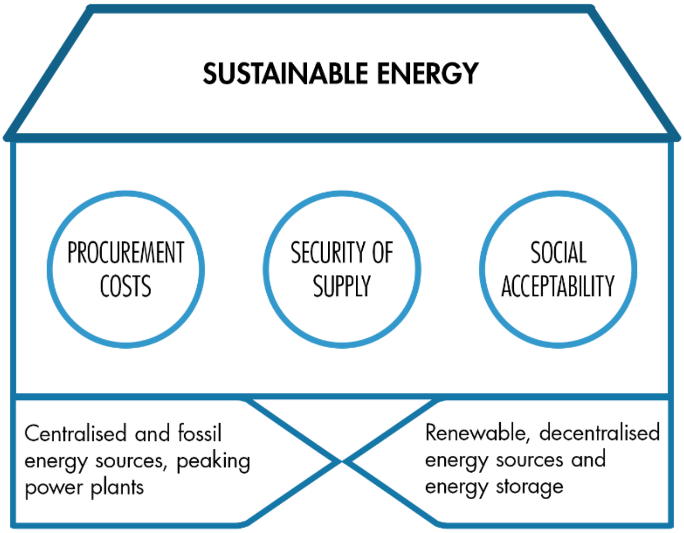
http://www.vtt.fi/inf/pdf/visions/2017/V9.pdf

ART-ID	Sustenance: applications of the ARTs and evaluations of their effectiveness	Weight
1	Close analysis of preferences in order to plan a personalised diet.	3
2	Inspection of the microorganisms in food and the origin of food. The impact of one's own genome and microbiome on personal dietary recommendations. Development of GMO food.	20
3	Measurement of the need for food and suitability of food by monitoring vital signs.	10
4	Food safety – control of the shelf-life and freshness of foodstuffs.	5
5	Personal ability to identify the composition of foodstuffs in a shop or on a plate. Measurement of agricultural and animal husbandry processes and the properties of raw materials.	10
6	The robotisation of food production benefits from the development of imaging technology.	3
7	In practice, a material scanner requires transmission and reception capability in the IR or THz band, and it is useful to have more than one waveband and a cell, similarly to a multispectral camera.	3
8	Indoor farming is fully dependent on the efficiency of the colour of the LED lighting required by the plants and the price of LED lighting.	10
10	The irradiation of food is a means of preservation.	1
11	Ordering food and discussing it with a robot kitchen makes the process feel more natural.	3
12	Guidance and learning of the robot cook, planning of individual nutrition and optimisation of growth conditions.	10
13	Pattern recognition platforms speed up the product development of agricultural robots and kitchen robots.	5
14	Recognition of emotions to determine taste preferences.	3
15	Discussing food with a robot kitchen is easier than using menus.	3
16	Robots performing agricultural work on fields and ranches require a real-time situation picture of their environment, including recognising materials.	5
18	The preparation and cultivation of food involves a vast number of recipes and tricks. Compiling these into teaching materials for artificial intelligence is useful.	5
19	AR glasses can provide guidance in all phases of food production and preparation.	10
26	Modelling cell metabolism in order to simulate the effect of food on health in a simple way will require an increasing amount of computing power.	5
28	A self-driving car contributes to urban farming and decentralised cultivation of food by delivering food cost-effectively from farmers directly to consumers.	3
29	Lightweight freight transport equipment facilitate the distribution of foodstuffs and delivery of food produced at urban farms to households.	3
30	Quadcopters can be used to perform agricultural measurement and control tasks as well as spraying and some of the planting.	3
36	In the event of the destruction of bees and other pollinators, it could be possible to develop robotic insects to perform pollination. This same need may apply to indoor farming.	3

ART-ID	Sustenance: applications of the ARTs and evaluations of their effectiveness	Weight
37	A robot cook requires touch-sensitive hands to be able to perform the same tasks as a master chef without problems. Sensitivity is also useful in handling animals and plants.	5
40	Self-correcting processes and swarm intelligence are well-suited for robotised farming.	5
41	In food production, a ubiquitous environment provides favourable growth conditions, and unique identification of each batch helps artificial intelligence learn from errors in the process.	5
42	Services for teaching robot cooks, teaching agricultural robots, and remote control services.	3
45	Cleaning dishes with the help of a lack of friction.	1
46	Food packaging benefits from insulation.	3
50	Separation techniques affect the raw materials needed for plant and meat cultivation and may affect the preparation of food. The circular economy affects nutrient intake.	5
51	Food safety improves when bacteria and impurities do not spread so easily.	3
53	The development of robots is beneficial to all phases of food production. Artificial muscle promotes the development of service robots.	3
54	Fresh water is essential to all phases of food production, and a growing number of people are living in areas in which the use of fresh water must be restricted.	10
56	Plants can be fitted with artificial parts to replace roots or leaves, for example. Cuttings with artificial roots, or an artificial nutrient fed to the productive part of a fruit.	3
57	Lifestyle choices and food are becoming more important – the idea of “your body is a temple” is becoming more common. This increases the need for personalised, clean and functional nutrition.	3
58	Microbots can determine the body’s need for food. They can monitor the vital signs of livestock, and both nanoparticles and microbots can be useful in plant nutrition.	5
59	With the help of genetic manipulation, plants and animals can be made to adjust to the conditions, and both them and microorganisms can be made to produce edible substances efficiently.	10
60	The manufacture of GMO products has become easy and precise.	5
61	Design of genetically modified plants and organisms, simulation of the body’s own cells and testing reactions to food.	5
62	An understanding of cell metabolism and knowledge of the microbiome help with the planning of individual nutrition. Hereditary tendencies can also be considered.	5
63	Humans eat organs, cells and their structural parts. Cell culture is an important potential source of nourishment.	5
64	Cell culture can produce nourishing food material, but the food also requires a pleasant texture in order to be tasty. It can be produced with 3D printing.	5
66	Raising beef cattle causes significant disadvantages and is ineffective. Replacing it with a biotechnical or cultured protein of good quality would be a great achievement.	20
67	The potential transformation of the food industry from cyclical agriculture to continuous and need-based, decentralised urban and factory cultivation.	20

ART-ID	Sustenance: applications of the ARTs and evaluations of their effectiveness	Weight
69	Storing genetic materials in gene banks for future needs. Refrigeration technology that preserves the structure of foodstuffs and freezes them quickly is becoming more common and efficient.	3
70	The improving efficiency and price of solar panels and LED lights may lead to it becoming sensible to cultivate plants more extensively indoors under LED lighting.	5
77	The use of local energy surplus in indoor farming is likely to become more common, the synergy is good.	3
78	Synthetic biomaterials and CO2 fertilisation enhance food production.	3
79	Small nuclear power plants can make indoor farming independent from the electricity grid.	3
84	Gamification of dietary habits can promote both sustainable development and nourishing meals.	3
88	Robot cooks and agricultural robots may need to be controlled under special circumstances. The least expensive good robot controller is often far away and remote control is needed.	5
90	Food production and local distribution are suitable for cooperative-type platforms.	5
91	Robot kitchens, robot farms and local food are well-suited for the platform economy.	5
92	The interfaces of food production robots and their components promote development, but separate tasks are left to individual manufacturers to solve.	1
93	Robot kitchens order the supplies from robot farmers when a customer orders food from a robot kitchen online. This chain extends to fertiliser that is ordered by a ploughing robot according to measurement data.	5
95	The connections between genetic materials and nourishment, the instructions for robot kitchens and robotic farming, shared lessons learned and experiences as well as artificial intelligence related to them – all of these are available in a cloud.	5
96	The AI of a robot cook can be global and so can the platform from which the food is ordered.	5
97	The food chain from raw materials to consumer products can be recorded in a blockchain up to the home delivery level of a single product.	3
98	Digitally produced experiences are linked to 3D printing of food. Global 3D modelling of food unites cultures.	3
99	Combining one's own genome, microbiome and nutritional information enables the development of lifestyle recommendations on an individual level and by many actors.	5
100	A remote cook can participate in demanding work phases with VR glasses, assuming that the remote cook and robot kitchen work on the same platform.	3

1.5 Energy supply



Scope of the value-producing network: The primary objective is need-based supply of energy to buildings, traffic, machines and processes. This means producing, refining, storing and distributing primary energy in a suitable form for a variety of purposes. Energy consumption is part of this examination in so far as the form of energy and need and appreciation for energy are concerned, but energy efficiency as such belongs to another value-producing network.

The most important values are related to procurement costs, the security of supply and social acceptability. The different efficiencies, storage needs and distribution costs of different forms of energy affect the decisions of both individuals and society. The externalities relating to the use of energy depend on the forms of energy used and their production, storage and distribution methods. At the level of society, all of these impact the social acceptability of energy production and consumption. The need to maintain the security of supply leads to contingency costs in many critical needs for energy.

The means and values of transformation: Today, the supply of energy is for the most part based on fossil fuels, nuclear power, centralised refining of primary energy in industrial processes and distribution through electricity, heat and fuel distribution networks.

Renewable energy sources and new energy storage techniques are increasingly challenging previous energy solutions. The utilisation of solar energy in local production of electricity and heat is becoming increasingly inexpensive at the global level, and it is estimated to eventually fall below the production costs of competing forms of energy in most areas.

Converting solar and wind power into gaseous and liquid fuels promises to solve the energy storage problem in a way that will simultaneously make part of the electricity grid and district heating network unnecessary.

The production cost of solar electricity has decreased by approximately 15% every time that the installed base has doubled. This trend pertains separately to traditional solar panels and new thin-film technology. Thin-film technology allows the power generation property to be laminated as part of buildings' surface materials. It seems completely possible that the production cost of solar electricity will fall to one fourth of the current cost within 20 years. Then it would fall radically below the costs of all forms of fossil energy.

Battery technology is evolving rapidly. The energy density of batteries may multiply compared to current batteries in the 2020s. The storage cost may decrease to €20–30 per kilowatt hour in large energy storage facilities. Battery life may exceed 10,000 charge/discharge cycles and the charge time may drop to a tenth of what it is now. New inexpensive battery materials, rapidly growing investments in product development and a wide range of theoretical and experimental breakthroughs observed at research laboratories make this bold prediction relatively clear and risk-free. The various necessary properties of batteries will lead to a more specialised variety of batteries and radically more extensive utilisation of batteries, at least in properties, traffic, robotics and electricity grids.

In the future, local storage of solar heat may be significant in conjunction with geothermal heat in northern areas. This need may grow with the increase in the proportion of solar energy and pressure to store energy and control consumption. Ensuring the supply of energy during winter may also favour small local power plants operating with kite energy, particularly in sparsely populated areas.

Fuel cells generate electricity and heat from liquid fuels, gases and solid matter with the help of chemical reactions. The raw material used may be hydrogen, methane, methanol or various salts, acids and metals, for example. The prices of fuel cells are expected to continue decreasing, and, as their use becomes more common, their market is estimated to grow tenfold over the next decade and continue growing rapidly after that. Fuel cells are used in local energy production. Their efficiency is high, and the equipment is quiet. The equipment can be scaled to a very small size, enabling the generation of heat and electricity for households.

The usefulness of fuel cells will be highlighted if solar and wind power can be easily converted into synthetic fuels in the future. Laboratory tests carried out on metal-organic framework materials (MOF) have yielded results in which as much as 20% of the solar energy landing on a panel is converted directly into fuel, with the carbon dioxide and water in the air acting as raw materials.

The primary values that promote development are related to sustainability, independence from the electricity grid and a spirit of experimentation. In the future, cost consciousness and security of supply may become new drivers of development. Awareness of climate change and other ethical values and the desire to save costs increase interest in the elasticity of consumption.

The means and values of the dominant regime: According to the data of Statistics Finland, energy consumption was 371 terawatt hours in 2016 on the Finnish scale, of which electricity accounted for 85 TWh. Industry accounted for 45% of end use, with the heating of buildings accounting for 26% and traffic for 17%. Fossil fuels accounted for 38% of total consumption, with renewable energy accounting for 34% and nuclear energy for 18%. The value of energy products imported to Finland was €7.2 billion, with the value of exported energy products being €3.9 billion. Forestry byproducts, such as logging waste and black liquor, account for a significant part of energy production.

Industry consumes the bulk of both fuel and electricity. Operators aim to utilise condensation heat generated from industrial processes as district heat. Electricity is generated in a centralised manner and distributed via transmission and distribution networks. The transmission cost per unit for industry is significantly lower compared to the transmission costs paid by other companies and households. A complex electricity market system is used to ensure security of supply. It encourages the maintenance of rarely needed peaking power plants and reduction of peak consumption.

The electricity market is strongly regulated, and the pricing of regional transmission network operators is cost-based. Operators are not allowed to participate in selling electricity, and they must organise the transmission of electricity in their area. The electricity transmission price is standardised, and the transmission cost within an area is practically the same regardless of any cost caused by an individual transmission line. The electricity tax is tied to the amount transmitted, and in total the transmission price and tax can amount to over 60% of the price of electricity paid by the consumer. Electricity generation is a competitive industry, but some production forms are subsidised, while others are subject to a licence.

The current mainstream is built to secure inexpensive energy for the centralised production structure and the import industry. Guaranteeing a regional cost level independent of the place of residence by means of the electricity grid and centralised production is a right provided for by law. The incentives for storing energy have been left at a low level, with transmission network operators prevented from storing energy and the benefit to users being minimised with the help of taxation that is based on the amount transmitted. Current control is in no way technology-neutral, and it effectively prevents change.

The benefits, risks and inhibitors of change: The rapid decrease in the price of solar energy and battery technology is reducing energy costs, particularly in countries in which solar energy is available comparatively regularly. In the few and sparsely populated northern countries such as Finland, the benefits are not as great due to increasing storage costs. This will lead to the weakening of the competitive edge of Finnish industry, which has benefited from relatively inexpensive energy costs, irrespective of whether solar energy is used in Finland or not. The prerequisites for renewable forms of energy are also improving in Finland, and the need to import energy or raw materials for energy is decreasing.

The expanding use of geothermal heat, solar energy and fuel cells is reducing the significance of centralised energy production as well as the electricity and heat distribution system related to it. Property-specific production avoids the costs of the electricity grid if it stores energy locally. This may reduce the need for a centralised infrastructure and any costs and vulnerabilities related to it, particularly in sparsely populated areas. Overall security of supply will improve and susceptibility to crisis will decrease.

Robotisation, the electrification of transport and the transition to indoor farming will materially increase the proportion of electricity in energy consumption. On the other hand, industry transitioning to less expensive energy may reduce the amount of electricity consumed by industry. Risks include major needs for write-offs in structures relating to energy production and distribution, fuel possibly stored by households and intentional slowing down of changes due to power politics and opportunistic reasons, among other things. The risk is increased by the fact that the periodicity of energy investments in company bookkeeping extends considerably further into the future than their profitability can be predicted. The profitability of energy production and distribution depends on government decisions in major issues.

Factors that slow down change also include people's expectation of power coming from a socket and the occasional irrationality and emotionality of politics.

Change is placed in a different light if small mass-produced nuclear power plants become practical and their licensing practices allow efficient decentralisation of nuclear power. However, this does not prevent the realisation of a change similar to the decentralisation predicted above in areas in which the distribution alone of electricity generated in a centralised manner is more expensive than its local generation.

Growing professions and skills shortages: New professions emerging from the change or growing due to it include e.g. local energy mechanic, local energy storer, energy storage predictor, fuel cell vendor, wind turbine maintenance technician, fuel distributor, off-grid maintenance inspector, solar panel cleaner and energy scrap recycler. The number of energy cooperative officers and energy advisers should also be growing, and the need for energy sector know-how should completely change from its current status.

Policy objectives of the change: Selling of electricity should be allowed regardless of the national grid by utilising the internal networks of small communities. An experimental law should be stipulated for these kinds of electricity cooperatives that are based on microgrid thinking. Shared use and exchange of electricity should be enabled in them as a peer-to-peer activity in structures similar to a sharing economy, separated from the obligations related to the national grid. Kite energy should be allowed first in an experimental mode and distinguished from the handling of other aircraft. Energy storage should be allowed as part of the operations of a transmission network operator. This can be done, for example, so that the user rents storage space if needed when electricity is inexpensive and uses the electricity storage when electricity is expensive or the capacity limit is about to be exceeded.

The regulation concerning the manufacturing and storage of fuels and use of fuel cells by households should be reviewed. The depreciation practices of the energy industry should be controlled so that the depreciation periods do not exceed the profitable lifetime permitted by law and that due care is followed in this matter as stipulated by the Accounting Act. Due care means taking into account that prices may decrease as a result of technological advancement, leading to the shortening of the profitable lifetime.

An obligation similar to roaming activity in a telephone network should be imposed by law on transmission network operators to make it possible to voluntarily lend a socket. The borrower could specify the amount of electricity that he/she would like to have transferred from the invoice of the socket's owner to his/her own invoice. This would allow operators with adequate mutual trust to use each other's sockets without administrative issues. This would facilitate the mobility of electric cars and autonomous robots in particular.

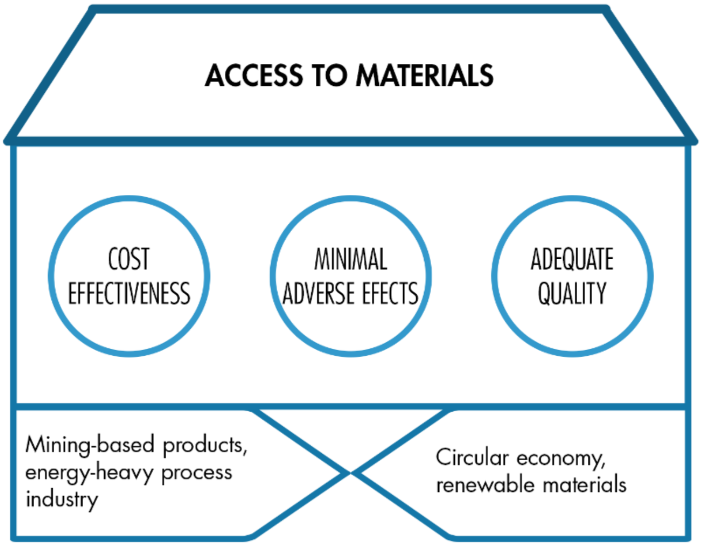
Special national characteristics: The northern location and other natural conditions of Finland, as well as the sparse population and extensive heavy industry, affect the energy solutions used in Finland in many ways. The need for seasonal storage and the distribution network cause higher costs than average.

http://www.stat.fi/til/ehk/2016/04/ehk_2016_04_2017-03-23_tie_001_fi.html

ART-ID	Energy supply: applications of the ARTs and evaluations of their effectiveness	Weight
7	IR reception transforms thermal radiation into electricity. Its potential applications include improving efficiency, harvesting thermal energy and wireless energy transmission.	5
9	Rectenna solar cells and the capturing of photons in plasmons allow better recovery of energy in several wavebands.	10
12	Optimisation of the storage capacity, energy production and maintenance of the grid.	3
25	Energy storage with new electronics materials and more energy-efficient electronics.	3
28	A self-driving car as a MaaS service is easier to electrify than a privately owned car, as the majority of cars are only required to be in driving condition during rush hours.	5
33	An electric, lightweight inland barge affects the form in which energy is distributed and consumed.	3
39	Printing a solar panel surface on structures.	3
42	Robotised cleaning services are needed for solar panels.	1
46	The amount of energy wasted decreases in heated or cold facilities, thermal energy storage facilities and transmission of district heat. Increases the popularity of cold rooms.	1
47	3D printed metamaterials can generate fuel from sunlight. 3D printed structures also serve as batteries, capacitors and solar cells.	5
49	Many nanomaterials are significant raw materials for new energy sources and energy storage.	5
50	Bioenergy is produced from waste that cannot be recycled. The development of the separation technique improves the quality grade.	3
51	The functionality of solar panels and windmills improves with the help of dirt-repellent surfaces.	3
53	It will become easier to orient solar panels according to the Sun's location in the sky.	3
54	The improving efficiency of the production of fresh water will increase the use of energy for this purpose if self-produced fresh water becomes more affordable than alternative methods of obtaining fresh water.	1
55	Smart materials are related to things such as batteries, other energy storage, solar energy and its conversion into fuels as well as fuel cells. Simulation is an important development technique.	3
56	Use of bacteria and algae in structures that generate electricity or raw material for energy.	5
59	Genetically manipulated microorganisms can produce raw material for energy as well as material suited for energy production and storage.	3
61	Development of artificial cells for manufacturing raw material for energy and equipment for energy economy.	1
67	LED farming will be a major consumer of energy and reducer of the need for load following plants.	5

ART-ID	Energy supply: applications of the ARTs and evaluations of their effectiveness	Weight
70	Solar energy is gradually becoming the least expensive form of energy, and it is already the most inexpensive one among decentralised forms of energy production.	20
71	Heat storage plays an important role in minimising heating costs in northern conditions, while cold storage is important in warm areas.	3
72	Enables continuous energy production with the help of renewable energy.	20
73	The development of battery technology will increase the proportion of electric vehicles in transport. This will have a significant impact on the electricity grid's transmission needs and the structure of energy consumption.	5
74	The generation of synthetic liquid fuels with solar and wind energy will establish an inexpensive and easily transmitted long-term energy store for balancing recurring seasonal variation.	10
75	The use of renewable synthetic fuel in fuel cells enables carbon-neutral driving, heating and seasonal/reserve power with low storage costs.	10
76	Hydrogen can be efficiently and effectively separated from water with electricity and light and recombined with oxygen into water if hydrogen storage can be easily carried out.	10
77	Decentralised energy and striving to break away from the grid will become more common and affect the profitability of centralised solutions and the grid.	5
78	The use of CO2 as raw material may make fossil fuels carbon-neutral and increase their acceptability if the processes participate in the recovery of CO2 from flue and process gases.	5
79	Small nuclear power plants can eliminate the need for an electricity grid, and they can be scaled quickly when mass-produced, particularly if small-scale fusion or fission reactions can be made inexpensive.	10
80	New methods of recovering energy facilitate the supply of renewable energy and make energy regionally less expensive at times.	5
81	High-performance lasers can be used to achieve fusion energy.	5
82	Wireless energy transmission to mobile devices and other devices facilitates their operation.	3
83	Vehicle electrification significantly affects the ratio of energy forms, increases the use of electricity and acts as an electricity store, most likely smoothing fluctuations in demand.	5
84	In addition to helping reduce consumption, gamification of energy consumption helps balance peak loads.	3
85	Mining of electronic money consumes a great amount of energy and may help balance the variation in energy demand.	1
86	Microfinancing is suited for many local energy projects.	1
92	The interfaces of energy production robots and their components promote efficient energy production, but tasks are left to individual manufacturers to solve.	1
93	Trade in the electricity grid is already partially carried out between machines, and it is expanding and becoming decentralised. Mobile autonomous robots must be able to buy electricity across their area of mobility.	5
95	Anticipation of storage needs according to crowdsourced information.	1
97	Electricity trading in a peer-to-peer network can be recorded in a blockchain.	1

1.6 Materials



Scope of the value-producing network: Access to materials used in the manufacturing of goods, the chemical industry and construction is the objective of this value-producing network. This definition excludes foodstuffs and raw materials for energy, but the objectives do include raw materials of food production, such as fertilisers.

The most important values are cost-effective access to raw material and other material necessary in one's operations, minimisation of adverse effects, and adequate quality. If the production is highly capital- or people-intensive, any interruptions are expensive, and the access to raw material must be secured. Adverse effects include any harm caused to people or the environment as a result of both the production and use of raw material. Functional perspectives taken into account include manufacture, use and recycling.

The means and values of transformation: The current dominant regime primarily relies on the mining industry, forestry or other energy-intensive process industry and mass production that uses large raw material streams. The challenger regime offers materials that are renewable and efficient from a process technology or functional perspective. We are also heading towards circular economy, low-temperature processes, advanced structures and a need-based economy of smallness.

Graphene and other nanocarbons are an example of the potential of new materials. At the laboratory level, they can at least be used to passably replace the primary purpose of use of each rare metal, with the exception of gold jewellery. In their ideal forms, nanocarbons are much stronger than steel because of the allotropes of carbon. Their raw material can come from the carbon dioxide in the atmosphere, for example. In theory, the production cost can even be established at the level of traditional industrial raw material in the structures of the construction industry and heavy mass-produced goods.

Nanocellulose offers many graphene-like properties, but cellulose is used as the raw material in its manufacturing. Nature produces a wealth of other materials suitable for raw material, and by mimicking nature, it is possible to produce fibres that are significantly stronger than steel in terms of tensile strength and more resilient than aramid fibres, such as Kevlar. Biotechnology also allows the bacteria and moulds in nutrient solutions to produce finished raw materials at room temperature. These raw materials are equivalent to the hardest and most resilient known materials.

New ways to process raw materials produce very light and strong structures. One example is aluminium foam. 3D printing can also be used to create honeycomb structures and laminates with functional properties that clearly exceed those of known materials, even if no raw materials of the traditional mining industry or large amounts of energy are used in them. With new fibres and renewable bonding agents like lignin, it will likely become possible to reduce the use of mineral-based materials, such as steel, concrete and asphalt, during the period examined in this report and ultimately eliminate the mining industry completely.

Artificial intelligence, robotics and sensors that recognise materials allow efficient recycling outside current industrial symbiotic relationships and household recycling bins. Robots can move about in human environments and collect any necessary raw materials from landfill sites, for example. Autonomous ships that are powered by solar energy and collect and compress plastic waste floating in the water have already been designed for oceans. This collected plastic has been used to manufacture building blocks, roof tiles and even entire buildings.

Circular economy involves designing goods on the terms of recycling. Industrial symbioses are part of this way of thinking. Product identification labels and the information on the material content that is added in conjunction with manufacturing for the purpose of recycling goods removed from use can be implemented in a decentralised manner with blockchain technology. Gamification of the material environmental load promotes sustainable development.

The most important innovative values are related to environmental protection, enhancement of processes and financial improvement of the competitiveness of raw materials and processes, in addition to enabling new types of product properties.

The means and values of the dominant regime: The current industrial and logistics infrastructure is built to transport massive raw material streams from the sources of the mining industry and the petroleum industry to refineries and production facilities and from there to assembly lines and distribution. The stream of trains, ships and trucks flows in the service of this structure. A significant part of the necessary structures is a result of society's long-term investments. These structures are also taught by vocational institutions and economic decision-makers. By means of the attention economy, events relating to these structures are given a great deal of media coverage. When the profitability of investments is calculated, the annual depreciations are kept small, and the investments are assessed to be free of risk.

Production models that utilise circular economy, new raw materials and decentralised and biological processes are taught with significantly less resources than traditional teachings.

The structures and regulation supporting them are limited. A part of the regulation even prevents new, more sustainable procedures, as the regulations have been drafted with consideration to old raw materials and their strengths.

The main values preserving the mainstream are related to export and regional policy, as the practices related to them are intended to maintain and grow the existing production structures.

The benefits, risks and inhibitors of change: The adverse effects of raw materials used by the metal and chemical industries are significant despite many actions being taken to conserve nature and energy. This problem applies to mining, oil drilling, separation techniques and other refining activity. Replacement of these raw materials with materials that place less of a load on nature and the human environment is worth pursuing.

The structure of many new materials and processes requires less capital than traditional methods. Furthermore, their easier decentralisation allows the massive raw material logistics to be reduced. The new materials are also in many ways better than the old ones, and they may improve the competitiveness of the products in the eyes of not only customers who promote natural values. Several of the new raw materials can be manufactured or found locally, which has a positive impact on the balance of trade and employment.

One risk to be considered is the fact that investments and know-how are tied to current raw materials and material streams. This may cause extensive needs for write-offs and structural unemployment if the change in global demand is rapid. Even at the level of the employees' identity, industry is tied to the materials it uses, and it may refuse to notice the change in time, which is what happened in the case of the transformation of the paper industry.

Investments in the process industry are typically massive, with long-term effects. In Finland, society supports the existing operating model at the level of education, investments in infrastructure and export efforts, but also through inexpensive industrial energy. This is another factor that hinders recognition of the need for change.

Growing professions and skills shortages: The change will result in the following new professions, for example: A biomaterial tutor teaches bacteria and yeasts with genetic modification to produce new materials and structures. A nanosurface engineer and nanofibre engineer design new materials and their manufacturing methods and applications. A nanocarbon structure designer and MOF designer are material structure designers for special needs. A material modeller is a common term for these and other professionals who design materials by using computer techniques.

The number of separation technicians and recycling technicians will grow significantly, and their expertise will shift into a materially more technical direction. Recycling strategy planners will be important decision-makers along with industrial designers. A raw material needs analyst will find out which raw materials should be used at a given time and, as the raw material selection and manufacturing methods multiply and the individual production increases, this need will grow rapidly.

Policy objectives of the change: The need to regulate GMO material production needs to be reviewed. The replacement of concrete and iron with new structural materials should be made easier by developing common recommendations and approval procedures. The utilisation of mineral products should be perceived as a burden to the natural resources balance sheet in the same way that using stocked raw materials affects the balance sheet. Therefore, in the national economy calculations, decrease in existing resources, externalities and unsecured liabilities should be registered alongside income as a deduction subtracted from the income.

Material requirements should be made functional in their entirety instead of the actual materials being mentioned in the regulations. Users of recycled materials should be appointed recipients of environmental protection charges.

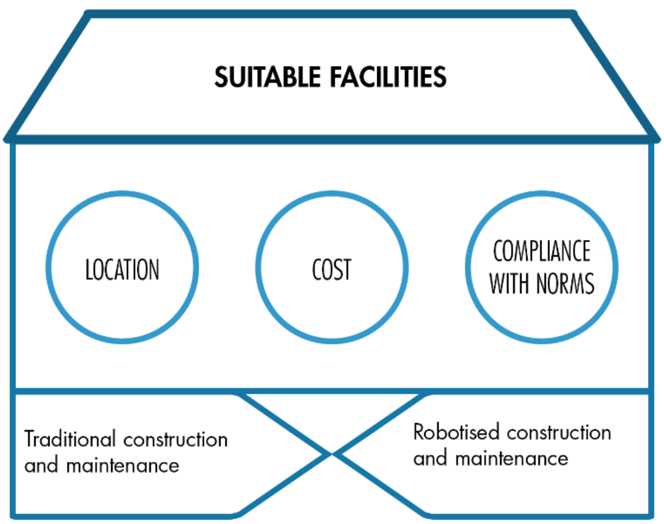
Special national characteristics: Finland is exceptionally dependent on the procedures described here as the dominant regime as well as the export industry based on these procedures. This may make it more difficult to react to change, but as the change is global, demand may decrease in individual industries as quickly as what happened to the paper industry at the turn of the millennium.

ART-ID	Materials: applications of the ARTs and evaluations of their effectiveness	Weight
2	DNA writing promotes the development of materials produced with synthetic biology.	10
4	Adjustment of production processes, the quality of products and monitoring the safety of production facilities.	10
5	Recognition of the properties of received raw materials and controlling and measuring their production processes with the help of a material scanner.	5
7	The examination of many raw materials requires spectrometers at these wavebands.	3
9	Expertise in plasmonics helps produce transparent, strong materials and optic, optoelectronic and electronic materials.	5
12	Designing of new materials and their production with artificial intelligence.	3
18	Raw materials, the recognition of their quality and their development, production and use involves a considerable amount of data that can be created to teach artificial intelligence.	3
25	With the help of flexible electronics, new electronic materials allow electronics to be added to many textiles and other adaptive and flexible surfaces.	3
26	The search for new compounds and metamaterials, recognition of properties and development of manufacturing methods all benefit from increased computing power.	5
27	A walking robot is useful in forestry activity.	1
30	Quadcopters can be used in planting trees and monitoring.	1
32	Using airships in transporting wood reduces the need for forest roads.	3
33	The plastic waste in oceans can be collected with robot vessels to be used as raw materials.	1
35	Asteroids contain great amounts of very rare metals that are used as raw material in many devices important to us. These metals are available to us with relatively minor adverse effects.	5
38	3D printing of goods leads to a significant need for new raw materials.	3

ART-ID	Materials: applications of the ARTs and evaluations of their effectiveness	Weight
39	3D printing of buildings requires the concrete and insulation to have special properties.	1
40	Materials grown by GMO bacteria.	3
41	Increasing the smartness of industrial processes allows the tolerances of raw materials to be relaxed and variation to be compensated by adjusting the process. This practice is already used in many places.	3
42	Robotised services in forestry.	1
43	The development of new raw materials, especially metamaterials, is likely to benefit from new methods of manipulating substances.	3
46	New light and strong or insulating materials enable numerous new applications and replace previously used materials.	3
47	3D printed metamaterials will be important because of their optics, electronics, strength, friction, separation technique and other properties.	5
48	Nanomaterials offer excellent properties for replacing mined minerals.	20
49	Development of the production of nanomaterials directly affects the price of many materials.	5
50	The use of waste and byproducts as raw materials will be easier with new separation techniques.	5
51	The production of many raw materials is easier in an environment that repels impurities, and the properties of raw materials are better when protected.	3
52	The manufacture of concrete with the current method results in a great amount of greenhouse gases. This adverse effect can be eliminated or considerably reduced by developing substitute materials.	10
53	Artificial muscle and skin are important materials for a great number of purposes. Flexible mechanical structures and robotics particularly benefit from this.	5
54	Fresh water is one of the key raw materials in most processes. There is a shortage of water in many areas with inexpensive energy. Local production decreases transport costs and adverse effects.	5
55	The simulation of chemical phenomena is key in the identification of new necessary smart materials and the development of their manufacturing processes.	5
56	Controlling microorganisms to produce the desired materials and patterns.	5
58	Nanoparticles and microbots can produce raw materials together with microorganisms.	3
59	With sunlight, GMO microorganisms can produce a variety of materials and raw materials, including medicine, fuels and biofilms.	5
60	GMO techniques have become easy and accurate. They contribute to the development of GMO-based material production.	3
61	Genetic engineering and development of artificial cells for the needs of raw material production. Artificial cells will likely become more important than GMO cells in material production.	10
63	Cell cultures produce significant materials and raw materials.	5
64	In order for cultured cells to be suitable as raw material, their structure must be adapted to fit with the other components. This is realised with 3D printing.	3
67	Raw material efficiency improves in a closed cycle.	3
68	Biological fibres are very important and evolving raw materials.	10
70	Many new materials can be produced with the help of inexpensive solar energy.	5

ART-ID	Materials: applications of the ARTs and evaluations of their effectiveness	Weight
71	Use of solar mirror systems in raw material production may be efficient. Converting waste heat into electricity to improve the efficiency of the process industry.	3
78	Local manufacturing of nanocarbons and hydrocarbons from CO2 means making the raw materials available locally without causing harmful effects and by reducing them.	10
79	Small nuclear power plants, particularly inexpensive fission, can make the production of raw material independent of the electricity grid.	3
80	Energy that is periodically and regionally inexpensive affects the regional and temporal distribution of raw material production.	3
81	Many materials, such as laser-induced graphene (LIG), can be made with the help of a laser.	3
83	The extensive growth in demand for batteries affects the demand for rare metals.	3
84	The gamification of recycling, starting from the recyclability of purchases, helps improve material cycles.	1
90	Platforms and voluntary work may provide significant support for recycling.	3
92	The interfaces of material production robots and their components promote development, but separate tasks are left to individual manufacturers to solve.	1
93	Trade between machines further standardises material properties.	1
96	Designing of new tailored materials can be a global AI service.	3
97	Materials can be recorded in a blockchain as material batches for recycling in a way that links them to products and remains until scrapping.	3

1.7 Built environment



Scope of the value-producing network: The objective of this value-producing network is for people, animals, equipment and plants to have the facilities they need for mobility and activity with regard to location and conditions. The design, construction, maintenance and demolition of facilities and routes is included in this network, as are route technology and the building services engineering related to facilities.

The most important values in this activity are location, cost and compliance with norms. Norms involve different types of land use plans and construction regulations as well as provisions on maintenance. Land use plans are usually a result of long-term preparation, political decision-making and reconciliation of a variety of values. The geographic location of facilities and their location in relation to traffic routes significantly affect value, with built facilities being the most valuable in places with the highest number of facilities. The social environment is an important value relating to location, as are the distances to services and workplaces. In costs, we are moving towards a lifecycle approach, in which the aim is to take the service life, maintenance costs and environmental effects of facilities and routes into account in decision-making.

The means and values of transformation: The built environment is changing comparatively slowly. Almost all the facilities and routes already built will still be in use in 2037. The majority of the facilities and routes to be built in the near future will be built in accordance with plan provisions and building regulations that are already in effect. However, the methods of construction and maintenance, as well as the use of facilities and traffic routes, may change significantly by 2037. The substantial enhancement in construction practices and significant change in usage needs may also speed up the renewal of the building stock to some extent.

Construction has been very people-intensive, but robotisation makes it possible to automate casting, brickwork, painting, the transfer of materials and many installation and finishing tasks. 3D printing of buildings, bricklaying robots and painting robots are in the pilot phase. Construction is becoming automated, both in prefabrication carried out at factories and in on-site construction. Maintenance tasks are becoming robotised, starting from lawn mowing and cleaning of floor surfaces. Automation will progress to the maintenance of streets and roads, in addition to more demanding tasks.

The development of transport affects routes as well as the need for and layout of facilities. Hyperloops may be able to link city centres that are hundreds of kilometres apart as efficiently as subways currently link suburbs. The robotisation of transport may, together with sharing economy, make Mobility as a Service so flexible that owning a car will no longer be considered necessary to those living in suburbs and even in sparsely populated areas.

Development will have a radical effect on travel chains that can comprise a self-driving car, a subway, a Hyperloop and an electric bike, for example. City centres can more easily be designated as car-free places, and parking facilities can be utilised for other purposes. Versatility is increasing in the design of both facilities and residential environments. The communality of urban environments is planned more closely than before.

In residential construction, facilities are designed for the purposes of sleeping, spending time in front of a television, cooking and personal hygiene. Robot kitchens, virtual reality and indoor farming are changing the need for facilities relatively quickly. Robot cooks may lead to shared kitchens becoming more common, and indoor farms may take over empty parking garages. For their part, VR and AR glasses would make padded, windowless rooms useful. Adaptable, versatile facilities will become more popular. In addition to residential spaces, there will also be radical changes to the facilities required for trade, services and manufacturing with regard to their location, purpose of use and transport needs.

New construction materials will transform buildings into energy producers and enable the construction of sturdy, very light and insulating structures. Through mobile, general-purpose robots that constantly monitor their surroundings, building automation is progressing to a level at which building automation can also be applied to older buildings at a low cost.

The most important innovative values are systemic efficiency, individuality, experiential nature, ease and the proximity of services.

The means and values of the dominant regime: The real estate and construction industry employs approximately 300,000 people in Finland. The built environment forms approximately 70% of the national wealth. Building investments account for approximately two thirds of the annual fixed investments. Construction and buildings account for some 40% of all energy use. Construction is subject to very strict norms, and political decision-making controls construction with regard to the allowed locations, purposes of use and routes, as well as materials and appearance.

The construction of routes is primarily decided upon by municipalities and the state, which are also responsible for maintaining the route infrastructure with tax revenue. The practical implementation is carried out by institutions owned by public entities, and private contractors. Construction and maintenance are for the time being carried out with traditional methods, using human-operated machines and traditional materials.

The building stock is built in permitted locations on owned or rental plots, funded partly with public funds and partly with private funds. The builders and developers go through a great deal of effort to obtain permission to build in attractive locations. The construction costs are also taken into account. Most customers are unable to estimate lifecycle costs, which is why the purchase price, location and suitability of the facilities for their purpose of use are the main objectives. The quality of construction is for the most part determined by the authorities. Migration to large cities is continuously increasing the regional differences in building values.

Most of the work related to construction is performed on site, and automation accounts for a very small part of the process, with the exception of components of building services engineering, such as MEP technology and various prefabricated components. Construction errors are common, with moisture damage in particular causing significant costs and harm.

The most important values that maintain the practices of the dominant regime are dependency on motoring, people being accustomed to the old ways, unwillingness to take risks, the significance of location and purchase price in choices, normativity and the slow adaptation of norms to digitalisation.

The benefits, risks and inhibitors of change: If dependency on passenger cars decreased materially, urban structures could be built denser, with more sensible traffic arrangements. MaaS-type mobility enhances the use of routes, speeds up mobility, frees up parking areas for other purposes and allows services to be located more densely.

The means of telepresence reduce the need for transport and improve the functionality of routes, but they also reduce the significance of facilities used as meeting places. Solutions like telepresence, robotics, Hyperloop and passenger aircraft make it easier to live in sparsely populated areas. As travel time decreases and remote work becomes increasingly easy, the expansion of the commuting and services area will increase the GDP and even out differences in value among the building stock around the country.

The automation of construction and maintenance will lead to a significant risk to employment. The increasing complexity of materials and purchasing of robots that participate in construction may also lead to the weakening of the terms of trade if the robots and new materials are imported, replacing domestic materials or local labour.

When talking about change, it is important to emphasise the slowness of the change in the building stock and route network as well as the conservative nature of the sector. On the other hand, we should keep in mind the spread of electricity and indoor toilets. Today, these are also standard features in buildings that had a ground floor dedicated to horses a hundred years ago. Usage needs are now changing more rapidly as new opportunities become available, leading to a wide-scale need for renovation.

Growing professions and skills shortages: Growing new professions include e.g. community designer, social architect, car park re-designer, living environment analyst, controller of the use of space, property control room supervisor, builder robot mechanic and instructor, robot building material regulator, robot construction foreman, robot controller and architect, remote maintenance supervisor and maintenance robot trainer.

Policy objectives of the change: Unique identifiers should be provided for structures and spaces to make it possible to find their location, composition and other information about them through a cloud service. The interface should be open and maintained throughout its lifecycle, from designing to demolition and additional activities after the demolition. The information should be in a universal robot-readable format behind a standard software interface.

Accessibility regulations should be renewed in preparation for robot-assisted mobility and maintenance performed by robots. Maintenance robots moving autonomously on public routes and working on properties should be enabled. Regulations related to windows should be amended so that natural windows can be replaced with display surfaces. The use of solar panels as surface materials should be allowed and any regulation restricting it should be prevented. Effects of indoor cultivation on buildings should be studied. Land use planning should take into account driverless transport as a service and its reducing impact on the fleet as well as the opportunity to increase the use and routes of lightweight traffic devices as car dependency decreases.

Special national characteristics: Winter conditions pose a challenge to maintenance.

https://kti.fi/wp-content/uploads/Kiinteist%C3%B6alan-yhteiskunnallinen-ja-kansantaloudellinen-merkitys-2014.pdf

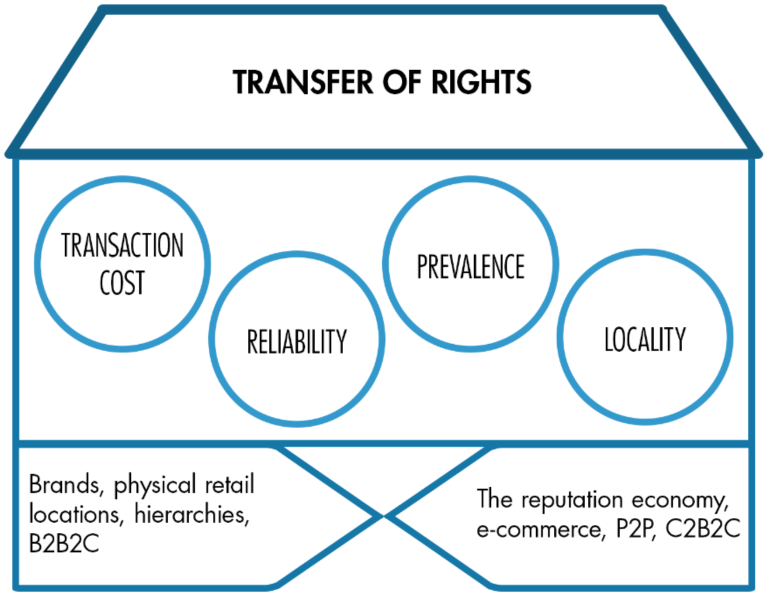
ART-ID	Built environment: applications of the ARTs and evaluations of their effectiveness	Weight
1	Optimal adjustment of environmental conditions for personal preferences, and mapping of individually annoying places or conditions.	5
3	Adjustment of building conditions, such as temperature, for the body's needs.	5
4	Measurement of a building's indoor air and water quality. Measurement of mould and other special impurities in a building.	5
5	Monitoring the condition of a building and analysing the materials as needs for repair are detected. Monitoring the building's indoor air quality.	5
6	Imaging will help create digital routes for robot mobility.	3
7	Fast telecommunication, harvesting of energy in sensors, research needs in maintenance – all of these require transmission/reception capability at these wavebands.	5
8	LiFi networks are faster than current WiFi connections and may replace them. LED walls, illuminated wallpapers and display walls may replace lamps, windows and television sets.	10
9	Transparent aluminium, structural colours, display surfaces produced with plasmonics.	5
11	Moving about in a built environment with the help of voice guidance, and identifying and managing facilities and maintenance needs related to facilities by talking to the "structures."	3
12	Control of maintenance needs, maintenance guidance, designing of lightweight, aesthetic structures and route guidance.	5
13	The built environment and maintenance involve a great variety of situations and needs as narrow segments. Half-finished platforms are important to development.	5
14	Locks can be replaced with facial recognition, the recognition of emotions can influence the soundscape and lighting. Maintenance can be personalised.	3
15	The built environment can guide travellers, and the traveller can express needs for maintenance through speech.	3
16	Maintenance robots require a real-time situation picture of their environment, as do robots that autonomously participate in construction.	5
17	The robotisation of maintenance requires the robot to be able to recognise and manage the shapes of the objects it handles correctly.	3
18	Construction, construction errors and maintenance involve a great deal of material that could be taught to artificial intelligence.	3
19	Smart glasses or AR glasses could guide people through routes, point out maintenance tasks, convey instructions from experts and display measurement data as well as design and history information.	10
20	An expert can use VR glasses to provide instructions to a maintenance worker who wears AR glasses. VR glasses also make it possible to remote control maintenance robots as necessary.	5
21	The most natural way to remote control a maintenance robot is by using haptic interfaces that are based on movement.	3
22	IoT in the built environment produces a great deal of sensor data, which can facilitate maintenance if the sensor data is available.	3

ART-ID	Built environment: applications of the ARTs and evaluations of their effectiveness	Weight
24	The current public-key encryption of IoT devices can be broken.	3
25	Sensors and optical surfaces connected to structures are becoming increasingly versatile.	3
26	Increasing computing power allows a shared, real-time 3D model of the built environment to be updated and maintained for the needs of robot mobility and maintenance.	5
27	Walking assist devices allow people with reduced mobility to use facilities without a wheelchair, making accessible construction less necessary. The robotisation of maintenance requires a walking robot.	10
28	A self-driving car as a MaaS service radically reduces the need for parking space. Robotisation of the maintenance of streets and roads. Transport of maintenance robots to sites to be maintained.	10
29	The value of buildings within easy, robotised distribution will rise, and the need for route maintenance will increase. The need for covered routes will increase.	5
30	Autonomous monitoring of route safety and the condition of structures, limited maintenance of difficult sites. Distribution by quadcopter requires a place for the quadcopter to leave air deliveries.	5
31	Space should be reserved for landing places on the roofs of buildings in densely built areas, with other central fields or abandoned parking areas reserved as landing places elsewhere.	3
32	Continuous air surveillance and airborne telecommunication base stations will improve the functionality of the built environment and facilitate maintenance.	3
33	Continuous living on water will increase in warm zones. The significance of waterways and accessibility by water may increase.	1
34	The travel speed and a lack of schedules within a 200 km radius between different city centres will unite them into one commuting and services area.	10
35	Satellite measurement and monitoring will facilitate maintenance.	1
36	Robotic insects can perform monitoring inside buildings, ventilation piping and other areas that are difficult to access.	1
37	The automation of several maintenance tasks related to construction and buildings requires touch-sensitive robot hands.	3
38	The 3D printing of maintenance tools and spare parts is increasing in importance. The printing of lamps, handles, cover plates and other small items will likely also increase.	3
39	The 3D printing of buildings enables beautiful, unique and functional structures that utilise materials efficiently.	10
40	Self-learning maintenance that is guided by IoT data on the built environment.	5
41	With the built environment able to recognise its own maintenance needs, it can direct the process by itself. When a person detects a problem, its cause must be pointed out and identified for the system.	10
42	Robotised maintenance services for streets, yard areas and roads, robotised collection of wastewater and waste, roof surveillance, and construction and renovation services.	10
45	Reducing the need to clean surfaces with the help of a lack of friction.	3
46	The lightness, strength and insulation of structures are important properties in buildings. New materials allow the construction of structures that are substantially lighter and more extensive.	10
48	Structures and coatings can be made strong, lightweight and durable.	5

ART-ID	Built environment: applications of the ARTs and evaluations of their effectiveness	Weight
49	The use of nanomaterials in structures will become possible as prices decrease.	3
50	Maintenance produces byproducts that can be utilised. Separation techniques will improve indoor air quality and enhance the utilisation of waste.	3
51	Cleaning of wall and window surfaces will become easier, the adverse health effects of door handles, railings, other gripping surfaces and indoor air quality will decrease. Mould damage will decrease.	3
52	Reinforced concrete has a laborious structure and causes carbon dioxide emissions. Replacing it with better materials will facilitate the 3D printing of materials and reduce harmful effects.	10
53	Artificial muscles allow the maintenance needs of many devices to be reduced.	3
54	The ability to produce fresh water will reduce the need to construct water pipes and wells.	1
57	Population growth will speed up and construction will increase. The age distribution will change. This will affect the need for facilities and their purpose of use.	3
59	Genetically modified bacteria can e.g. be used to produce an organic and renewable roof surface that utilises solar energy.	1
66	Replacing meat with cell culture or plant proteins would have a significant impact on agricultural buildings as well as food industry and commercial premises.	5
67	Indoor farming will change the need for space. The need for arable land and greenhouses will decrease and the use of indoor spaces in cultivation will increase. The need for moisture resistant indoor spaces will increase.	5
68	Adding fibres to structures, such as cement, can replace iron.	3
70	Solar panels becoming flexible and integrated with structures allows all built surfaces to be transformed into solar panels.	10
71	Heat storage in the north and cold storage in the south are essential from the perspective of energy efficiency if they can be implemented cost-effectively.	5
73	The robotisation of maintenance requires efficient battery technology.	5
74	Artificial photosynthesis can be implemented on the surfaces of buildings.	10
75	Together with renewable energy, inexpensive fuel cells (easily stored material) make it possible to break away from the electricity grid.	5
77	The need to expand the electricity grid will decrease.	3
79	Small nuclear power plants can reduce the need for an electricity grid.	5
80	Wind energy, wave energy and similar energy sources require investments to be made in the electricity grid and energy storage, unless their energy is used locally for the production of raw material, for example.	3
81	Lasers can be used to clean surfaces and join structures together.	3
82	The built environment can support wireless electricity transmission. Wireless IoT devices are more inexpensive than wired devices to place, retrofit and replace.	5
83	Electrification requires an adequate electricity distribution network to be built for vehicles.	3
84	Gamification promotes maintenance carried out in the spirit of communal work as well as the energy efficiency of buildings.	1
85	Time banks can be significant in maintenance carried out within a local community.	1

ART-ID	Built environment: applications of the ARTs and evaluations of their effectiveness	Weight
87	Maintenance will become easier when the required expertise is easier to obtain and ensure.	3
88	AI detects many needs for maintenance and guides the maintenance personnel in their tasks in an optimal way. Remote control of maintenance robots will be an important job.	5
89	In the built environment, many things are adjusted from a control room. Authentication and encryption are important challenges.	3
90	Some maintenance tasks can be carried out as communal work and through platforms.	3
91	Maintenance of the outdoor spaces of properties is well-suited for the platform economy.	5
92	Some construction and maintenance tasks can be implemented with the products of an individual company, while other tasks benefit from the solutions of a versatile ecosystem.	5
93	Maintenance will probably in part become e-commerce between IoT equipment and robots.	5
94	Maintenance robotics and IoT systems for the built environment require an effective, wireless 5G network in order to function extensively and smoothly with global products.	10
96	Some of the building and maintenance robots can be guided and managed by a global AI.	3
97	Transactions related to properties and maintenance can be recorded in a blockchain.	3
98	The built environment is the place in which we enjoy digital art. Buildings will incorporate 3D caves, padded rooms for VR users, etc. Windows may be replaced by digital walls.	5
99	Usage pattern information on buildings helps to optimise maintenance and energy consumption.	3
100	Remote control of maintenance equipment and design with VR glasses. Windowless spaces with AR glasses and similar display walls. A platform ensures compatibility with the content.	3

1.8 Exchange



Scope of the value-producing network: The objective of this value-producing network is the transfer of ownership and access rights. This definition includes actions that particularly contribute to exchange, such as contractual and financial transactions and communicating information about the range of services or products to potential customers. The definition does not include paid work within organisations – in terms of transaction cost theory, the scope of this value-producing network includes market transactions but excludes hierarchies. However, the definition is considered to include the exchange of rights outside the monetary economy, including forms of cooperation such as open source code and exchange such as the reputation economy.

The most important values are the transaction cost, reliability, prevalence and locality. Transaction costs include search costs, bargaining costs and delivery costs. Reliability includes the ability to deliver, responsibility and ethical compatibility. Prevalence includes flexibility in delivery methods, delivery times and means of payment as well as the range of products and services. Locality includes geographic and cultural closeness or another group identity.

The means and values of transformation: Trade is undergoing a transition. In addition to the marketing of goods and services, purchase transactions are also migrating to the web. Traders are becoming global and crossing national borders. E-commerce delivers the goods to the customer through a general logistics network. Online shops serve as their own marketing channels, and they do not use external channel marketing in the manner of traditional trade. Brand trust is replaced by customers' product-specific likes and recommendations based on comparisons on social media. Because of the decentralised logistics and high level of automation in e-commerce, the subcontractor networks can be massive. Payment traffic operates electronically, and the means of payment may extend to cryptocurrency. Changes can take place quickly.

Exchange between companies is becoming activity between machines that is guided by data systems and artificial intelligence. The decisions and emotions of end customers and other profiling may affect this activity as much as internal data of component suppliers and companies. Similarly to consumer trade, trade between companies is also transitioning to platforms. They serve as marketing and transaction channels, also offering the services of a trusted third party as a background for the product features. Platforms may account for a significant proportion of the added value. Platforms reduce customer loyalty.

E-commerce has grown rapidly in consumer business, expanding from services to goods. A significant proportion of Finns purchases products from foreign online shops on a monthly basis. The benefits of e-commerce include easy, product group specific comparisons, searching with search engines, a wide selection and credible presentation of customer experiences. Another benefit is ease, particularly with regard to product groups that are not part of the selection offered by shops that sell daily consumer goods.

The operating conditions of e-commerce are improved by delivery lockers, the spread of courier services and the fact that customers are used to online payments. The robotisation of logistics is substantially reducing the delivery costs of individual products compared to bulk deliveries. The development of logistics does not contribute to the latter to the same extent as it does to retail.

The Europe-wide Payment Services Directive (PSD2) opens up the interface to bank accounts so that online shops can become payment service providers if they wish. This will both simplify the use of online shops' services and increase internationality. On the other hand, the GDPR complicates e-commerce software and places services within and outside the EU in different positions.

Other important characteristics of sharing economy, besides a transaction platform, include the scoring of both services and their users and having a public complaint practice. This crowdsourcing increases trust. Contractual practices will expand with the help of blockchains so that trusted third parties will no longer be needed to authenticate agreements. Emotion data has a guiding effect on the development of both product ranges and marketing. Customer data can easily become a subject of trade.

In crowdsourcing, the common goal is more important than trust. Crowdsourcing achieves economies of scale without the participants becoming organised in a committed way. The benefits are divided either between the participants or everyone who is interested in the results. One good example of crowdsourcing is Wikipedia. Specialisation and exchange are realised, but the financial transactions are limited in number. In both crowdsourcing and the sharing economy, activity that produces well-being migrates outside the monetary economy.

With AI taking its place as the customer's assistant, marketing and our own social network may become less important as sources of recommendations. AI serves as the customer's representative, conversing with the customer and finding and comparing products and services available online. Search engine optimisation will lose its place if it is not known how each learning AI can be influenced. Instead of the interests of its user, AI may also take the interests of its developer into account. Companies that develop smart agents for their customers include Microsoft, Amazon, Facebook and Google, among others.

The unique identification of goods and facilities is transforming physical surfaces into digital user interfaces. Identifiers allow services related to goods to be decentralised, crowdsourced and also automated. An AI can take on item-specific roles, so that it depends on the item being handled how the AI reacts to us at a given time.

Virtual reality and augmented reality are making e-commerce increasingly realistic. The products look natural in their imagined environment. Virtual reality combined with robotics makes the delivery of services time- and location-independent. Robots used as the main devices can deliver physical services purchased via online shops to the customers' homes in real time. For example, the remote control of a cleaning robot can be provided via the Internet.

The most important values innovating trade and exchange are individuality, ease, the extensive range of products and services offered, peer trust, and time and location independence.

The means and values of the dominant regime: The trade of goods and exchange of services are still primarily implemented in the traditional manner, although information networks already affect all activity. Products and services are advertised in the media, trust arises from brands and is directed at companies engaging in trade, and goods are picked up from shops or delivered to customers by the seller or its subcontractor. Services are local and tied to the office of the seller or customer. Banks play a key role in payment traffic, and the authorities contribute significantly to the verification of agreements as well as the control of trade and services.

The trade sector employs approximately 300,000 people in Finland. A third of commercial properties is related to trade and other types of exchange. In this context, turnover is not a meaningful indicator of activity, as this value-producing network covers all financial transactions with the exception of the payment of wages.

Services are provided by public entities, the third sector and companies. Many services are publicly financed, including most of the social sector, education services, transport services and safety and security services. The bulk of trade is provided by the private sector. Both trade and services are produced with hierarchic structures, with the degree of automation being relatively low, with the exception of the services of the financial sector and the warehouse activity of major companies involved in trade.

The most important preserving values are related to the desire for safety, paternalism, hierarchic ties, salaried work and unwillingness to try out new things.

The benefits, risks and inhibitors of change: As a result of changes, many transaction costs will be reduced. Products and services will become easier to compare, the range of products will expand, and products and services will be less tied to any one place. Digitalisation will simplify the crowdsourcing and automation of services. Reduced hierarchy may lead to income inequalities decreasing on average.

The risk is that control may become more difficult and the responsibility of consumers may increase. Unemployment security relating to salaried employment will become problematic when exchange taking place without the authorities noticing becomes easier. The tax base may also become narrower as products become digitalised, services become crowdsourced and globalised, and digitalisation reduces the prices of products and services. The dependency on global platforms may increase, weakening the security of supply. The proportion of platforms in both consumer trade and P2P exchange, but especially in B2B trade, may increase greatly. This will become a risk if a significant proportion of the exchange margins and labour rise from the national level to the global level.

The factors slowing down this change are related to consumers' purchase habits and urban structures that are designed for traditional trade and exchange. Advertising-funded media and the closed logistics of trade and industry continue to serve the operating methods of the dominant regime, as do the regulatory practices. Individual local distribution is poorly organised, and the sharing economy and services such as crowdsourced C2B2C services are not regulated.

Growing professions and skills shortages: Platform economy will create a significant number of new jobs. Growing or new professions include e.g. platform selection consultant, artificial intelligence assistant trainer, artificial intelligence personaliser, local exchange catalyst, identity inspector of goods, identity manager, reputation economy manager, professional praiser, platform lobbyist, artificial intelligence optimiser, artificial intelligence lobbyist and self-service kiosk manager.

Policy objectives of the change: The portability of the data of customers collected and stored by platforms should be ensured. With regard to responsibilities in P2P exchange, it must be ensured that responsibilities of the platform and seller remain separate and the responsibility for investigation in exchange between small operators shifts more to the customer and, with regard to conveying feedback, to the platform. The P2P exchange platform must be responsible for transactions and realisation of the paid service.

Reputation economy marketing responsibilities should be regulated so that cheating becomes more difficult. For example, trusted reviewers are needed. The taxation of P2P exchange and its platforms should be reviewed, and we should strive to utilise the strengths of crowdsourcing in promoting small operators. The setting for the local distribution infrastructure should be regulated so that operators have sufficient incentives to create digitally opened lockers in walking distance from residential areas for exchanging goods without meeting the other party. This requires city planning measures.

Special national characteristics: Finland's export activity is, to a great extent, dependent on investment goods. The potential migration of the trade of investment goods to international platforms may lead to a significant loss of added value.

http://www.tilastokeskus.fi/static/media/uploads/tup/kantilinpito/digitalisaatio_bkt.pdf

http://www.postnord.fi/globalassets/suomi/tutkimukset/verkkokauppa_pohjoismaissa_2017.pdf

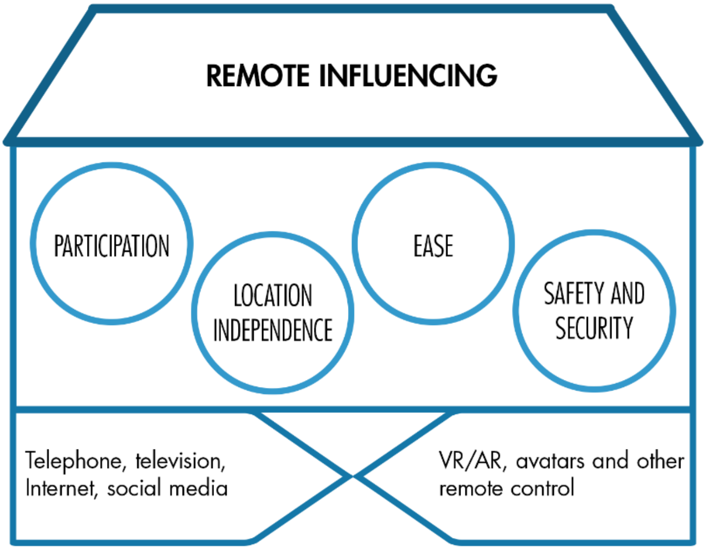
https://ec.europa.eu/growth/industry/policy/digital-transformation/big-data-digital-platforms_en

ART-ID	Exchange: applications of the ARTs and evaluations of their effectiveness	Weight
1	Reading thoughts helps convey needs, the available supply and trust.	1
2	Authentication of the origin of biological materials with the help of DNA.	3
3	Health diagnostics systems help recognise needs.	1
4	Assurance of the quality of products and transport with the help of biochips.	3
5	The ability of the general public to analyse the material of received products increases trust and eliminates counterfeit goods.	5
11	The ability of people who do not share a language to engage in trade with each other requires interpretation. The same applies to services and e-commerce, which must present and understand things in the customer's language.	10
12	Optimising stock and product selection, searching for the best products and target groups, stock exchange and identifying problem situations will all benefit from artificial intelligence.	10
13	Platforms will increase competition in AI applications and reduce the establishment of dominant operators. Competition in platforms and applications transfers value from the developer to the user.	10
14	E-commerce may behave in a personalised manner. Facial recognition facilitates transactions. Recognition of emotions assists the other party or machine with pricing, for example.	5
15	The user's personal agent can discuss the needs of its owner and search for goods and services online. Verbots/chatbots can handle a significant part of trading.	5
17	Misunderstandings will decrease in the trade of goods, and customers will get a clearer understanding of the goods. The goods may even be viewed in their intended environment with VR/AR technologies. This will facilitate the placement of orders.	3
18	Each party that extensively engages in exchange has a wide range of data material.	3
19	AR glasses are an essential platform for the exchange of intangible products and experiences. AR glasses can be used to examine the properties of goods available for sale.	3
20	VR glasses can be used to view and choose products in online shops.	3
22	Situations related to exchange, when recorded in their entirety, will produce a great amount of data, the analysis of which will contribute to exchange.	3
23	The enhancement and increasing availability of artificial intelligence will affect trade, particularly by reducing reliability, search costs and comparable costs.	5
24	It will become possible to break the encryptions of bank accounts and cryptocurrencies as well as other public-key encryption methods. This will force trade to undergo extensive reorganisation.	10
26	Decentralised transactions based on a blockchain will become more affordable.	10
28	Distribution to households can be implemented affordably. Customers can get to shops affordably by car without the shop requiring a wide parking area.	10
29	Many-to-many type exchange without centralised nodes will become easier, and the conditions of small local operators will improve.	3
30	Local manufacture will become easier with distribution by quadcopter enabling direct deliveries.	1
32	The telecommunication network can be extended to larger areas as a unified whole.	3

ART-ID	Exchange: applications of the ARTs and evaluations of their effectiveness	Weight
33	Many small deliveries by waterway will be facilitated. For example, smuggling will become easier.	1
34	The significant geographical expansion of easy physical service and work areas will affect exchange.	3
35	Comprehensive, global telecommunication connections can be implemented with the help of satellites.	5
38	The 3D printing and other flexible manufacture of goods will decentralise production, making it local. Immaterial exchange through e-commerce is increasing globally thanks to local manufacturing.	3
39	Architectural models are becoming parameterised printing models and subjects of exchange.	1
40	Recommendation systems, such as that of the Amazon online shop, in which feedback on successful sales is combined and suggested as the next options.	5
41	A ubiquitous environment and the unique identities of goods allow the ordering and reception of goods to be fully automated.	10
42	Robotised, remote-controlled shopping trips with a VR avatar and delivery services.	5
44	A robotic tailor converts the sale of ready-made clothes into a service.	5
47	Some pharmaceutical materials can be printed at pharmacies. A pharmacy is a natural place for the manufacture of personalised medication, allowing wholesale to become partly digitalised.	3
50	Industrial symbiosis means that one organisation's waste is a raw material for another organisation. This exchange will become more efficient and mature into circular economy as separation techniques evolve.	5
51	The sharing economy will become easier as the need for cleaning decreases. The shelf-life of goods will increase.	3
54	The inequality in access to fresh water increases the need for trade between regions.	1
57	The significance of personal habits increases as the average age of the population rises.	1
59	Genetically modified articles may become a significant area of immaterial and material exchange.	3
62	Knowledge about ourselves decreases search costs, clarifies needs and reduces the risks of trade.	3
67	Food trade will change radically as production decentralises and spreads to cities.	3
69	The transactions required by genetic materials and organ transplantations will become easier.	3
70	Energy production will become decentralised and energy trading may decrease or become localised.	1
71	Solar heat and heat stores are local in nature and decrease exchange.	3
72	Grid-level energy storage enables electricity transmission that is based on day-time and night-time consumption, thereby allowing peak loads to be balanced without peaking power plants.	5
74	Synthetic liquid fuels make it possible to stop the exchange of electricity as well as the oil trade and replace these with fuel cells and photosynthetic panels.	5

ART-ID	Exchange: applications of the ARTs and evaluations of their effectiveness	Weight
75	Enables the easy use of private load following plants and staying outside electricity trading.	3
77	Energy trading will become localised.	1
84	The gamification of cooperation that is based on communal work will increase efficiency and reduce transaction costs, in addition to boosting team spirit.	3
85	Cryptocurrencies clearly affect the monetary economy and enable forms of exchange for which account transactions or cash are not a good fit.	5
86	Crowdfunding helps in the pre-marketing of products under development and in funding the development. Microfinancing involves sharing risks and information in debt relationships.	3
87	Giving a demonstration of actual skill instead of showing an old certificate reduces the risks in exchange.	3
89	Tor enables anonymous orders and deliveries. Encrypted telecommunication is a very important feature for all confidential (incl. criminal) exchange.	20
90	The platforms for local manufacture can be used to promote local exchange and recycling of goods.	3
91	Exchange is made easier when the work related to it migrates to platforms, as the transaction costs and structures of trust of platforms are inexpensive and functional.	10
92	Robot ecosystems and their well-defined interfaces contribute to specialisation and facilitate exchange between subcontractors and clients and also on a broader level.	3
93	A significant proportion of all trade will be conducted between machines in the future. Humans discuss their needs and preferences with a smart assistant, which then finds the desired product or service and makes the trade.	20
94	Mass-produced global and smart broadband products require a 5G network or a similar network.	3
95	Cloud services are a key coordinating structure for exchange, for example via the platform economy but also on a significantly broader level.	10
96	Exchange platforms can all be controlled by a global AI. Exchange AI assistants and lenders, accounting and auditing AI can all work globally.	10
97	All rights, agreements and transactions can be recorded in a blockchain. Separate registrars are not needed if the blockchain can not be broken.	10
98	Exchange of experiences is a growing area that can involve VR worlds or physical equipment. This exchange requires shared interfaces, standards and service platforms.	5
99	MyData data can be merchandise. MyData provides the seller with an opportunity to offer something suitable for needs. Data portability provides added value.	10
100	Objects being exchanged can be seen from different angles with VR/AR glasses. Glasses also make it possible to sit next to another person and have a conversation. Platform compatibility is required.	3

1.9 Remote impact



Scope of the value-producing network: This value-producing network produces remote impacts and means of influencing things and events in places in which the influencer is not present in person. These places do not have to be physical. The scope of this value-producing network therefore includes a variety of influencing methods used in communication, virtual reality and remote control.

The most important values are participation, location independence, ease, safety and security. Participation involves empathy, earning and the desire to influence things and people. Location independence refers to having an opportunity to participate directly, by invitation or voluntarily, in a situation taking place elsewhere without travelling there, regardless of one's own location. Ease, speed and access to the means of remote influencing are the main desirable values. Safety and security include data protection and not having to travel anywhere. Safety and security also include the ability to restrict unlawful remote influencing.

The means and values of transformation: There have been great changes to the means of remote influencing. Global IT platforms allow individuals and organisations to be disturbed or controlled by means of communication. Viruses, social media, cryptocurrencies and the dark web are growing channels of influence. Remote-controlled robots and missiles, the disturbance of devices connected to the Internet and artificially created infectious diseases are means that have previously been possible to major national operators, but they are becoming accessible to increasingly small operators. Active participation and physical labour are also becoming possible on an everyday level by means of telepresence.

With the advancement of machine vision, robots will be able to perceive their surroundings more clearly. Control of dynamic movement will lead to inexpensive devices that move on two or four legs within their environment. New robots that can move by foot, by flying, on water or on wheels are announced almost on a weekly basis. When combined with other functionalities, these devices can serve as tools for telepresence and remote work. These types of robots are referred to as avatars in this report.

For the time being, the most common avatars are toys, camera drones and videophones intended for telepresence that move on two wheels. Many types of remote-controlled robots suitable for earthmoving, carrying loads, manipulating objects and even performing surgical operations are becoming more common.

The user's view of the avatar's environment will improve once 5G networks become more widespread. 5G networks will also allow more devices to connect wirelessly to data networks. VR glasses and other virtual technology provide a natural user interface for remote controlling avatars. On the other hand, the development of artificial intelligence is improving the ability of devices to move and influence their surroundings autonomously.

Together with artificial intelligence, VR and AR technologies are producing new methods of remote influencing. For example, the geopositioned virtual lures included in the game Pokémon GO have been used to increase the number of customers in cafés. In other words, fictional information placed at real-life coordinates creates actual events. On the other hand, this also results in false information that looks real becoming commonplace. It is already possible to converse face to face with another person over a video call while making the other person believe that he/she is talking to President Obama, who is standing on the Market Square in Helsinki.

The most important innovative values are efficiency, ease and the safety and security of individuals. Ease includes easy accessibility, and safety and security include the opportunity to influence others without putting oneself at risk.

The means and values of the dominant regime: Traditional, centralised communication with messages that spread via media is still the most important method of remote influencing. Advertisements, phone calls and email are mainstream alongside social media. Systematic influencing of a target group with traditional methods is still very common. Physical methods of remote influencing are primarily used by armies, but many geographically decentralised processes and devices are being measured and controlled using data networks.

Written instructions, required written reports and a variety of norms are an essential and traditional method of remote influencing. This influencing involves an extensive bureaucracy. In international activity, customs duties, trade wars and international agreements have also been normal influencing methods extending beyond a country's own borders, in addition to diplomatic and military threats.

There are over 9 million mobile phone subscriptions in Finland. Practically everyone has a physical mailing address. The great majority of people keep up with television broadcasts or radio channels at least through the Internet if not through more traditional receivers. The use of printed media and similar websites is likewise substantial and extensive. Social media is also part of daily life for most Finns. Over 180,000 information security incidents are reported in Finland every year.

The most important preserving values are related to appreciation for physical presence, norms and habits as well as disregard for the effort undertaken by the arriving party.

The benefits, risks and inhibitors of change: The most important benefit of the change is decreased need to travel. Remote influencing helps commuting and services areas expand virtually and enhances interaction. This increases participation and improves regional equality. As the need to travel decreases, so does the number of delays. More versatile methods of remote influencing improve the quality of influencing and reduce mistakes. A phone call or email is replaced with telepresence that is conveyed with the help of VR and AR technologies and avatars but looks natural.

The risk of hybrid warfare and terrorism increases as cyberattacks become easier to carry out. Even toys can be harnessed as weapons to spread false information, harmful chemicals, diseases and explosives. Damage can be inflicted from behind national borders almost without risk of being caught. Extortion and fundraising are also possible on a global scale. The protection of privacy will decrease and an increasing number of professional tasks can be handled through remote-controlled avatars from behind national borders.

This change is being slowed down by the fragmentary nature of current communication practices, many of their systemic characteristics and the regulated environment. Means of communication hold symbolic meanings that are difficult to replace. The spread of avatars is being slowed down by the contradictory nature of the motive related to the adoption of the technology: the receiver's investment and the arriving party's saving. Robots have limited mobility, and the benefits are often left unrealised if someone must first go and transport the robot to the location where telepresence is needed, for example. In many situations, physical presence is a legal requirement.

Growing professions and skills shortages: The ability to perform physical work without commuting will increase the demand for services in which an expert performs the requested task using an avatar. There will be more jobs related to the organisation of services that enable telepresence. Jobs related to the prevention of risks of remote influencing will increase substantially. Growing professions include e.g. avatar cook, avatar musician, avatar doctor and avatar maintenance officer. Cyber security guard, VRAR counsellor, trainer of robotised remote work, avatar guide customiser, avatar prevention officer, artificial intelligence controller, data analyst and IoT risk analyst will also become necessary professions.

Policy objectives of the change: Using an avatar to access public services should be enabled. Maintenance and monitoring should be carried out with avatars wherever appropriate and experiments should be initiated quickly. Legislation related to these practices should be reviewed. The assigning of responsibility to an autonomous robot, a partly autonomous or completely controlled avatar and remote controller should be reviewed and clarified. Avatar telepresence should be equated with physical presence in as many cases as possible. This principle has an impact on numerous legislations and their implementation. One example is copyright, in which the concept of a private event should be extended to private telepresence. Individualised mass communication carried out through artificial intelligence and social media should be regulated in a way that prevents deliberate and extensive manipulation with incorrect information.

Special national characteristics: Finland is an exceptionally open and international economy with a low population density and long distances to services. The IT capabilities of the citizens are better than average, but the area in which the Finnish language is spoken is very small.

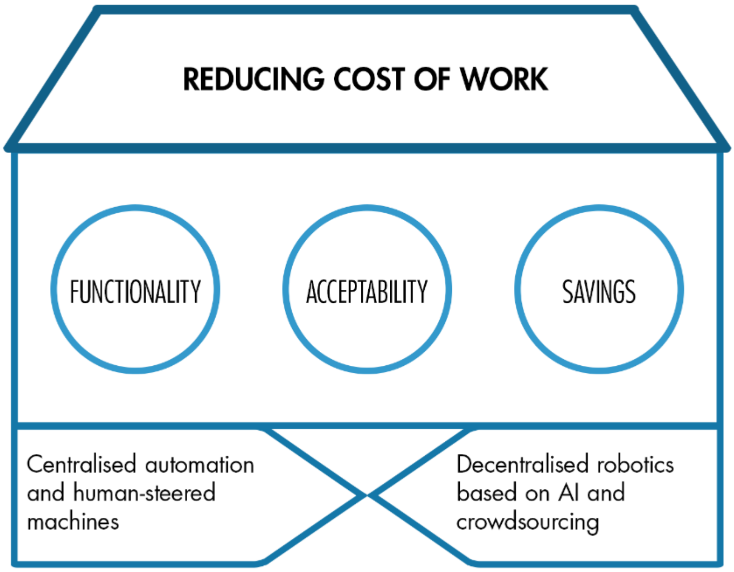
https://www.viestintavirasto.fi/attachments/Viestintaviraston_strategiaesite.pdf

ART-ID	Remote impact: applications of the ARTs and evaluations of their effectiveness	Weight
1	Conveying emotions to an avatar and people or to manufacturing processes via telecommunication networks.	5
2	DNA memory as a massive centralised data warehouse. Development of synthetic life that will spread across the world.	3
3	Remote control of a robot assistant can be based on data conveyed by the robot about the condition of the body of the person being assisted. Remote diagnostics, remote coaching and AI coaching.	3
4	The operation of remote-controlled devices is easier with sensors that can recognise gases and liquids.	3
5	Telecare, distance counselling and robot-assisted remote work become easier when data is available about the material composition of the objects being handled or surrounding objects.	5
6	Remote control requires a clear picture of the environment of the controlled device.	5
10	Remote-controlled devices can explore their surroundings with laser techniques.	3
11	Interpretation is essential when we want to influence speakers of foreign languages. Talking machines and software are essential means of remote influencing.	5
12	Artificial intelligence is a useful tool in avatars, as well as in other types of remote influencing.	5
13	Platforms make it relatively easy to develop talking applications that operate in data networks and seek to spread ideas. A platform itself has a wide-ranging impact.	5
14	Falsifying the face and speech of a well-known figure on video is a highly efficient method of remote influencing. The impact is heightened when combined with reading of emotions.	10
15	Verbots/chatbots can be given tasks and they can participate in countless online discussions and learn and copy the most influential arguments.	10
16	The mobility of telepresence robots is made easier by their ability to produce a model of their environment, so that the user does not have to notice all obstacles and uneven places.	1
19	Users of AR glasses can be guided by controlling an avatar within his/her field of vision. A remote guide can see the shared field of vision through his/her own VR glasses.	5
20	In the remote control of robots, VR glasses are the most natural way to see the robot's surroundings.	5

ART-ID	Remote impact: applications of the ARTs and evaluations of their effectiveness	Weight
21	The most natural way to control a telepresence robot, or avatar, is based on the user's own movements, mimicking of these movements by the robot, and haptic feedback.	5
22	Increasing memory capacity contributes to digitalisation, which facilitates remote influencing.	3
23	Artificial intelligence becoming increasingly efficient and inexpensive increases its remote impacts because digitalisation is not bound by distance.	5
24	Breaking public-key encryption opens up great influencing opportunities. Quantum communication provides reliable channels encrypted from all operators.	10
26	Less and less resources are required to produce increasingly realistic recordings and media content, thereby influencing increasingly large numbers of people by means of artificial intelligence.	5
27	Natural and free telepresence in the human environment requires a walking avatar.	10
28	Telepresence robots can be delivered to their destinations efficiently. Self-driving cars can be remote-controlled, and their passengers will consume a great amount of media content while travelling.	5
30	Remote influencing is easier through drone surveillance and weaponised drones.	3
32	An aircraft can be flown to the other side of the world and be used as a base station that transports and controls robots, for example. Telecommunication connections promote remote influencing.	3
33	Remote-controlled and robotic waterborne vessels provide a clear opportunity for remote influencing things and events.	1
35	Satellite connections offer comprehensive global telecommunication connections for both the needs of the media and the remote control of robots.	5
36	Robotic insects can monitor discretely and perform materially minor tasks.	3
37	Influencing through telepresence will become more versatile if the avatar can walk on two feet and has sensitive hands like a human. Controlling an avatar is natural, and an avatar has a wide range of capabilities.	3
38	A 3D printing model may spread quickly and be 3D printed across the world.	3
41	The manufacturer, seller or similar party can afterwards add data to uniquely identified goods, with the receiver being able to view the data with the help of the product's identity.	5
42	Teaching robotised services multiplies the impact extensively.	10
44	A robotic tailor allows clothes to be designed as a remote service.	3
47	Unique design of materials is becoming a global activity with 3D printing of materials becoming more common.	1
53	The development of robots to be more similar to humans is increasing the potential and impacts of telepresence.	5
56	Electronics added to plants and animals allow them to be influenced from afar.	1
58	Microbots can be used to control bodily functions without the knowledge of the individual.	1
60	GMO techniques have become easy, and instructions can be conveyed digitally. A genetically modified organism can spread rapidly on a global scale.	5

ART-ID	Remote impact: applications of the ARTs and evaluations of their effectiveness	Weight
64	When a suitable printing model is developed somewhere, it can soon be reproduced globally.	3
66	The use of cultured meat for food increases the possibilities of remote influencing in food production through 3D printing and bio-design of meat.	3
67	Farming can be controlled remotely, and the overall functionality of robot farming can be delivered globally.	3
70	The manufacturing of remote-controlled, solar-powered devices with almost limitless mobility will become easier.	3
73	Robots used for remote influencing require efficient batteries.	3
77	The nature of remote influencing will change when off-grid solutions reduce our dependence on the electricity grid, but they are partly within the scope of remote control.	1
85	Cryptocurrencies facilitate cross-border criminal influencing.	3
87	Flipped learning constitutes remote impacting. Explanations no longer have to be given at the same physical location or by the organisation granting the degree.	5
88	An AI foreman can be located wherever, as evidenced by the example of Uber. The ability to remote control robots also transfers the actual work performance to be carried out afar.	10
89	Tor enables anonymous communication and influencing. The encryption of messages and ensuring authenticity are key elements in remote influencing.	5
91	The operation of platforms can be influenced very easily at the global level above platforms.	20
92	Robot ecosystems allow the same components and software to be used extensively in a variety of equipment. The impacts of individual choices can be global.	5
93	As trade migrates to platforms and the Internet, remote influencing will become easier.	5
94	Remote influencing requires telecommunication standards. Influencing through robots requires low latency, high speed and general ICT interfaces.	5
95	Today, cloud services are the only easy way to achieve an extensive intangible impact.	3
96	Any kind of remote influencing can in principle be carried out by a global AI.	20
97	Remote influencing is easier if a blockchain is used for certifying a contract or transaction instead of a registration authority or pledgor in compliance with local legislation.	5
98	Art and experiences are ways to influence other people. By digital means, this can be done irrespective of their location as long as the parties have shared platforms.	5
99	The GDPR moderates remote impacts but it simultaneously creates practices for data portability that enable even more extensive remote influencing.	3
100	VR glasses are used for remote control. A person using AR glasses can be influenced by placing holograms in his/her visual field. The platform ensures compatibility.	5

1.10 Automation of work



Scope of the value-producing network: Human labour is being replaced by machines at an accelerating pace. The most common objective is to reduce costs and effort caused by work. Machines are also being used to reduce the dangers related to work and improve the quality of work. In general, machines enable material well-being that separates us from Stone Age people.

The most important values are the functionality, acceptability and cost of machines. Functionality involves ease of use, operational reliability and quality matters, i.e. that the work results are as desired. Acceptability involves the danger, heaviness or unpleasant nature of paid work, the impact of work on status, and privacy protection. Costs comprise fixed and variable costs as well as possible risks and various externalities caused by manufacturing and use.

The means and values of transformation: Compared to today's repetitive automation or specialised machine power requiring continuous human control, new machines have increasingly versatile capabilities while still being autonomous. Robots can move independently from place to place and can e.g. process materials, take measurements or guide humans according to a need or wish detected by the robot itself.

Robots and 3D printers manufacture a wide range of items. Mobile robots can take care of logistics or perform environmental maintenance tasks, such as taking cuttings from grapevines, weeding or ploughing snow. Machines can also make observations, model things with the help of artificial intelligence and learn to recognise deviations and the best operating models.

The versatility of new machines is based on an increase in information processing capacity and the development of algorithms as well as organisation structures and mechatronics that utilise them. In 3D printers, this is for example visible in the fact that every printout is assembled from microscopic grains or hardened liquid droplets, the smallest detail at a time, without the complexity increasing production costs.

Gripping devices are being developed for robots in order for them to be able to use other tools. In robots of the future, the capability for flexible, customised production and service will be combined with the capability to move from place to place as needed. A robot will be able to paint The Last Supper on the kitchen wall, cook and serve a meal, play music, clear the table, clean the house, and water the flowers.

The most promising branch of artificial intelligence is based on systems that can learn. In other words, machines are taught rather than programmed, with the teaching carried out in layers. This is referred to as deep learning. The learning can be based on a model, created by a designer, within which the machine tries out different alternatives by simulating the model's operation. The learning can also be based on extensive data presented to the machine, based on which the machine forms categories and causal relationships. The data can be categorised or uncategorised, and as many as a hundred million pictures have been found to be useful in teaching some tasks. In other words, a large amount of data is needed to teach tasks to artificial intelligence if we want to start from the basics.

The continuously decreasing price of machines, increasing versatility, mobility and autonomy facilitate their shared use. Shared use can be realised both by crowdsourcing the development work and through the sharing economy related to utilisation.

Machines are able to adapt to new needs quickly and effortlessly. When the need for repetition decreases, so does the required scale of production. Customised production of goods and services can compete with economies of scale. Decentralisation of production will become profitable for many reasons, such as savings in logistics costs, fewer delays and the provision of customised, versatile services nearby.

The most important innovative values are 24/7 service, efficiency, price and social inhibitions.

The means and values of the dominant regime: In present-day society, the greatest amount of attention is paid to machines that perform repetitive work or need to be constantly controlled by humans. On the one hand, we have automatic machines operating at mass production lines, with each of them performing a relatively clear and often simple work phase as part of a larger industrial process. On the other hand, we have tools such as excavators or chainsaws that are used by people in order to perform specialised work phases with the help of mechanical power. Existing machines serve information technology by compiling and sorting large amounts of data independently or by functioning as word processing programs and calculators, as replacements for a pen and paper, enhancing an individual's work.

According to the data of Statistics Finland, machines and vehicles account for a little over 10% of the national wealth of Finland. Machines are required for almost all work tasks, and the ability to use them is an essential part of a professional's skill requirements. Humans are also surrounded by machines in their everyday life. You could even say that modern life largely takes place in a world created by machines. Despite this, our machines continue to perform repetitive tasks only, or they are clearly under our control. They do not currently think for us or adapt independently to our situations and needs.

The most important preserving values are related to professional identity being threatened by smart machines as well as a general fear of autonomous machines and the requirement for work to be performed by humans, as we are used to. People want to emphasise the value of human labour and mutual closeness between people and oppose robots that seemingly threaten this closeness.

The benefits, risks and inhibitors of change: With work performed by machines becoming flexible, production batches can be reduced in size without the costs increasing. This will lead to more versatile local production, lower logistics and storage costs, more extensive product ranges and lower hierarchies. When machines require less human control, it results in a decrease in the costs of goods and services and decreased competence requirements. The sharing of machines also becomes easier. As the sharing economy expands to autonomous machines, an increasing number of tasks can be performed with the help of these machines.

One risk posed by crowdsourcing and self-reliance is a potential reduction in the tax base. Another scenario that is considered to be a potential threat is the harnessing of machines controlled by artificial intelligence for harmful purposes. AIs that control physical equipment via cloud services in data networks are particularly vulnerable to disruptions in telecommunication and failures of terminal devices. In addition to simple failures, an AI may draw unexpected conclusions. Liability issues are often problematic in such situations, and misdirected liabilities do not encourage anyone to develop safer machines. AI also involves possible IPR problems and privacy issues. The job market is undergoing a great transformation, with many professions changing substantially and jobs disappearing as a result of machines performing an increasingly large part of current work.

This change is slowed down by people being used to the old ways and unable to see new opportunities. This inability is contributed to by a lack of investment in identifying new opportunities and the old-fashioned nature of education. The business skill required for many jobs that could now once again be performed locally with the help of mechanisation has almost disappeared, which is why new local companies are not being established even though the technical capabilities exist. The service industry is also not accustomed to the idea of services becoming robotised. Most people think that robots are only suitable for factories and repetitive work. The spread of mobile machines is restricted by their technical incompleteness, which limits their mobility in environments built on the terms of humans. Regulation further restricts the independent mobility of robots in public spaces.

Growing professions and skills shortages: Robots do not only reduce work when they replace old procedures. Development, management and maintenance of the robots provides jobs, as does marketing, training and organising the services they provide. Many services become so affordable with robots that the amount of work in the price elasticity areas increases in its entirety. Robots also cause harm and danger and preventing those increases people’s work. Fast-growing and new professions will include, for example, robot security inspector, robot insurance appraiser, robot field maintenance technician, robot foreman, robot trainer, robot work planner, robot energy manager and robot transporter.

The new jobs are mainly related to enabling the work done by robots and minimising harms caused by it.

Policy objectives of the change: Legislation should aim for providing easy access to work done by robots for as many people as possible. The introduction of robots should be expedited with the help of references offered by innovative procurement by public administration. Responsibility related to robot mobility and work done by robots should be clarified. At the moment, the limits of the responsibility of the manufacturer, teacher, owner and buyer are unclear. The disturbance of robots should be criminalised. Robots should be allowed to monitor their environment, and the control of robots should be clarified, especially in the case of robots moving autonomously in a public environment. The relationship of robots and other artificial intelligence to the General Data Protection Regulation (GDPR) should be resolved quickly. Interpretation should strive for a solution that intervenes as little as possible with the easy usability of robots in assisting individuals. The knowledge base related to and supporting robot mobility should be placed in the same position with physical infrastructure.

Special national characteristics: Finland has high-level expertise in artificial intelligence and robotics. For robots that move and work in outdoor spaces, the weather conditions in Finland are exceptionally demanding for a large part of the year.

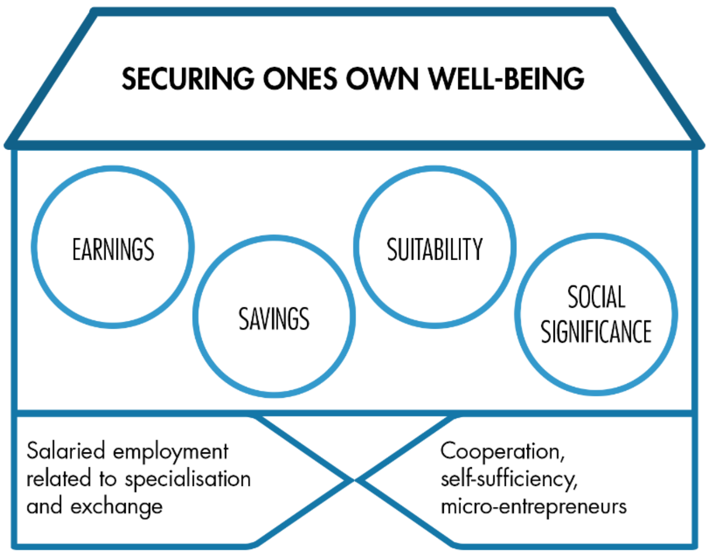
ART-ID	Automation of work: applications of the ARTs and evaluations of their effectiveness	Weight
1	Personal service robots provide a better service when they are able to "read minds."	3
3	Many personal services will improve when the machine is aware of the condition of the body of the person it serves.	3
4	The flexible operation of machines becomes easier when they are able to recognise liquids and gases.	3
5	The autonomous operation of robots becomes easier when they understand what type of materials and soil they are dealing with at a given time.	5
6	Machines must be able to perceive their surroundings and any other mobile objects around them in order to function sensibly in changing situations.	10
7	Machines require the IR, THz and GHz bands in order to communicate efficiently with their surroundings.	3
10	Autonomous machines such as a robot vacuum cleaner and weeding robot can explore their surroundings with laser techniques and perform operations by using a laser or a particle accelerator.	5
11	A machine's ability to communicate with speech is essential in versatile service work.	5
12	The performance of versatile tasks or tasks that vary based on situations and needs by a machine requires either the continuous presence of a human being or a learning artificial intelligence.	20
13	The development of AI for autonomous machines intended for narrow segments becomes easier via platforms. Platforms also facilitate the transfer of machine skills.	10
14	A service robot's operation improves when it is able to recognise faces and emotions and project the appropriate expression onto its own face.	10

ART-ID	Automation of work: applications of the ARTs and evaluations of their effectiveness	Weight
15	Many service tasks can be transferred to machines when machines have a sufficient ability to discuss the matter. The machine asks people to assist if necessary.	10
16	Robots moving within their environment must be constantly aware of their surroundings and anything else moving around them.	5
17	Machines must have an understanding of the objects around them. Modelling these objects and teaching these models to the machines speeds up their learning.	3
18	Many industries already have teaching material prepared for AIs, or such teaching material is easily available in their continuous operations and can be produced in connection with the rest of the process.	10
20	Machines learn their jobs better if it is easy for a human to guide them when necessary.	3
22	Robotisation is progressing with the help of AIs that learn better the more digitised learning material is available about each situation.	3
23	The growing energy efficiency of AI makes it easier to make increasingly small machines intelligent.	10
25	Continuation of Moore's law promotes digitalisation and the replacement of human labour with machines.	3
26	In a great number of tasks, a lack of computing power is for the time being preventing AIs from learning and perceiving their surroundings in the manner required for the robotisation of work.	10
27	A walking robot is able to move to all places where people work.	5
28	The capability of robots to travel aboard other robots without human assistance will radically expand their potential usage.	10
29	Distribution and warehouse logistics will become robotised.	3
30	Many work tasks are automated by transport and surveillance by quadcopters and drones.	5
31	Autonomous control of aircraft enables lightweight air taxis intended to transport one person.	3
32	Many measurement and monitoring tasks of outdoor spaces can be assigned to robots.	3
33	When oceanography and ocean cleaning tasks as well as transport tasks of waterborne traffic are automated, many tasks can be carried out more efficiently than currently.	3
35	Machines require telecommunication connections. In sparsely populated and undeveloped areas and aboard aircraft and ships, these connections are based on satellites.	3
36	Robotic insects and other UAVs produced with the help of biomimetics can be used for monitoring and other tasks when used as swarms.	3
37	A robot equipped with human-like touch-sensitive hands and AI is able to mimic and perform similar tasks as humans.	10
38	3D printing reduces the need for assembly.	5
39	Brickwork, the manufacturing of moulds and reinforcement work will decrease.	3
40	Self-organising control structures replace managerial work by coordinating employees to work locations based on their proximity, skills and preferences.	5

ART-ID	Automation of work: applications of the ARTs and evaluations of their effectiveness	Weight
41	A ubiquitous environment with data that is easy for a robot to read allows robots to operate sensibly in this environment.	5
42	Through remote control, AIs learns to perform tasks more autonomously. The majority of robots that replace human labour operate in service tasks or manufacturing of goods.	5
44	The manufacturing of clothes is currently labour-intensive work, and it is becoming robotised.	5
47	The ability to print medicine and other materials will reduce chains and labour.	5
50	Machines are able to distinguish raw materials in a way that people can not do economically. The work performed by machines gives significant added value.	3
51	The need to clean machines will decrease while their usability will increase.	3
52	Replacing reinforcement steel with materials that are easier for 3D printing will simplify the automation of construction.	3
53	Artificial muscles enable small and large, comparatively maintenance-free robots that operate in the natural environment similarly to humans or animals.	10
56	Cyborg-like pollinators may solve problems in the pollination of plants as the climate changes.	3
57	Due to the slow elasticity of the pension system, the number of pensioners in good physical condition will increase. Increasing of the dependency ratio will increase the need for mechanical services.	3
61	Part of current labour can be replaced with artificial cells.	1
63	Replacement of animal husbandry with cell cultures cultivated by machines.	3
64	Animal husbandry can be replaced with cell culture and 3D printing.	5
66	It is easier to robotise cell cultures than cattle farming and slaughtering.	3
67	LED farming facilitates the robotisation of food production.	3
69	The development of refrigeration technology facilitates the centralisation of the food industry and automation that is based on economies of scale, in addition to increasing the need for robot logistics.	3
70	Autonomous devices can operate continuously with solar energy outside the electricity grid.	3
73	Mobile autonomous machines operate primarily with electricity, and their spread requires battery technology to be developed further.	5
81	High-performance lasers as robot tools perform many tasks related to machining and assembly.	3
82	Wireless electricity transfer facilitates the continuous operation of mobile electrical devices.	3
87	In flipped learning, part of the teaching is provided by machines.	3
88	Robot-assisted work, such as remote control, helps the robot learn to become more independent.	3
91	Platforms standardise work in a way that facilitates the replacement of human labour with machines.	3
92	Modularity and the creation of an ecosystem with the help of shared interface definitions speeds up the development of robotics and facilitates the creation and maturation of innovations.	3
93	The ability of machines to trade with each other facilitates the robotisation of work.	5

ART-ID	Automation of work: applications of the ARTs and evaluations of their effectiveness	Weight
94	Machines must have a high-speed telecommunication connection, the latency must be low and the network must be in accordance with the general standard in order for the machines to operate smoothly.	5
95	Machines can share data via cloud services and combine what they have learned.	3
96	Global AI learns from extremely comprehensive materials and is able to share the learning cost with a very large user base.	5
97	Blockchain-based transactions are easier to automate than services of public authorities.	3
98	AIs are able to simulate actors, musicians and other artists.	3
99	The GDPR in its present form prevents the intelligent use of artificial intelligence in personal customer services.	5

1.11 Work and income



Scope of the value-producing network: The primary purpose of human labour is to secure our own well-being and that of family and friends and promote the things that matter to us. The scope of this value-producing network includes the exercise of social power in its various forms and also performances within a subsistence economy. The maintenance of taxation capability, shopping and pickpocketing each represent work and income within the meaning of this report, so the definition used here is broader than the normal concept of work.

The most important values of work are related to earnings and savings, the suitability of a job to our own tendencies, and the social significances of work. Earning includes compensation, the right to other benefits and the opportunity to advance. Savings can be considered to include benefits achieved through self-service and a subsistence economy without having to sacrifice previously collected means of exchange for this purpose. The suitability of a job is linked to our own abilities on the one hand and our own set of values on the other hand. Social appreciation for work and the relationships related to it are also important values for many people. One important goal of society is considered to be the division of the conditions for work and earning among all members of society.

The means and values of transformation: In developed countries, work is primarily divided into unspecialised domestic work and regular, specialised, paid work organised through hierarchies. Paid work has become so dominant that it is often referred to simply as work, while any activity performed for one's own needs is commonly referred to as free time. The transformation of work forces us to think about work as a more extensive phenomenon.

The boundaries of paid work, entrepreneurship and subsistence economy will change in the future. Artificial intelligence, the sharing economy and robotisation make the important tools and expertise required for productive work easily available. Differences in work productivity and need for specialisation may decrease as a result. The platform economy also facilitates occasional employment relationships, crowdsourcing and sharing of the results of communal work.

The sharing economy and platform economy partly refer to the same thing. Individual people report their needs or willingness to work and available resources to a data system that organises activity. The data system takes care of monitoring and invoicing as well as the conformity of the process with the required form.

With crowdsourcing, services can be scaled up and made regionally comprehensive, with a wide area of specialisation. The services can rely on the employees' own resources. With a few exceptions, AirBnB does not own any rooms and Uber does not own any cars. One important form of crowdsourcing is related to immaterial resources. Wikipedia and Linux are demonstrations of the power of collaboration. A great number of new services shares data provided by users and pictures, models and advice they have developed.

In platform-based work, organisations form networks that are independent of geographical location and loosely tied to the platform. Marketing is carried out as global P2P communication via social media. The transaction costs decrease as artificial intelligence and tools used for remote work become more advanced. By means of avatar robots, augmented reality and virtual reality, platform-based work is expected to become increasingly versatile and gain strength in relation to traditional paid work. Work is performed for a customer or some other group, with the role of supervisor being played by a platform that measures and rewards performance according to customer satisfaction or the opinion of a peer group.

Digitalisation provides us with advice on an increasing number of tasks as well as tools that automatically perform the work phases correctly. Tools also monitor the quality of the output. Semi-finished products will increase and the sharing of tools will become easier. This will create an economy of smallness that will lead to a decrease in silo-based specialisation, both between individuals and on a regional level. Smaller and smaller organisations are capable of doing an increasing number of things. The economy of smallness is making work tasks more comprehensive and transferring them from the sphere of paid work to a subsistence economy.

In the future, consumers will be able to use their own and shared smart machines to make objects, clothes and even medicine, buildings or vehicles for themselves. This signifies a return to a family-centric subsistence economy. It is also becoming increasingly possible to produce energy and food by ourselves. Expertise in medicine, design or maintenance can be crowdsourced in the form of communal work with the help of artificial intelligence and platforms. Avoiding taxes in the exchange of expert work will become more common with robotised remote work becoming more common and crossing national borders.

The most important values of the challenger regime are self-reliance, the ability to take risks, freedom, responsibility and a desire to experiment.

The means and values of the dominant regime: Most paid work now comprises controlling and using a variety of machines or interacting with other people. Jobs based on the use of physical strength are an increasingly small part of paid work.

Work is tied to large-scale production because of the natural economies of scale resulting from production and repetitive automation. Alternatively, economies of scale can result from artificial regulation of society. They are often produced for the promotion of the interests of power structures and hierarchies. Operators include labour market organisations, public and private monopolies and a variety of oligopolies.

The dominant regime is ownership- and capital-oriented, and various privileges have a major impact. Private privileges include intangible rights, among other things. States and politics play a major role in business economics both nationally and globally.

Large differences in work productivity, which have been strengthened with regulation, have enabled high taxation that is based on paid work and the exchange of its output. Society takes a commission fee of roughly 75% as tax-like fees when two middle-income people exchange work performances. This exchange is economical to the parties to the exchange only if the difference in profitability is threefold. Large income disparities naturally allow high-income earners to purchase work from low-income earners even if the purchased services do not involve any temporal work productivity differences.

Because of the tax wedge, households pick up the items they purchase from shops in person and run any other errands in which the productivity differences are low. Because of the comparatively minor income disparities and high tax wedge, any work tasks with minor personal productivity differences have become a self-service and transitioned to the sphere of subsistence economy if this has not been the case from the beginning. Today, it is more cost-effective for a painter to lay the brickwork for his/her house personally and for a bricklayer to paint his/her house personally even if each of them is slower than the other in these tasks. The productivity difference must be larger in order for the paid work to be worth it.

With tax-like fees, society pays for a great amount of services and transfer payments that are used to secure the livelihood of pensioners, students and unemployed people, for example. This model has worked well while the economies of scale have been large.

Approximately 2.3 million Finns are engaged in paid work. Of this number, 1.5 million have continuous and full-time employment contracts, while 800,000 are engaged in atypical employment. Almost all households handle all or most of their domestic work by themselves. A significant proportion of so-called free time is used for travelling related to paid work and picking up groceries and goods. Within the dominant culture, behaviour is strongly guided by paid work and the expectations and professional identities related to it. This is also a consequence of the education system and regulation.

People are defined in a dichotomic way, i.e. based on an either/or principle, as recipients of earned income or entrepreneurial income, employed or unemployed and as those on work-related leave or pensioners. Wage and benefit systems are based on these same dichotomies that preserve the old way of thinking. The most important preserving values are a desire for safety, desire for a hierarchy, desire for comfort and fascination with great stories.

The benefits, risks and inhibitors of change: The meaningfulness of work increases when work tasks and expertise become more comprehensive and less hierarchic. Regions and individuals becoming more self-sufficient reduces susceptibility to crisis and transaction costs. A platform economy increases openness and eliminates middlemen and managerial ladders, increasing the work's efficiency. Increasing self-reliance so that people can make their own goods and produce their own food, energy and any knowledge and skills they require by themselves will change society rapidly.

When the standard of living no longer depends on earned income, the consideration of the effects of transfer payments becomes more difficult. The tax base can diminish significantly as a result of the sharing economy, self-reliance and crowdsourcing transferring labour away from the monetary economy. Increasing the tax wedge further will create a negative cycle. Transfer payments may also make a transition to a subsistence economy an attractive option if the conditions for it improve materially in the anticipated manner.

This change is slowed down by strong social and mental ties to paid work. Work and particularly paid work performed for other people holds great symbolic value for the one performing the work. Homes are poorly equipped for independent manufacturing or remote work. Education prepares people for paid work and hierarchic organisations. The economies of scale are still substantial, and they are maintained by decreasing logistics costs. In many industries, work is highly regulated, and exchange is difficult to implement outside current organisations.

Growing professions and skills shortages: The biggest change in doing work is caused by the growth of the platform economy. The growth of self-sufficiency and voluntary work also plays a major role in the change, and future professions will emerge related to them. Examples of new professions include e.g. platform auditor, platform police officer, online work (predictor, freelancer, reputation vendor), platform manager, authority facilitator, local service dealer, micro-insurer, self-sufficiency consultant and community manager.

Policy objectives of the change: The most important regulatory objective of the change is to facilitate micro-entrepreneurship and platform work. Simplified rules should be developed for the income and cost calculation of shared resources. The obstacles to cooperative-type activities and subordination to the market economy should be dismantled and the development of platform cooperatives should be supported. Employment legislation should be made location-independent, so that remote work could be controlled and working would not necessarily require physical presence. Transactions of the sharing economy should be standardised, and research into a modern subsistence economy should be increased.

Special national characteristics: A Nordic welfare state is a globally divergent phenomenon. The rapid increase of the dependency ratio is increasing the challenging nature of the transformation of labour.

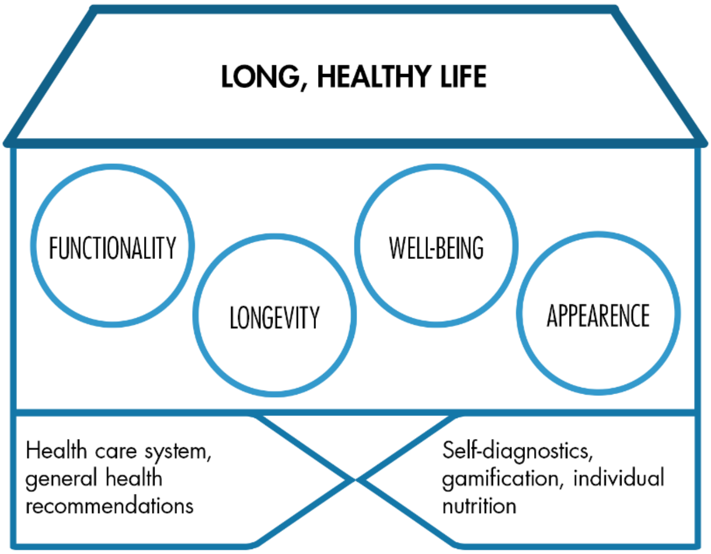
http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/80549/TEMrap_34_2017_verkkojulkaisu.pdf

ART-ID	Work and income: applications of the ARTs and evaluations of their effectiveness	Weight
1	An emotion worker can read thoughts or allows his/her thoughts to be read. Thoughts can be used to control robots or other tools faster than by hand.	3
5	Human labour will become easier when a measuring device identifies the composition of each material object.	3
6	Imaging is part of digitalisation that promotes the benefits of artificial intelligence and the platform economy, centralising intellectual work while decentralising physical work and the expertise related to it.	3
11	Machine simultaneous interpretation introduces the possibility for both local and remote work regardless of one's own language skills.	10
12	Artificial intelligence can teach and assist people whose inadequate skills and knowledge would otherwise prevent working. This kind of supportive intelligence facilitates the completion of several jobs.	20
13	Platforms diversify the applications of AI and lower their price through increased competition. This reduces inequality in skills and democratises labour.	5
14	The work efficiency of humans will improve when machines can recognise emotions.	
15	Work efficiency will improve with the use of communicative machines.	
17	Digitalisation promotes the location independence of work. 3D models of objects can be worked on, moved and combined virtually, after which a robot can do the same physically.	3
18	Teaching AIs is one of the broadest jobs of the future. Choosing and collecting teaching materials and evaluating their rate of success are elements of this work.	5
19	Through augmented reality, people can be present as holograms in each other's physical surroundings. As a job, this can be for the purpose of counselling, entertainment, etc.	5
20	VR glasses allow robot-assisted activity in a variety of control, maintenance, counselling, service and assembly tasks, for example.	10
21	The remote control of robots that move like humans and can be controlled with the movements of a human body will be an important job in the future. Haptic control and gesture control will become more common in all types of work.	5

ART-ID	Work and income: applications of the ARTs and evaluations of their effectiveness	Weight
23	AI becoming less expensive will contribute to the spread of supportive intelligence, which will even out differences in skills, lower hierarchies and reduce economies of scale and the need for specialisation.	10
26	The advancement of digitalisation will speed up the release of work from being tied to a location. Realistic VR/AR worlds, to which part of the work will relocate, require an increasing amount of computing power.	5
27	Walking assist devices will increase people’s ability to perform heavy work.	3
28	Professional driving will decrease. Commuting time will become time used for work. Work will be less tied to any one location.	5
29	The distribution and availability of local production will become easier.	3
30	Easier local distribution and monitoring will open up many tasks that have previously been performed as a self-service or neighbourhood assistance.	3
31	Easier mobility will provide new job opportunities.	1
32	Continuously flying devices will increase jobs in remote control and remote monitoring.	1
33	Robotisation of waterborne traffic will increase remote control and remote monitoring jobs.	1
34	As the commuting and services areas expand, specialisation and opportunities for earning income will increase.	3
35	The increasing of satellite connections promotes global communication equality and opportunities to participate in job markets created by the Internet.	3
37	Robotised work will become easier when a robot’s hands can repeat the movements of our own hands, with VR glasses showing the situation as though we were doing the work ourselves and with sensations of touch conveyed to our own fingers.	5
38	Local manufacturing and customised production will increase the need for measurement, design, packing and selling.	5
39	The selling of design work and models will increase.	1
40	Work carried out by people will be gamified and, in its own way, become more independent and self-organising.	1
41	Digitalisation will release work from being tied to a location. On the other hand, a ubiquitous environment will increase the need for local problem-solvers and maintenance personnel.	3
42	Avatar services will release service work from being tied to a physical location.	5
54	Easier accessibility to fresh water will increase work opportunities in areas that are currently suffering from a water shortage.	5
56	Expanding human skills with cyborg-like skills will increase efficiency.	3
57	The self-sufficiency of people of pension age in good physical condition will grow. Organisations that are based on personal power structures and social ties will grow further.	5
63	The option of cell culture will increase self-sufficiency.	1
64	Cell culture, indoor farming, and 3D food printing promote self-sustainability.	3
67	The increase in small-scale food production will expand the subsistence economy.	3
70	In sparsely populated areas, energy can be acquired self-sustainably, which will probably increase self-sufficiency.	3

ART-ID	Work and income: applications of the ARTs and evaluations of their effectiveness	Weight
71	Local heat production will increase self-sufficiency.	1
74	Local energy increases local work.	3
77	Self-sufficiency may increase as dependency on centralised structures decreases.	1
80	Devices for recovering kinetic energy are typically mechanical structures, the design, installation and maintenance of which requires a considerable amount of human labour.	5
84	Gamification of work tasks will increase learning, direct activity and reduce the need for supervisory work.	5
85	Time banks will increase services provided between people with the same income.	1
86	Crowdfunding and microfinancing can promote new types of projects for which it would otherwise be difficult to obtain funding. This way, they can provide work and earning opportunities.	3
87	Job opportunities will increase when most skills and knowledge can be obtained online and proficiency can be demonstrated easily.	10
88	Many people will have an AI as their supervisor and perform their work under a platform. Work will also increasingly often involve remote controlling a robot.	5
89	Global work and trade that avoid taxation will increase.	1
90	Communal platforms will increase work by facilitating exchange.	5
91	Platforms will provide a varying amount of work. Instead of pleasing a supervisor, work will depend on individual customer satisfaction and the success of the platform.	10
92	The development of robot ecosystems will make expertise global and extensive.	3
93	Work directly included in trade and transactions will decrease, but an increasing range of products and services will require its guide and explainer.	3
94	A global high-speed network promotes the opportunities for global remote work.	3
95	IT services can be established without investing in computing capacity.	3
96	The transition of work can be regionally very fast due to globalisation.	5
98	Work may increasingly involve providing experiences. Bloggers and vloggers will certainly be joined by VR and AR influencers once suitable platforms are created.	5
100	Remote control, remote guidance and remote entertainment become meaningful jobs with VR/AR glasses. Platforms ensure the compatibility between glasses and content.	5

1.12 Health care



Scope of the value-producing network: The primary objective is for people to lead healthy lives for as long as possible. The most important values are the functionality of the mind and body, longevity, well-being and appearance. This value-producing network includes the prevention and curing of diseases that affect the functionality of the mind and body. This includes maintaining physical and mental health and correcting problems relating to appearance and behaviour that disturb social relationships. Lifestyle medicine and biohacking fall within this value-producing network. Correcting deficiencies related to the functioning of the mind and body with the help of tools or a constantly assisting environment is included in the next value-producing network.

The means and values of transformation: The current mainstream of health care includes statistics-based recommendations issued by the authorities as well as bureaucratised health monitoring and treatment of illnesses through officially monitored outpatient care and institutions, primarily in compliance with the Current Care Guidelines. This situation will change.

Today, people independently treat the symptoms of the common cold, stomach flu and simple wounds and rashes. Technology already allows the genome and cell metabolism to be identified on an individual basis. In the near future, people will be able to use household equipment to monitor the condition of their bodies more closely than the laboratories of central hospitals have been capable of until now. Based on this data, an AI, assisted by an expert if necessary, will be able to provide a statement on any necessary lifestyle changes and need for treatment.

In addition to reactive care, the means of proactive care and early recognition of symptoms will improve, particularly in self-care. This is promoted by things such as the development of AI and various biomarkers as well as the spread of self-care measurement devices. These procedures prevent problems from becoming serious and various epidemics from spreading.

The FDA, which controls health care methods in the USA very strictly, has approved several iPhone accessories for diagnostic purposes. For example, patients can photograph their retina or eardrum by themselves and send the photo to a doctor for a medical opinion. Accessories to smartphones are capable of a wide variety of measurements. AIs will also make automatic diagnoses possible. The two winning finalists of the Tricorder XPRIZE competition developed portable devices that can be used by laypersons to diagnose several common medical conditions precisely.

DNA sequencing is becoming so inexpensive that, in addition to our genome, it will likely become practical in the near future to also determine the state of our protein metabolism and the body’s bacterial strain as well as the genome of the cells we eat as food on an individual basis. The significance of these data is being understood better every year, and personalised medication will become easier.

In modern medicine, short chemical molecules and their side effects are used to replace certain deficiencies in the regulation of cell metabolism. In the future, it will be possible to correct a problem at the level of its original root cause. Dietary recommendations will also become personalised, and their effectiveness can be monitored at the cellular level. By means of gamification, AI, digital tattoos and self-diagnostic implants, this will become a continuous way of life.

One manifestation of health care that is based on self-care is the biohacker movement. It involves adjusting people’s lifestyles with the help of self-diagnostics and nutrition in order to promote health. One specialised form of this is patient organisations. Their members voluntarily try out new treatments and compare their experiences. The consumerisation of diagnostic tools will enhance this activity. With new methods of biotechnology, even complex molecules can be synthesised in home laboratories. This opens up a path to extensive human experiments. Patients can synthesise medicine for themselves and share their experiences with the help of peer-to-peer communities.

The research into extending the human lifespan is at the cusp of a potential breakthrough. Researchers have been able to extend the healthy lifespan of mice by roughly 30%. This has been possible with several methods that substantially differ from each other. The same methods are now being tested on humans. In mice, they not only slow down aging but also heal many age-related diseases, such as dementia, dilated cardiomyopathy, wrinkly skin and loss of muscle strength. The concretisation of this research may lead to a radical increase in voluntary treatments.

The mental health challenges are great, and public health care is unable to provide adequate services to prevent the continuous increase in mental health problems. With the help of AI, various agents of socialisation, peer assistance and gamification can provide new voluntary and communal methods for improving mental health.

The most important innovative values are related to the idea of the body as a temple as well as concern for our own well-being and aging or those of the people close to us. Personalised functional nourishment, a desire to experiment and distrust in general recommendations and diagnostics increase the desire for self-reliance.

The means and values of the dominant regime: A balanced diet and a regular lifestyle are the most important methods for maintaining health. The primary operating model related to them is population-level research as well as general recommendations and more compelling regulations issued based on such research. General recommendations and norms are used to influence the food industry, institutional kitchens and personal choices, for example. Regulations and behavioural education are also used to influence mobility, sleeping habits, the use of alcohol, drugs and tobacco as well as traffic culture.

The treatment of diseases falls to professions that are closely monitored by the authorities, with the exception of minor ailments and infectious diseases. Bureaucratised procedures are prevalent, regardless of whether we are talking about institutional care, outpatient care, medication, rehabilitation or surgical procedures. The development and marketing of medicine is also strictly regulated. Diagnostics and treatment measures based on diagnostics are the exclusive right of medical professionals, and the distribution of medicine is based on prescriptions issued by doctors. Nurses are allowed to perform similar tasks to some degree, and pharmacies distribute some self-care medicine without a doctor's prescription.

The social services and health care sector employs some 400,000 people in Finland. This figure also includes restoration of the ability to function, which will be discussed in the next value-producing network. According to the data of the National Institute for Health and Welfare, the Finnish health care expenditure in 2015 amounted to almost €20 billion. Specialised health care accounted for some 7 billion of this amount, with public primary health care accounting for some 3.7 billion and medication for 2.5 billion. The rest comprises care facilities for the chronically ill as well as private health care costs. The share of the food industry and other work and costs related to lifestyle-related health is difficult to distinguish from other activity.

The most important preserving values are trust in institutions, privacy concerns, public health ideology, nanny mentality and the idea that everyone is bound by the same rules.

The benefits, risks and inhibitors of change: The main benefit of the change can be considered to be an increase in individuality. This occurs both through people's personal initiative and through health care taking people's individual characteristics and needs into account over population-level statistical recommendations.

When an individual has a better understanding of his/her condition and options, he/she is better able to choose how to act. General recommendations are not often convincing, as the correlations are not strong, and there is great dispersion. In other words, something that is unsuitable for most people may be a completely unproblematic method for others. Individuality and self-reliance may help enhance monitoring and maintenance of health and decrease health care costs.

The increase in self-reliance involves a risk of alternative medicine. Incorrect information may cause harm if it spreads to both lifestyles and medication. The anti-vaccination movement is a good example of this. Another danger is that patients who have looked into things on their own may find themselves in opposition of medical professionals who rely on the Current Care Guidelines.

Measurements performed by patients themselves may lead to growing liabilities in forcing public health care to check the claims presented to them. Already, many treatment measures are only launched after the patient has gone to a private health care facility and undergone examinations which public health care has refused to carry out. After such examinations have proven the patient's suspicions to be correct, public health care has become aware of the problem, so to speak, and admitted the patient in for treatment. This trend is likely to intensify as people increasingly take the initiative. Errors in independently performed measurements will likely also lead to many unnecessary measures.

The risks of self-reliance also involve a loss of privacy. New measurement devices allow people to determine not only the condition of their own body but also details about the condition of the mind and body and lifestyle choices of other people. Some of the cloud services related to measurement devices also require permission for more extensive utilisation of personal data. Future risks also include the manufacture of pharmaceutical substances not only for people's own needs but also in a harmful way to other people and the environment.

The transition to functional personalised diets is slowed down by the fact that people are used to processed meals and institutional kitchens. Only households and gourmet restaurants have the proper capability to produce personalised food. Authority is highly significant, and people are either not accustomed to self-diagnostics or the equipment is undeveloped. Official practices and regulation do not support a change.

Growing professions and skills shortages: Health is a vital thing for people, and individuals can use more of their resources on it if the effectiveness is clear to them. Numerous new jobs will emerge from individual health care. Examples of growing professions include DNA analyst, microbiome counsellor, biomarker interpreter, charlatan teaching how to use self-diagnosis tools, self-diagnostic tool maintenance technician, biosecurity jurist (judge, council member, attorney), bioconsultant, medication printer, DNA modifier, amino acid cook, well-being coach, diagnostic coach, self-diagnosis inspector, digital therapist, implant installer, digital tattooist, biodetective and biorisk mapper.

Policy objectives of the change: Publicly funded information sources of doctors should be made public information. Self-diagnosis guidelines should be developed, and equipment used for self-diagnosis should be tested and inspected. DNA testing of the population should be developed and favoured.

Nutritional recommendations should be tied to information about the person's genome, and equipment enabling gamification should be encouraged by the society for this purpose. Responsibility limits of the doctor, patient and pharmacy should be revised, taking into account the development of self-diagnosis. The responsibilities of equipment manufacturers should be defined in relation to self-diagnosis. The control and certification of self-diagnosis equipment and lifestyle applets should be organised. The public funding of expensive individual treatments should be prioritised based on careful analysis.

Special national characteristics: The Finnish population's personal initiative, level of education and ability to use IT equipment are at a high level. Finland is the most rapidly ageing country in Europe. The export of health technology is significantly high.

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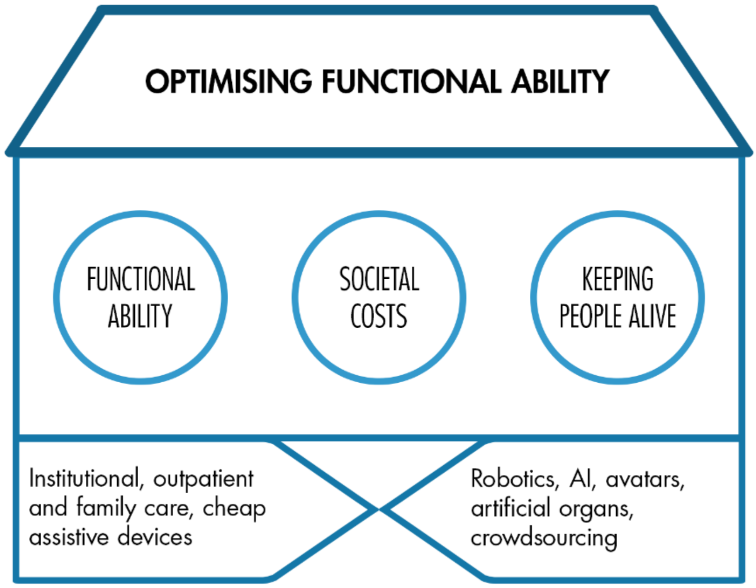
ART-ID	Health care: applications of the ARTs and evaluations of their effectiveness	Weight
1	Reading and influencing emotional states may impact healthy lifestyles.	5
2	Dietary and lifestyle changes planned with the help of the individual's genome and microbiome improve health. Monitoring food genomes increases food safety.	10
3	Monitoring of the state of the body allows health to be gamified and is helpful in detecting deviations relating to health and lifestyles as well as early symptoms of diseases.	20
4	Detecting diseases, unhealthy environments and impurities in food will become easier.	5
5	A material scanner can recognise unsuitable substances in food and breathing air.	10
8	The adjustability of the colours of LED lights and indoor farming may promote health.	3
9	Plasmonics can be used to make nanomachines that monitor health. They communicate through the body or cling to cancer cells and kill them.	5
10	Small particle accelerators, THz-waveband femto lasers, etc. enable the examination of the body and early detection of possible problems.	5
11	Interpretation is needed in cases of illness in which the patient and doctor do not speak the same language.	3
12	Artificial intelligence is able to monitor early symptoms, diagnose illnesses, advise on healthy lifestyles and encourage their adoption.	10
14	Emotional machines can have a positive impact on health.	3
15	A communicative (emotional) machine can have a positive effect on health.	3
18	Health applications are constantly producing teaching material.	3
20	VR glasses can create physically stimulating environments, such as ball games, battle situations, obstacle courses, etc.	1
21	Interfaces that react to body movements will transform the use of computers into a physical activity.	3
23	Personal assistants will become increasingly capable supporters.	3
25	It will become possible to place electronics inside the body.	10
26	Modelling cell metabolism in order to simulate the effect of food on health in a simple way will require an increasing amount of computing power.	5
31	In case of illness, air taxis will be significantly faster than ambulances.	3
41	Indoor air and other conditions can be adjusted to be favourable to health.	3
50	Separation techniques can make it possible to filter out unhealthy substances from food and also from blood circulation.	3
51	The number of infectious diseases decreases when antibacterial coating is applied to contact surfaces.	1
54	Clean water is essential to health on a global scale.	5

ART-ID	Health care: applications of the ARTs and evaluations of their effectiveness	Weight
56	Continuous detailed monitoring of the body makes it easier to maintain health. Cyborg-like adjustment can contribute to functional ability, making it better than normal.	10
57	Lengthening of healthy life expectancy increases risk-related care. Radical lengthening of healthy life expectancy seems possible.	20
58	Nanoparticles and microbots can monitor and adjust vital functions and heal diseases.	10
59	Genetically engineered medicine and functional foodstuffs can be produced individually at home.	5
60	The adult human genome can be corrected. GMO food can be made more healthy than natural food on an individual level.	10
61	The ability to simulate an individual's cells makes it possible to ensure that these cells react to foodstuffs, medication and lifestyles.	5
62	Understanding cell metabolism, the microbiome and the genome is necessary when avoiding individually unhealthy lifestyles and planning personalised nutrition.	20
63	Regrowing damaged organs is an important part of maintaining health. Cultured cells can be sprayed to replace damaged ones.	5
64	A new organ can be printed to replace a damaged one.	5
65	Dementia is one of the great encumbrances of society both financially and on an individual level.	20
66	Cell cultures can be programmed to produce personalised nutrition as needed.	5
67	Increasing production that is based on individual needs and improving freshness by utilising local manufacturing will enhance the health effects of food.	3
69	Treatment of trauma patients will become easier if their vital functions can be stopped for the duration of the planning and organisation of their treatment. The quality of foodstuffs will improve.	3
82	Wireless electricity transfer enables sensors that require electricity to be placed inside humans.	3
83	Internal combustion engines increase unhealthy fine particle concentrations in breathing air.	3
84	Gamification of health and lifestyle significantly promotes health.	5
96	A human being is the same everywhere and diagnostics can be the same, as can a major part of lifestyle coaching.	10
99	Transfer of health-related data enables use of alternative services.	1

1.13 Redressing disabilities



Scope of the value-producing network: The objective is to compensate functional deficiencies and optimise the functional ability of a person in everyday life with assistive devices and by facilitating the living environment. This definition includes the care of children, elderly people and disabled people. Various prostheses and other assistive devices, such as glasses and dentures, also fall within the scope of this value-producing network. It excludes the means of maintaining health that are mentioned in the previous value-producing network.

The most important values are functional ability in everyday life, the costs and benefits to society and keeping people alive. Functional ability in everyday life can be achieved independently or through continuous care. The costs and benefits to society can be calculated through the corrective investment made by society or the functional ability and years of life gained. In the case of seriously ill people, keeping people alive may be the objective of the caring organisation without it being the individual's own objective.

The means and values of transformation: The activity of the dominant regime is based on institutional care supported by society, home care, informal care and simple prostheses, wheelchairs, rollators and other assistive devices. New opportunities are unlocked by robotics, avatars, AI, artificial organs and crowdsourcing.

During their lifetime, almost all people experience some type of deterioration in their eyesight that is usually corrected with glasses. The development of optics and optoelectronics has introduced the possibility of correcting a part of colour-blindness with filtering glasses or contact lenses. Damage to the eye can be repaired with surgical procedures by adding artificial optic nerves, an artificial retina or an artificial lens. The abilities of these implants will at least partly exceed the natural abilities of humans.

The visually impaired already have access to machine vision applications that allow them to recognise objects, spaces, routes and facial expressions. These applications can tell a visually impaired person what is in front of him/her at a given time or guide him/her with his/her sense of touch. Similar tools are available for the hearing impaired. They show any speech heard by a microphone as text or visualise sounds by other means. Hearing aids are also evolving, and middle ear implants have been developed.

Prosthetic legs and arms are becoming robotised, and they can be connected to the human nervous system or even to the brain with a brain implant, allowing their movements to be controlled with thoughts. Wearable robotic legs that strengthen the body's own movements are available for people with muscle weakness or partial paralysis. There have also been successful trials with paralysed people being implanted with neural implants that have allowed neural signals to bypass the damaged parts of their nervous system.

Pacemakers are common, but many other artificial organs are currently under development. For example, an artificial pancreas produces the amount of insulin required by the body in real time. A sleeve placed around a weak heart to strengthen its beating is under development, as are artificial muscles, subcutaneous measurement devices and medicine dispensers.

Children, elderly people and other people with limited functional capacity may already have a wristband or mobile phone that they can use to call for help in an emergency. In the future, both them and adults with full functional capacity can have a personal AI assistant that monitors their actions, warning them of dangers and reminding them of past and future events. This type of assistant can monitor traffic and the rest of the person's surroundings, the function of the body and the actions of other people.

The most important innovative values are the idea of a good life, personal initiative, staying active in old age, proactivity of family and friends, awareness and the great cost of institutional care.

The means and values of the dominant regime: In the current situation, elderly people with weak legs are provided with a rollator and younger people with reduced mobility are provided with a motorised wheelchair if their functional ability cannot be returned with rehabilitation or surgical means. Prosthetics are rarely robotised, and a loss of functional ability very often leads to retirement from work and admission to institutional care. The measures are based on guidelines and are for the most part financed by society. New methods are only being tested to a limited degree and they are not widely known.

Society allocates a great amount of funds to accessible construction and other accessibility features, as well as personal assistance and institutional care provided for people who have lost their functional ability, while allocating very little funds to the recovery of people's functional ability with the help of new types of assistive devices.

Various deficiencies and limitations in functional ability apply to all people in different stages of their lives. The direct costs of social services in Finland are approximately €7 billion, most of which are caused by deficiencies in functional ability within the meaning of this value-producing network. Deficiencies in functional ability also cause other costs. The direct costs of accidents at home and during free time alone amount to almost €1 billion, excluding the imputed costs of loss of life.

The greatest individual deficiency in functional ability that causes costs is dementing disorders, the total costs of which are estimated to be approximately €4 billion in Finland. The loss of income caused by incapacity for work amounts to some €8 billion.

Assistive devices account for such a limited amount of all costs that instead of warranting their own category in statistics they are categorised as a clearly minor part of the costs of medication and supplies. For comparison, accessibility increases construction costs by €100–200 million annually, depending on the computing method.

Values that preserve the current operating model include paternalism or protection, equal treatment instead of need-based treatment, and the prioritising of keeping people alive over enabling them.

The benefits, risks and inhibitors of change: The most important benefits of this change are an increase in independent coping, better quality of life, a decrease in institutionalisation, a decrease in accident proneness and restoration of working capacity. New assistive devices also reduce the need for accessible construction and personal assistance. The benefits apply to all groups that require assistance and extend to society as a whole.

The greatest risks can be considered to be speed of the change, experimental artificial organs and the surprising effects of artificial intelligence. Attention must also be paid to cyber threats if the devices that are essential for people's functional ability are susceptible to cyberattacks. For example, the recall of installed pacemakers in 2017 due to data security risks is food for thought. Erroneous instructions issued by an AI or an excessive dose of insulin administered by an artificial pancreas can put people's lives at risk.

The change is slowed down by the conservative and strictly regulated operating culture of health care institutions, the most important value of which is the fulfilment of norms. People can easily become submissive, particularly when their functional ability deteriorates. They may also shy away from visible assistive devices if they are a new type. A person walking with the help of robotic legs or a camera may think that he/she will encounter unfortunate situations.

The sector's focus on public services, paternalism and treatment of elderly patients with a terminal care oriented mentality are not suitable for promoting the adoption of new innovations in order to improve the quality of life. The adoption of new assistive devices does not fall properly within any key operator's professional identity. It is much easier for medical professionals to learn about new medications promoted by major pharmaceutical industry operators than the new products of small and poorly represented companies that provide assistive devices.

Growing professions and skills shortages: Growing and new professions include e.g. prosthesis adjuster, prosthesis printer, instructor of AI assistants and AI controllers, avatar care assistant, avatar remote controller, escort companion, artificial organ grower, artificial organ inspector and brain implant configurator. The new professions are related to adjusting, configuring and adapting assistive devices, a social void created by automation, supporting robotised remote work and artificial organs.

Policy objectives of the change: The most important legislative objectives include generally improving the status of assistive devices in relation to e.g. accessible construction and especially promoting robotic limbs, assisting people with early-stage dementia by means of artificial intelligence, digitising and gamifying rehabilitation, supporting crowdsourcing aid platforms, incorporating avatar assistive devices in the support system and promoting aids related to artificial intelligence and augmented reality for visually impaired people.

Special national characteristics: Health technology plays an exceptionally large role in Finland due to the rapidly ageing population, high level of social security, high level of education in the field, and export.

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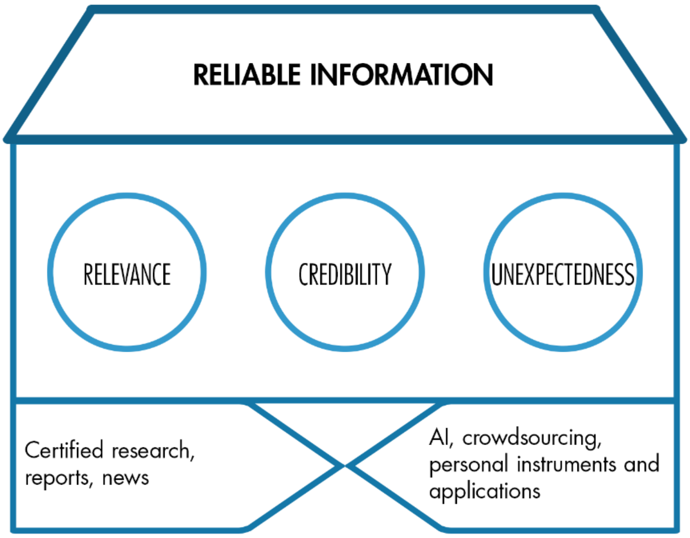
ART-ID	Redressing disabilities: applications of the ARTs and evaluations of their effectiveness	Weight
1	The reading and modification of thoughts are highly essential areas of development with regard to depression, memory disorders and prosthetics.	5
2	The identification of hereditary diseases and predispositions requires the DNA to be read.	5
3	Deficiencies in functional ability can be corrected by monitoring the condition of the body and e.g. with medication or by requesting help automatically when necessary.	10
5	A deficiency in a person's own functional ability can be aided with a device that recognises materials. The purpose of this may be to compensate the person's senses or cognitive abilities.	3
6	Machines that perceive the surroundings are beneficial to visually impaired people and many other people with limited functional ability. Imaging plays a key role in pattern recognition.	3
11	Speech technology is an important aid to deaf, mute and visually impaired people for various reasons.	10
12	Artificial intelligence can assist in deficiencies in functional ability, such as sensory impairment, as part of various prostheses and as a general counsellor for a person with a memory disorder, for example.	5
14	Facial and emotion recognition aids the visually impaired.	3
16	Modelling of the environment is essential for people with visual impairment and reduced mobility.	3
17	In order to print prosthetics and other assistive devices, the place where the device will be fitted must be modelled.	1
19	Glasses can be used to correct red-green colour blindness, night blindness and deficiencies in perception or attentiveness.	3
20	In a virtual world, a person is able to experience and do many things with the help of avatars that would not be possible in the real world.	3

ART-ID	Redressing disabilities: applications of the ARTs and evaluations of their effectiveness	Weight
21	Functional prosthetics and exoskeletons are partly based on motion controllers and haptics.	3
23	As artificial intelligence becomes more efficient and “lighter,” it can be used to support increasingly minor deficiencies.	3
25	Electronics that are permanently placed within the body as part of it will be made possible.	10
27	Helping people with low strength in their legs and even paraplegic people walk.	10
28	Deficiencies in functional ability do not prevent independent use of a self-driving car.	10
29	Deficiencies in functional ability do not prevent independent transport of goods.	5
37	Functional prosthetic arms are evolving rapidly.	1
38	The manufacturing of customised prosthetics is easier with 3D printing.	1
42	Avatar services for people with limited functional ability make it easier to cope with everyday life.	3
46	The lightness and strength of prosthetics and assistive devices are important properties.	3
53	Prosthetics and exoskeletons will become increasingly natural with the help of artificial muscles.	5
56	Artificial organs and prosthetics restore functional ability and increase capabilities.	20
57	The potential for healing age-related problems already exists.	5
58	Microbots can compensate deficiencies in vital functions.	3
59	A genetically modified pig can be raised with organs that are suitable for a human.	3
60	Growing of genetically modified artificial organs contributes to the restoration of functional ability.	5
62	Deficiencies in the functional ability of the body can be compensated artificially when the functional mechanisms are understood well enough.	10
63	A deficiency in functional ability can be corrected with cultured cells that compensate the deficiency if the body is unable to generate the required cells itself.	3
69	Organ transplantations become easier to carry out when longer transport times are allowed as cryogenics improves.	3
73	Exoskeletons and many prosthetics require efficient batteries.	5
82	Wireless transmission of the electricity required by artificial organs and prosthetics is a key benefit.	3
84	Gamification may help people with limited mental capacity make sensible choices.	1
86	Microfinancing can promote projects that restore the borrower’s working ability. This is particularly significant in areas with poor social security.	1
88	Many people could restore their working ability through guidance that takes their emotional state and skill level into account and provides guidance immediately when needed.	3
91	People with limited functional ability may cope well at home and be able to complete many useful things online.	3

ART-ID	Redressing disabilities: applications of the ARTs and evaluations of their effectiveness	Weight
92	The use of robots as prosthetics, exoskeletons and other assistive devices will become easier.	3
93	Machines can help people with limited functional ability with shopping.	3
94	Securing functional ability may require the help of a cloud service and a high-speed connection to it.	1
96	The contribution of a global artificial intelligence to restoring functional ability is limited.	3

1.14 Acquiring information



Scope of the value-producing network: The purpose of this value-producing network is to provide people with reliable information on the things that interest them. This definition includes both an individual's own direct observations and measurement data as well as information acquired from other people directly or via media. It excludes procedural skills and the ability to perceive larger patterns. In this context, information refers to all observations and interpretations of them, including any stories made up by people and events occurring in virtual reality.

The most important values are related to the relevance, credibility and surprising nature of information. The relevance of information is determined based on its usefulness for the situation and need in question. Information can help create a situation picture or be useful in aspirations for power, for example. Credibility may be based on the authority, presentation or experience of the source of information. Credibility is often a more important quality for information than accuracy. Information can be trusted because of its practical nature or rhetorical effectiveness. The surprise element is the factor behind curiosity and the thing that often leads to a re-examination of threats and opportunities.

The means and values of transformation: The information complying with the dominant regime is gathered by organisations and published by the media. Trustworthiness is based on the nature of the organisation or person conveying the information. Our direct sense perceptions only comprise visual perceptions of our surroundings and few experiences of foodstuffs and goods. We tend to trust the image we see on television, for example, as though we personally witnessed the event being shown.

The world is becoming immediate and seemingly straightforward. Studies are published immediately as draft versions before a peer review. Messages are often even purposefully misleading, and we may be individually shown messages that appear to come from respected mass media. On the other hand, we can also easily reach other people through peer-to-peer media and actively compare our observations.

Search engines and AIs also help us evaluate the truthfulness of the messages we receive. A variety of search engines provides us with a great number of search results about our local region and other things that interest us. With measurement devices, we can study the things around us and compare the results with other people interested in the same phenomena through cooperation networks.

Measurement devices are rapidly evolving and becoming commercialised. Materials and substance compositions can be identified with optic means. For example, infrared spectrometers are already available, both as an accessory and standard equipment to smartphones. In the future, DNA readers will become household items, and many other optical, biomechanical and electronic devices will make it very easy for us to identify molecular compositions in our food, environment and even the air exhaled by other people, for example. We are also learning to recognise weaknesses in structures or hereditary qualities in humans with everyday tools.

AIs interpret facial expressions and gestures to identify tendencies, intentions and emotions. Crowdsourcing adds photos of almost all people, places and interesting situations to the Internet. Search engines and social media help us locate original sources and gain direct access to them. The statistics for platforms also show us the extent to which other people have been interested in things. Crowdsourced cameras that map terrain tell us where berry picking spots, mushrooms and easy access routes are located. Peer experiences also tell us the quality of hotels, restaurants, government agencies and numerous other services and various goods.

Sharing false information is becoming increasingly easy. A fake video can already be created with limited resources. The person chosen as a target may do or say things on the video that he/she would never do or say in reality. It is also increasingly easy to detect the false nature of false information if the credibility of the information comes under suspicion. Through social media, the mistakes of traditional media and the people in power are made increasingly visible. On the other hand, social media and search engines also make it possible to wrap ourselves in a bubble of false or one-sided information if our ability to distinguish falsified, biased and inadequate information from accurate information is poor.

The most important values that promote the change are related to people's social curiosity and interest in their local area. This phenomenon is also amplified by distrust towards authority figures. Fear and a normal level of caution increase independent desire to look into things. This desire is also increased by a desire to be useful, which provides strength to social media. For many, the easiest way to feel useful is by sharing information that they have gained either through their own observations or via online search engines.

The means and values of the dominant regime: Today, most of the information obtained by people is produced with the help of traditional media, research institutes, the bureaucracy and our own visual observations. The paradigm is based on certified information. The information in social media is for the most part originally conveyed by traditional media; the most common topic in social media discussions is editorial information first published by the media.

Traditional media publishes stories written by its journalists and assistants. The main focus is on current topics. The media almost always acquires its information from experts and representatives of public authorities and companies. Some of the information is dressed up as entertainment. The use of presentation techniques makes the information seem important even if it is not relevant to the person's own situation or sphere of life.

A key element in the media is the competition between channels over readers and viewers who follow the media in question. The most important method of communication for both sellers of products and services and promoters of various ideologies is advertising and appearances in content channels followed by the target groups. Communication is partly funded by the sender of the message, for example in advertising-funded media or media produced by public authorities with tax funds, and partly by the recipient.

Research data is generated by research institutes and companies engaging in product development or market research, and it is also gathered by companies for the authorities. In an increasing number of cases, information gathered with public funds is so-called open data, and it can be processed further by private operators. Map data is a good example of this. However, most of the information gathered with public funds is not available in practice, as it includes confidential information about companies and citizens or information that is not released for wider use for some other reason.

In Finland, people spend 7.5 hours per day browsing various media. A significant proportion of the media content consumed is entertainment. According to Service Sector Employers Palta, the information and communication service sector in Finland employed 100,000 people in 2016, yielding roughly €20 billion. Direct funding granted by the government to research institutes is roughly €2 billion. This does not include research work funded by companies and municipalities or normal gathering of information by the authorities or information gathering that is an obligation imposed on companies. The gathering of information is part of almost all work.

The values preserving the current dominant regime include, above all, faith in the authorities, dependency on current sources of information, and the nature of news and information as relaxing entertainment when the problems are nothing new and far removed from our own everyday life.

The benefits, risks and inhibitors of change: When we are provided with current information relating to our immediate environment, its relevance is remarkably high compared to general and occasionally gathered information. Information relating to our own bodies, foodstuffs and the environment helps us understand the concrete causes and consequences of events and avoid harm in a way that recommendations based on general statistics are incapable of.

Clear information about other people facilitates interaction with them. Direct access to observations, the original sources of information, information archives and peer experiences improves the quality and credibility of the available information. The ability to choose what information we are presented with, as well as the method of representation, reduces the risk that various middlemen, regardless of whether they are researchers, authority figures or vendors, would edit the information or cut away parts of it to serve their own purposes.

This change involves a great many risks. Independent information seeking increases the risk that people will form groups that strengthen the members' inaccurate notions. The global nature of many platforms also increases the risk that external parties may interfere in the flow of information. Systematic falsification of communication and interference by foreign government actors are already notable activities. Another risk to be considered is the fact that people do not always have the ability to interpret their direct observations or put them into the right perspective. The tools used in independent information seeking may also be faulty or of poor quality, and the information sources thought to be original may be falsified.

The change is slowed down by dependency on existing information sources and routine-like repetition. Social networks and the discourse within force the participants to follow the mainstream. The methods of gathering and disseminating information are established and in many respects standardised by the authorities and supported with public funds. The spread of artificial intelligence and personal agents in Finland is slowed down by the small area in which Finnish is spoken.

Growing professions and skills shortages: The biggest phenomena changing the work scene are the fact that measuring instruments are becoming common as well as the crowdsourcing of information and artificial intelligence. As a result of the change, more popular and new growing professions include e.g. big data analyst, data modelling analyst, information architect, controversial information investigator, data acquisition crowdsourcer, source analyst, context modeller, measuring instrument inspector, artificial intelligence educator, virtual guide, mushroom and berry picking remote guide, super skill trainer, digital material producer, lie detector expert and fact inspector.

Policy objectives of the change: The capacities of consumers to independently identify dangers should be increased, in addition to their capacities to control food, the condition of their own body and the environment. Activities of the authorities should be steered so that they support this kind of observation instead of only regulating and controlling centralised processes.

Properties, municipalities and farms should produce information with IoT devices for the needs of big data analytics and citizen and corporate GIS applications. As for big data, the obligation to collect and disclose should be viewed from the point of view of the benefits gained by the citizens and in relation to global crowdsourcing. Assigning responsibility to platforms of crowdsourced information in order to ensure the quality of the information presented should be looked into.

Intentional misleading by clearly distorting facts for political, economic, military and religious purposes should be sanctioned. AI assistants should be equated with prostheses, and their use should not be prevented by invoking privacy or other intangible rights.

Special national characteristics: The area in which the Finnish language is spoken is small. The research into artificial intelligence is of a high standard, with a high level of education and IT infrastructure.

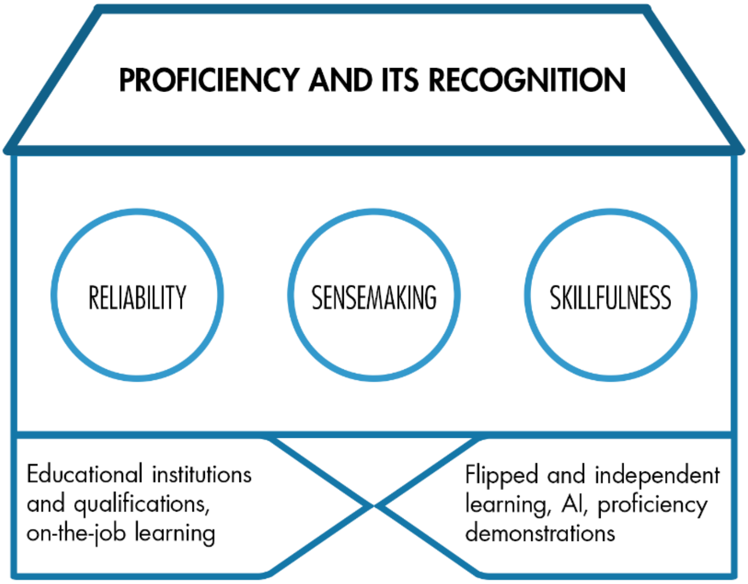
https://www.palta.fi/informaatio-ja-viestinta-22017/

ART-ID	Acquiring information: applications of the ARTs and evaluations of their effectiveness	Weight
1	Reading thoughts is an essential ability with regard to self-awareness and archiving of observations. Direct feeding of sensor data and artificial intelligence to the brain speeds up and enriches the acquisition of information.	10
2	Reading DNA facilitates the identification of the predispositions of people and organisms and identification of people, while writing DNA facilitates massive storage of data.	20
3	Self-awareness of the causes and consequences of the body under various conditions, learning the body's limitations.	5
4	Identification of gases and liquids: increased environmental awareness on an individual level. Easier and more versatile gathering of crowdsourced research data.	10
5	A material scanner is a direct way to gather information about the molecular composition of objects, plants, foodstuffs, goods and the environment.	10
6	Seeing into places that could otherwise not be seen. Knowing where we are. Imaging helps robots tell their locations and identify objects that humans cannot identify.	10
7	Awareness of the surroundings with the help of a material scanner, the ability to communicate quickly through nearby base stations.	5
9	A material scanner is partly based on plasmonics.	3
10	Femto lasers, DIAL lasers, laser distance measurements and particle accelerators are used to obtain a wide range of information.	5
11	The ability to follow texts and speech in a foreign language is an essential source of information, particularly when travelling but also when moving to a region with a different local language and when learning about other cultures.	5
12	Artificial intelligence helps a lot with perception. Artificial intelligence reaches an expert level in many tasks and is of great help to a layperson.	20
13	The wide variety of applications will increase further and quality will improve, particularly in the narrow segments of perception, thanks to existing platforms. It will become easier to combine areas of expertise.	3
14	A great many people are unable to properly read other people's expressions or remember or recognise their faces. A tool for interpreting these is useful in many situations.	5
15	Artificial intelligence assistants are extremely useful when they are familiar with the needs and situations of their users and constantly perceive the environment and point out important considerations.	5

ART-ID	Acquiring information: applications of the ARTs and evaluations of their effectiveness	Weight
16	With the help of artificial intelligence, GIS data about the events occurring in our environment, compiled from various sources, can produce an excellent overall picture of a great variety of things, also identifying their causal relations.	5
17	3D models of various objects and learning materials produced about them help us recognise objects with the help of artificial intelligence.	3
18	Crowdsourced entry of measurement data and identified photos into an application that is found to be useful by its users teaches artificial intelligence how to produce information.	5
19	GSI data can be added into our field of vision. Combined with artificial intelligence and sensor data, glasses can show a heat map of our surroundings as well as its materials, sound waves and human emotions, for example.	3
20	VR glasses allow us to explore intellectually enriching virtual worlds.	3
22	The number of IoT devices is increasing rapidly, as is the amount of data available. Whether or not we can detect new details and correlations depends on whether they are recorded.	10
23	An artificial intelligence that is used more extensively and learns more rapidly will help us notice more.	10
24	Breaking public-key encryption provides access to a great amount of private information.	10
25	Transmitters, display devices, photodetectors and lenses made of graphene as well as other applications of optoelectronics and components of optical computing.	10
26	The identification of materials and the simulation and anticipation of biological and chemical phenomena produce a great deal of data but require more computing power.	5
28	Self-driving cars continuously gather a great amount of detailed data about the traffic environment.	5
30	Drone surveillance with versatile measurement equipment produces a great amount of data.	5
32	Devices that continuously fly at a height of 20–30 km can easily and continuously photograph an urban area with enough detail to detect small birds. An AI can deduce a great deal based on the photos.	10
33	Autonomous waterborne traffic particularly increases the information obtained from seas.	1
35	The increasing number of satellites and improving quality of camera technology and other measurement devices will increase the amount of data on occurrences in space, on the ground and in the atmosphere.	3
36	Swarms of inexpensive robotic insects can map their environment very quickly and meticulously.	5
41	IoT devices and flows of goods produce a great amount of data which AIs can process into proposals for measures, forecasts and sensible observations.	10
42	A robotised monitoring and mapping service.	3
46	Lightweight and sturdy materials enable autonomous devices that map the characteristics of the environment.	1
50	Separation techniques provide information about the environment.	1
53	Artificial muscles enable the energy-efficient mobility and mass production of robotic insects and other small, mobile robots that gather data.	1

ART-ID	Acquiring information: applications of the ARTs and evaluations of their effectiveness	Weight
55	Simulation at the atomic level offers a radically faster way of identifying new phenomena and developing new types of measurement equipment compared to traditional methods.	5
56	Adding electronics to plants, animals and people increases knowledge about their vital functions both at the individual level and in general.	5
58	Microbots can gather and send information about the vital functions of people and animals.	3
61	A great amount of information is generated by simulating life.	5
62	Increasing our understanding of cell metabolism and the microbiome helps us get more information about the living environment.	3
64	Cell culture and 3D printing of organs can produce experimental organs that can be used for testing medications or poisons and learning about their effects.	3
65	Treatment of dementia helps patients notice/remember observations.	1
69	The brain can be frozen so that a person’s memories can be read later.	5
70	The number of devices that can traverse the terrain and waters autonomously, as well as independent observation devices connected to the telecommunication network, will likely increase.	3
73	Autonomous observation tools, equipment installed outside the electricity grid and solar-powered equipment require efficient batteries.	5
82	Wireless electricity transfer facilitates the placement of sensors everywhere.	3
84	The operator of a gamified application obtains a large amount of user data.	3
87	With flipped learning, an explanation is always available to an increasing number of things.	3
88	A large amount of information is generated in robot-assisted and platform-based work.	3
89	Anonymous networks are helpful in information leaks, while encryption is helpful in acquiring confidential information.	3
90	Platforms are an important information source about activity, choices and interests.	3
91	A great amount of information is amassed above a platform, with the platform primarily distributing data on demand and confidential data to its users.	3
92	Modularity allows a variety of measurement equipment to be connected to robots.	3
93	With machines and smart assistants engaging in trade, this yields a considerable amount of comparative data and transaction data.	1
94	A 5G network allows a great number of IoT devices to be connected to it inexpensively and enables the transmission of large amounts of data as well as a low latency. It therefore helps in the gathering of data.	5
95	Cloud services help process the gathered data into an understandable form.	3
96	Sensors that collect information are always local, but the interpretation and learning of their data can be done globally.	5
97	Blockchains are more reliable globally than local registry authorities.	1
98	Like systems accumulate extensive data about preferences on platforms.	3
99	The GDPR drastically limits the individual’s ability to know something about other people.	5
100	VR/AR glasses bring to our view all information and book knowledge of all simulations, IoT devices, artificial intelligence and material scanners in their exact locations. Platforms standardise the content.	10

1.15 Proficiency and its proof



Scope of the value-producing network: The main objective of this value-producing network is the required proficiency and its proof. This definition includes procedural and systemic skills and the ability to see the big picture and acquire knowledge and skills. Proof of proficiency refers to the demonstration of skills, knowledge and understanding to people who also know the same things but especially to people who do not know them. In many cases, someone who does not understand the task at hand needs to be convinced that the expert is able to handle it. This definition excludes information acquired via information sources or by making observations as well as summaries of such information.

The most important values are the recognisability of proficiency, understanding of meanings as well as procedural and systemic skills. Numerous professions require specific education or a competence-based qualification, while others only require professional skills demonstrated in some other way. Many procedural and systemic skills are a combination of extensive practice and tendencies, ranging from skills related to physical strength to planning skills. In order to understand meanings, we must be aware of the big picture and the interactions related to it while also understanding the situation at hand.

The means and values of transformation: The major part of education provided at educational institutions which focuses on teachers, reading and writing, has traditionally been the most valued provider of skill and understanding. In addition to making learning materials widely available, information technology also allows teaching situations to be experienced regardless of time and location.

It is increasingly possible to transition from teaching to learning by trial and error. Simulators allow students to test their own skills and perception at a level of difficulty that contributes to their learning. An AI can correct their performance and provide an adequate number of stimuli to motivate them to learn. As automatic test environments, AIs and simulators can also help demonstrate adequate proficiency.

Numerous educational institutions, commercial organisations and third sector operators have made lectures, exercises and learning materials related to school subjects and university courses available in data networks as both free-of-charge and paid training programmes. The variety of material available is particularly extensive in English. Many educational institutions offer online courses free of charge but charge a fee for degrees.

Some educational institutions are gradually transitioning to the flipped learning model, in which explanatory or leading lectures are replaced by teaching videos that students can watch independently. Training exercises and group assignments are carried out at school under supervision. When exercises are completed on computers, the software monitoring the exercises can draw the teacher's attention to the students who require his/her special attention. The same monitoring software can guide other students in their independent learning.

Simulation is not a new teaching method, but its use has been comparatively limited. As computers and software become more advanced, simulation provides opportunities to observe the dynamics and causal relationships of an increasing number of phenomena. A student can enter the phenomenon, affect the situation and see what happens as a result of his/her actions. In addition to physics and chemistry, it is possible to simulate the operation of machines, the interactions of nature, humans or the economy, and historical events. When simulations are gamified and the students are given goals, the resulting learning process is rapid and motivation-inspiring, immersing the students in the phenomena.

New visual aids also contribute to simulation and understanding things. With virtual glasses, students can explore spaces and events in a three-dimensional environment. In a virtual world, moving things around looks a touch more real than watching the same things happening on a screen. Many things become easier to perceive when they can be seen in a natural light. AR glasses also facilitate learning and simulation by showing visual aids and their movements virtually to many people at the same time in their normal environment.

AR glasses are a better way to teach someone to work with their hands than any other method. For example, to a piano student AR glasses can show ghost hands in the correct position, placed exactly where the student's hands should be at any given time. With various imaging tools, the glasses can also show the state of the environment. For example, seeing sound sources, heat or an electric field in real time as characteristics of their locations through AR glasses can help students link their observations to this information and perceive any problems and phenomena independently.

Artificial intelligence and many new measurement devices and search engines reduce the need for instrumental learning. Learning does not only mean becoming proficient in some foreign language's grammar but also knowing how to use as appropriate tools as possible for language checking. Proficiency is increasingly coming to mean having a pragmatic understanding of larger entities, significances and tools. The significance of learning to learn, knowledge networks and tools that facilitate understanding will increase.

It is apparent that proficiency will be gathered from an increasing number of sources in the future, and that it will also become outdated much more quickly. The most important factor for future success in basic education will be learning to learn and the use of tools that reduce the need for inessential learning. The degrees issued by educational institutions can be replaced with competence-based qualifications that measure the acquired proficiency, rather than course completions approved by the educational institutions. Competence-based qualifications should not depend on whether a student is enrolled in an educational institution that is authorised to issue degrees in the discipline in question.

Instead of degrees, various other demonstrations, such as certificates related to private microdegrees, peer evaluations, customer evaluations, demonstrations of skill and competitions have already become important methods of evaluating proficiency in many fields. Management of reputation and reputation networks, as well as search results and reputation assessments generated by search engines and artificial intelligence, is increasing in importance. Journeyman's demonstrations, portfolios and mentoring are an essential part of this perspective.

Contextuality becomes important in proficiency as the degree of complexity increases. Phenomenon-based learning, phenomenon-based recognition of proficiency and planning of learning paths with pragmatic evaluations guides learning to learn and the acquisition of metadata. The use of reference methods will expand outside academic research. In peer evaluations, it is not always important how proficient the other experts think we are at something, as proficiency is broken down into countless contexts. What is important is how well the people whose problems we solve and needs we satisfy think we performed.

The means and values of the dominant regime: School and studies have not changed much over the last one hundred years, despite many professionals in the field claiming otherwise. Textbooks, exercises, lectures and discussions were already used as methods of education during Plato's era. Over the course of history, the authorised evaluation of formal learning, established actor structures, silo-based and reductionist teaching and proficiency has only changed superficially. Teachers, lecturers and professors are the authorities who possess the best knowledge and evaluate the student's proficiency. They seek to convey their own understanding of the subjects they teach to their students.

In Finland, students apply to study at higher education institutions with the help of certificates earned in lower education institutions, the matriculation exam and entrance exams. Based on their performances, the students admitted to educational institutions obtain a degree or qualification as proof of their proficiency and the right to use the title granted by the institution. Proficiency gained and demonstrated elsewhere or courses completed at other educational institutions can be counted towards the degree in some cases. As a general rule, it is not possible to demonstrate proficiency in order to gain an academic degree in any other way.

Many teachers, lecturers and professors are already of advanced age, and they have not renewed their skills much since learning their knowledge of the field at a young age from another professor of advanced age. The tradition of teaching work lends itself to ensure that the content of teaching is old-fashioned, which is also visible in studying. Combining research and teaching rectifies this only to a limited degree.

Many people acquire most of their skills and understanding while working in their profession. Some skills are generalised, but specialisation leads to an increasing part of expertise becoming organisation-specific and useful only in the organisation in question and in the technology environment that existed at the time when the expertise was gained.

The Finnish Ministry of Education and Culture accounts for €6.6 billion of the state budget. Most of the funds is clearly allocated to organising education. Combined with the financial contribution by municipalities, the direct investment in teaching is over €6 billion in Finland. Compared to this, the investment in private education and on-the-job learning is marginal. Almost 100,000 people in Finland teach as their primary job. There are almost 1.3 million people with a degree or qualification in Finland, with 1.4 million students enrolled at educational institutions of various educational levels.

The most important preserving values are related to degree requirements, the introversion of the teaching profession, appreciation for titles and one's own old expertise, alienation from reality, being led by a trade union, and appreciation for authoritarian institutions.

The benefits, risks and inhibitors of change: The most important benefit of the change is enhanced learning. This is promoted by the opportunity for individual advancement, direct feedback and topics and learning methods that suit the students' own interests. A key benefit of the change is the opportunity to modernise content more rapidly than the teaching profession is capable of. At the age group level, beneficial changes include the diversification of the things learned and improved ability to use tools that reduce the need for inessential learning.

The most important benefit of the separation of those that grant degrees from educating institutions is the elimination of entrance exams as a factor that determines one's life and having the opportunity to learn the necessary skills online in one's own learning style and with the most suitable materials. Of particular importance is the capability to expand on-the-job learning and include the private sector in the modernisation of teaching.

One risk to the change is teachers' unwillingness to change and lack of skill. Too many lack the expertise required for organising new types of learning opportunities, such as the ability to identify which skills would actually be useful to people as members of society and for their own future well-being. Educational institutions have partly changed direction, but this change is limited as a whole and with regard to the available opportunities.

Factors that particularly slow down the change include the deeply rooted institutional culture of teaching, the fact that educational institutions are tied to a location and the major role that degrees play in hiring. Regulation either speeds up or slows down the change, but combined with the great power of professors and other teachers and organisations its impact will most likely be primarily obstructive to the change.

Broadly speaking, teachers do not understand new technology or possess the skill to apply it in their teaching. This situation is unlikely to change without a redefinition of the areas of responsibility and goals. The private sector has the necessary flexibility but not the adequate pedagogical ability, funding or rights to grant degrees.

Growing professions and skills shortages: Growing and new professions resulting from the change include e.g. organisation physician, multiple intelligences organiser, artificial intelligence examiner, AI psychologist, AI-assisted cyborg, gamification officer, context analyst, meta analyst, simulation producer, simulation developer, proficiency inspector, remote trainer, proficiency network officer, proficiency path counsellor, remote learning mentor, certification manager and social media reputation improver.

Policy objectives of the change: In order to promote change, proficiency demonstrations required by degrees should be separated from the education and entrance exams of educational institutions. Qualification requirements for public appointments should be changed to contextual. Customer evaluations of the capability of public services should be made public. All public education should be produced in information networks on MOOC platforms. All basic education should be transformed into flipped learning, which would require the job descriptions of teachers, lesson hour quota and principles of compiling study materials to be changed.

Methods of simulation and gamification should be increased in teaching, content of teaching should be renewed and content should be regularly evaluated by actors other than teachers. Study materials of public education should be made freely available by crowdsourcing or public funding, and exercises should be carried out with artificial intelligence so that the feedback is immediate.

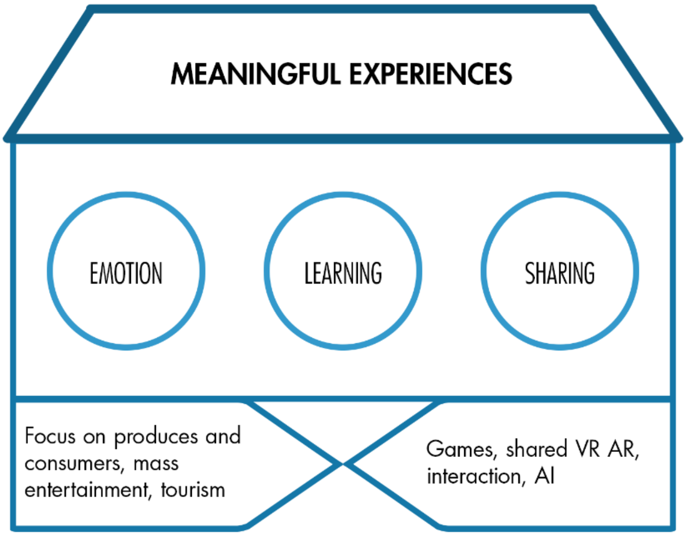
Special national characteristics: The quality of teaching and the expertise of teachers are at a particularly high level when measured with traditional means, but there is a rapid downward trend.

http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/80702/Yleisesite%202017.pdf

ART-ID	Proficiency and its proof: applications of the ARTs and evaluations of their effectiveness	Weight
1	Transferring the teacher's motor control and emotions to the student by reading the brain.	5
3	Teaching materials related to the condition of the body, and artificial intelligence that guides learning.	3
5	Combining learning and assessment of proficiency with context with the help of a material scanner.	1
6	Imaging allows the material required in teaching to be gathered, while positioning allows the teaching to be placed in the relevant context.	3
11	Speech technology helps the user learn and understand foreign languages. It also helps the user show his/her own proficiency to someone speaking another language.	5
12	Artificial intelligence can evaluate the proficiency of a person. Demonstrating proficiency will become easier for a layperson and be separated from the institution that provided the education. Artificial intelligence is also important as a teacher.	10
13	The development of applications for demonstrating proficiency will become easier.	3
14	In teaching, facial expressions help the message get through more efficiently. When teaching software is able to read emotions, it is able to encourage the student and improve its own operation.	10

ART-ID	Proficiency and its proof: applications of the ARTs and evaluations of their effectiveness	Weight
15	An AI can have conversations with the student and help him/her understand necessary things or ensure they were understood. Verbots/chatbots can also evaluate proficiency.	5
19	Instructing crafts assignments is very natural with AR glasses, and making signs is also comparatively easy.	5
20	Environments simulated with VR glasses help the user understand cause-effect relationships between things and also show whether he/she has understood the relationships or not.	5
21	Interfaces convert seeing into action and knowledge into skill.	3
23	Artificial intelligence will become a constant presence, measuring our skills and correcting our mistakes.	5
27	Walking assist devices can teach us dance moves, an ergonomic running style or a safe way to walk in a forest.	1
38	3D printing of prototypes and journeyman's demonstrations is a very easy way to demonstrate proficiency and learn what works or pleases others and what does not.	5
55	Simulation techniques provide a very good tool for demonstrating proficiency. The behaviour of materials can be understood more easily than before with simulation.	10
56	Measurement of the body's condition increases self-awareness.	1
57	More and more formal proficiencies are outdated, and the need for demonstrating proficiency regardless of studies is increasing.	5
61	Simulation of life makes it possible to learn to understand and demonstrate proficiency.	5
65	Healing memory disorders facilitates the transfer of skills.	3
84	Gamification is an efficient teaching method that helps demonstrate proficiency.	10
86	Microfinancing and crowdfunding are visible proof of other people's faith in the quality of skill.	3
87	Flipped learning and demonstration of proficiency to a third party will change the nature of teaching and degrees. Business certificates have already partly transitioned to this model.	20
88	Proficiency is transferred from a human to a robot and from that robot to other robots.	3
90	On a platform, proficiency is demonstrated with likes from customers or peers.	3
91	In platform-based work, proficiency is demonstrated with likes and verbal customer evaluations.	5
94	Wireless networks significantly facilitate required learning.	5
96	In principle, a global artificial intelligence can learn and teach the basics for virtually all kind of proficiencies. A global artificial intelligence can also efficiently evaluate the proficiency of a person.	20
97	Theses, etc. can be recorded in a blockchain in an indisputable way.	3
98	Proficiency on a platform is indicated by likes.	3

1.16 Producing experiences



Scope of the value-producing network: The primary objective of this value-producing network is to provide people with experiences. This definition includes all experiences produced in the hope of financial, political, military and ideological benefits or power as well as experiences produced for various purposes in social relationships.

It excludes all experience-producing events in which the production of experiences is unintentional from the perspective of the creators or a meaningless side effect.

The most important values are emotional experiences, the joy of realisation and shared experiences. An emotional experience is evoked by empathy or a personal situation. Its source may be a story, music, food or other sense perceptions and stimuli. Realisation and exceeding one's own limits evokes joy in many people, regardless of the subject matter. An experience shared with someone important to us brings us closer to each other and provides substance for interaction. Many experiences can become addictive.

The means and values of transformation: Today, experiences are produced with the help of traditional entertainment, culinary enjoyment, physical activity and social interaction. Stark division into producers and consumers dominates modern production of commercial experiences, even though almost all forms of traditional experiences are participatory in nature.

Technological advancement has freed up time for experiences. Many experiences have also become time- and location-independent. People are already listening to music while walking down busy streets, and soon music videos will be shown as holograms around the walker. Digitalisation is making experiences democratic.

The abundance of technological experiences will also give rise to the opposing idea of asceticism. Many experiences are achieved through ethicality, by realising some type of a mission. These mission experiences are produced, and they can even be used to mobilise large numbers of people for the creator's own purposes. Of course, this phenomenon is not new if we compare it to the Crusades, for example.

Computer games are an example of a new way to participate in stories. A game provides a shared environment and stimuli for shared experiences. There are always like-minded people from around the world with whom we can play through a data network. New technologies provide ample opportunities for adventure travel, art experiences and nature trips as highly realistic experiences. On the other hand, increasing artificiality needs authentic experiences to balance it. This is strengthened by a desire to stand out from the rest. Experiences that pass for authentic are increasingly being produced by industrial means.

VR glasses can be used to create an illusion of actual presence in a virtual world. Experiences can be very powerful, even deceiving the body. For example, it is common for people wearing VR glasses to fall down when watching a virtual environment tilt while standing up. The accuracy of VR glasses is for the time being inadequate, but it is evolving rapidly. In addition to VR glasses, development is also underway on data gloves that convey the user's movements to a virtual world and allow any objects touched in the virtual world to be sensed by the user's skin and muscles. Other bodily sensations and the soundscape can also already be conveyed to the user of virtual reality.

AR glasses are about to evolve to a level at which illusions that seem real can be added to the user's actual environment. AR glasses are also able to recognise phenomena in the user's surroundings with the help of artificial intelligence and optical sensors and emphasise them in an experiential way. The Pokémon GO phenomenon proved that even collecting cartoon monsters tied to GPS coordinates on a mobile phone screen has the power to inspire people and mobilise them. Sensations integrated into reality can evoke considerably more powerful experiences than this mobile phone application.

Producing physical experiences is becoming increasingly easy with robots. In the future, robots will be able to prepare gourmet meals, paint art on the walls, massage our shoulders or play the violin. Sex robots have become a phenomenon of their own in Japan, for example. Robots can operate autonomously or with remote control. Robotics allows experiences to be transmitted regardless of location.

Artificial intelligence makes it possible to recognise human emotions and preferences. With this information, an AI is able to adapt its operation to each individual's way of thinking and produce the desired emotions and experiences. Adapting the virtual environment, the operation of robots and the emotions of virtual people to situations and goals in a suitable manner will lead to powerful, individually tailored experiences.

The most important values that help innovate the production of experiences are related to creativity and a desire to influence other people. Digital services monitor the choices and experiences of their users. This data is used to control both the user and other people by means of predictive analytics. From the perspective of the people having the experiences, the most important innovative values are related to sociability and desire for experiences. Escapism plays a key role in this, as virtual reality allows everyone to be rich, healthy and free from their real-life worries.

The means and values of the dominant regime: Today, most experiences are produced to promote the objectives of entertainment. In this context, entertainment also includes art and documentaries produced to satisfy people's recreational interests.

Experiences are produced by cinematic and literary means as well as in the form of audio recordings. Music, theatre and choreographic expression, architecture, design, urban structure, restaurants, nature trails and playgrounds all produce experiences. All organisations, political parties, municipalities and administrative sectors as well as companies, denominations, recreational groups and publishers seek to produce experiences.

The dominant regime is for the most part divided according to the producer–consumer axis, and it sticks to the traditional means of conveying experiences. The public authorities are perhaps not providing bread and circuses for the common people of Rome, but the breakdown into content for common people and the elite is still visible in valuations. We support theatre, the press, literature, sports, music, opera and physical activities. The culinary culture, tourism, social interactions, stimulants and experiences produced by advertising can make do without support. People usually do not want to mix teaching and work with experiences, and a renewal of the production of experiences based on technological opportunities is often shunned.

Peaceful family life with communal events is one of the most important experiences. Traditional forms of outdoor activity, such as hunting, fishing or gathering, as well as other types of outdoor activity, gardening and cooking are part of our everyday lives.

In Finland, there are less than 100,000 jobs in the cultural sector. This figure includes only part of the people who produce experiences for a living. In 2016, the tourism sector generated some €4 billion in income comparable to export, and 7.7 million people visited Finland. This is in addition to extensive domestic travel. The tourism sector employs 140,000 people in Finland. Physical activity accounts for a low proportion of the national economy but plays a major role in people's everyday lives when we include not only sports but also moving about in natural and urban environments for the purpose of exercise and experiencing things. The current experience structure is also represented by karaoke bars, narcotics and violence.

The most important preserving values are related to the inactivity caused by the producer–consumer structure, the addictive nature of experiences, the emphasis on authenticity, the feeling of being physically and solidly present, the target groups of advertising, and other perspectives related to benefits and power in the production of experiences.

The benefits, risks and inhibitors of change: People are inspired to become more active when experiences become increasingly participatory. If the experiences are based on simulation of reality, they simultaneously increase proficiency and skills. Passive knowledge may be turned into active skills. Cooperation-oriented online games increase social skills and planning ability. The feeling of immersion produced by virtual reality may reduce the need for travel, but it may also make people more familiar with distant places and increase their desire to travel there.

Augmented reality increases the meaningfulness and experientiality of our immediate surroundings. Experiences produced with robotised avatars and augmented reality increase job opportunities by radically decreasing transaction costs.

This change involves clear risks. Powerful experiences that can be felt online and in virtual realities may cause addiction. Forming social bonds in a special online group and attaching meaning to the group instead of one's physical environment may alienate the individual from the people within whose physical sphere of influence he/she is. This may increase the risk of physical conflict. Together with virtual technology, artificial intelligence may influence people's desires and preferences strongly, against their will and without their notice. The potential for misuse is significant.

This change is slowed down by the social structures through which society maintains hero myths and illustrious deeds as well as the operational conditions for the production of experiences. For example, the media and education guide people to appreciate and pay attention to old ways of producing experiences, such as sports and traditional forms of art.

Growing professions and skills shortages: It is obvious that new technology opens up enormous opportunities for experiences. Growing new professions include e.g. location information expert, virtual service manager, virtual remote guide, virtual decorator, parlour game assistant, e-sports coach, e-athlete, experience guide, real VR star, VR event coordinator, VR therapist, online game coach, AR/VR haptic costumier and haptic supporter.

Concierge services will be extended to everyday hedonism and there will also inevitably be sex robot pimps. Virtual travel officer, substitute traveller, experience stimulator and experience developer will emerge as new professions. Experience producers are needed for developing working in companies and customer experiences. Robotisation will lead to craftsmen once again becoming a major occupational group. They will control machines used in individual production and finalise these "handicrafts" produced by tools.

Policy objectives of the change: The phenomena of virtual reality and augmented reality should be regulated as a private and public space and taken into account in the Copyright Act. The police's right to access VR facilities should also be clarified and defined on the basis of this allocation. In order to assign responsibility to artificial intelligence, a framework and practices should be created that will make it possible to record the actions of the artificial intelligence that essentially affect an individual. Individually generated intense experiences could have serious consequences for a person, and the potential disadvantages of this area should be explored extensively, both on the part of deliberate influence and drug-like use. The distinguishability of AR signs and advertising should be considered, in addition to subconscious and manipulative influence as part of the experiences.

Special national characteristics: Finland has an exceptionally high level of technological expertise in new areas of technology as well as exceptionally high public support for old structures.

http://tilastokeskus.fi/til/klt/2005/klt_2005_2007-08-31_tie_001.html

https://mara.fi/toimiala/tilastoja-ja-tutkimuksia/matkailu https://www.mara.fi/toimiala

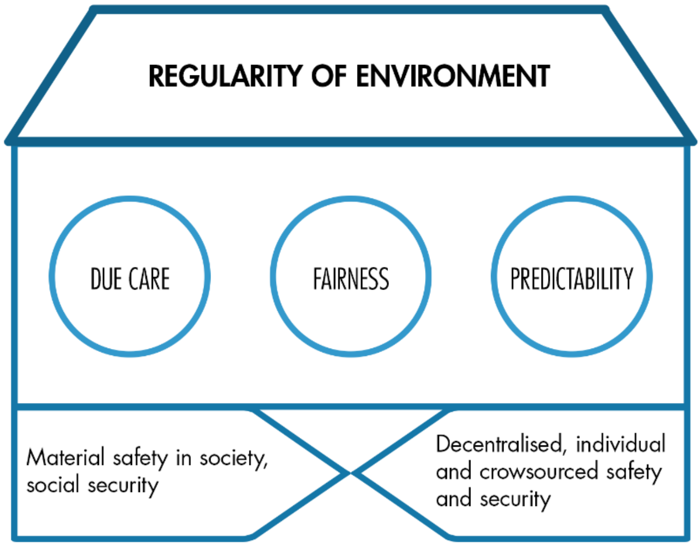
http://www.stat.fi/tup/tietotrendit/tt_10_06_liikunta.html

ART-ID	Producing experiences: applications of the ARTs and evaluations of their effectiveness	Weight
1	Direct transfer of feelings and sensations to the brain is a radical way to share experiences.	20
3	Many types of physical activity and experiences involve bodily sensations and effects, the monitoring of which, together with recording their highlights, may enrich the experience.	3
6	Imaging is required for 3D movies and the creation of realistic VR game worlds. Imaging and positioning are required for AR experiences.	5
7	Fast, wireless connections are a necessary requirement for VR/AR.	10
8	LED technology enables a wealth of experiences with the help of VR/AR glasses, display walls and indoor farming.	5
9	In principle, plasmonics enables superior display devices, directional antennas for mobile devices, micro lasers pointed directly at the retina, etc.	5
10	Femto lasers can be used for creating 3D images in the air. Lasers can produce light art.	3
11	The ability of games, robots and animated characters to speak and understand speech is important. Speech that mimics selected people and their emotional states intensifies experiences.	5
12	Artificial intelligence can be used for producing art experiences, companion computers, characters, natural and emotional landscapes and for assisting in the production of entertainment.	10
13	The development of applications that produce experiences will become easier and the number of experiments will increase.	3
14	The recognition and projection of emotions are important in producing experiences.	10
15	A communicative and learning AI toy is an experience. A game that responds uniquely to the player is an experience. In future network games, it will be impossible to tell which players are humans.	10
16	Real-time modelling of the environment is a key factor in AR applications, in which artificial elements are embedded in reality.	5
17	Easy 3D imaging of objects helps produce virtual worlds as well as transfer objects to an augmented reality.	3
18	Interactive, experiential applications can gather information about the reactions and emotions of the users as well as try out and form an understanding of the effectiveness of the stimuli.	5
19	AR glasses easily add experiential characters and editing to reality.	10
20	Virtual worlds are very experiential – the experiences can also be made more powerful than movies at the physical level.	10
21	We can move about physically and feel sensations in a virtual world.	5
22	The more memory that is available and the faster the processing speed is, the richer the virtual worlds created are.	5
23	The characters, landscapes and narratives created by artificial intelligence will become increasingly rich as artificial intelligence becomes less expensive and more efficient with the help of the generation of processors prepared for it.	5

ART-ID	Producing experiences: applications of the ARTs and evaluations of their effectiveness	Weight
25	Graphene-based display devices and electronics inside the body enhance experiences.	3
26	The realism of VR/AR/AI worlds and simulations will continue to improve as computing power increases.	10
27	Dancing and other abilities of legs increase experiences. Walking robots can produce experiences in the natural human environment.	5
28	On a Finnish scale, the elimination of the need to hold a steering wheel will free up roughly a billion hours that can instead be used for remote work or pleasures greater than driving.	5
29	Many new lightweight vehicles are experiential in nature.	3
30	Flying skills competitions can be held for helicopters, with the pilot and passengers travelling aboard the helicopter with the help of VR glasses. Quadcopters have been used to replace fireworks.	1
31	Flying in a light aircraft is an experience that will be increasingly easily available in the future.	1
33	Foiling is an exciting way to move on water in all of its forms. Robotisation facilitates and diversifies waterborne traffic in many ways.	3
34	Fast relocation from one place to another will increase leisure travelling and be an experience in itself.	1
35	Space tourism is not relevant for many people, but it does fund development. The opportunity to view the ground in real time via numerous satellites is a spying experience.	1
36	The ability of robotic insects to find people in need of rescue as a swarm, function as personal safety cameras or replace bees in pollination contributes to safety. There are also harmful applications.	5
37	A robot that produces art with an AI, plagiarises museum art, varies the art according to its surroundings and uses tools intended for humans with its hands is able to produce a wide variety of experiences.	5
38	3D printing can be used to easily produce unique, beautiful and fascinating objects.	3
39	3D printing allows buildings and their surfaces to be made experiential easily.	5
40	Monitoring activities that are self-organising and lead to emergence is an experience.	1
41	A ubiquitous environment that reacts to people's expectations is an experience. Talking with objects is an experience, even if the thing talking on the objects' behalf is a cloud service taking on the objects' role.	5
42	An avatar can be used to play music, cook food, dance or play games, and a robot can do the same things, controlled by artificial intelligence. Entertainment and experience services are becoming robotised.	10
44	A robotic tailor allows inexpensive, unique, snug and striking clothes to be made at almost the price of the fabric.	5
45	Lack of friction holds significant potential for experiences, and plausibly so does levitation.	3
46	Flying is an experience, floating is an experience. Lightweight and sturdy materials make it possible to produce many experiential tools for physical activity.	3
47	Some 3D printable materials can be very experiential.	1
48	Experiences can be created with the help of sturdy fibres and fabrics.	3

ART-ID	Producing experiences: applications of the ARTs and evaluations of their effectiveness	Weight
53	A human-like robot is an experience.	5
54	In many areas suffering from a water shortage, easy production of fresh water will enable experiences produced by plants.	3
55	New smart materials produce experiences in the form of surfaces, clothes and structures, for example.	3
56	Experiences are produced by the ability of organisms to produce light or grow to the desired shapes, for example. Controlling the brain with an implant allows the emotional state to be influenced artificially.	5
57	In many respects, an increase in the average life expectancy will have an unpredictable but essential impact on the appreciation for experiences and solvency.	5
59	Bacteria or yeasts can be guided to produce narcotics.	3
60	Biological modification produces experiential plants and organisms.	3
61	The creation of virtual life is an experience.	1
63	Cell culture can be used to produce extinct or very exotic species as food, including dodo meat, panda, passenger pigeon or mammoth.	3
64	Cell culture and 3D printing allow the exotic cultured cells to be produced in a fascinating shape and with a tasty structure.	3
65	Dementia is a significant constraint to enjoying experiences.	3
66	Cultured meat can be very exotic, both genetically and in texture.	5
67	A private garden and possible GMO production can provide experiences.	3
68	New fibres make it possible to produce experiential clothing and furniture as well as structures and surface materials for objects, among other things.	3
73	All experiential equipment – digital companions, AR glasses or other equipment that we carry around with us – require efficient, lightweight batteries to work well.	10
84	Gamification produces experiences in everyday tasks.	3
87	Learning is often an experience, and it may even become addictive.	1
88	People can produce experiences for each other via robots.	10
91	Paid individual experiences require terminal devices as well as a platform.	3
94	A fast wireless connection, low latency and a large number of IoT devices enrich the view through VR and AR glasses and the operation of experiential robots.	5
95	Experiential content requires cloud computing and storage services. They must be located near enough to prevent latency from disturbing the experience.	3
96	A global artificial intelligence will be able to embroider experiences culturally and locally. The experience industry will rely on artificial intelligence to a significant extent and on a global basis.	5
98	With the advancement of digital technology, there is very little difference between a physical and a digital experience. A digital experience is easier to produce, and an AI is particularly productive in this task.	10
99	Preferences are saved on experience platforms, from which they can be transferred to other platforms based on conditions defined by the GDPR.	3
100	A standardised AR/VR platform is important for content production in order to ensure the sufficient size of the market and the profitability of development work. Platform development enables content of good quality.	5

1.17 Safety and security



Scope of the value-producing network: The most important objective in this value-producing network is the regularity of the operating environment. Regularity refers to freedom from external threats as well as the ability to promote one's own goals within the scope of known and predictable ground rules. Safety and security are increased by standardising the conditions and compensating individual risks, for example if a person is at risk of accident or falls ill.

This definition covers a necessary livelihood, social security nets, maintenance of order, civil defence and various measures related to asset protection, product safety, prevention of environmental damage and identification of risks or insurance coverage.

The most important values are due care, fairness and predictability. Due care involves a desire to sacrifice a part of one's own freedom and wealth to minimise future risks while also accumulating wealth in preparation for surprises. In a sense, pension security must also be seen in this light. Fairness includes material and intangible integrity as well as shared ground rules and a desire to exercise power. Predictability includes a need for regularity, planning and curiosity.

The means and values of transformation: Traditionally, we think that we need protection against crimes, accidents, diseases and border violations. We lock our doors ourselves, but the main responsibility for safety and security is borne by the authorities in a Western society. In the future, the threat scenarios will change. Centralised monitoring that targets producers and protects consumers no longer functions well with society making everyone into a producer and with borders becoming porous and virtual. An increasing part of safety and security must be produced closer to the individual.

Data security applies to an increasing number of people when an increasing part of our lives relies on the functionality of computers and data networks. In addition to our data, our identity can also be stolen, and we can even be prevented from accessing the data on our own computer with encryption. Someone can act in our name and sign agreements. People can be threatened and blackmailed from beyond national borders by anonymous strangers. Both material and intangible threats can target an individual in ways that the centralised mechanisms of society are not capable of reacting to in an optimal way.

Objects are becoming increasingly smart. Cars drive themselves, robot cooks prepare meals. All smart functions are connected to the Internet, and the data security risks may grow to great proportions very suddenly. Cyber threats may involve manipulation of our own technical appliances, but remote-controlled devices that transport toxins or bombs may also become common. It is also increasingly easy to insert dangerous parts or substances into objects delivered to us in a way that cannot be prevented by external control.

In the 2020s, self-diagnostics will provide us with information about any problems in our bodies. We will know accurately what type of health risks threaten us, how probable they are and how we can avoid them. We will also be able to measure the quality of our food by ourselves, which is what we should do in the future. A centralised system is unable to help us in this at a level of detail that many of us think is necessary.

Artificial intelligence monitors our surroundings and warns us of dangers. Misuse of bank accounts, people who behave in a threatening manner, objects coming flying at us, breaking and entering, stealing a handbag or the strange composition of foodstuffs may all set precautionary measures in motion. Artificial intelligence will also be able to monitor the equipment we use and make sure that it is not interfered with without permission. Artificial intelligence will record events into a cloud as evidence and call for help as necessary.

Peer-to-peer information provides us with excellent information in almost real time. If product information is organised correctly, it is possible to obtain immediate feedback from users about any problems with a product batch. Similarly, crowdsourcing can provide information about regional dangers.

The most important innovative values are related to fears, a feeling of unsafety, a desire for experimentation and distrust but also increasing awareness of various risks.

The means and values of the dominant regime: Traditional actors that ensure our feeling of safety include the police, fire department, defence forces and hospitals. As society has become more complex, the number of controllers has grown. For example, control is carried out on our behalf in Finland by the Finnish Safety and Chemicals Agency (Tukes), Finnish Transport Safety Agency (Trafi), the Finnish Food Safety Authority (Evira), the Regional State Administrative Agencies (AVI), Finnish Medicines Agency (Fimea), the Ministry of Education and Culture (OKM), the Ministry of the Interior (SM), the Radiation and Nuclear Safety Authority (STUK), the Supervisory Authority for Welfare and Health (Valvira), the Finnish Communications Regulatory Authority (Ficora), Natural Resources Institute Finland (LuKe) and the Finnish Border Guard. To a large extent, the control measures target clear interfaces. National borders are controlled, as are manufacturers, service providers and standardised service processes. This control is periodic and only works if changes to it are not rapid. The control mechanisms are designed for industrial structures and large-scale production.

The Finnish Defence Forces employs 12,000 people. Every year, 22,000 people complete their military service in Finland. The Ministry of Defence accounts for almost €3 billion of the state budget. This figure does not include the imputed cost of lost working hours. The Ministry of Justice accounts for almost €1 billion of the budget, with the Ministry of the Interior accounting for some €1.5 billion. With regard to safety and security, the administrative sector of the Ministry of Transport and Communications accounts for hundreds of millions of euros. If we consider the social sector, acute health care and the insurance sector to be safety actors, they are also counted among the major actors.

The most important preserving values are normativity and trust in the authorities, service providers, the justice system and society's helping hand.

The benefits, risks and inhibitors of change: Centralised risk prevention should in the future be decentralised due to the risks becoming dispersed. Cooperation between the business community and the authorities is highlighted, but it alone is not enough. We can no longer think that control only applies to the producers or sellers of goods and services, as the number of producers and produced goods continues to increase, and products are influenced via telecommunication networks after they are completed and sold. In the future, control must be carried out as a continuous process and increasingly often near the individual during the actual use of the product or service. Artificial intelligence and new measurement devices make this possible without imposing unreasonable requirements on individuals. Through crowdsourced control, the authorities can also acquire a remarkably good and extensive situation picture and evidence of any misconduct.

The risks of the change include an increased dependency on the use of technology, decreasing of privacy protection and decreasing of feelings of trust. In any event, the risks will increase, and the main question in the change will be whether individuals will be provided with better conditions for managing the risks or whether the authorities will seek to retain control until the situation becomes untenable. Perhaps the greatest risk lies in the new need for safety and security being left entirely to the proactivity of private actors and citizens, with the authorities mainly obstructing this type of increase in safety and security by relying on norms that are based on outdated ideas.

The change is slowed down by people's trust in public authorities as well as new types of problems remaining at a manageable level for the time being and the realised risks having become a shared responsibility. Regulation prevents the change relatively efficiently, and hierarchic control continues to be strengthened. The nature of the problem is not understood widely, and extensive reconsideration of the structure of public authority is not on anyone's agenda. For the most part, questions about which authority should be concerned about the operation of a refrigerator connected to the Internet in the event of a denial-of-service attack or a hacker ruining the foodstuffs inside by taking advantage of a vulnerability in the refrigerator only serve to confuse traditional actors who are holding on to their crumbling comfort zone. Dependency on international IT services continues to increase.

Growing professions and skills shortages: The decentralisation of threats and their increasing complexity will generate many new types of jobs and skills requirements. Growing new professions related to safety and security include e.g. cloud security service consultant, cyber security consultant, home security technician, security janitor, self-sufficiency planner, personal security remote controller, cyber security police, manipulation detective and fake news prevention officer. Assessors of the impact of international crises and risk analysts will also be needed more in the future.

Policy objectives of the change: The change can be promoted by many measures. Peer-to-peer security information platforms should be catalysed and a framework created for them. The authorities should help in the launching of operations. Capacities should be developed for cyber security operations and the authorities should support households in cybercrime and fake news prevention. Personal security cameras should be allowed, and the artificial intelligence related to them should be clearly defined as not being subject to the EU's General Data Protection Regulation (GDPR). The role of super sense platforms should be investigated, and shifting the emphasis to monitoring performed by the consumer should be explored. Threats and harassment in the virtual world should be inspected and the capability of people to move safely in public virtual market places should be ensured.

Special national characteristics: The expertise in Finland is extensive and of a high standard.

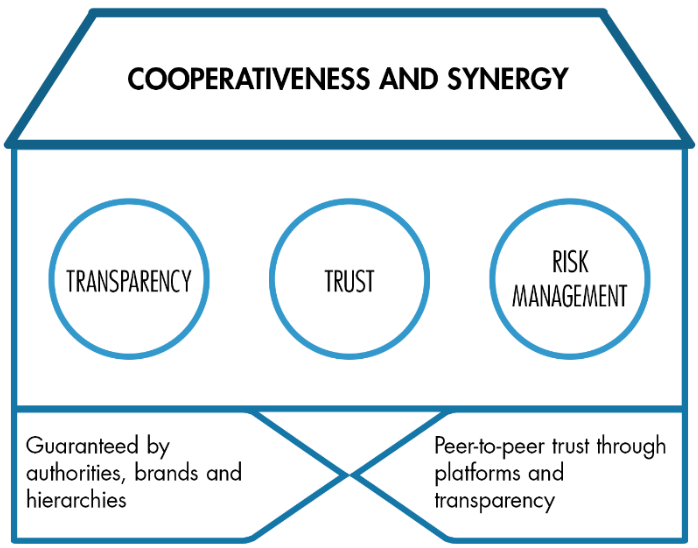
ART-ID	Safety and security: applications of the ARTs and evaluations of their effectiveness	Weight
1	Screening a person's emotions and thoughts during an interrogation/interview.	3
2	DNA-based identification, identification of food, DNA certificates, synthetic bioweapons.	10
3	In the event of an accident, sudden illness or violent situation, an automatic alarm is a safety factor.	5
4	Receiving a personal warning about dangerous chemical conditions, etc.	3
5	Some substances are dangerous to some people. In addition to these substances, a material scanner can protect us from counterfeit medications, explosives, weapons and people under the influence of drugs, for example.	10
6	The ability to see around corners promotes not only traffic safety but also the safety of soldiers and rescue workers, for example. Positioning is a clear safety factor.	5
7	A great number of safety and security systems use several different wavebands for communication and measurement.	5
8	LiFi networks are impossible to eavesdrop on if there is no connection penetrated by light. Indoor farming improves security of supply.	5
10	The information provided by laser scanners increases security, and devices that operate with lasers can both threaten and protect people. Particle accelerators might accidentally kill people.	5
11	The capability to easily imitate human speech is a security risk. The capability to be understood in a foreign language increases safety.	5
12	Artificial intelligence can detect security problems and guide safe practices on a case-by-case basis.	5
13	Safety challenges will increase as the development of artificial intelligence becomes easier, allowing smartly moving and operating autonomous equipment to be developed by amateurs.	3
14	Facial recognition is a significant safety factor. The recognition of emotions can be used to warn people of potential risks.	5
15	Security-related interviews can be automated and anomalies may become easier to find using verbots.	5

ART-ID	Safety and security: applications of the ARTs and evaluations of their effectiveness	Weight
16	Control tasks will become easier when a shared, real-time 3D model of the environment is available.	5
17	The recognition of objects that jeopardise safety will become easier.	1
18	Control data about normal situations helps artificial intelligence detect deviations.	3
19	Smart glasses or AR glasses increase safety by uploading video of their field of vision to a cloud service in real time and by recognising and warning about risk factors.	5
20	VR glasses are required for walking into dangerous places and situations with an avatar.	1
21	Handling dangerous situations with remote control benefits from interfaces.	1
22	Security is based partly on gathered data and deviations detected in these data. The more extensive the amount of data gathered, the easier deviations are to detect.	3
23	The fact that artificial intelligence is becoming more commonplace both increases risks and facilitates their identification.	3
24	Quantum computers break public-key encryption, and quantum communication allows criminals and others to communicate undetected.	20
25	New materials make it possible to implement physical certificates and make sensors that examine safety risks.	3
26	Increasing computing power increases risks, but it also helps predict and detect them.	5
27	The free mobility of robots increases both safety and risks.	5
28	A self-driving car can eliminate most of the approximately €2 billion in annual damage costs resulting from traffic. In the wrong hands, a self-driving car is a significant safety risk.	20
29	Traffic safety will decrease and robotised transport equipment can be used as weapons.	5
30	Quadcopter surveillance will increase safety, while the potential use of quadcopters as weapons will reduce it. By collecting their own energy, devices can fly from other countries to individual locations.	10
31	Air safety has traditionally been better than road safety. The police and rescue services will arrive on the scene more quickly.	3
32	Continuously flying devices can continuously film an urban area with enough detail to detect small birds. The tapes can reveal criminals' arrival and escape routes.	5
33	Robot ships eliminate the insecurity and mistakes of the crew. Lightweight hulls make ships unsinkable.	3
34	Traffic safety will increase when a Hyperloop replaces some of the road traffic, assuming that there will still be vehicles driven by humans among the traffic as well as situation-specific surprises.	3
35	Improving of satellite connections will both increase and reduce safety. National territory can be disturbed with devices remote-controlled via satellites.	1
36	Robotic insects will contribute to safety with their ability to survey their surroundings as a swarm and provide assistance in rescue missions by looking for people in need of rescue and by functioning as personal safety cameras.	3
37	Safety will increase when dangerous tasks can be performed through an avatar equipped with hands.	3

ART-ID	Safety and security: applications of the ARTs and evaluations of their effectiveness	Weight
38	3D printing can be used to produce dangerous objects without other people's knowledge. Expertise is not required, as the models can be shared online. The printed objects may also be unintentionally dangerous.	3
41	IoT devices produce control data that increase security, but the IoT devices themselves are a major data security risk. Unique identification of objects will prevent theft and counterfeit products.	5
42	Control, safety and security services are becoming robotised.	3
46	Insulation protects food from impurities, and structures provide protection from moisture damage.	1
48	Sturdy fibres can be used to make bulletproof clothing or clothing that otherwise increases safety. Structures equipped with sturdy fibres can be a clear safety factor in earthquake-prone areas and other situations in which structures are susceptible to strain.	5
52	The strength and durability of construction materials has a significant impact on safety.	3
54	Lack of clean water is a health risk. The capability to produce one's own drinking water increases safety in crisis situations.	3
55	Simulation will help eliminate the risks of chemicals.	3
56	The capability to control the bioproduction of organisms is a chemical and biological risk.	5
57	The proportion of men who are at an age in which they are prone to hazardous behavior will decrease, which will increase safety.	3
58	Nanoparticles and microbots are a safety risk when misused.	3
59	Households and small groups can produce biological materials, including those which are dangerous.	5
60	The easy accessibility and poor professional understanding of genetic modification technology, which is due to the strict regulation of the practical application of genetic modification, is a major risk.	5
61	Safety both increases and decreases through a better understanding of life. Artificial cells may be harmful and dangerous or useful.	3
65	Dementia is a significant risk for the patient him/herself.	3
66	Animal diseases will be reduced in cell culture, and quality control will increase as production is decentralised.	3
67	Individual cultivation both increases and reduces safety. The security of supply increases.	3
70	Autonomous, decentralised energy reduces dependency on electricity grids and their disruptions.	5
71	Self-sufficiency with regard to heat increases security of supply.	1
72	Grid-level energy storage reduces interruptions in operation.	1
73	Portable control devices and control systems not connected to the electricity grid require batteries.	3
74	Fuel self-sufficiency is a significant safety factor.	5
75	Monitoring equipment and base stations can operate on a fuel cell and fuel tank.	3
77	Security of supply will increase when the off-grid capabilities improve.	1
79	The development of decentralised energy production will increase security of supply at the local level.	3
81	Lasers and other directed-energy weapons can be used effectively to repel drones, aim weapons, mark the target and incapacitate the enemy.	5

ART-ID	Safety and security: applications of the ARTs and evaluations of their effectiveness	Weight
85	Cryptocurrencies increase cross-border crime. Time banks reduce the problems of social exclusion.	3
87	More reliable verification of proficiency would increase safety.	1
88	AIs acting as foremen in tasks with wide impacts and the great number of remote-controlled, mobile robots are clear safety risks that must be taken into account.	5
89	The Tor network enables criminal activity beyond the reach of control authorities.	5
92	Interfaces related to modularity provide hackers with an extensive operating environment in which they can utilise known weaknesses. The susceptibility to risk increases, even if the quality of security improves.	5
93	The migration of trade over to machines may lead to systemic risks in the security of supply.	5
94	The impacts of a 5G network on security are varied.	5
95	The location of cloud services impacts national security and the protection of companies' trade secrets.	3
96	A global artificial intelligence is a threat to national security, but it may increase the security of an individual citizen in some respects.	5
97	Blockchain is relatively safe at the moment but, as quantum computing develops, existing chains can be corrupted and a decentralised system is difficult to fix.	5
98	Digital experiences may cause addiction.	3
99	The GDPR hampers the organisation of security on an individual level but protects the data of an individual.	5
100	VR content can be dangerously intense emotionally or cause other problems.	1

1.18 Collaboration and trust



Scope of the value-producing network: The objective of this value-producing network is to increase cooperativeness in things that produce synergy benefits. Society is established in interaction with others from the tasks that increase the size of the shared pot. In a just society, everyone can achieve more through collaboration than by working alone.

The scope of this value-producing network includes factors that particularly serve cooperativeness, such as understanding the needs and capabilities of potential collaboration partners as well as trusting the agreements concluded with them. The need for trust is relative to the risk, which is why this value-producing network includes things that mitigate risks. This definition excludes the objectives described in the other value-producing networks for promoting collaboration, such as safety and overcoming distances by means of logistics or telecommunication.

The most important values are related to transparency, trust and risk management. Transparency makes it possible to identify both needs and opportunities. It also strengthens faith in the activity being as promised. In addition to transparency and a threat of sanctions, trust may also be based on the feeling that the benefit is truly shared, i.e. that everyone is in the same boat. In addition to the aforementioned, risk management is also linked to collaboration and the coordination of the input and output related to it. If the benefits of collaboration are distributed in small portions between the parties, the temptation remains low. Betraying this trust will not lead to great benefits or losses.

The means and values of transformation: Most of our current transactions are built on hierarchic trust and cultural norms. We believe that products and services are as described to us by the seller because the authorities control production and trade. We believe in those who borrow money for the same reason, but we may demand guarantees and guarantors. Breaches of contract and false advertising may also be subject to sanctions and compensation.

However, it is increasingly often the case that the control described above is not fully suitable due to the changed nature of the modern collaboration. We purchase products from foreign online shops or auction platforms. We purchase services from private individuals through platform companies. We may undertake projects with very different types of people online and give them our time. We share our information on various platforms. In return, we expect to see results from the collaboration. Instead of normal financial activity, the funding for our collaborative projects may come from crowdfunding.

Trust is normally based on a natural understanding of shared benefits or an agreement that seeks to ensure that the collaboration is advantageous for the various parties. An understanding of the shared benefits may be established by many means. For example, the common entity may require the skills of a large number of parties. If participation is effortless or in one's own interest, there is no need to fear free riders. Communal projects, such as Wikipedia and Linux, have been highly productive, and trust in the usefulness of collaboration and the functionality of the collaboration structure has increased continuously.

When the stakes required for collaboration are uneven, actions are required to increase trust. The opportunity for revenge is offered to the party who invests first as a potential sanction that it can impose. In other words, the other party increases trust by exposing itself to a potential revenge if it fails to carry out its part of the collaboration. The simplest sanction is a public reprimand. This is particularly efficient if a credible platform is offered for it. The intermediary, such as AirBnB, Booking.com or Amazon, shows customer evaluations to other potential customers. This provides credibility to their subcontractors' promises.

The simplest feedback is related to likes or showing the amounts of sales and returns. On a more general level, we can refer to the reputation economy. The parties provide their reputation as collateral and increase their reputation based on successes.

Transparency of the activity increases trust. Credible presentation of feedback is part of transparency. Opening up operating methods can e.g. refer to real-time image material, continuous observations of the process or quality certificates granted by third parties. Transparency can also be increased by certifying each product, space and service with a unique identity and making the actions taken in relation to this certification available to other parties in a cloud service maintained by a trusted third party.

A blockchain is the most notable new method of transparency. A blockchain is a decentralised system in which the transactions are certified for all parties by encrypting them as part of a continuous chain. Anyone can prove the authenticity and origin of documentation. A blockchain removes or automates the role of the trusted third party in many respects. The best-known blockchain system is Bitcoin, and a great number of new projects supported by significant parties are under development.

Crowdsourcing, which is based on customer accounts, partnerships and general interest, is emerging alongside the financing of new collaboration projects and investments that is based on securities, guarantees and other traditional banking and investment activity.

The most important innovative values are related to globalisation, communality, a desire for innovation, ease and openness.

The means and values of the dominant regime: The dominant regime is based on cultural norms and the activity of public authorities. On the one hand, information that impacts trust is being prevented from accumulating on the grounds of privacy. On the other hand, contractual transactions and compliance with regulatory norms are being monitored in many ways. In other words, the preconditions of communal trust and self-organisation are limited, while the operating area of societal, institutionalised trust has been expanded.

At its core, the current trust hierarchy is represented by the financial sector, which monitors the solvency and credit practices of banks. Banks monitor the payment traffic and creditworthiness of their own customers. Failure to pay back debts leads to a loss of creditworthiness within the banking system and an appropriate sentence and distraint by public authorities.

Most of the activity by public authorities involves control and certification of collaboration or identifying needs for sanctions. Consumerism, labour legislation and other norms established to protect the weaker party are examples of this. Quality control, which is often related to the content of transactions, and actual verification of transactions have been integrated into the same body of work.

The banking sector is the broadest of the sectors mentioned. The interest income of Finnish banks in 2016 totalled €4.3 billion, with the fee and commission income totalling €1.9 billion. At the same time, their administrative costs amounted to €2.6 billion, and their profit was €2.7 billion. The total value of the balances was €426 billion. At the end of 2016, their equity accounted for 6.2 per cent of this number.

The most important preserving values are the justice system, hierarchy in decision-making, nationalism and appreciation for the protection of privacy.

The benefits, risks and inhibitors of change: By analysing transaction costs and bodies of work within a hierarchy, we can calculate the costs of trust structures. An exact estimate may be impossible to calculate, but we are clearly talking about several billion euros per year. Peer-to-peer trust and the reputation economy provide incentives to improve the quality of activity in the roles of seller, collaboration partner and customer. Decreasing hierarchy and growing trust networks reduce the risk of abuse of power and the structure-related risk of partial optimisation.

Increasing transparency decreases the search and contractual costs as well as the risk of uncertainty. The providers and needers can find each other more easily and become convinced of the sensibility of their collaboration. Through crowdfunding, good ideas that are found to be necessary can obtain funding from potential customers against a reputational risk. This provides funding to many ideas that would not have obtained funding via banks, the stock market or established operators in the sector. Transaction costs decrease as the automation of platforms reduces the amount of work. The reputation economy enables extensive crowdsourcing, particularly in producing information. The large number of actors also improves the quality of the available information.

The risks of the change are related to structures such as pyramid scams as well as potential conflicts between international platform-based activity and national legislation. Risks arise from undeserved trust in operators that give a trustworthy picture of their activity with false means. The mechanisms of decentralised trust are not managed or controlled systematically, which easily leads to mistakes.

The change is slow because trust is often built slowly. It is easier for us to trust old organisations that we are familiar with, and a good reputation takes longer to earn than a poor one. Customs and habits also slow down the adoption of new practices. In addition to these factors, numerous provisions dictate that things should be done in the prevalent ways. On the other hand, platforms based on peer-to-peer trust are already widely in use. The General Data Protection Regulation may significantly complicate the decentralisation of trust structures.

Growing professions and skills shortages: Currently, a large number of legal practitioners, software designers, and economists who negotiate agreements are employed by structures of trust. The transition of structures of trust significantly affects the content of their jobs. New and growing professions include trust leader, trust consultant, voluntary work lobbyist, crowdsourcing recruiter, P2P work moderator, motivation planner and predictor and crowdfunding manager.

Policy objectives of the change: The most important objectives should include clarifying sanctioning and control activities related to P2P trust structures, defining certification levels for different levels of P2P trust, moderating network effects in order to avoid dominance, clarifying the ownership of volunteer work content and blockchains, formalising P2P trust on the same kind of level as regulatory approval and degrees, and increasing competition in record keeping as well as transferring it, where appropriate, to P2P networks both in the private sector and public registers. The possibility of standardising metadata and interfaces related to trust should be clarified.

Special national characteristics: Finland is at the forefront with regard to trust structures.

https://www.suomenpankki.fi/globalassets/fi/raha-ja-maksaminen/maksujarjestelmat/suomen-pankki-katalystina-maksuneuvosto/mn07_digitalisaatio_ja_fintech_suomessa.pdf

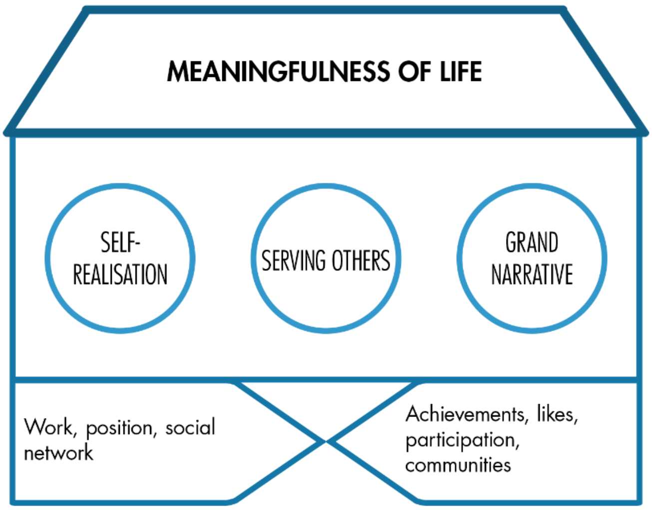
http://www.stat.fi/til/llai/2016/04/llai_2016_04_2017-04-18_tie_001_fi.html

ART-ID	Collaboration and trust: applications of the ARTs and evaluations of their effectiveness	Weight
1	Sharing emotions and ideas presumably increases cooperativeness. Identifying needs is helpful in satisfying them.	5
3	Trust increases in a care relationship if monitoring of the patient's vital functions indicates that the patient is recovering. Trust in relevant dietary, lifestyle and medicinal recommendations will increase.	3
4	Easier inspection of received products increases trust.	3
5	The ability to reliably identify the origin or composition of any received material increases trust and cooperativeness and reduces transaction costs.	5
11	Interpretation enhances collaboration between people who speak different languages.	10
12	Artificial intelligence identifies frauds, which increases trust and collaboration. Artificial intelligence also helps to perceive needs and solutions which adds its positive effects.	5
13	Collaboration will increase amongst AI developers and AI applications due to common AI platforms.	5
14	Facial recognition and analysis of emotions increase trust.	5
15	Verbots as part of the platform economy improve collaboration between people.	3
17	Collaboration in the creation of goods requires components to be coordinated. The models of existing structures contribute to collaboration.	1
19	AR glasses enable hologram-level meetings and the telepresence of another person as a guide and mentor.	3
20	VR glasses allow us to be present in a shared virtual reality. This may promote cooperativeness to the same degree as the telephone does compared to a letter.	3
23	The impact assessment of neural processors is multifaceted, but the decentralisation and enhancement of artificial intelligence will impact trust and collaboration in many diverging ways.	5
24	Trust in existing public-key encryption will crumble. Trust in the total encryption of quantum communication will grow.	5

ART-ID	Collaboration and trust: applications of the ARTs and evaluations of their effectiveness	Weight
26	Decentralised transactions based on a blockchain will become more affordable. Realistic situations will be increasingly easy to falsify.	5
28	The billion hours (on a Finnish scale) freed up from driving can be used for entertainment or collaboration.	3
31	Local collaboration may become more efficient with the help of automated logistics.	1
34	As the commuting and services areas expand, collaboration will improve.	3
35	The origin and privacy of data received via the global satellite network will be easier to trust than the trustworthiness of data received via a network shared by several operators.	1
37	Telepresence through a convenient avatar improves cooperativeness.	3
38	Collaboration will increase in modelling projects, for example, when each participant can make his/her own copy of an object modelled together with others. A Wikipedia of goods can easily grow to great proportions.	3
41	A reliable identity related to goods and the information behind this identity facilitate continuation orders, maintenance, warranty issues, transport, resale and rental.	5
51	Shared use of objects will become easier with the help of antibacterial and repellent surfaces.	1
55	Simulation enables collaboration among large groups as well as open innovations.	1
61	Simulations enable extensive collaboration and open innovation.	3
65	A person with dementia is not actually capable of collaboration with new people.	3
70	A substantial investment in highly volatile production without essential variable costs lends itself to increase cooperativeness.	3
84	Gamification is part of many structures of trust, for example in the form of likes, and it promotes both willingness and capability for cooperation when the trust becomes visible.	10
85	Cryptocurrencies enable structures of trust in activity occurring outside the law and outside banks. Time banks increase cohesion locally.	3
86	Crowdfunding and microfinancing platforms increase capability for collaboration.	5
87	A better understanding of other people’s current proficiency increases trust, and the capability to acquire and demonstrate proficiency flexibly increases capability for collaboration.	5
88	The platform economy produces an image of a reliable service and a fair operating environment that is the same for everyone.	3
89	Anonymity increases criminals’ and rebels’ capability for collaboration. Authentication and encryption also increase legal, confidential collaboration.	3
90	Platforms increase trust and capability for collaboration.	3
91	Platforms increase capability for collaboration by producing confidential data and calculating transaction costs.	5
92	The cooperativeness of subcontractors and various clients and customers in the field of robotics will increase radically when robotics starts incorporating connectivity and replaceability at the modular level.	5

ART-ID	Collaboration and trust: applications of the ARTs and evaluations of their effectiveness	Weight
93	Decreasing transaction costs and information about trustworthiness gathered by machines enable an efficient sharing economy.	5
94	Improving communication connections to the level of a shared virtual reality will improve collaboration.	5
95	Use of the services of trusted third parties increases capability for collaboration.	5
96	A global artificial intelligence can identify needs of exchange and optimise them effectively. People can learn to trust it, and collaboration can increase significantly.	10
97	A blockchain facilitates collaboration and increases trust.	3
99	The forced customer data portability obligation increases collaboration.	3
100	Exchange is possible if the platform is shared.	3

1.19 Existential meaning



Scope of the value-producing network: The objective of this value-producing network is the feeling that one's own existence and actions are meaningful. Relevant terms in this context include "meaningfulness of life" by Viktor Frankl and the concepts of "existential meaning" and "purposeful life."

Many of the value-producing networks in this report describe indirect methods or means and objectives that have seemingly become goals by themselves. Existential meaning can truly be considered to be one of the ultimate life goals. People in general want to feel that their existence is at least meaningful but preferably also useful part of some greater entity.

The scope of this value-producing network includes ideologies or stories that create existential meaning. Group identities help us understand existence as part of some greater objective through which our own existence or actions feel meaningful.

The most important values are related to self-realisation, serving others and a grand narrative or a mission related to some group identity. Self-realisation manifests as a role that is realised through the pursuit of external appreciation, pleasures or status. It can also manifest as conscious actions according to one's calling. Existential meaning stems from a desire to live, learned notions and ideas or other people and nature.

The means and values of transformation: With the Western set of values shifting from collective to individual in emphasis, work and work-related roles have become the focus of meaningful life. Existence is more often determined according to professional identity than according to one's place of residence, religion or family. Existence is also determined according to what we wear and consume and how our employer behaves. Tolerance is becoming an increasingly important value, but it is important for our existence to repel anything that we do not want sticking to us.

With specialisation and exchange increasing, work has become narrow in scope while the rise of the level of abstraction has reduced its concreteness. Permanent professions create identities and group identities through roles, whereas atypical employment is determined more strongly by the idea of action and accomplishment. Modern work is often performed by employees for the needs of people who they will never see, in an organisation whose values they do not share and for a supervisor whom they do not like. However, the shared belief in the meaningfulness of a company's operations is becoming an increasingly important motive for recruitment and customer loyalty. Working life has become a field of contradictions. Because of this, many companies make the effort to establish a mission for themselves that their employees and customers can identify with.

Digitalisation and robotisation unlock new types of comprehensive work roles in which meanings are the focus and the work is performed for the members of one's own community either in data networks or the local community. The impacts of the work are more easily visible than in industrial work. Particularly the measurement of work performance and gamification, when carried out correctly, can increase the meaningfulness of existence and actions at the individual level.

Meaningfulness is often felt through the group identity with which we identify. During the pre-industrial period, work was performed for one's own household and village community whose respect one earned as a result. A group identity was usually established through the village community or family. It is possible that the evening out of differences in proficiency and artificial intelligence will reduce the significance of professional identities and restore the local community's status as the most important peer group. If hierarchies unravel and the proportion of local manufacturing increases, the amount of work performed for the local community may once again increase. The appreciation of the group for whom we generate benefits may once again become more significant than the group with whom we compete. It is possible to return to a situation in which we for the most part satisfy our own needs and those of our local community by ourselves, at which point i.e. gardening may once again become greatly significant.

The Internet has materially facilitated contact with people who are meaningful to us. Doing things together and achieving things in digital communities will gain ground as the possibilities offered by the virtual world expand. The virtual world will grow into a meeting place and work environment for increasingly large groups. With AR glasses, we can be constantly in contact with our immediate circle as though we were in the same place. This may once again shift our set of values towards a more collective emphasis. At the same time, this may reduce the importance of external status and status achieved with money.

In social media, an increasing number of people feel that publishing photos of their garden, crafts or cooking is meaningful. More and more people also seek to produce things online that others will appreciate with their likes. It seems obvious that a digital presence opens up an important channel for those whose photos no one previously had any time to look at and whose poems were left hidden in their desk drawer. The tools of giving and sharing have changed radically. At the same time, the scope of sharing has grown to a global level, making it easy to find like-minded people.

Besides keeping a pet, people will find new significance in raising an AI, building virtual worlds, having a hero's reputation in a game world and helping those in need in games. Fostering and maintaining ideologies and promoting hobbies that are important to us has also become easier with the help of data networks. Global problems are constantly being discussed and new methods are constantly being proposed for solving them. We can provide assistance in the company of people whom we believe in and whose methods we can identify with. The impacts of our own actions are also more visible than when we donate money to a cause.

The desire for meaning can be used in many ways. In the past, those who were disappointed in their lives could be recruited by armies, for example. Today, we can find a community of purpose online through various "isms." People need a purpose for their life and easily accept one that satisfies this need with communal means that tell a grand story. A recent example of the utilisation of this phenomenon is ISIS. But the phenomenon is not new. However, data networks and globalisation provide the phenomenon with new dimensions and proportions.

The most important innovative values are rebelliousness, achievements, likes, participation in a grand story and online or local communities.

The means and values of the dominant regime: Common methods of motivation related to work include job titles, honorary titles, degrees and financial compensation. The dominant regime includes many rewarding positions, for example in teaching, nursing, real estate, jurisprudence and trade, in which the usefulness of the work can be seen in the eyes of the customers. But even in this type of work, appreciation is most commonly sought from peer groups through one's professional identity.

The scope of the work is often closely defined, and there is little opportunity to influence the content of the work. In many cases, people feel their work to be important only because of the money they earn for it. We find significance in hedonistic values, the well-being of our immediate circle and social experiences. In individualistic cultures, these involve self-centredness and selfishness as well as intolerance, which is also a common characteristic of a collective culture and the mechanical solidarity that is often related to it.

In its current form, work is for the most part tied to a location and hierarchy. The feedback we receive for our work is sporadic and rarely related to the actual purpose of the work. The uncertainty related to employment relationships and the major role of supervisors in guaranteeing the continuity of the work have elevated pleasing the supervisor into the most important practical value. Conflicts with one's supervisor and a lack of a shared view of the purpose of the work easily leads to the work being viewed as a necessary evil in order to fund the meaningful part of one's life. Any problems related to existential meaning easily lead to social exclusion, depression and seeking comfort in stimulants.

We do a great deal of voluntary work that is meaningful to us in associations, political parties, recreational circles and the church. Meaning can arise from a cause promoted by a community, the benefits gained from an activity, one's circle of friends or appreciation, for example. We also engage in a great amount of voluntary aid work outside organisations, for example by helping neighbours and elderly persons.

In Finland, the Evangelical Lutheran Church of Finland is the largest actor whose primary objective can be considered to be a purposeful life. In 2016, it had some 20,000 employees, 4 million members and €890 million in income. In addition to religion, sports also provide people with goals. Several hundred million euros are spent on maintaining sports facilities and providing sports organisations with grants every year, and these organisations have roughly a million members. The media uses a great deal of resources to highlight the appreciation for sports. Spirit-lifting sessions and rituals to strengthen group identity within companies, third sector operators and professional groups are also part of extensive organised activity.

The most important preserving values are a fear of change, desire for comfort, achieved or pursued status and pressure by society.

The benefits, risks and inhibitors of change: The strengthening of professional identity as the primary group identity makes it more difficult to feel that one's work is meaningful. Switching this group identity into another which includes ones customers increases the meaningfulness of the work. Then the work benefits the members of our own identity group and they are the ones who appreciate the results of our work. A possible change towards more comprehensive and responsible work as well as clearer measurement of work performance contribute to our ability to feel that our work is meaningful. The opportunity to choose recreational groups and social communities regardless of geographical location and to acquire knowledge and skills in order to achieve the things that we find to be important also contribute to the feeling of meaningfulness for their part.

Digitalisation enables new types of communities of purpose and more comprehensive work performed directly for the beneficiary, but the rigidities and uncertainties relating to proficiency and working life make it challenging to transfer to a position that is meaningful to us. In other words, finding a meaningful job may be difficult for many people even if such positions do become available. Disappointment in the event of unfulfilled expectations may lead to frustration and disruptive behaviour. In this state of mind, data networks may enable us to find communities of purpose that are destructive. The need for purpose is not always channelled into actions that the rest of society considers to be positive.

The change is slowed down by the fact that a great number of people have the type of position and income in their current societies that they do not want to give up for an uncertain future. The existing structures involve a great deal of symbolic meanings, and the creation of new meanings requires a systemic change. The current dominant regime supports traditional meanings and operates according to the operating models of hierarchic and local structures.

Growing professions and skills shortages: New and growing professions include e.g. value consultant, meaning designer, gamification officer, self-sufficiency consultant, self-sufficiency supply vendor, life management guide, virtual living environment developer, cohesion manager, needs hunter, logo therapist, gestalt therapist, tribal manager, AI friend shepherd, e-sport manager, noise cancellation technician and AI awareness mechanic.

Policy objectives of the change: The removal of obstacles to an economy of smallness promotes the increase of existential meaning. In practice, this means reducing the burden of bureaucracy, especially among small operators. New community of purpose contributions should be generally recognised when only traditional forms of action are currently publicly emphasised. The decision-making power should be delegated from the physical local level and state to societies. A subsistence economy should be enabled at the community level, at least in terms of production, energy, education and food. Obstacles to development and experimentation should be dismantled. Regulatory needs that prevent or moderate the emergence of harmful isms or destructive ideologies should be clarified.

Special national characteristics: There is a great number of organisations in Finland, and the national culture is very uniform and secular from an international perspective.

https://jyx.jyu.fi/dspace/handle/123456789/38285

https://evl.fi/tietoa-kirkosta/talous

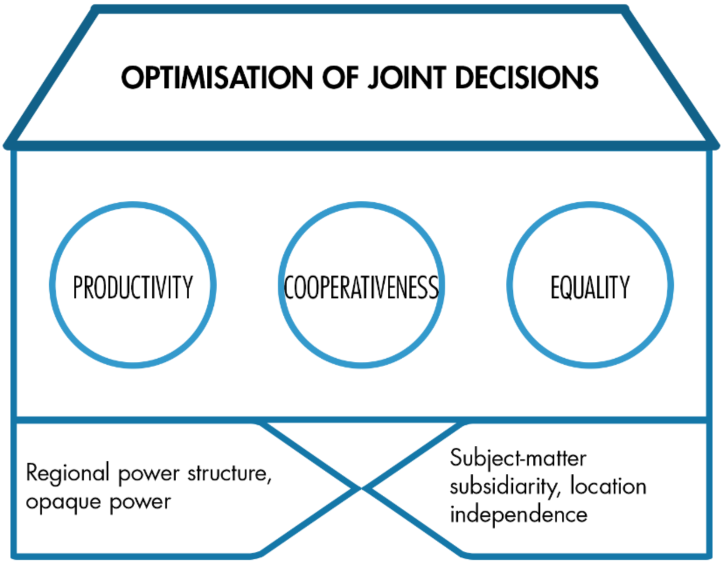
http://www.liikuntaneuvosto.fi/files/380/vln_toimintakatsaus_19112015_final.pdf

ART-ID	Existential meaning: applications of the ARTs and evaluations of their effectiveness	Weight
1	Building our own identity and purpose through self-awareness and by means of gamification, for example.	5
2	Self-awareness through knowledge of the genome, such as understanding our roots. Synthetic stories written in the DNA as continuity, and the creation of synthetic life as part of a great story.	5
3	Life itself is a meaningful thing to most people, and if the impacts of our own actions can be seen in the well-being of our body, our actions more easily become meaningful.	5
5	The development or identification of materials can become a hobby and part of the substance of life if we can reliably measure it ourselves.	1
7	If we can receive reliable information, such as information provided by a thermographic camera on whether the person we are dating is in love, it may add purpose to our lives.	3
8	Nothing is as important as gardening. LED lighting provides this classic understanding even to modern city residents. Living from hand to mouth feels meaningful.	5

ART-ID	Existential meaning: applications of the ARTs and evaluations of their effectiveness	Weight
11	Speech technology enables talking characters to which we can grow attached like we do to pets. Interpretation opens up opportunities for more extensive influence.	5
12	Teaching AIs can be one of the meanings of life and represent the continuity of one's own thoughts or the development of memes instead of helping fellow men and animals.	5
14	Helping an emotional machine can feel meaningful. Reading a person's emotions helps a machine seek meaningful questions and tasks.	10
15	A human being perceives a conversation as being meaningful and as having an existential meaning. A talking machine is a more intense conversational partner than a book and can strengthen the sense of existential meaning.	3
16	The conflict pointed out by Manuel Castells between the space of flows and the space of places fades when digital means and physical locations are merged through mixed reality. This impact is described in more detail in the book Digital Cities III.	3
19	When we learn to look beneath the surface to understand the world and acquire information about it more easily. When we are accompanied by virtual pets that are able to learn, life can feel more meaningful.	3
20	Virtual worlds can be communal and shared, and they can become more important places for living, education and building than our physical environment.	10
22	Recording life in detail and in its entirety is meaningful and makes life more meaningful, at least for some people. The same does not apply to forgetting.	5
23	It is difficult to predict the impact of artificial intelligence becoming part of our everyday lives. Some people will become empowered, while others will become marginalised. This division will become different from what it is now. Humanity will change.	10
24	Due to many turbulences associated with trust, many people's belief in the existential meaning of life wavers. The multiverse idea makes choices unnecessary at the philosophical level.	3
27	Decrease in mobility constraints facilitates self-realisation and a meaningful life.	5
28	The freedom of mobility increases capability to lead a meaningful life.	3
34	As the commuting and services areas expand, opportunities for creating meaningful communities and being part of them will increase.	3
35	The conquest of space is a mythical story that is meaningful to many people.	3
37	In addition to virtual reality, telepresence will become increasingly important and almost equal to physical presence. Touch and the sense of feeling in fingers make it almost real.	3
38	3D printing facilitates many hobbies. Physical objects and their preparation feel meaningful, and 3D printing is used by numerous hobbyists and inventors in various fields.	3
39	When more space is given to creativity and individuality in buildings, it may increase the meaningfulness of life.	1
41	The history information of objects, plants, etc. as well as teaching or gossiping virtual personas and their independent communication can bring meaning to life.	3
44	Clothing is part of our identity, and a robotic tailor enables individuality at a low cost.	3

ART-ID	Existential meaning: applications of the ARTs and evaluations of their effectiveness	Weight
50	Sustainable development is an important pursuit and continuity is one of the cornerstones of a meaningful life.	3
53	Human-like machines that learn with the help of an AI can themselves become important.	5
54	In many areas suffering from a shortage of water, easy production of fresh water allows people to garden and produce their own food, for example.	3
57	Lengthening of healthy life expectancy increases opportunities to search for a meaningful life.	10
60	Editing of an adult human's genome makes a man become his own creator, and those for whom life is a performance will have access to new tools.	3
61	Simulation of life leads to important questions about the meaning of life.	3
65	A person with dementia loses a great part of his/her purpose of life.	10
66	Animal welfare is a very important and meaningful objective for many people.	10
67	Nothing is as important as gardening – this idea will gain followers.	5
69	Cryogenic freezing of the human genome and the capability for procreation are part of the meaning of life through a feeling of continuity.	3
70	Renewable energy is part of the battle to save the world.	3
71	Renewable energy is part of the battle to save the world.	3
74	Renewable energy is part of the battle to save the world.	3
77	Self-sufficiency increases the feeling that our own work and existence are meaningful.	3
84	Changing our own behaviour in a way that is visible to others increases its meaning.	5
85	Time banks increase the meaningfulness of communal work.	1
86	Communal work projects and campaigns increase communal meanings and build group identity.	3
87	Question: "Who are you?" In our answer, we often name our profession or degree and place of residence. Lowering the tresholds of degrees would increase meaningful existence.	5
90	Strengthening of the local community facilitates the meaning of life.	3
91	Platforms offer low-threshold work that could prevent social exclusion. A platform can also allow us to demonstrate our skills without obstructing intermediaries, as proven by YouTubers.	5
94	High-quality presence of a VR/AR world can increase the sense of existential meaning.	5
96	A global artificial intelligence can affect existential meaning in many unpredictable ways.	5
98	Art is one of the purposes of life, and digitality unlocks great opportunities.	5

1.20 Power structures



Scope of the value-producing network: The objective of this value-producing network is the optimisation of joint decisions. Every organisation has interest groups, and the organisations serve as a functional framework for their collaboration. Each interest group has its own objectives. The objective of the power structures of an organisation is to combine these interests and function together in a purposeful manner in decision-making.

The purpose of this section is not to assess the objectives of the interest groups but to focus only on what type of organisational methods and power structures best meet the objectives of the interest groups. Problems mostly arise due to opportunism and incompetence. The main focus is on the actions of public authorities that mainly use shared resources, but the division between the market, hierarchy and self-reliance and any changes occurring therein are also included in the scope of this value-producing network. This also includes the transfer of decision-making authority from the national level to a global level or from a collective level to the individual level.

The most important values relating to decision-making are productivity, cooperativeness and equality in public activity. Productivity refers to the relationship between the objectives and sacrifices of the interest groups, while cooperativeness refers to the ability of decision-making to organise productive joint activity. Equality can refer to many different things, depending on the interest group.

The means and values of transformation: Public authority is organised according to a geographic division into municipalities, regions, states and their unions. States have a material impact on business operations. The exercise of power in organisations is almost without exception organised by delegating responsibilities to a financial hierarchy of responsibilities or through qualitative and financial control into a matrix.

Digitalisation frees us from being tied to a time and location and automates simple decision-making. The demarcation between public and private tasks should be revised in the changed situation. Multinational companies, the effects of cross-border networks and social media are transferring power outside national borders.

The subsidiarity principle related to democracy originally meant that each matter should be decided by those to whom it primarily applies. At first, this was not solely a matter of geographic proximity. Subject-based proximity was another important principle. Participatory decision-making is a step back towards this subject-based proximity. Today, funds are divided between each cog in the wheel of a bureaucracy, but they should be allocated more clearly to target groups whose values and choices are respected in decision-making.

Increasing complexity has led to the problem that the same people participate in decision-making in several different fields. This problem has decreased in companies due to regional conglomerates being replaced by specialised national and international chains. Government agencies are similarly specialised, but each small municipality handles all the matters of the municipality by itself, similarly to a local conglomerate, either directly or through complex joint municipal authorities.

Administration could be decentralised with the help of the subsidiarity principle being based on the subject matter. Each subject-specific administration could be independent of geography, and competing administrations could exist for all tasks that are not tied to a location. The decision-makers would be chosen by democratic means separately for each subject area by those to whom the subject in question primarily applies. Land use planning and municipal infrastructure would perhaps not be competitive administrative sectors, but sectors such as education, social services and building control could work in a competition model. This does not refer to market-based competitive advantage but competitive advantage within public administration.

A great number of administrative matters can be handled routinely. The amount of human labour is often unnecessarily high due to administrative regulations. Laws, decrees and the organisation of control mechanisms have forced municipalities to operate in ways that are inexpedient for the municipalities themselves. Executing administrative regulations with the help of artificial intelligence, gamified systems, simulation and crowdsourcing would make regional administrations significantly better equipped to perform their own duties efficiently and perfectly. On the other hand, the state administration would be better able to take special regional characteristics and the diversity of individual needs into account.

Platform cooperatives in data networks are bodies managed by their members for the organisation of joint administration and marketing. In platform companies and platform cooperatives, the decision on the acceptance of each assignment is made by a member. Members can include users or providers of the services, depending on the platform. The platform offers assignments, collects feedback about them and handles communication targeted at potential customers. The platform also handles accounting, invoicing and, if necessary, work supervision. Platform cooperatives could be provided with considerably large responsibility for many of the administrative tasks related to present-day democracy.

The demarcation of markets and hierarchy could be carried out according to the teachings of Oliver E. Williamson, who won the 2009 Nobel Prize in economics. According to these teachings, matters that easily result in a natural monopoly should be managed hierarchically, while matters that maintain a competitive situation should be managed by markets. Technological advancement is rapidly changing the division of which matters are suited to be managed in which way. The more technical options and less public funds that a matter involves, the better it is suited for the market. In contrast, shared platforms and interfaces and control of large, repetitive matters are suited to be handled by public authorities. In addition to these, questions of equality and social justice must naturally also be taken into account.

The most important innovative values are comparativeness, interchangeability, openness, the possibility to choose and competition.

The means and values of the dominant regime: Structural power is wielded by political parties, the management elite of large companies, bureaucracies, advocacy groups and the media. Management plays a key role in existing bodies of work, regardless of whether we are talking about companies, public authorities or the third sector. Extensive legislation, a multitude of control mechanisms and a complex jungle of working life practices increase required management. This makes operation difficult, particularly for small companies. Complex management can generally be claimed to both weaken the quality of decisions and increase inequality through the artificial favouring of large-sized companies.

Power is pursued and used to favour one's own interest groups. This applies to all structural power in public organisations, companies and the third sector. Other people's money is easily misused if control is insufficient or the indicators are misleading. A typical problem inherent in large investments and the financial sector is extensive open-endedness, which makes it impossible to determine profitability, with calculation being based on beliefs. In the mining industry, post-treatment and dismissal of harm caused to third parties leads to the same problem. Despite this, bonuses are still paid for them. Board members also like to choose each other for boards and to serve as CEOs in ways that establish a circle of mutual loyalty and drive to promote the interests of their own circles.

The information required by public authorities is often gathered with the help of actual cost accounting and other reporting obligations imposed on organisations. A considerable proportion of the working hours of people who perform physical labour is spent on delivering this monitoring data. The utilisation rate and necessity of these data are often debatable, and these functions could be rationalised with the help of digitalisation and by dividing tasks differently. However, this is not always possible without amending legal provisions.

Local government is the largest individual sector of administration. The joint operating expenses of Finnish municipalities amounted to €36.7 billion in 2016. At the time, there were 313 municipalities and 144 joint municipal authorities, each of which have made both political decisions and official decisions for the needs of all administrative sectors of the municipality in question. The competitive tendering required by competition law is often too demanding and laborious, and the decisions are very complex especially for members of municipal councils, who cannot have expertise in every field.

The impact of general government finances and regulations on companies and private households significantly exceeds the size of general government finances. For example, banks lend money that they themselves have not earned or received from lenders; instead, their lending is based on the status awarded to them by society. This status is clearly a case of privilege, similarly to mining operations and many other uses of shared resources. The responsibility for the use of the great decision-making power granted by this privilege does not extend to citizens for the time being, and very few citizens understand the extent of the great, lawfully secret power to control the economy that banks have.

The values that maintain the existing structure include conservatism, normativity and focus on the question presented by Plato about how we should choose who makes the decisions. The mechanisms of the decentralisation of democratic decision-making are very rarely contemplated. The only alternative we usually talk about is the market.

The benefits, risks and inhibitors of change: If the political decision-making by public authorities were changed from region-based to subject-based, it would increase the expertise of those making the decisions. In practice, decision-making would be democratised and the subsidiarity principle would also be given space in matters that are not tied to geography. If regional government gave room to competing administrations comprising elected representatives, it would increase freedom of choice, comparability, an experimental approach and the quality of decisions.

Decisions are often based on poor information. The gathering of information with the help of crowdsourcing, data collection automation built into processes and simulation of alternatives would improve the quality of decision-making. Encoding norms into interactive, gamified platforms and artificial intelligence would enable more flexible control.

The risks of such a change include increased costs of parallel administration if economies of scale exist. On the other hand, municipality-specific administration is already being carried out under more than 300 parallel councils, and these administrations also partly overlap with the administration of the state, joint municipal authorities and subcontractors.

Increasing participatory democracy at the subject-specific level and establishing competing subject-specific administrations in place of the existing municipal administration would hardly be heavier than the current practice. Confusion may be a significant risk if the voters do not want to elect decision-makers separately for administrative sectors, preferring to elect only one decision-maker for a municipality, one for a region, one for Parliament and one for president. Equality could also become a risk if competing administrations were implemented in an unequal manner. This matter could be promoted in a comparatively risk-free manner by first transferring a single area to be managed by democratic platform cooperatives.

Factors that slow down this change include the long administrative tradition and the fact that it is difficult to even imagine conceptual changes to the current situation, among other things. For many, democracy means electing municipal councils, Parliament and a president as well as the officialdom elected by politicians. The existing division of responsibilities between administration, the private sector and citizens, as well as the existing structures, are built into a great number of laws. Technical preparedness to utilise parallel administrations and models of decentralisation and platform economy is at a good level in Finland, but these alternative administrative models are neither well-known nor being discussed even at the conceptual level.

Growing professions and skills shortages: Decision-making information systems will change substantially due to the IT skills of citizens, digitalisation and artificial intelligence. This will also affect the regional distribution of power. New and growing professions resulting from the change include e.g. simulation expert, crowdsourcing coordinator, data reliability analyst, happiness operator, career operator, ecosystem developer, metadata coordinator, artificial intelligence reliability supervisor, administrative gamification officer, caller for administration tender, artificial intelligence administration moderator, artificial intelligence administration inspector, prioritisation effect simulator, administration platform developer and administration platform moderator.

Policy objectives of the change: Resource balance based calculation should be used instead of gross domestic product. Consideration of externalities should be developed. Review of issues that are suitable and unsuitable for market operators should be performed systematically based on the transaction cost theory created for the purpose, instead of sphere of influence thinking. Greater transparency and social responsibility should be required from organisations operating based on privileges granted by society.

Subject-based division should be looked into in relation to the administrative subsidiarity principle, and the responsibilities of municipalities should be further reduced in matters in which distances are not that important. Responsibility for the development of administration platforms should be assigned to someone, and a framework should be created for an artificial intelligence administration. A democracy of alternative administrations should be prepared. The management system of large administration offices should be reviewed, and a politically elected administration board or an elected management should be considered as alternatives. The decision criteria and their simulation must be made transparent, and citizens must be provided with public simulation models.

Special national characteristics: The Finnish power structure is very club-like.

http://www.stat.fi/til/kta/2016/kta_2016_2017-06-02_tie_001_fi.html

ART-ID	Power structures: applications of the ARTs and evaluations of their effectiveness	Weight
1	Reading thoughts and emotions produces great power, the use of which against one's will is not acceptable in democratic countries under normal conditions.	3
4	More extensive availability of environmental information at the citizen level leads to higher quality decisions in politics, including accurate information about mould in buildings or other air quality.	3
5	The extensive ability of citizens to indisputably recognise problems improves the quality of decisions.	5
11	When interpretation is always available, it facilitates understanding and improves decisions in situations in which information is provided to decision-makers in a foreign language.	3

ART-ID	Power structures: applications of the ARTs and evaluations of their effectiveness	Weight
12	Artificial intelligence can be used for raising issues affecting decisions and backgrounds of decisions, evaluating the quality of decisions and showing the best choices in relation to goals.	20
13	Platforms facilitate the AI projects of various interest groups.	3
14	Falsification of the facial features, voice and facial expressions of decision-makers, even in a real-time video call, may lead to problems in decision-making. Reading emotions provides more information for decision-making.	5
15	A personal artificial intelligence agent can help decision-makers find and remember the issues needed for decision-making and negotiations and promote smooth administration.	3
16	An improved situation picture leads to better decisions.	3
18	Simulation models and their adaptation to expert data helps us understand causalities and teach AI to assess alternative decisions.	5
20	Experiencing the factors that influence decision-making through virtual reality and in a shared space improves the quality of decisions.	5
22	Recording details instead of summaries makes it possible for an AI to detect causalities at the micro level and helps identify wrong generalisations.	3
23	The enhancement of AI allows increasingly fine phenomena to be analysed, and the role of decision-makers may become narrower alongside the strategic player, AI.	10
24	The changes will be great and “surprising” because decision-makers have not anticipated them and the impact on the competency of decisions is clearly negative.	5
26	The enhancement of simulations and AI improves the information available to decision-makers.	10
34	As the commuting and services areas expand, differing substantially from regional limits, tensions will increase and making of good decisions will become more difficult.	5
35	Increasingly accurate information acquired via satellites of both the state of the Earth and events will improve the knowledge base of decisions.	1
38	Physical scale models facilitate decision-making. 3D printing facilitates this.	1
40	The idea of self-organising processes and their modelling simultaneously develop social modelling as a self-organising process.	3
41	Data accumulated about the environment increases the knowledge base of decisions.	3
42	Many services are global, transferring decision-making to the global level.	5
50	Understanding the circular economy is one of the key decision-making issues. Becoming more common increases understanding. Systematic modelling helps decision-makers.	3
54	Easier production of fresh water reduces power disputes between regions.	5
56	The boundary between human and computer will become blurred, making it difficult to interpret laws.	5
57	Those who have risen to power can retain their position longer, which may increase tensions between progressive and conservative people.	5
58	In totalitarian states, microbots may be used to subdue nations.	5

ART-ID	Power structures: applications of the ARTs and evaluations of their effectiveness	Weight
61	Simulation is an important method of testing the quality of decisions. In this case, simulation can be used to demonstrate the effect of various harmful substances, medications and food on people.	5
77	Self-sufficiency will increase and become separate from collective activity.	3
84	Decision-making becomes easier when people's goals and the things they value become visible.	5
85	Cryptocurrencies may increase bribery and extortion.	3
86	In crowdsourcing, power is transferred from production companies and investors to customers.	10
87	Decisions are often based on outdated proficiency, as many sectors do not require proficiency to be demonstrated formally after the completion of one's studies.	10
88	AI has demonstrated its capabilities in many optimisation and game strategy tasks.	10
89	Secret agreements, extortion and other opaque activity make room for many decisions to be made against the interests of the interest groups.	3
91	Platform owners are significant wielders of power who are guided by user data about all services performed. Platforms are often global.	5
92	Interfaces are inherently global, and they often establish limits for easy decision-making. Decisions pertaining to interfaces are not made at the national level.	5
93	In e-commerce, decisions are made between a local customer and a global trader.	5
94	Decision-making on network infrastructure has shifted to the global level.	5
95	Decisions pertaining to cloud computing and storage have moved to the global level.	5
96	Decision-making can become very challenging if a multitude of artificial intelligence services optimise the whole and manage the details. Many decisions will be made at the global level.	20
97	Structures of trust will shift outside national operators and to ownerless structures. The exercise of power by the state may be insufficient in conflict situations.	5
98	Crumbling of the world view when some people live in the shared physical world while others live in their own virtual worlds. Decision-making will become more difficult.	3
99	People are more in charge of the information collected of them and can use information as a means of payment. This reduces the power of platforms and increases the potential of collaboration.	5

2 Application level: individual technological breakthroughs

The world is often changed by individual devices, such as the telephone, or processes, such as agriculture. However, many seemingly simple devices or processes are based on a great deal of both scientific and technological development, infrastructure created over the course of history, socioeconomic changes and pent-up needs.

This chapter describes a hundred rapidly developing ARTs. The numerous research and development news compiled under these ARTs open up prospects that revolutionise the world. Many of these innovations may still be at the level of a scientific breakthrough, or the first modest and extremely expensive products may be taking their first steps towards becoming widely spread. They also include more mature technologies that are approaching a price level or level of performance that will give them completely new meanings.

This list of one hundred ARTs that will radically change the world was compiled to include the most promising technologies that should enter the market during the 2020s. They are expected to have a wide impact by 2037. In order to make it to the list, the principles of the solution must have been explained in a scientific publication.

A criterion for listing an individual technology is its significant instrumental impact on society or everyday life. It must save costs, facilitate everyday life or increase comfort, strengthen power structures or weaken them. The breakthroughs listed are tool- or method-oriented. They are mainly described based on their functionality, and there may be several alternative technical implementations. Each ART may enable several applications if the enabler of the different innovations is partly the same.

The radical technologies described are graded into seven levels of maturity:

1. The scientific principle that enables the breakthrough in the area of application has been proven to be possible at the level of a theoretical model, published by a research team from a reliable research institute. The observation is recent, and there appears to be academic interest in the subject.

2. The scientific model enabling the breakthrough in the area of application has been verified with concrete laboratory testing, and the operating principle has been demonstrated in a peer-reviewed publication. The research groups are funded, and the academic motivation is clear. Progress appears to be taking place.

3. The laboratory prototype leading to the breakthrough in the area of application has been demonstrated. The laboratory prototype clearly indicates that some material problem that previously prevented the breakthrough has been solved and the necessary functionality has been achieved. Possible problems relating to production costs or durability have yet to be solved at this level. The research groups are funded, and the academic or commercial motivation is clear. The progress is recent, and the new opportunities presented are significant.

4. PoC (Proof of Concept). A functional prototype has been scientifically or commercially demonstrated to meet the requirements of commercialisation in terms of its functionality and viability for production. In terms of its functionality, the prototype must clearly exceed the benefits of previous solutions or involve lower production costs than previous solutions after the economies of scale have been taken into account. The progress is recent and clear.

5. A competition situation with several well-capitalised market actors developing the production prototype after the PoC phase, or a production prototype clearly in the finishing phase, with investments made to launch production. The progress is fast-paced.

6. Products are being delivered to customers in increasing amounts. The economies of scale are expected to reduce prices considerably. The areas of application are expected to expand. R&D activity is at least partly based on internal financing, and the expansion of production has been clearly financed. The progress is recent.

7. Competing products are being delivered, and customer demand is on the rise. Competition is internally financed to a significant degree, and growth is financed by major industrial companies, a wide clientele or venture capitalists. The development of product properties involves significant known potential.

The ART can comprise several technologies in different stages. If their areas of application deviate significantly from each other and the potential benefit is divided among different technologies within the value-producing networks, average scoring is used. The maximum value is used when the functionality is largely the same.

A radical technological solution often combines understanding of different disciplines. The term radical is also applied to incremental development that arises from the production volume, methods or standardisation and unlocks radically innovative potential applications as a result of the technology becoming widely spread or the prices decreasing, for example. In this context, the term anticipated radical technology (ART) is also applied to social innovations and structural social changes for which technological advancement provides a framework.

The ARTs are grouped according to their spheres of influence. The following sections first describe the group-specific impacts before introducing each ART.

Groups of technological breakthroughs

Technology groups	
1	Instrumentation and telecommunication
2	Artificial intelligence and algorithmic deduction
3	Digitalisation of sensory data and processing
4	Transport, mobility and logistics
5	Production of products and services
6	Material technology
7	Biotechnology and pharmacology
8	Energy technology
9	Digital crowdsourcing platforms
10	Globalising technology interfaces

The one hundred radical technological solutions listed were evaluated with the RTI model described in this report. The maturity levels described above are used to predict the probability of the impacts. The final score is calculated by adding up the value-production network-specific evaluations of the effectiveness of the applications, as described in the previous chapter, and multiplying the sum with the probability indicated by the maturity level described above. The table used in the evaluation includes 2,100 separately evaluated items that were verified by the authors of this report.

These observations were gathered with the active contribution of the following 213 people, each of whom contributed at least one of the 2,000 sources that were included in the article database. The people who contributed at least three sources are indicated in italics, while those who contributed ten sources are indicated in bold and those who contributed over 30 sources are indicated in bold and underlining. We would also like to thank all of the approximately 2,500 participants of the group Tulevaisuusvaliokunnan radikaalit teknologiat -joukkoistus (Radical technologies crowdsourcing group of the Committee for the Future), who have helped us evaluate the significance of the findings with their comments.

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Structure of the description of the ARTs

The notation **** is provided in the heading of each ART to indicate the technology's estimated effectiveness. The section *Scope or target area of the ART* describes the key objective of the technologies chosen for the ART.

The section *General description of the development* includes a general description of the unsolved problems of the ART or the subjects of development efforts. The *Resources and motive for development* are examined separately, with the aim of indicating the scope and nature of financing. For example, it is relevant to mention whether the ART involves a research motive, venture capital or the profit margin being invested in research in a competition situation. Various types of financing lead to objectives that differ from each other. Information is helpful in the evaluation of the maturity level.

Progress since the previous report is an important section that provides a brief description of recent events. This section partly overlaps with the headings of the sources listed directly below. These sources are the key observation data of this report, and repetition of the most important observations is not considered to be a problem.

The section *Interesting sources* lists the source material of the report in relation to the ART in question. For each relevant news topic or research result, we have chosen a source that represents it as well as possible. In most cases, the source is a popular science article, as actual scientific publications are often very difficult to read and behind a paywall. All of the links were checked and fixed on 16 February 2018.

2.1 Instrumentation and telecommunication

Measurement technology is evolving continuously. We acquire information about the environment and ourselves with increasingly sensitive sensors. For example, genetic heritage, the composition of various substances or the condition of the body can be determined in many respects with very inexpensive equipment. Sensors may gather the energy they require from their surroundings, and they can be communicated with wirelessly. Through telecommunication, we can upload all the information we have gathered to global cloud services.

The number of smart devices is expected to double over the next five years. At the same time, devices are being equipped with sensors that collect an increasingly wide range of information, and wireless sensors are evolving to be so small and inexpensive that they can be easily placed in the environment and even in human bodies. In addition to sensors, many devices that activate and guide functions have become more advanced.

The impact of lasers and plasmonics extends beyond measurement and telecommunication. Technologies allow optical properties to be manipulated and impact among others also materials technology and military technology.

As a result of development, people continuously receive more information about themselves and their environment, and an increasing number of functions can be influenced remotely. Both recorded and real-time information and controllability enable advanced automation. Robot-assisted work can be performed regardless of the location of the employee controlling the robot. Many processes can be monitored to such a level of detail by automation that observation by humans is not necessary.

Instrumentation and telecommunication	
ART-ID	**The ARTs in the group**
1	Reading and editing thoughts from the brain
2	DNA reading and writing (full genome)
3	Personal health diagnostics systems
4	Lab on a chip
5	Material scanner – hyperspectral camera
6	Environment 3D scanning & positioning
7	IR, THz and GHz transmitters and receivers
8	LiFi networks and other LED technology
9	Plasmonics and photonics
10	Small particle accelerators, femto and nanolasers

2.1.1 Reading and editing thoughts from the brain (001) ***

Target area of the ART: Human senses do not produce all the information we want in our brain. Our senses are limited and they easily sustain damage. The ability of the brain to control the surroundings through gestures and movements may be weaker than desired. Our senses do not tell much about the functioning of the brain itself. This ART includes solutions that provide the brain with information, bypassing the senses, and solutions in which the functioning of the brain directly influences measurement devices or actuators. The solutions may require devices placed inside or outside the skull.

General description of the development: Robotic arms have been successfully controlled directly by the brain in many tests. Signals measured from the brain have also been tested in controlling smart glasses. A brain has been successfully linked to another brain, with thoughts transferred between them. Words being thought have been successfully identified from brain images.

In addition to sensors glued to the head, remote sensors placed inside the head have also been developed. After their useful life, they can melt and become part of the metabolism. Biocompatible implants, such as graphene-based implants, have also been researched.

A brain has been controlled from outside the head with laser beams and other electromagnetic radiation. These technologies have been successfully used to mitigate the symptoms of Parkinson's disease, improve learning outcomes and even influence thoughts. In the USA, DARPA has launched a project to link a brain bilaterally to data systems, with considerable accuracy.

Resources and motive for development: The most extensive research activity in this area is based on a medical motive. In addition to general functioning of the brain, researchers are researching and developing increasingly accurate methods for understanding and treating functional impairment in individuals. Activity taking place in the commercial sector and recreational groups may grow to significant proportions. Researchers seek to control computers and robots with simple EEG sensors attached temporarily to the head.

Impact on value-producing networks, ART 1																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	0	1	3	0	0	5	1	5	3	3	5	5	10	5	20	3	5	5	3	***255

Progress since the previous report: The closest equivalent ART was "2.26 Thoughts monitored from brain and action based on them," which ranked in the third group. The category has now been expanded and made bilateral. There has been rapid progress, particularly in the areas of brain implants and prosthetics. Experimental treatment measures have already yielded results, and the easiest parts of them are becoming established.

Interesting sources published after the 2013 report (001)	
Short description of the link	**link**
Writing speed of 12 words per minute with a brain implant	https://www.nextbigfuture.com/2016/10/direct-brain-sensing-technology-allows.html
More precise brain implants with coils	https://singularityhub.com/2017/02/22/new-tech-makes-brain-implants-safer-and-super-precise/
Controlling a robotic arm with thoughts	http://www.cnet.com/news/mind-controlled-prosthetic-arm-now-reality/
Chemical/optical/electrical link to the brain with flexible fibre	https://news.mit.edu/2017/multifunctional-tiny-fibers-brain-0221
Paralysed person googles with ease using a brain implant	https://singularityhub.com/2016/11/02/scientists-hook-up-brain-to-tablet-paralyzed-woman-googles-with-ease/
Two students cooperate through a brain-to-brain connection	http://www.iflscience.com/brain/mind-meld-brains-cooperate-without-words
A brain implant improved memory	http://www.sciencealert.com/for-the-first-time-ever-scientists-have-boosted-human-memory-with-a-brain-implant
Neurosky EEG controls smart glasses	http://techcrunch.com/2014/07/09/forget-ok-glass-mindrdr-is-a-new-google-glass-app-that-you-control-with-your-thoughts/
Controlling a paralysed hand through a direct link to the brain	http://blogs.mathworks.com/headlines/2016/04/20/neuroscience-and-machine-learning-restore-movement-in-paralyzed-mans-hand/
Memory codes and the concept of memory implants	http://www.technologyreview.com/featuredstory/513681/memory-implants/
A mouse successfully controlled with a brain implant	http://www.eurekalert.org/pub_releases/2015-07/nion-fbp071615.php
A paralysed person controls a flight simulator with a brain implant	http://defensetech.org/2015/03/02/this-woman-flew-an-f-35-simulator-with-her-mind/
An artificial neuron mimics the chemical signalling of a nerve cell	http://www.ecnmag.com/news/2015/06/artifical-neuron-mimicks-function-human-cells?et_cid=4641606
Thoughts into text with ECoG at 54% accuracy	https://www.weforum.org/agenda/2017/04/technology-that-could-turn-your-thoughts-into-text/
EEG-based control of a robot	http://www.kurzweilai.net/how-to-control-a-robotic-arm-with-your-mind-no-implanted-electrodes-required
Accurate reconstruction of faces by reading roughly 200 brain cells	https://singularityhub.com/2017/06/14/forget-police-sketches-researchers-perfectly-reconstruct-faces-by-reading-brainwaves/
Graphene can be safely interfaced with neurons	http://scitechconnect.elsevier.com/graphene-safely-interact-neurons-in-brain/
A biodegradable sensor the size of a grain of rice inside a brain	http://arstechnica.com/science/2016/01/in-a-brain-dissolvable-electronics-monitor-health-then-vanish/
AI converts images in the brain into visible images	https://www.biorxiv.org/content/early/2017/12/30/240317
Controlling a rat's thirst with a laser & light-sensitive neurons	http://www.livescience.com/49568-thirst-switched-off-brain.html
Powering graphene implants without damaging cells	http://news.mit.edu/2016/power-graphene-implants-without-frying-cells-0923

Interesting sources published after the 2013 report (001)	
Detecting infrared light with a brain implant	http://www.telegraph.co.uk/news/science/science-news/9875931/Scientists-create-sixth-sense-brain-implant-to-detect-infrared-light.html
Researching brain disorders with nanocarbon sensors	http://www.aalto.fi/fi/current/news/2016-11-09-006/
Words decoded from thoughts during epilepsy surgery	http://www.newscientist.com/article/mg22429934.000-brain-decoder-can-eavesdrop-on-your-inner-voice.html
Bittium, a small EEG for field use	https://www.bittium.com/products__services/medical/bittium_brainstatus
Nanobots into the brain, Diamandis & Kurtzweilin	https://www.linkedin.com/pulse/rays-wildest-prediction-peter-diamandis
Simulation and partial digitalisation of a rat brain	http://www.nytimes.com/2015/10/09/science/rat-brain-digital-reconstruction-human-brain-project.html?_r=0
Controlling a robot with an EEG headset	http://www.wired.com/2014/08/mind-controlled-robot
A flexible, durable EEG sensor on the skin	http://spectrum.ieee.org/tech-talk/biomedical/bionics/a-braincomputing-interface-that-lasts-for-weeks
Dishonesty is researched with FMRI and the brain adapts to dishonesty	http://www.nature.com/neuro/journal/vaop/ncurrent/full/nn.4426.html

2.1.2 DNA reading and writing (full genome) (002) ****

Target area of the ART: The genome of viruses and all living things includes the essential information about their functioning principles and origin. DNA is also a potential memory store and the code of both the biology of living things and synthetic biology. DNA and RNA codes are read and written for many different reasons.

This ART includes the various sequencing and writing technologies that are aimed at sequencing the full genome or writing a DNA/RNA sequence of the desired length. Changing a specific part is addressed elsewhere, in ART 60.

General description of the development: The most inexpensive device capable of sequencing the full genome is MinIOn, at a price of $1,000, including the related equipment. At the time this report was written, the most inexpensive service through which a person could order his/her genetic information and its explanation cost $300. The prices have decreased rapidly.

MinIOn is inexact, but the graphene-based nanopore technology it uses has been developed further. It has been found in simulation that technology makes it possible to sequence the genome at 90% accuracy without false positive results, at a speed of 66 billion base pairs per second. At that speed, the full human genome could be sequenced 32 times in a second, with the number of mistakes reduced to a tenth of the previous time per each sequencing performed. In other words, science will likely enable a fast, practically flawless and very inexpensive DNA sequencer in the future.

In terms of its practicality, genetic sequencing may become comparable to photography in the future. In practice, it will probably become possible to sequence not only our own genome but also the genome of other people, animals, food and diseases on a routine basis.

The genome can now be written very reliably. The written genome can be implanted back into a living cell. In research projects, researchers have input wide data into the genome of organisms and then read the same data from there. If the written DNA is kept in a powdery form, it lasts for a long time, and current technology allows 700 terabytes of data to be stored in one gram of DNA powder.

Resources and motive for development: The greatest financers of the development of DNA sequencers are medicine, the food industry and natural sciences. Increasingly efficient DNA sequencers are being developed for their needs. Researchers in nanotechnology also have their own scientific motives for researching radical technologies for this fashionable and well-financed sector.

Consumers' interest in their own roots and possible hereditary diseases is giving rise to a growing need for equipment. In the future, it is to be expected that consumers' interest in their environment and what they eat or what disease they are afflicted with will also increase the need to develop equipment. The development of DNA writers relies on the research units of IT companies and academic researchers, and there is no wide commercial market for them for the time being.

Impact on value-producing networks, ART 2																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	1	3	0	20	0	10	0	3	3	0	0	10	5	20	0	0	10	0	5	0	****630

Progress since the previous report: Section "2.1 Routine and complete DNA sequencing" of the previous report did not include writing in the sense meant here, but it did include genetic editing techniques, which have been given their own section in this report. This topic ranked in the most important group. The new principle, in which DNA is pulled through pores in graphene, had just been invented. It has now been commercialised into a useful, inexpensive, pocket-sized device. Technologies that are several times faster and more reliable have been simulated.

There are already several devices usable in field conditions on the market. The production cost of mainstream technologies has dropped to almost a tenth of what it was four years earlier, and they are rapidly becoming more widely used. The methods of identifying and archiving the DNA sequences read have also evolved. The interest in writing DNA is spreading from the research community to companies, and trials to write messages embedded into the DNA of naturally spreading organisms and fully synthetic genomes have been launched.

Interesting sources published after the 2013 report (002)	
Short description of the link	**link**
€120 million in funding for Oxford Nanopore and mapping of the human genome	http://labiotech.eu/oxford-nanopore-interview-pocket-sequencer/?platform=hootsuite
NIST: DNA sequencer concept, 70 million pairs per second	http://spectrum.ieee.org/nanoclast/biomedical/devices/a-superfast-dna-sequencer-based-on-motion-detection
Illumina promises $100 as the price of the human genome	http://www.illumina.com/company/news-center/press-releases/press-release-details.html?newsid=2236383
Fast DNA sequencing, graphene and optical antennas	http://phys.org/news/2014-11-unique-graphene-nanopores-optical-antennas.html
Description of user experiences of the DNA sequencer MinION	http://www.nature.com/news/pint-sized-dna-sequencer-impresses-first-users-1.17483
A small device that identifies microbes quickly (within hours)	http://spectrum.ieee.org/at-work/start-ups/startups-t2-biosystems
Whole genome sequencing for $300–1,000, content description	http://nextbigfuture.com/2016/01/whole-genome-sequencing-for-330.html
Battery-powered PCR DNA sequencer for field conditions	http://gizmodo.com/the-worlds-first-handheld-dna-sequencer-is-a-genetics-l-1626992774
Genome sequencing at under $1,000	https://www.genome.gov/27565109/the-cost-of-sequencing-a-human-genome/
Data storage in DNA as a Microsoft project	http://techcrunch.com/2016/04/27/genetics-startup-twist-bioscience-teams-up-with-microsoft-to-store-the-worlds-data-in-dna/
The USA sequences the DNA of a million Americans	http://www.reuters.com/article/2015/01/30/us-usa-obama-precisionmedicine-idUSKBN0L313R20150130
A video written into the DNA of bacteria and retrieved at 90% accuracy	http://www.bbc.com/news/science-environment-40585299
Fast search and combining of DNA data in a database	http://spectrum.ieee.org/biomedical/diagnostics/software-helps-gene-editing-tool-crispr-live-up-to-its-hype
Fast insertion of DNA into cells, researchers have an experimental device	http://www.eurekalert.org/pub_releases/2016-02/miot-ndm021816.php

2.1.3 Personal health diagnostics systems (003) ****

Target area of the ART: The human body is susceptible to many types of disorders. Physical activity, nutrition, infectious diseases, illnesses, emotional states and environmental conditions may affect the functioning of the body. This information may be of interest to the person in question or someone else. The condition of the body may also affect the devices attached to the person and his/her environment.

This ART includes practical technologies used to measure vital functions in everyday life. The focus is on functional entities and their key enablers, rather than individual sensors.

General description of the development: Devices intended for continuous or frequent measurement of people's physiology are now evolving and becoming more common very rapidly. Accessories available for Apple iPhone include an ultrasound device, microscope, ophthalmoscope, otoscope, ECG and several other measurement devices. Some of these have already been approved by the Food and Drug Administration of the United States. The devices are partly intended for field use by health care professionals, but a significant number of them are suitable for consumers to monitor their own state of health. Apple has developed a system for consumer use, where doctors can remotely access the measurement data from these consumer devices.

Rapid development has been reported in the areas of very inexpensive blood count and microwave stethoscopes. Glucose sensors have been attached to skin or contact lenses, and our haemoglobin level can be measured from a photo of the eyelid taken by a mobile phone. A dialysis belt weighing 5 kg and increasingly advanced diagnostics wristbands are among the most recent news.

New tests, such as an HIV and syphilis test costing $34, will enter the market as accessories to mobile phones. The identification of diseases from exhaled breath and breathable skin patches that monitor vital signs are undergoing rapid development.

The Tricorder XPRIZE competition was won by two portable devices that reliably identify several named diseases when used by ordinary people. It is very likely that many diseases and medical conditions can be reliably identified by patients themselves at home, starting in the 2020s.

Resources and motive for development: Both research methods and equipment are being developed for the needs of medical research. Some of the methods require continuous monitoring of the patient. The electronics industry is developing equipment for use by consumers to monitor the vital signs of both healthy and sick people. In addition to medical research and treatment, consumer interest is another important motive for the development work. Consumer interest has led to the creation of many companies through crowdfunding.

Impact on value-producing networks, ART 3																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	3		10	0	0	5	1	3	3	0	20	10	5	3	3	5	3	5	0	****420

Progress since the previous report: The corresponding section in the previous report was "2.7 Continuously monitored personal health," which ranked in the top group. The

Tricorder XPRIZE competition and its ambitious goals had been announced, but the monitoring of vital signs was at a very simple level in the consumer goods on the market at the time, and there were very few accessories suitable for this purpose available for smartphones.

The consumerisation of devices intended for monitoring vital signs and the development of measurement devices that move within the body collecting information and devices attachable to the skin have been particularly rapid since the publication of the previous report. Breakthroughs have been made in the ability of these devices to communicate by radio both from inside the body and from the surface of the skin.

Interesting sources published after the 2013 report (003)	
Short description of the link	**link**
17 diseases identified from exhaled breath, tests on 1,400 people	http://pubs.acs.org/doi/full/10.1021/acsnano.6b04930
Winners of the Tricorder XPRIZE announced	http://tricorder.xprize.org/teams
Digital tattoos equipped with a 5G antenna and other electronics	https://www.sciencedaily.com/releases/2016/05/160527190522.htm
Dozens of blood tests with a small device (DMI rHEALTH)	https://www.rhealth.com/rhealth-technology/
A flexible display surface for digital tattoos	http://tech.firstpost.com/news-analysis/e-skin-can-embed-a-display-on-human-skin-just-like-a-tattoo-309834.html
Top 10 body implants introduced	https://wtvox.com/2014/10/top-10-implantable-wearables-soon-body/
A digital tattoo as a remote controller, MS & MIT	http://www.theverge.com/circuitbreaker/2016/8/13/12460542/mit-microsoft-research-gold-leaf-smart-temporary-tattoo
A bio-processor from Samsung for measuring vital signs	http://motherboard.vice.com/read/with-samsungs-bio-processor-wearable-health-tech-is-about-to-get-weird
Genetic mutation analysis on the field with a smartphone microscope	https://phys.org/news/2017-01-smartphone-microscope-cost-effective-dna-sequencing.html
A graphene tattoo measures 5 different vital signs	http://spectrum.ieee.org/nanoclast/semiconductors/nanotechnology/graphene-temporary-tattoo
Diagnosing ear infections at home	http://spectrum.ieee.org/tech-talk/biomedical/devices/diagnosing-ear-infections-with-a-new-smartphone-gadget-
Small, cheap measurement device for continuous monitoring of blood levels	http://www.eurekalert.org/pub_releases/2015-10/epfd-mcb102215.php
Dialysis belt Purifier undergoes testing by the FDA (5 kg)	http://io9.com/this-medical-device-is-a-major-gamechanger-for-kidney-p-1658564050
Continuous glucose level monitoring with a digital tattoo	https://bioscholar.com/engineers-create-a-temporary-tattoo-for%c2%a0painless-sugar%c2%a0monitoring%c2%a0/
Monitoring blood alcohol levels with a skin patch	http://www.eurekalert.org/pub_releases/2016-08/uoc--fwe080216.php
Samsung's diagnostics wristband Simband & API	http://www.cnet.com/products/samsung-simband/

Interesting sources published after the 2013 report (003)	
5 sensor materials for self-diagnostics devices	http://spectrum.ieee.org/tech-talk/biomedical/devices/5-materials-innovations-that-will-make-new-medical-devices
A review of smartphone-based scientific instruments	https://cacm.acm.org/magazines/2018/1/223882-smartphone-science/fulltext
G-putty sensor, blood pressure, pulse, etc.	http://www.sciencemag.org/news/2016/12/supercharged-silly-putty-can-detect-spider-footsteps
Diagnosing the flu at a breath at home	http://www.digitaltrends.com/cool-tech/flu-breathalyzer/
A microwave stethoscope detects water in the lungs, etc.	http://spectrum.ieee.org/biomedical/diagnostics/microwave-stethoscope-lets-physicians-peer-into-the-lungs
A contact lens measures glucose levels	http://www.engadget.com/2014/01/16/google-smart-contact-lens/
A smartphone and lens costing $2 as a microscope	http://www.3ders.org/articles/20140427-make-your-own-3d-printed-microscopes-for-as-little-as-2-dolloar.html
The award-winning BACtrack wristband for alcohol monitoring	http://www.reuters.com/article/us-usa-health-alcohol-idUSKCN0YB2T1
Phillips: cardiac imaging added to a smartphone plug-in ultrasound device	https://t.co/z1g60kwsgf
A quick test identifies impurities in ground meat within minutes	https://phys.org/news/2017-11-technique-impurities-ground-beef-minutes.html
Chip-based ultrasound imaging technology	https://spectrum.ieee.org/the-human-os/biomedical/imaging/new-ultrasound-on-a-chip-tool-could-revolutionize-medical-imaging
Tattoo ink indicates the body's condition by changing colour	https://news.harvard.edu/gazette/story/2017/09/harvard-researchers-help-develop-smart-tattoos/
A digital tattoo that measures blood flow	http://spectrum.ieee.org/tech-talk/biomedical/devices/flexible-sensors-measure-blood-flow-under-the-skin
A $34 HIV & syphilis test device as a smartphone accessory	http://www.extremetech.com/extreme/198945-34-accessory-detects-hiv-syphilis-and-works-with-any-smartphone
Measuring haemoglobin from a mobile phone photo of the eyelid	http://www.eyenaemia.com/

2.1.4 Lab on a chip (004) ***

Target area of the ART: Chemical complexity is increasing constantly. We have a constant need to know what substances exist in our environment. This may be related to the quality or safety of products but also adjustment of production processes, identification of diseases or monitoring of the natural or built environment.

This ART includes sensors and measurement devices that can identify the composition of liquids and gases through physical contact so that the method is not only optical. The focus is on "lab-on-a-chip" (LOC) technology, in which a single circuit, printed sensor or small mass-produced device is able to quickly identify a great number of substances that it touches.

General description of the development: The development of LOCs is rapid. New sensors and diagnostics applications have recently been implemented for recognising e.g. predisposition to cancer, a wide range of viruses with a single test, recognising cancer from exhaled breath and recognising a risk of suicide from blood.

Bacteria have been modified to recognise cancer, a drug test has been printed on paper, and a wide-scale mapping of viruses and proteins can be carried out with a pocket-sized device as a combination of a sensitive sensor and optical analysis. LOCs that quickly recognise the markers of many diseases and devices that use these LOCs have entered the market.

Solutions have been developed for energy problems with sensors placed inside blood vessels and cells. According to research data, a radio transmitter that transmits through the body can now be implemented at a size of 1 mm*1 mm*10 mm. Inkjet technology has been successfully used to print sensors and electronics on paper. Many graphene-based sensors are also becoming very inexpensive.

Mould spores are being recognised at research level, gas sensors are being designed for clothing to warn us of conditions hazardous to health, and gas chromatographs are becoming inexpensive. Trials have been launched to digitise and print smells. An increasingly large number of things can be deduced based on information from sensors.

Resources and motive for development: Important developers of LOCs include the electronics industry, the chemical industry and academic research. Motives for their development particularly include the cost-effectiveness of processes, safety, the precision of academic research and the trade of measurement devices for the needs of industry and consumers.

Impact on value-producing networks, ART 4																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	5	5	3	5	0	10	5	3	3	3	0	5	0	10	0	0	3	3	0	3	***264

Progress since the previous report: The best equivalent of this section in the previous report was "2.2 Biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms," which ranked in the top group.

Tests that previously required cultivation can now be conducted quickly with small devices intended for field conditions. At the research level, gas detectors have become more sensitive to a decisive degree. A small device reported by Nature can break a sample down into 170,000 different branches with microchannels and optics and recognise the molecules of each section of a channel. The aim is to identify elements such as proteins and viruses in samples.

Sensors printed on paper have also evolved rapidly, and besides reagents it is now possible to print electronics on surfaces. This enables a wide variety of inexpensive tests that are printed as needed.

Interesting sources published after the 2013 report (004)	
Short description of the link	**link**
A multifunctional, inexpensive, printed biochip	http://www.pnas.org/content/114/8/E1306.abstract
A comprehensive range of blood tests/proteins optically, EPFL	http://www.scienceworldreport.com/articles/13249/20140303/complete-medical-check-up-chip.htm
Highlights of the development of lab-on-a-chip technology	http://pubs.acs.org/doi/full/10.1021/acs.analchem.6b00377
Mobile DNA testing device Q-Poc (gene-specific)	http://www.quantumdx.com/devices.html
Electronics on paper with inkjet and laser technology	https://www.sciencedaily.com/releases/2016/09/160901152112.htm
Plasma jet printing of nanomaterials	http://www.eurekalert.org/pub_releases/2016-03/aiop-pnw031816.php
General virus test ViroCap under development	http://www.upi.com/Health_News/2015/09/29/New-test-detects-all-the-viruses-that-infect-people-animals/7991443551878/
Precise graphene biosensors – description of the differentiation mechanism	http://phys.org/news/2015-06-graphene-biosensors.html
Flexible gas sensors for clothing	http://www.smithsonianmag.com/innovation/thin-sensors-on-our-skin-in-our-clothes-may-warn-us-environmental-hazards-180956127
Detection of cancer in blood at 50% accuracy without false positives	https://www.nbcnews.com/health/health-news/blood-test-finds-cancer-symptoms-start-n793181
Gasera's portable prototype for detecting drug precursors	http://www.tekniikkatalous.fi/innovaatiot/huumeongelmaan-keksittiin-suomalainen-ratkaisu-kayttoon-2019-3481908
Digitisation and printing of smells with iPhones, transmitted across the Atlantic	http://themindunleashed.org/2014/06/first-scent-message-transmitted-aross-the-atlantic-via-the-internet.html
A graphene surface captures the desired cells from blood	http://news.mit.edu/2017/graphene-sheets-capture-cells-efficiently-0303
Diagnosing cancer from breath at an accuracy rate of 82%	http://www.rdmag.com/news/2015/09/sniffing-out-cancer
Small gas chromatography system (with a hybrid circuit)	http://www.eurekalert.org/pub_releases/2015-04/vt-ntp041315.php
VTT printed a drug test on paper	http://www.eurekalert.org/pub_releases/2015-04/vtrc-vpa041315.php
Graphene-based biosensors – potential to be generic	http://www.upenn.edu/pennnews/current/2015-01-15/latest-news/new-graphene-based-biosensor-triple-threat
Flexible, inkjet-printed electronics	http://www.eurekalert.org/pub_releases/2015-04/pu-ilm040815.php

Interesting sources published after the 2013 report (004)	
A microchip on nanofibril paper	http://spectrum.ieee.org/tech-talk/consumer-electronics/portable-devices/green-microchips-created-on-cellulose-nanofibril-paper
E. coli-lux tests mould spores, etc. (dissertation by Janne Atosuo)	http://www.tekniikkatalous.fi/innovaatiot/tama+tulee+tarpeeseen+suomessa+kehitettiin+uusi+menetelma+homevaurioiden+tunnistamiseen/a1062992
Analysing suicide risk from blood	https://www.smithsonianmag.com/innovation/blood-test-app-may-help-identify-patients-at-risk-suicide-180956404/
Sensors that detect precious metals, etc. in waters in mining areas	http://www.eurekalert.org/pub_releases/2016-02/uon-nrf021816.php

2.1.5 Material scanner – hyperspectral camera (005) ****

Target area of the ART: There are many materials and substances in our environment that have interesting properties, but we cannot or do not want to take a sample of them to study. Because each substance reflects photons in a different way and radiation can also change its form in different ways when it penetrates various substances, these qualities can be used to determine the material's composition. This can be applied to the sugar content of a substance, the authenticity of medications, locating methane leaks or analysing exhaled breath, for example.

This ART includes technologies that identify substances based on the radiation they let through or reflect without the device being in direct contact with the object examined.

General description of the development: A spectrometer measures the intensity of the different frequencies of radiation. Because the composition of a material affects radiation, this method makes it possible to deduce the composition of a radiating substance or a substance that reflects radiation. The recognition of molecules within the infrared frequency band is based on the "fingerprint" of the radiation reflected. This recognition can be more precise in the terahertz frequency band. It is even possible to form an image of the molecular structure.

The most inexpensive commercial material scanner is SCiO, which costs $299. In Finland, Spectral Engines has been developing a similar technology. At greater distances, research is being carried out in Finland on applications of a material scanner in military use. For example, camouflage fabrics stand out from the rest of the terrain. This technology is referred to as a hyperspectral camera or multispectral camera, for example, with the former emphasising the more flexible and less discrete utilisation of frequency bands.

DIAL Lidar systems can be used to recognise methane eruptions from a plane. On the streets, they can be used to detect the alcohol content of the indoor air in a passing car. By measuring the reflections of the WiFi frequency, we can monitor moving people and other objects through walls and measure their pulse, for example. In addition to those mentioned above, another important technology that measures material composition is magnetic resonance imaging. A small-scale version based on permanent magnets is under development.

Resources and motive for development: This research area has evolved from the needs of astronomy. Important financers of this development include medicine, military technology, the food industry and material technology. SCiO was created with crowdfunding, and Spectral Engines originates from a VTT research project. Competition in the consumer electronics industry is a rising motive for development.

Impact on value-producing networks, ART 5																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	10	5	10	0	5	5	5	5	5	3	10	3	10	1	0	10	5	1	5	****515

Progress since the previous report: “Material radar,” section 2.40 in the previous report, ranked in the top group. Progress has been fast since then. At the time of the 2013 report, information was not available on consumer products and application of the technology was minor in the fields of industry or medicine, even though many potential applications were envisioned. Now, there are several manufacturers of food scanners, several operators are testing consumer-level medical devices, there is significant industrial use, and the devices are being used for many different purposes ranging from military use to chemical safety. The first smartphone integrated with an IR spectrometer is on the market.

Interesting sources published after the 2013 report (005)	
Short description of the link	**link**
The SCiO material scanner integrated with a smartphone	http://www.theverge.com/circuitbreaker/2017/1/5/14180740/changhong-h2-scio-molecular-sensor-hands-on-ces-2017
Development of a food scanner	https://www.washingtonpost.com/lifestyle/food/this-groundbreaking-technology-will-soon-let-us-see-exactly-whats-in-our-food/2016/03/26/763fb9ca-f070-11e5-89c3-a647fcce95e0_story.html
The SCiO material scanner in test use	http://spectrum.ieee.org/view-from-the-valley/at-work/start-ups/israeli-startup-consumer-physics-says-its-scio-food-analyzer-is-finally-ready-for-prime-timeso-we-took-it-grocery-shopping
A hyperspectral camera/material scanner for a mobile phone	http://www.vtt.fi/medialle/uutiset/tulevaisuuden-kuluttaja-analysoi-ymp%C3%A4rist%C3%B6%C3%A4%C3%A4n-ja-vaikka-ruoan-laatua-k%C3%A4nnyk%C3%A4ll%C3%A4
The Specim hyperspectral camera and material scanner	http://www.specim.fi/iq/
A nanoscale metamaterial hyperlens	http://www.buffalo.edu/news/releases/2015/05/039.html
An hBN hyperlens sees details as small as 30 nm in size	https://phys.org/news/2017-12-hyperlens-crystal-capable-viewing-cells.html
A food scanner	https://www.indiegogo.com/projects/tellspec-what-s-in-your-food

Interesting sources published after the 2013 report (005)	
Detection of bacterial growth with a laser spectrometer (TDLAS)	http://www.eurekalert.org/pub_releases/2016-03/tos-lhs031616.php
A material scanner in Finland	http://www.tekniikkatalous.fi/innovaatiot/2015-01-09/Terrorismin-torjuntaan-lis%C3%A4%C3%A4-v%C3%A4lineit%C3%A4---Jyv%C3%A4skyl%C3%A4n-yliopisto-kaupallisti-uuden-rikostutkintamenetelm%C3%A4n-3258169.html
An ultrafast microscope for visualising matter at the atomic level	https://www.colorado.edu/today/2016/02/16/ultrafast-microscope-used-make-slow-motion-electron-movie
Measurement of people (vital signs) through walls	http://newsoffice.mit.edu/2014/could-wireless-replace-wearables
A WiFi radar captures the human figure through walls	http://rfcapture.csail.mit.edu/
A hyperspectral camera	http://www.tiede.fi/artikkeli/uutiset/hyperspektrikamera_voi_kutistua_kannykkakokoon
The “quick” NanoMRI	http://spectrum.ieee.org/nanoclast/biomedical/imaging/new-technique-brings-nanomri-a-step-closer-to-commercial-applications
Progress on the rHEALTH scanner – approved by the FDA for research use	https://www.rhealth.com/rhealth-technology/
Imaging with nanometre resolution	http://www.eurekalert.org/pub_releases/2015-09/aiop-msi092515.php
A DIAL Lidar system detects alcohol in cars driving by	https://www.extremetech.com/extreme/184050-engineers-create-the-first-laser-breathalyzer-for-drive-by-dui-enforcement
Nanoscale 3D video in almost real time	http://www.eurekalert.org/pub_releases/2015-12/miot-mcn121415.php
Reading a book through the covers on THz frequencies	http://news.mit.edu/2016/computational-imaging-method-reads-closed-books-0909

2.1.6 Environment 3D scanning & positioning (006) ****

Target area of the ART: We need information about the geometry of our environment and about our own location in relation to the rest of the environment. Mobility, building engineering, repetition of shapes or understanding the nature of objects are examples of needs. Both people and mobile machines in particular need 3D shapes and their own location data in relation to a modelled reality.

This ART includes sensor technologies relating to environment 3D scanning and positioning, but not actual 3D modelling or pattern recognition.

General description of the development: The development of laser- and spaser-based Lidar systems has been rapid. They can be used to make a 3D dot cloud of the environment and identify the distances, shapes and movement speeds of objects. Lidar measures how long it takes for signals it sends out to return and uses it to deduce distances. In other words, Lidar is a more advanced version of laser distance measurement.

Lidar systems are an important part of autonomous transport, and they are even being used in quality robotic vacuum cleaners. Lidar systems are often used together with other means of measuring distances, such as radars and infrared radars, each of which affects the penetration of the beam, the distance, the precision of the created image and the materials observed.

Laser is not the only method for measuring distance. Images taken from different directions can be compared to each other, and distances can be calculated with the help of the changes in angle. With structures such as compound eyes, the same phenomena can be achieved without a traditional lens, directly producing three-dimensional images. This requires photons coming from different directions to be distinguished from each other and the observations to be combined by computational means. Similar methods can be used to form images of objects located around the corner, people behind a wall or a material structure by analysing how pulses of laser light are reflected back or penetrate a substance. All these areas are undergoing rapid development, primarily at the research level.

Location can also be measured in relation to satellites or other radio beacons. GNSS systems have become more precise, even allowing centimetre accuracy under good conditions. If necessary, beacons can be added to these systems to improve precision. Satellite positioning is often used together with inertial equipment that allows location data to be maintained in a GNSS system's blind spots.

Resources and motive for development: Lidar systems are being developed for the needs of the rapidly widening market of autonomous transport. The great production volumes expected will affect investments in product development. New antenna technologies, orientation without moving parts and new frequency bands are also being researched in academic circles due to both scientific interest and the social significance of the subject area.

Computational imaging and flat cameras are being researched due to academic motives and the long-term business operations of the electronics industry. The objective is to increase scientific understanding and create new research tools and new applications for consumer electronics.

Impact on value-producing networks, ART 6																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	20	20	3	3	0	0	3	0	5	10	3	0	3	10	3	5	5	0	0	0	****651

Progress since the previous report: This ART combines two sections of the original report, namely "2.38 Cheap Lidar" and "2.39 Lenseless camera and image construction based on data analysis," each of which ranked in the second highest group.

The prices of Lidar systems have fallen considerably, and their quality has improved. In addition to mechanically rotating devices, solid-state devices are also under development.

A radical reduction in prices is anticipated with increasing production volumes. Short-range solid-state Lidars have already become inexpensive, and promises have also been made about inexpensive solutions suitable for use in vehicles outdoors.

The use of radar and THz frequency bands in imaging has become more common, and progress has been made in the capability to remove noise resulting from rain and fog from the image, for example. Flat cameras have advanced with the help of both computational image formation and a lens based on diffraction. These methods have also been applied to the examination of things at the microscopic level, use of wide and pliant surfaces as camera surfaces and recognition of hand positions in a user interface, for example.

Interesting sources published after the 2013 report (006)	
Short description of the link	**link**
A $250 Lidar with a range of 40 m	http://spectrum.ieee.org/automaton/robotics/robotics-hardware/sweep-lidar-for-robots-and-drones
A Lidar on a chip	http://spectrum.ieee.org/tech-talk/semiconductors/optoelectronics/mit-lidar-on-a-chip
Development prospects of inexpensive Lidar	http://spectrum.ieee.org/transportation/advanced-cars/cheap-lidar-the-key-to-making-selfdriving-cars-affordable
Velodyne: The VLS-128 meets the needs of level 5 autonomy	https://www.theverge.com/2017/11/29/16705674/velodyne-lidar-128-autonomous-vehicles-driverless-cars
GPS with centimetre-level accuracy	http://spectrum.ieee.org/cars-that-think/transportation/sensors/centimeterlevel-gps-positioning-for-cars
A radar for small devices	http://www.fujitsu.com/jp/group/mifs/en/resources/news/press-releases/2017/0605.html
Computational imaging through materials, a review	http://www.nature.com/news/optics-super-vision-1.16877
The OPAL Lidar under difficult conditions	https://www.researchgate.net/publication/268194694_Characterization_of_the_OPAL_Obscurant_Penetrating_LiDAR_in_various_Degraded_Visual_Environments
Flat metamaterial lenses for the IR/THz band	https://phys.org/news/2017-11-ultrathin-flat-graphene-metalenses-gain.html
Several newcomers to the market of inexpensive solid-state Lidar	https://www.forbes.com/sites/alanohnsman/2017/12/20/quanergy-ramps-up-low-cost-lidar-production-as-laser-vision-battle-intensifies/
Adaptive solid-state Lidar, 300 m – accuracy of 0.1 degrees	https://www.technologyreview.com/s/609718/a-new-sensor-gives-driverless-cars-a-human-like-view-of-the-world/
Lensless imaging with the FlatCam, an overview	http://arxiv.org/pdf/1509.00116v1.pdf
The SPAD camera sees around corners	http://spectrum.ieee.org/tech-talk/semiconductors/optoelectronics/camera-that-tracks-hidden-moving-objects-could-aid-rescue-missions-and-avoid-vehicle-collisions
Femtosecond lasers in network analysis	http://spectrum.ieee.org/tech-talk/at-work/test-and-measurement/femtosecond-lasers-drive-a-new-generation-of-network-vector-analyzers

Interesting sources published after the 2013 report (006)	
A flexible camera surface & computational imaging	http://news.discovery.com/tech/gear-and-gadgets/wallpaper-camera-wraps-around-any-surface-160415.htm
Lensless ultraviolet imaging with a resolution of 26 nm	http://www.osa.org/en-us/about_osa/newsroom/news_releases/2015/pushing_the_limits_of_lensless_imaging/
Rapid development of CMOS imaging chips	http://www.eetimes.com/document.asp?doc_id=1325655
Lidar vs radar	http://spectrum.ieee.org/tech-talk/aerospace/aviation/laser-makes-more-accurate-radar-system
Hitatchi is developing a lensless camera	http://www.hitachi.com/New/cnews/month/2016/11/161115.html
An inexpensive, precise, flat lens (diffractive)	https://www.sciencedaily.com/releases/2016/06/160602151840.htm
An inexpensive Lidar for braking	http://spectrum.ieee.org/cars-that-think/transportation/sensors/cheap-lidar-for-automatic-braking

2.1.7 IR, THz and GHz transmitters and receivers (007) ***

Target area of the ART: Microwaves, terahertz waves and infrared waves fall between radio waves and the wavelengths of visible light. Each of these frequency bands has special characteristics in terms of how beams advance or are reflected by materials, how much information they can be used to convey and how demanding their modulation and reading the modulated signal is.

In addition to communication, these wavebands can be used for energy transmission and analysis of materials and distances, for example. As the frequencies in question are clearly higher than radio technology, the digital manipulation of signals and waveforms in particular requires great speeds from optoelectronics and electronics.

General description of the development: The best-known applications in the gigahertz range have been radar, telecommunication and microwave applications at the lower end of the frequency band. For example, at 3 GHz, we talk about 10 cm wavelengths. An essential factor for development has been the ability to make antennas shorter than a wavelength.

New technologies allow terahertz waves to be manipulated and analysed. There are already specialty shops for devices based on terahertz waves. Research results and practical applications are being created in abundance. The THz waveband allows relatively precise radar images despite snow or rainfall, for example.

In spectroscopy, the THz waveband produces more detailed information than the infrared waveband because its lower amount of energy does not disturb the examined object as easily. THz waves can be used to make wireless communication several times faster than the WiFi signal in the GHz waveband.

Precise reception of signals in the infrared waveband enables fast communication as well as wireless transmission and reception of energy and devices such as thermographic cameras and material scanners. An efficient infrared receiver that transforms radiation into electrical signals can recover thermal energy from processes in which the temperature difference is too low to be otherwise utilised efficiently.

Resources and motive for development: The electronics industry is developing and equipping its devices with increasingly fast methods for the needs of telecommunication. This development directly serves the rapidly growing needs of a wide range of consumers. In the areas of energy transfer and recovery and more versatile analysis of waveforms, the motive for development is narrower and more long term. The research is academically interesting and active in all areas.

Impact on value-producing networks, ART 7																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	10	0	3	5	3	5	0	0	3	0	0	0	5	0	10	5	0	3	0	***285

Progress since the previous report: The closest equivalent of this section in the previous report was "2.44 Graphene based terahertz devices," which ranked in the second most important group.

Since the previous report, researchers have learned to handle both gigahertz waves and terahertz waves considerably more easily. Single microchip solutions have been introduced in both areas, with researchers managing to equip the same chip with an antenna and even a directional antenna.

A terabit per second speed has been achieved between cities through a fibre connection. In the WiFi band and THz band, researchers have developed fully passive or very low energy circuits that receive the power they need from the signal they receive.

A focus lens has been implemented for THz waves, and a THz receiver has been printed on flexible material. Several sensitive photodetectors have been developed for the IR band both for recognising beams and turning them into electrical energy.

Interesting sources published after the 2013 report (007)	
Short description of the link	**link**
A THz transmitter and receiver on a single chip	https://phys.org/news/2017-02-future-terahertz-chips.html
THz in spectroscopy	http://www.photonics.com/Article.aspx?AID=56212
Nokia & DT: Demonstration of a terabit fibre connection	https://www.engadget.com/2016/09/18/nokia-terabit-fiber-optic-speeds/
Internet of nanothings – THz nanoantennas as a network	http://www.buffalo.edu/news/releases/2016/11/002.html
Passive WiFi (almost no power)	http://www.eurekalert.org/pub_releases/2016-02/uow-uea022316.php

Interesting sources published after the 2013 report (007)	
A chip that produced millimetre waves (GHz band)	https://techcrunch.com/2017/02/07/tiny-chip-looks-deep-inside-your-body-with-millimeter-wave-radiation/?ncid=rss
Interscatter – a non-powered antenna reflects a modified received wave	https://techcrunch.com/2016/08/17/devices-could-recycle-radio-waves-instead-of-transmitting-them-with-new-interscatter-technique/
An online store for THz equipment has been opened	http://www.prweb.com/releases/terahertz/032014/prweb11686016.htm
Sensitive photodetector for the UV to IR range	https://www.eurekalert.org/pub_releases/2016-11/au-ldw111416.php
Graphene plasmonics for the THz to IR range	http://pubs.acs.org/doi/abs/10.1021/nn406627u
A flexible THz detector (with thin film technology)	https://www.theengineer.co.uk/graphene-detector-terahertz/
Detection of IR beams and energy harvesting with graphene	http://www.photonics.com/Article.aspx?AID=61020
A THz transmitter delivers speeds of over 100 Gb/s	http://spectrum.ieee.org/tech-talk/telecom/wireless/new-terahertz-transmitter-outshines-the-competition
A sensitive microwave photodetector made of graphene	http://spectrum.ieee.org/nanoclast/semiconductors/materials/first-graphene-photodetector-to-operate-in-the-microwave
A 60 GHz antenna with a CMOS circuit	https://www.intechopen.com/books/microwave-systems-and-applications/innovative-techniques-for-60-ghz-on-chip-antennas-on-cmos-substrate
Doubled speed through a radio	http://www.technologyreview.com/news/532616/simple-circuit-could-double-cell-phone-data-speeds/
A lens for THz waves	http://www.eurekalert.org/pub_releases/2016-03/bu-rdn031416.php

2.1.8 LiFi networks and other LED technology (008) ***

Target area of the ART: Visible light has many areas of application. Its use has been limited by challenges relating to the production of light and adjustment of the desired wavelength. In recent years, LED technology has become more common due to its energy efficiency and flexibility. It is based on electroluminescence. Light is created in a diode as a result of a current when an electron drops to a lower level of energy through a hole in the diode. This releases a photon, the wavelength of which corresponds to the drop in the energy level.

LED technology has reduced the cost of telecommunication in optical fibres. The high efficiency of new LED lights and the capability to choose a precise wavelength to emit have decisively improved the cost-effectiveness of cultivation based on artificial light. LED technologies have also enabled high-quality TV monitors and other display surfaces.

General description of the development: The operating principle behind LED was invented at the beginning of the 20th century. The first functional LED was achieved in the 1960s. At first, LED lights were small, one-coloured lights. High-powered LED lamps were still expensive at the beginning of the 2000s. With the help of new electronics materials, LED technology has advanced rapidly, and its range of applications has widened.

LED technology that is suited for wireless room-specific communication has been named “LiFi connection.” Data transfer is based on the very high switching speed of LEDs. The theoretical speed is 10,000 times higher than the presently widely used wireless WiFi connection. Researchers have achieved a speed of 224 Gbps. The first LiFi product, Li-1st, was published in 2014.

In display devices, OLED displays have widely replaced other technologies. Large-sized and precise 4K displays are becoming common consumption electronics. QLED technology competes with it. In QLED technology, quantum dots made into graphene allows diodes to produce light with high efficiency at varying wavelengths. So-called microLED technology is anticipated to replace OLED technology and other technologies, particularly in portable devices and later in large-sized and increasingly precise display surfaces.

In lighting, LED technology has become relatively widely used in the 2010s. The market for energy-efficient lighting is excepted to continue to grow to $300 billion on a global level by 2025. Improving efficiency, decreasing prices and the capability for wavelengths favourable to plants is continuously increasing the popularity of artificially lit indoor farming.

Resources and motive for development: The development motive is strong in the areas of the lighting industry, entertainment electronics and telecommunication technology. Of the areas mentioned, LiFi is still at the launch phase, and customer financing does not yet support significant product development investments. All the subject areas involve significant academic interest.

Impact on value-producing networks, ART 8																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	0	0	1	10	0	0	10	0	0	0	0	3	0	0	0	5	5	0	5	0	***234

Progress since the previous report: The closest corresponding sections in the previous report were “2.24 Large haptic screens” and “2.96 LED ‘radio’,” which ranked in the second and fourth groups, respectively. At the time the previous report was written, the term LiFi was not yet in use. Now LiFi networks are being introduced for commercial use. Products include LiFi USB adapters and LiFi lamps, among other things.

Large display devices were rare at the beginning of this decade. LED first replaced the backlight previously used in LCD displays. Now, OLED displays that are rapidly becoming common already feature coloured LEDs and none of the older LCD technology.

Furthermore, QLED technology that uses quantum dots and is capable of great colour saturation has been placed on the market. Another technology expected to enter the market is microLED technology, which is anticipated to first take over parts of the market for small wearable devices, and the delivery volumes are anticipated to rise to hundreds of millions of pieces over the next few years. Very high definition 8K and 2K display devices based on microLEDs have already been demonstrated.

At the time the previous report was written, LED lamps were still expensive. Progress has been fast since then. The prices of LED lamps have plummeted, making indoor farming a rapidly rising sector. Illuminated surfaces are now being discussed as something new thanks to LED technology.

Interesting sources published after the 2013 report (008)	
Short description of the link	**link**
PureLiFi 15Gb/s, laser-LiFi to reach 100Gb/s	https://www.nextbigfuture.com/2017/10/led-and-laser-wifi-replacement-can-boost-speeds-to-100-gigabits-per-second-without-interference.html
LiFi achieves 224 Gbps speed	http://www.electronics-eetimes.com/en/li-fi-achieves-224-gbps-data-transmission-speeds-with-room-scale-coverage.html?cmp_id=7&news_id=222923915
LiFi USB stick	http://bloom.bg/2mppxTU
The market for microLED is expected to grow rapidly	http://www.eenewsanalog.com/news/microled-display-market-poised-lift-0
The first passive QLED quantum dot TV on the market	https://www.forbes.com/sites/johnarcher/2017/09/19/what-is-qled-and-why-does-it-matter/
A photonics modem (NASA)	http://www.kurzweilai.net/nasa-engineers-to-build-first-integrated-photonics-modem
Google Glass 2.0 could be powered by microLEDs	http://www.techradar.com/news/google-glass-comeback-could-be-powered-by-over-eye-micro-led-displays
Energy-efficient lighting to be valued at $300 billion in 2025	http://news.sys-con.com/node/4190907
Ultraviolet LED in disinfection	http://www.savonsanomat.fi/uutiset/talous/led-suutari-sai-kansainvalisen-laatupalkinnon/1971147?pwbi=d845cd2b75ec522f8b82403277f0555b
A quantum dot-base white-blue LED	http://www.eurekalert.org/pub_releases/2015-06/hu-niu060515.php
LiFi identification, etc.	http://spectrum.ieee.org/tech-talk/telecom/wireless/fujitsu-forges-lifilike-qr-code

2.1.9 Plasmonics and photonics (009) *

Target area of the ART: Plasmonics describes the complex interaction of light and electricity. When electrons vibrate as a group in a substance, e.g. similarly to the rippling of water, these waves of energy are referred to as plasmons. A single plasmon is a quantised quasiparticle. If the vibration occurs near a photon's frequency, it prevents the photon from passing through a material. Vibration occurring at a surface can reflect the photon or even capture it and form a new quasiparticle, an exciton-polariton, together with a plasmon.

The quality of the material affects the vibration of electrons, but it is also affected by the shape and size of the object. In order for effects, such as structural colours, to be added to visible light, the shapes should be in the lower 400-nm range. The understanding relating to this can be used to produce transparent materials, identify surface materials and modulate light, for example.

With graphene, plasmonics has been used successfully to create clear effects that control light and electricity. A considerable proportion of research takes place within the visible light band as well as the terahertz and infrared bands. Several other materials are being tested to develop various practical applications.

General description of the development: By modulating the frequency and phase of light, researchers have sought to multiply the capacity of individual optical fibres. Photonic interconnects have been miniaturised and the proportion of photonics in circuit technology has increased. Attempts have been made to circumvent the slowness of electrons and heat dissipation from resistors by using signals based on photons.

The utilisation of optical vortices is being researched. This involves modulating the axis angle of individual photons in communication. The same wavelength can be used to modulate not only amplitude and frequency but also the axis angle. The only thing limiting the amount of information transmitted is the increase in the axis angle's adjustment and detection accuracy. In theory, an individual photon can incorporate a great amount of chosen information if its angle can be read precisely.

Plasmonics is used to implement small comb antennas that direct the transmission signal. The reception of the signal by the closer or farther branches of the comb is delayed with plasmonics so that the angle of the wave transmitted or received is as desired. The antennas can also be made shorter by slowing down the speed in which light progresses. In this way, antennas shorter than the wavelength can be made to work well in integrated circuits.

Transparent materials developed include bright aluminium and electromagnetic absorbers, among other things. Researchers have also developed a black material with a reflectivity of only 0.035%. Applications of plasmonics in identifying materials and energy recovery are described in the other ARTs.

Resources and motive for development: Most plasmonics research is carried out based on academic interest, but telecommunication and the electronics industry are also increasingly interested in this field.

Impact on value-producing networks, ART 9																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	0	0	10	5	5	0	0	0	0	5	0	3	0	5	0	0	0	0	*99

Progress since the previous report: The closest equivalent ART in the previous report was "2.97 Wireless transmission 2.5 terabytes per second (vortex beam)," which ranked in the second most important group. After the publication of the report, it turned out that the testing equipment is very sensitive and demanding, and progress has in that respect been slow at the level of publications. However, clear progress has been made with testing equipment implemented on a nanoscale, and it appears obvious that the technology will become practical during the period examined.

The use of plasmonics in microchip-level directional THz and IR antennas is a new and rapidly progressing field, as are optical frequency comb applications. Spaser technologies are also progressing rapidly. The most recent piece of news at the time this report was written was a 22 nm spaser that kills cancer cells within the body after detecting them.

A nanoscale lens has been made using graphene. Photon antennas, plasmonic imaging methods and devices that can be implemented with Weyl particles are also among recent studies that you can explore by clicking the source links below. It is apparent that the entire field of plasmonics will create significant new innovations, the character of which cannot be widely evaluated at this time. The impacts will at least extend to material technology, telecommunication, medicine and optics.

Interesting sources published after the 2013 report (009)	
Short description of the link	**link**
Measurement of exciton-polaritons in graphene, the wavelength can be adjusted	http://nanotechweb.org/cws/article/tech/70494
A nanoscale spaser kills cancer cells	http://news.gsu.edu/2017/08/21/spaser-can-kill-circulating-tumor-cells/
Plasmonics enables a circuit-level directional antenna in the THz/IR range	https://arstechnica.com/science/2017/07/a-future-for-light-powered-wireless-connectivity-thanks-to-graphene/
An image sensor for the IR and visible light range (quantum dots)	https://www.eurekalert.org/pub_releases/2017-05/iiop-gaq052617.php
A nanoscale vortex beam generator	https://www.nature.com/articles/srep29547
High-throughput detection of virus by plasmonics	https://link.springer.com/chapter/10.1007/978-94-024-0850-8_13
Photonic interconnects inside a processor microchip	http://www.eurekalert.org/pub_releases/2015-12/uoc--edf121815.php
1 Tb/s data transmission with optical frequency combs in one waveband	http://www.scienceworldreport.com/articles/14261/20140425/using-light-and-microresonators-for-ultra-fast-data-transmission.htm
The production method of nanoantennas (light) advances	https://www.eurekalert.org/pub_releases/2016-04/iu-hn-042716.php
Type II Dirac fermions, Weyl particles usable in devices?	https://physics.aps.org/articles/v10/74
A transparent electromagnetic absorber	http://www.eurekalert.org/pub_releases/2015-07/au-rdt072015.php
Nanoscale photonics with copper, solves problems	http://www.eurekalert.org/pub_releases/2016-02/miop-ppa022516.php

Interesting sources published after the 2013 report (009)	
Nanoscale light-emitting device	http://www.eurekalert.org/pub_releases/2015-07/uow-nld071315.php
An efficient electro-optic modulator the size of a bacterium	http://www.mwee.com/news/electro-optic-modulator-size-bacteria-cut-energy-use
A quick plasmon-based way to turn electricity into light	http://news.mit.edu/2016/new-way-turn-electricity-light-using-graphene-0613
Tuning of the IR to THz range with moiré nanosphere lithography	http://www.nanowerk.com/spotlight/spotid=44242.php
A nanoscale lens from graphene	http://www.gizmag.com/optical-lens-one-billionth-meter-thick/41588/
Graphene nanoribbons emit an intense adjustable light	https://phys.org/news/2018-01-individual-graphene-nanoribbons.html
Photonic molecules	http://phys.org/news/2013-09-scientists-never-before-seen.html
Photon mass drag hypothesis	http://www.aalto.fi/fi/current/news/2017-06-30/
A method for imaging THz plasmons	http://phys.org/news/2016-11-on-chip-thz-graphene-plasmons.html
The black material Vantablack absorbs all but 0.035% of visual light	http://www.independent.co.uk/news/science/blackest-is-the-new-black-scientists-have-developed-a-material-so-dark-that-you-cant-see-it-9602504.html

2.1.10 Small particle accelerators, femto and nanolasers (010) **

Target area of the ART: The synchronisation of visible light or other photons provides laser beams with special characteristics. A synchronised beam retains its direction better than a normal ray of light. A greater amount of energy can be packed into the same small area. The beam can be used for communication or measurement, and it can be used to affect targets. High-performance lasers can e.g. be used to cut thick steel, but high-performance lasers and their weaponised use is addressed in another ART. Lower-performance lasers can be used to make goods with a 3D printer, perform eye surgeries and carry out numerous other tasks.

For measurement purposes, a laser beam can be modulated as a function of time. This makes it possible to deduce when a reflected signal was sent and how long a distance it has travelled. A laser can transmit beams as a continuous beam or as short bursts. The latter case is typically referred to as a femtosecond laser.

Other particle beams, such as electron beams, are in some aspects similar to lasers. Particle accelerators accelerate electrons, protons or other elementary particles to great speeds. High-energy particle beams are used to study and manipulate the properties of matter.

General description of the development: Lasers in general and femtosecond lasers in particular have evolved rapidly. The minimum size of lasers has decreased radically, and the range of wavebands has expanded from microwaves all the way to X-rays. Lasers have become tuneable; the frequency band can be changed quickly. Even the consecutive pulses of femtosecond lasers can be sent at different frequencies.

Particle accelerators have traditionally been very large devices. Now it is possible to shrink them into the size of portable devices and even the size of a microchip. In addition to actual elementary particles, plasmons and other quasiparticles can be generated on a microchip level. Development has progressed so rapidly over the last few years that the potential applications of the existing capabilities are not even fully understood.

Resources and motive for development: The primary driver of development is academic research. This technology has significant applications, but the impacts are long-term in the sense that companies' product development motive for the development of new technologies is not sufficient. On the other hand, academic research advances constantly, and the research contributions seem to be considerable.

Laser technology has already had a great impact on telecommunication, medicine, consumer electronics, industry and autonomous transport. This impact can be expected to grow materially in the future, with increased interest from companies.

Impact on value-producing networks, ART 10																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	5	5	3	1	0	0	0	0	3	5	0	5	0	5	0	3	5	0	0	0	**160

Progress since the previous report: This ART is new and was added because of very rapid development in this field. An example of recent development: the entire spectrum of visible light has been reproduced with one laser adjusted in real time. Potential areas of application for this ART include display devices and LiFi networks.

Researchers have been able to reduce both microwave lasers and terahertz lasers to the size of a microchip. The pulses of femtosecond lasers have been amplified to five petawatts (1,015 W) of power. Great short-term intensity produces effects that cannot be achieved with the same amount of energy over a longer period of time due to heat transfer, for example.

Researchers have successfully reduced the size of particle accelerators. A device that can fit on a table can sling electrons to energy levels of several giga-electron volts. It seems possible that small devices can be used to produce the same quality particle beams that have until now required accelerators spanning several kilometres.

Interesting sources published after the 2013 report (010)	
Short description of the link	link
A particle accelerator on a chip, speculation on applications	https://www.engadget.com/2017/10/30/slacs-accelerator-on-a-chip-could-revolutionize-modern-medici/

Interesting sources published after the 2013 report (010)	
A tuneable nanolaser & THz	http://www.nature.com/ncomms/2015/150420/ncomms7939/full/ncomms7939.html
A graphene nanolaser (spaser)	http://www.extremetech.com/extreme/180728-graphene-spaser-brings-optical-computing-to-the-nano-scale
An inexpensive femtolaser for surface finishing	http://www.eurekalert.org/pub_releases/2015-08/fopu-sia082015.php
A miniaturised particle accelerator on a chip	http://phys.org/news/2013-09-chip.html
Study of graphene in magnetic fields could lead to new THz lasers	http://phys.org/news/2014-11-magnetic-fields-lasers-elicit-graphene.html
A rice-sized microwave laser	http://www.natureworldnews.com/articles/12016/20150116/rice-sized-laser-leads-the-way-in-quantum-computing.htm
A white laser with quantum dots	http://spectrum.ieee.org/tech-talk/semiconductors/devices/the-first-white-laser
A small, efficient particle accelerator, tabletop model	http://phys.org/news/2014-12-world-compact-tabletop-particle.html

2.2 Artificial intelligence and algorithmic deduction

Artificial intelligence and algorithmic deduction are objects of wide global attention because of many recent breakthroughs. In the future, an increasing number of data processing tasks can be automated. This will lead to leaderless organisations on the one hand and more complex bureaucracy on the other hand. Development is focused on self-learning systems. The attention is no longer on machines solving pre-programmed problems but their ability to learn from the situations they encounter and progress towards new solutions somewhat similarly to researchers or children.

In demonstrations, artificial intelligence is able to identify human diseases, play video games it is previously unfamiliar with, recognise image content, solve middle school level mathematics problems and even achieve scientific breakthroughs, for example.

New actors have published flexible platforms for the development of AI applications. When a platform becomes common, this allows applications and devices developed for this platform to exchange skills. So if one robot identifies and solves a problem situation, it can share this information with other machines that use the same platform.

The impacts of AI are not limited to data processing. AI allows robots and devices operated by humans to recognise their environment and learn to perform tasks. Development is assessed to have a highly significant impact on existing jobs and even social structures. The aim is to limit the use of AI in military technology. Devices that make independent decisions on killing will change the nature of war in unpredictable ways.

Artificial intelligence and algorithmic deduction	
ART-ID	**The ARTs in the group**
11	Speech recognition/synthesis and interpreting
12	Neural networks and deep learning
13	Pattern recognition and other AI platforms
14	Facial and emotion recognition and projection
15	Verbot/chatbot, talking/corresponding robots
16	Real-time 3D modelling of environment
17	Easy 3D imaging of parts
18	Deep learning material for expert AI

2.2.11 Speech recognition/synthesis and interpreting (011) ****

Target area of the ART: People take care of most things by talking amongst themselves if they are face to face with each other in the same space. People use machines through forms, switches and other operating methods, as there has usually not been a practical alternative for it. This has been due to the specific form or simple operation of machines on the one hand and the ambiguity of human speech and difficulty of interpretation on the other hand.

With the development of AI, applications are becoming increasingly diverse. At the same time, AI facilitates machine interpretation of natural language in both spoken and written form. Machine interpretation also facilitates communication between humans. Talking machines or machines that understand speech are also needed by mute, deaf and blind people, each group for their own reasons.

General description of the development: Several major organizations are developing machine translation with the help of learning AI. The scope of the user base is one of the prerequisites of learning. For example, Microsoft has added a simultaneous interpretation feature to its free-of-charge telecommunication application Skype. The test version supports English, Spanish, Italian and Chinese. Microsoft believes that the quality of the translations will improve with use. For text-based communication, Microsoft supports translation between 50 different languages. Speech recognition and translation features are also offered by many other operators in free-of-charge cloud services and smartphones.

There is a wide range of paid speech recognition software available, with the best of them reaching an accuracy of 95%. Speech recognition and translation are closely related to recognition of the meanings expressed by humans and the analysis of these meanings through frames of reference. Speech synthesis has advanced from producing understandable speech to being able to imitate the speaker’s own way of speaking in a foreign language or the way another chosen person speaks.

Resources and motive for development: The primary motive of research and development has changed to commercial. The ability to offer services and communication tools in as many languages as possible is important to global companies. Many of them also have access to the extensive teaching materials required to teach AI as well as feedback, which is necessary for learning. Academic research has clearly taken a backseat in this area, with the exception of imitation.

Impact on value-producing networks, ART 11																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	3	3	0	3	0	0	3	10	5	5	10	3	10	5	5	5	5	10	5	3	****558

Progress since the previous report: The corresponding ART in the previous report was "2.17 Automatic speech recognition and translation," which ranked in the second group. It has now been expanded to include speech synthesis. At the time the previous report was published, simultaneous interpretation of English speech to Chinese had just been demonstrated. Now that and many other language pairs are available both freely online and as commercial products. Speech recognition, translation and synthesis have all progressed from rule-based technologies to neural-based learning systems.

Several manufacturers supply or have promised to supply earpieces and microphones that allow people who speak different languages to hear each other's speech in their own language. The latest newcomer to the market is Google with its interpretation capacity of 40 languages. With speech synthesis, Lyrebird is able to simultaneously make speech mimic the speech of the chosen person. Speech synthesis has also been successfully controlled directly by a brain. A research patient with ALS can control a speech synthesiser through a brain implant.

Interesting sources published after the 2013 report (011)	
Short description of the link	**link**
The Lyrebird software mimics people in real time	https://www.scientificamerican.com/article/new-ai-tech-can-mimic-any-voice/
MS achieves a word error rate of 6.3% in speech recognition	http://blogs.microsoft.com/next/2016/09/13/microsoft-researchers-achieve-speech-recognition-milestone/
More natural speech synthesis – DeepMind's WaveNet – raw audio	https://deepmind.com/blog/wavenet-generative-model-raw-audio/
Google Pixel Buds: simultaneous interpretation between 40 languages	https://www.engadget.com/2017/10/04/google-pixel-buds-translation-change-the-world/
An earpiece translates in real time, pre-orders of Waverly's Pilot	https://www.gapyear.com/news/267902/new-earpiece-translates-speech-in-real-time
An earpiece that translates from Lingmo	http://www.wired.co.uk/article/translation-earpiece-one2one-released
A patient with ALS controls a speech synthesiser with a brain implant	https://www.ecnmag.com/news/2016/11/paralyzed-als-patient-operates-speech-computer-her-mind

Interesting sources published after the 2013 report (011)	
Simultaneous interpretation tool for Skype	https://www.pcworld.com/article/3022752/software/skypes-magical-real-time-language-translator-tool-goes-live-for-all-windows-users.html
Nuance's IVR for customer self-service	http://www.nuance.com/for-business/customer-service-solutions/loquendo-small-business-bundle/index.htm
An AI lipreads with 50% accuracy	https://arxiv.org/abs/1611.05358

2.2.12 Neural networks and deep learning (012) ****

Target area of the ART: Artificial intelligence, or AI, has been talked about for a very long time. The goal has always been to enable a machine to perform human tasks that have been unreachable with previous programming methods. Many of the things that are problematic for a machine come naturally to humans. Machine vision and pattern recognition, understanding spoken language, playing games, finding the best routes or methods of carrying things out and the ability to converse with humans are examples of typical challenges.

Algorithmic solutions and new programming techniques have been found for many programming tasks, resulting in the boundary of AI being moved further and further away, all the way to "true" understanding, whatever that means. The current mainstream development solves the problems in AI by means of technology that simulates neural networks and multi-layered deep learning. The goal is for a machine to be able to handle an increasing number of tasks.

General description of the development: The development of AI has sped up as a result of many problems in machine vision being resolved. The development has partly been based on self-organising maps invented in Finland. In contrast to them, learning and concept formation in deep learning occur in layers, rather than on a single layer. AI first learns the basics and then the larger entities and relations formed by these basics, layer by layer.

For the time being, the neural networks used by AI are simulated with ordinary computers and graphics processors, but equipment manufacturers are developing special processors for the computing of tensors used by deep learning algorithms, in addition to developing other processors that directly implement learning structures similar to the nervous system. This equipment development is addressed in more detail in ART 23.

AI can learn from relatively few observations and experiences if it has been provided with boundary conditions and a conceptual model. If the structure needs to be learned based on observations, the learning speed depends on whether the observations are pre-classified. It has been noted in complicated tasks that an AI has been unable to fully learn even after a million observations, and a hundred million additional observations materially improves the outcome. For the time being we can say that humanlearning requires much fewer observations, but an AI can process individual observations more quickly. The skills of an AI can also be replicated.

A key new method in the development of AI is using another AI that generates teaching material or provides feedback. Today, the learning of an AI comprises schooling the neural network, with positive and negative feedback playing a key role. Learning occurs quickly if the high-quality production of situations and feedback can be automated.

Resources and motive for development: In the development of AI, commercial interests have become dominant. Academic research is active, but breakthroughs are achieved by major companies like IBM, Google and Microsoft, which have access to massive data repositories required for teaching AI or the ability to organise their crowdsourced acquisition.

Impact on value-producing networks, ART 12																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	10	10	5	10	3	3	5	10	5	20	20	10	5	20	10	10	5	5	5	20	****955

Progress since the previous report: The closest corresponding ART in the previous report is "2.34 Predictive analytics based on self-organizing data," which ranked in the third group. At the time, the successes in self-organising AI were very limited and only suitable for solving a relatively narrow range of questions. This situation is changing rapidly. Learning AIs play a key role in autonomous transport, language translation, machine vision and many applications of the financial sector. AIs learn to play games by playing against themselves and learn to create images that look like humans with another AI criticising the deficiencies in the images.

AIs have learned to play both chess and Go better than master players. AIs have also solved mathematical problems. AIs can perform on the level of professionals in diagnostics, driving a car, image editing and several other tasks. In a language translation competition, an AI performed at the average level of professionals. In medical tasks, machine vision recognises certain anomalies better than the average professional. All of these breakthroughs are very recent.

Interesting sources published after the 2013 report (012)	
Short description of the link	**link**
Great results from neural machine translation, Google	https://research.googleblog.com/2016/09/a-neural-network-for-machine.html
Machine vision achieves a lower error rate than humans	https://siliconangle.com/blog/2017/09/27/google-brain-chief-jeff-dean-ai-beats-humans-computer-vision-healthcare-will-never/
Analysis of the limits and potential of AI in various areas	https://ai100.stanford.edu/sites/default/files/ai_100_report_0831fnl.pdf
AI – imperfect deduction, AI wins at poker	http://www.nature.com/news/game-theorists-crack-poker-1.16683

Interesting sources published after the 2013 report (012)	
MIT: AI is able to explain its reasoning	https://www.engadget.com/2016/11/01/mit-makes-neural-nets-show-their-work/
The pattern recognition ability of AI is improving constantly, statistics	https://www.eff.org/ai/metrics
A neural network (AI) develops a neural network	https://github.com/kootenpv/neural_complete
An AI solves a difficult mathematical problem	https://www.newscientist.com/article/dn25068-wikipedia-size-maths-proof-too-big-for-humans-to-check
GAN – AlphaGo Zero's skills quickly evolved beyond human level	https://www.youtube.com/watch?v=WXHFqTvfFSw
A $16 billion market for deep learning based diagnostics	https://ark-invest.com/research/deep-learning-based-diagnostics
Examples of deep vision, AI, deep learning	https://github.com/kjw0612/awesome-deep-vision
MIT: AI evaluates how memorable photos are	https://splinternews.com/mit-created-a-tool-that-will-tell-you-how-memorable-you-1793853617
NIMA (AI) recognises beautiful images	https://arxiv.org/abs/1709.05424
AI performs in the 75th percentile in an intelligence test	http://www.rdmag.com/news/2017/01/ai-model-created-performs-human-levels-standard-intelligence-test
Deep learning AI, background	http://www.ted.com/talks/jeremy_howard_the_wonderful_and_terrifying_implications_of_computers_that_can_learn
Mathematical patterns behind innovations, a model	https://www.technologyreview.com/s/603366/mathematical-model-reveals-the-patterns-of-how-innovations-arise/
Funding for AI start-ups on the rise	http://www.bloomberg.com/news/articles/2015-02-03/i-ll-be-back-the-return-of-artificial-intelligence

2.2.13 Pattern recognition and other AI platforms (013) ****

Target area of the ART: The development of AI for the traditional IT environment is a challenging task. The programming expertise required for an AI system, the vast amount of data required for teaching AI, and the great amount of computing power required for learning raise the bar high.

When pursuing useful applications, it is practical to choose devices and application environments that are intended particularly for the development of AI. These are referred to as platforms in this section. This ART includes processors that are particularly suitable for neural computing, full data centre services, complete AI development software or cloud services and even fully taught systems with regard to the lowest layers or models. The purpose of these platforms is to speed up the development of new AI applications and facilitate their use.

General description of the development: Processors optimised for AI have been developed by NVidia, IBM, Google and HP, among others. The development of processors is addressed in another ART, but it is also relevant to note in this section that many efficient development environments and platforms are tied to processes.

Several AI development environments are available as open source code. Extensive systems are offered by IBM, Google, Microsoft and Amazon, among others. Platforms may already be equipped with interpretation of natural and spoken language, and they may have been taught basic machine vision, which identified basic things from images.

Platforms are most commonly provided as cloud services that are paid for according to usage. Notable operators are constantly developing new generic capabilities and applications for their own platforms. These can be offered to consumers with funding from advertising, as part of the sale of equipment, as part of a platform's functionality or as part of expert systems developed for companies.

Resources and motive for development: The motive for financing platform development is clearly commercial. The proportion of academic research has decreased, but it continues to be significant in many application areas. Crowdsourcing contributes greatly to the collection of teaching material and feedback. Start-up funding makes it possible to compete on the platform market, at least in narrow segments.

Impact on value-producing networks, ART 13																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	3	5	5	5	0	0	5	10	5	10	5	0	0	3	3	3	3	5	0	3	****365

Progress since the previous report: The corresponding ART in the previous report was "2.30 Pattern recognition and pattern search services," which rose to the second most important group. Back then, new pocket cameras could recognise a smiling face, photo archives recognised familiar people and police cameras recognised register plates. No platform had yet emerged as a clear AI development platform, and deep learning had not yet been widely talked about.

Now, a great number of deep learning environments have been placed on the market as both software products and cloud services. Development has advanced in an increasingly open direction, particularly after Microsoft, IBM, Google, Amazon and NVidia understood how essential it is to attract consumers or major organisations to use their platforms in order for the platforms to learn as much as possible.

The competition in AI has been understood as competition between platforms in the same way that telecommunication practices or operating systems have been competing with each other. They are subject to the law of increasing marginal utility, i.e. an increase in the number of users increases value. Because of this, platforms are now being developed and offered to users through a low threshold. In addition to productised platforms and platforms offered as a service, AI software is also available with open source licences to those who want to create their own platforms or develop algorithms further.

Interesting sources published after the 2013 report (013)	
Short description of the link	**link**
Dr Watson in diagnostics, general description, benefits	http://www.businessinsider.com/ibms-watson-may-soon-be-the-best-doctor-in-the-world-2014-4
DeepMind becomes self-learning (unsupervised)	http://thenextweb.com/artificial-intelligence/2016/10/17/deepmind-ai-platform-can-now-learn-without-human-input/
Comparison of deep learning frameworks	https://github.com/zer0n/deepframeworks/blob/master/README.md
Google's image recognition is at a good level	https://www.engadget.com/2016/09/23/googles-ai-is-getting-really-good-at-captioning-photos/
The AI Amazon Echo	http://www.popsci.com/amazon-echo-first-artificial-intelligence-youll-want-home?dom=fb&src=SOC
Microsoft makes its AI openly available	http://techcrunch.com/2016/01/25/microsoft-moves-its-cntk-machine-learning-toolkit-to-github/
Google's AI is learning AI development	https://www.technologyreview.com/s/603381/ai-software-learns-to-make-ai-software/
Open AI, Musk	https://medium.com/backchannel/how-elon-musk-and-y-combinator-plan-to-stop-computers-from-taking-over-17e0e27dd02a

2.2.14 Facial and emotion recognition and projection (014) ****

Target area of the ART: The most natural way for a person to recognise another person is by the face. Faces and facial expressions are so important that the brain has a separate area for analysing them. Faces and facial expressions reveal a considerable amount about a person's character, state of mind and interests, and we are very interested in facial expressions.

When an AI recognises faces and gestures, a machine can monitor access rights or react empathetically to each person and his/her state of mind, for example. The projection of faces and facial expressions is also included in this ART. Seeing facial expressions helps us understand the meanings in communication.

This ART also includes facial recognition from the human genome. For example, this facilitates criminal investigation when DNA samples not matching any known samples are found at a crime scene.

General description of the development: Facial recognition by machines has been developed for a variety of purposes, ranging from familiar toys and automated sorting of digital images to the identification of criminals. The recognition of gestures and facial expressions helps machines learn the wishes of humans and change their approach as necessary. By understanding the dynamics of faces and facial expressions, we can animate the chosen faces for the needs of the film industry and game industry and the natural discourse between computers and humans, for example.

Machines are increasingly able to identify someone's emotions on his/her face. The identification of emotions and permanent features has been demonstrated by animating the speech and facial expressions of George W. Bush on the faces of several different public figures, for example. In the future, this means that we will be able to choose people we know or any public figure as characters in a movie, which is already possible in certain games.

The production of a facial image based on a DNA sample is now at a level that may be significantly useful in criminal investigation.

Resources and motive for development: Development is progressing as part of general AI development. Academic research plays a major role in the synthetic production of faces and emotions. The recognition of a face based on a genome is the only subject area in the ART that for the time being does not involve product development competition based on the electronics and entertainment industries or customer needs in the service sector.

Impact on value-producing networks, ART 14																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	1	0	3	0	0	3	5	10	10	3	3	3	5	10	10	5	3	10	5	****368

Progress since the previous report: The corresponding ARTs in the previous report were "2.14 Human recognition systems" and "2.15 Emotion management in robots and automatic recognition of emotions," both of which rose to the second most important group. The identification of humans has progressed rapidly. Inexpensive DNA readers are becoming commercialised. Craig Venter has demonstrated an application that produces a recognisable facial image based on a person's DNA sequence. Facebook and many other applications are able to recognise a person from a photo of his/her face, even if the photo it is compared to is taken from a different angle.

We can deduce from an image taken by a thermographic camera whether a person is in love, and machines can recognise the most important emotions. Obama's face has been animated, synchronising his lip movements and matching his other facial expressions with the tones of voice heard in recorded speech. The faces of numerous other well-known people have been animated in real time according to the facial expressions of another person shown on video.

The current status of the production of facial images is illustrated by a software that can make a natural-looking facial image based on a line drawing.

Interesting sources published after the 2013 report (014)	
Short description of the link	**link**
Animation of a well-known person, lip-synced to an audio tape	http://grail.cs.washington.edu/projects/AudioToObama/siggraph17_obama.pdf
A facial image from DNA, Venter	http://www.zmescience.com/medicine/genetic/dna-predict-face-voice-craig-venter-0432453/
Pepper the robot recognises emotions	http://edition.cnn.com/2014/06/06/tech/innovation/pepper-robot-emotions/
Facial recognition based on DNA (Penn State)	http://www.iflscience.com/health-and-medicine/forensic-scientists-build-crude-3d-mugshots-dna
MIT: AI recognises faces regardless of the angle	https://www.engadget.com/2016/12/02/mit-s-ai-figured-out-how-humans-recognize-faces/
A machine that recognises emotions	http://nemohanke.blogspot.fi/2015/06/kone-tietaa-tunteesi.html
FB facial recognition is improving	http://money.cnn.com/2014/04/04/technology/innovation/facebook-facial-recognition/
A Finnish team's AI creates realistic facial images	https://www.nytimes.com/interactive/2018/01/02/technology/ai-generated-photos.html
FaceRig – recognition & animation of facial expressions	http://www.indiegogo.com/projects/facerig
A thermographic camera recognises a person in love	http://www.reuters.com/video/2016/05/24/thermographic-camera-knows-if-youre-in-l
The AI Pix2Pix creates a facial portrait out of a line drawing	https://www.theverge.com/tldr/2017/6/6/15749754/pix2pix-auto-fill-neural-network-images-portraits

2.2.15 Verbot/chatbot, talking/corresponding robots (015) ****

Target area of the ART: Natural language is the most common and natural communication method for people. Forms and menus allow us to use machines efficiently if their tasks are limited and in specific forms. User interfaces that are easy for machines will become more difficult for humans the more versatile and flexible machines become.

The capability of computers and robots to converse with humans in natural language belongs to this ART, regardless of whether this discourse is written or oral. Pure speech recognition or synthesis is addressed elsewhere, in ART 11.

General description of the development: Machine capability to understand natural language and converse has been pursued since Alan Turing developed the test that was later named the Turing test. Succeeding in this test required discourse to be carried out between a machine and a person without the person realising that the other party is a machine. This goal has been pursued in many ways, such as by programming grammar and conceptual structures into a computer. This pursuit faces the problem that the meaning of words depends on the context and even the speaker's emotions.

The development of conversing data systems has sped up considerably since the approach to development changed from being based on rules to being based on learning and neural networks. Instead of modelling language, a machine is provided with a massive amount of conversations as learning material. The development of conversing machines is in many respects advancing together with language translation. However, there are differences in the goals. The conversing machines can always ask for further clarification if they do not understand something or they can even change topics similarly to humans. In both situations, the machines can ask for human assistance if they encounter an overwhelming challenge.

Large service companies have started using chatbots that converse in text in customer service on their websites, and verbots that use natural speech are being tested in telephone services. A chatbot can ask questions about customer satisfaction or what the customer is looking for. Teaching an AI to be good at customer service, even if it is already capable of fluently discussing the weather, requires extensive data on humans having similar discussions with the same content.

Computer companies have released general purpose conversational machines and software on the market for the needs of households. These are commonly referred to as intelligent agents. People can converse with these agents about everyday life or ask them to look for information and entertainment, for example. Agents can be used for shopping in online shops, booking tickets for a concert or maintaining the IoT equipment at home. Speech interfaces free up the hands for other tasks.

Resources and motive for development: The development of verbots and chatbots is promoted by general AI development. Additionally, there is strong competition between major IT companies. Demand arises in moderation with service companies pursuing cost-effectiveness and faster services, but also with households adopting technology to facilitate their everyday lives and for entertainment purposes.

Impact on value-producing networks, ART 15																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	5	0	3	0	0	3	5	10	10	5	3	0	5	5	10	5	3	3	3	****415

Progress since the previous report: This category is new and it has grown rapidly since the previous report. Microsoft, Google, Amazon and Apple have published their intelligent agents that operate through either the user's computer, mobile phone or a device with a similar appearance to a speaker that is kept on the table.

The use of verbots and chatbots in services has expanded rapidly. For example, banks in Sweden use chatbots, while Conversica's verbot is already being used by a thousand different companies in their telephone services. Verbot features have also been added to robots that may recognise speech as well as human emotions and react to emotions rather than speech. Computers are already common producers of news and other short articles.

Interesting sources published after the 2013 report (015)	
Short description of the link	**link**
A personal robot assistant	http://spectrum.ieee.org/automaton/robotics/home-robots/robotbase-personal-robot
1,000 companies use Conversica's verbot in their services	http://www.cnbc.com/2017/07/14/these-ai-bots-are-so-believable-they-get-more-dates-than-you.html
A verbot recognises human emotions with 95% accuracy (Emotibot)	https://techcrunch.com/2016/12/02/emotibot-wants-to-help-chatbots-know-how-you-really-feel/
Swedish banks use robotised chatbots	https://www.bloomberg.com/news/articles/2017-07-30/your-banker-is-always-in-sweden-rolls-out-the-robots
Chatbots, evaluation of the current situation and future prospects	http://www.bbc.com/future/story/20140609-how-online-bots-are-tricking-you
Google Home verbot announced	http://www.nytimes.com/2016/05/19/technology/google-home-a-voice-activated-device-that-already-knows-you.html?_r=0
A digital assistant that understands speech	http://time.com/4209859/amazon-echo-new-features-2016/
A robot writes news for the LA Times	http://www.bbc.com/news/technology-26614051
AP's financial news robot	http://www.theverge.com/2015/1/29/7939067/ap-journalism-automation-robots-financial-reporting
Viv – a personal assistant	https://www.theguardian.com/technology/2016/jan/31/viv-artificial-intelligence-wants-to-run-your-life-siri-personal-assistants
Alleviating depression with the help of a virtual character	http://www.tiede.fi/artikkeli/uutiset/masennus_lievenee_virtuaalihahmon_avulla
An android reads news	https://www.youtube.com/watch?v=Wyl72Re5110
MS's verbot trial in China	http://uk.businessinsider.com/microsoft-xiaoice-turing-test-in-china-2016-2
ASUS: $599 household robot Zenbo – verbot	https://www.youtube.com/watch?v=C_wO4vmG86w

2.2.16 Real-time 3D modelling of environment (016) ****

Target area of the ART: Healthy people understand their surroundings with their senses and automatically create a mental model of them. People are able to navigate familiar spaces by memory even in the dark. A machine must create a similar model of its surroundings in order to navigate them based on its own perception and assessment of the situation. Remote control also requires a view of the target environment. Models can be produced as records similarly to maps, but there are many temporary and moving elements in an environment that make a static record alone an insufficient solution, and at least the situation of the intended route must be perceived in real time.

The need for real-time modelling has increased rapidly as a result of autonomous transport and other machines moving within a dynamic environment. VR and AR technologies and the remote control of robots also generate new needs. This ART includes the actual creation and perception of a 3D model from the available observation data. The devices that collect this data are addressed elsewhere.

General description of the development: The greatest challenge in the 3D modelling of the environment is related to the spottiness of observations. For example, when an environment is measured with a laser or photos taken by a camera from different directions, the image created always comprises individual spots, so called point clouds. Due to rain or dust, many of the spots in the image may vary greatly in their distance to the camera, even if the devices themselves are perfectly accurate and impeccable.

If a measurement is performed with a low resolution, small things are easily left unnoticed. If these measurements are performed rarely, some of the moving objects may be left unnoticed. When a measurement is performed from a moving vehicle, it becomes more challenging due to the dynamics caused by the three-dimensionality of surfaces.

There are no theoretical problems involved in the creation of a real-time 3D model. The challenges include the speed of sufficiently accurate measurement and computing and the reliability of the model. Due to safety considerations relating to autonomous transport, a real-time 3D model is created based on several independent data sources in demanding situations. These sources must be consistent with each other.

The essential objects, such as people, animals, vehicles and the roadway, are identifiable in the models. Modelling is more difficult if the environment is complex. The degree of difficulty is high in natural forests, for example, and the weather conditions referred to above that affect visibility also increase the need for computing. Modelling indoor spaces is simple compared to outdoor spaces.

AR glasses create a real-time model of the space in which the user of the glasses moves. This allows virtual objects to be placed within the space in a natural way. A model is not necessary in remote control. The controlled device may generate a complete 360° view for the controller's VR glasses. The controller recognises objects from an image, and the viewpoint moves with the controlled device.

Resources and motive for development: The development of autonomous transport is the most important existing motive for real-time 3D perception of environments. Numerous IT companies are competing over the favour of the automotive industry and expected turnover from autonomous transport. The competition situation in the automotive industry is obvious, and the stakes are high. Academic research still plays a key role in testing details and radical technologies.

Augmented reality and interior modelling are progressing on the terms of the electronics industry. The development of 3D models is also being funded by the entertainment industry, but only in rare cases is it necessary for the models to be generated in real time.

Impact on value-producing networks, ART 16																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	20	20	10	5	0	0	5	0	1	5	0	0	3	5	0	5	5	0	3	3	****540

Progress since the previous report: The corresponding ART in the previous report was "2.32 Real-time 3D modeling of the environment," which ranked in the first group. At the time the report was written, Google's cars already generated real-time image of their surroundings. Microsoft's Kinect add-on generated a real-time model of an indoor space in the Fusion pilot project. The quality of modelling has improved considerably since the writing of the previous report. Functionality in rainy conditions and other problem situations has been developed.

Nvidia has introduced a processor that is fully capable of generating a model and recognising the objects within it with the accuracy required for autonomous operation. 360° images can be generated in real time, a 3D model can be generated of a soundscape, and features have been added to smartphones and AR glasses for the needs of real-time 3D modelling of the environment. Features have been added to robot vacuum cleaners and quadcopters for modelling the environment.

Interesting sources published after the 2013 report (016)	
Short description of the link	**link**
Lighthouse – a verbot that sees/remembers events at home	https://www.light.house/
Nokia's $60,000 OZO VR camera	http://www.pcmag.com/article2/0,2817,2495939,00.asp
Nvidia: real-time scanning & recognition of objects	https://makezine.com/2017/03/08/nvidias-new-tx2-board-dual-4k-camera-object-detection-real-time/
An acoustic camera, 3D modelling of sound	http://www.aalto.fi/fi/current/news/2016-05-12-002/
3D scanning and AI judging of sports performances	https://www.theguardian.com/sport/blog/2017/nov/04/ai-judges-gymnastics-olympics
A sound camera for the development of mechanics (SeeSV)	http://spectrum.ieee.org/tech-talk/at-work/test-and-measurement/zero-in-on-buzz-squeak-and-rattle
Google's Tango (3D modelling) in a quadcopter	http://spectrum.ieee.org/automaton/robotics/aerial-robots/autonomous-quadrotor-flight-based-on-google-project-tango
A real-time, mobile 3D scanner with 0.1 mm accuracy	https://www.artec3d.com/news/artec-leo-released

Interesting sources published after the 2013 report (016)	
360° recording with an inexpensive device	https://theta360.com/en/
Daily images of Earth	http://www.avaruus.fi/uutiset/maa-ja-lahiavaruus/maapallosta-julkaistaan-nyt-aidonvarinen-kokonaiskuva-paivittain.html
The whole of Denmark in Minecraft	http://www.uusisuomi.fi/tiede-ja-ymparisto/68522-tanskan-valtion-huikea-temppu-koko-maa-minecraftiin-11-koossa

2.2.17 Easy 3D imaging of parts (017) **

Target area of the ART: Our world is three-dimensional. Two-dimensional images limit us to the perspective chosen by the photographer. However, humans automatically comprehend the world they see as three-dimensional. Because of this ability, we recognise familiar objects in images. In contrast, recognising three-dimensional objects by comparing two-dimensional images is a challenge for machines. A machine requires a 3D model of the object or images of it from every possible angle in order to reliably recognise the object. We too require a 3D model of completely strange-shaped objects in order to understand its shape from all directions. 3D models are necessary when we want to produce copies of objects with 3D printers, for example, or use them as structural parts in virtual reality.

General description of the development: The 3D imaging of objects and spaces has evolved rapidly. Consumer-level devices are used to make easily recognisable 3D models. The spread of quadcopters and other autonomously moving devices has facilitated the modelling of wide spaces.

The price of precise 3D scanners is decreasing constantly. Other methods have been developed besides laser scanning. Similarly to laser measurement, ToF 3D sensing is also based on reflection delay times. DIAL lasers allow the surrounding surface materials to be incorporated in models.

Digital mirrors are slowly becoming common in shops, and their properties are limited for the time being. For example, a digital mirror can be used to view delayed image, which allows people to see themselves from behind. Our reflections can be shown with accessories, such as bags, that the shop does not physically have. Some mirrors allow the colours of the accessories to be changed. The objective is a digital mirror that models the person standing in front of it and shows him/her in the selected new virtual clothing.

Resources and motive for development: The development in this area is market-driven. The growth prospects are moderate, and basic technology developed for other reasons is opening up new opportunities for the development of applications in this ART. The need for 3D modelling is also increasing constantly. Academic research is limited. Crowdsourcing is producing a constantly increasing database of 3D models of objects.

Impact on value-producing networks, ART 17																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	1	5	5	0	0	0	3	3	0	3	3	0	1	3	0	3	1	1	0	0	**160

Progress since the previous report: The corresponding section in the previous report was "2.31 Effortless 3D imaging of parts," which ranked in the second highest group. Many inexpensive devices for 3D imaging were under development or existed as prototypes.

HP's Sprout is a recent example of a personal computer that includes a 3D scanner as a standard part. Sony's new Xperia smartphones also have a 3D scanner. 3D models can also be generated from video taken by other phones with various applications.

At the professional level, the price of laser scanners has decreased materially. The range of inexpensive 3D scanners has expanded, and their quality has improved. According to market forecasts, the sale of 3D scanners will increase at a rate or roughly 6% per year over the next few years, reaching $5 billion by 2022. The number of individual scanners will grow significantly more quickly.

Interesting sources published after the 2013 report (017)	
Short description of the link	**link**
Inexpensive 3D scanning/VR model of space, Matterport	https://www.facebook.com/techcrunch/videos/10153485781482952/?fref=nf
Accurate depth sensing in 3D scanning with polarisation	http://www.sciencedaily.com/releases/2015/12/151201141244.htm
A (ToF) 3D image sensor with an accuracy of 1% at a depth of 4 m	http://image-sensors-world.blogspot.fi/2015/12/pmd-and-infineon-present-improved-tof.html
Sony's new phone has a 3D scanner as standard equipment	https://www.sonymobile.com/global-en/products/phones/xperia-xz1/3d-creator/
MS video demo: 3D scanning with a mobile phone	https://www.facebook.com/techinsider/videos/604331676431859/
The 3D scanner market will reach $5 billion by 2022	https://globenewswire.com/news-release/2017/11/06/1175022/0/en/3D-Scanning-Market-Size-Trends-to-Reach-USD-5-06-Billion-by-2022-Zion-Market-Research.html
A 3D model with Kinect Fusion	http://spectrum.ieee.org/video/consumer-electronics/audiovideo/kinect-fusion-lets-you-build-3d-models-of-anything
HP Sprout – a PC with a built-in 3D scanner	http://www.ubergizmo.com/2017/01/hp-sprout-pro-g2-pc-with-3d-scanner/

2.2.18 Deep learning material for expert AI (018) **

Target area of the ART: Human skills take time and effort to develop. Specialisation is also problematic, as expertise is spread across several people, leading to a weaker overall picture. AI offers an opportunity to replicate humans' hard-earned special expertise.

Expertise requires extensive knowledge or experience. Obtaining the necessary data for teaching AIs and the recognition of significant areas of expertise for AI expert applications comprise the key content of this ART. Social media and crowdsourcing play a key role in the development work with regard to the acquisition of both data and feedback.

General description of the development: Deep learning is a relatively new concept. It entails teaching an AI about concepts and conceptual structures as well as the relationships between things, layer by layer. Learning is controlled by categorising information and choosing the conceptual level learned at any one time. Other terms used include reinforcement learning and feedback learning, in which an AI reinforces the structures that have participated in tuning successful performances similarly to the nervous system.

AIs are now being adopted in a wide variety of areas of expertise. A psychosis can be identified from speech, a cancer can be recognised optically, and a stroke can be predicted based on signals measured from the body. A smartphone can recognise the initial symptoms of Parkinson's disease, words can be recognised in thoughts, and a robot cook imitates cooking shows it has seen on video. The development of applications is now undergoing a very rapid phase, accelerated by comparatively recent breakthroughs.

Social media and widely used applications provide access to a great number of observations and feedback that are required by AIs. The current owners of social media platforms play a key role, but it is still possible to develop popular applications to which the users provide their data for teaching AIs.

Social media users proactively categorise the images or measurement results they provide and evaluate messages published by an application or people they know. By combining this information, an AI can draw conclusions about users and the claims and questions they have expressed. For example, an AI can become one of the conversationalists in a message thread. An AI learns to act in a way that receives increasingly positive feedback.

Users' smartphones are evolving constantly. The data gathered from their sensors, self-driving cars and other devices is accumulating rapidly. AR glasses and images captured by vehicles could be used to form an almost real-time model of the world. This is as massive an amount of teaching and situation data that an AI can get in a democratic society. Controlling these information flows is the objective of many parties.

Resources and motive for development: Academic research plays an important role in new areas of application. The technology is already so mature that even the short-term motives of companies are sufficient for piloting many expert applications. The motive for development is high among notable global providers of platform services, online shops and social media services as well as start-up companies financed by venture capitalists.

Impact on value-producing networks, ART 18																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	0	5	0	3	3	3	0	10	5	3	0	5	0	5	3	0	0	5	**150

Progress since the previous report: The closest corresponding section in the previous report was "2.19 Open data and big data," which rose to the highest group above all because most AI applications were included in the same category.

At the time the report was written, machine vision applications were immature, the self-learning capability of AI was not conceptually multilevel, and applications were essentially operating methods that were based on the optimisation of models created by experts or methods that deviated from extensive observation data, and they could detect relatively simple correlations.

The deep learning technique, the capability of AIs to teach each other and breakthroughs in machine vision have paved the way for many different areas of expertise. An AI can easily beat humans at games. Most stock market investments are now made by AIs. In medical diagnostics, AIs are in many areas better than humans. In industrial maintenance diagnostics, an AI that is familiar with its surroundings can anticipate maintenance needs better than humans. AIs can also beat the best fighter pilots in battle. Due to their inexpensiveness and speed, AIs can e.g. categorise images by topic, take care of simple legal tasks and drive a car.

Interesting sources published after the 2013 report (018)	
Short description of the link	**link**
China's AI prospects are good due to easy access to data	https://www.economist.com/news/business/21725018-its-deep-pool-data-may-let-it-lead-artificial-intelligence-china-may-match-or-beat-america
Amazon Go, an AI shop without checkouts	http://venturebeat.com/2016/12/05/amazon-launches-amazon-go-a-brick-and-mortar-grocery-store-that-does-away-with-checkouts/
Google's AI develops its own encryption method	http://arstechnica.co.uk/information-technology/2016/10/google-ai-neural-network-cryptography/
AI in electronic warfare	https://www.nextbigfuture.com/2016/09/darpa-applying-artificial-intelligence.html
An AI beats an expert fighter pilot in flight combat	http://www.popsci.com/ai-pilot-beats-air-combat-expert-in-dogfight
AlphaGo beats a Go grandmaster	http://www.wired.com/2016/03/googles-ai-wins-pivotal-game-two-match-go-grandmaster/
General description of Dr Watson	http://www.businessinsider.com/ibms-watson-may-soon-be-the-best-doctor-in-the-world-2014-4?IR=T
Detection of arrhythmia from ECG by an AI	https://arxiv.org/abs/1707.01836
An AI reads clinical notes to find links in cancer cases	https://www.newscientist.com/article/2078159-ai-reads-doctors-notes-to-find-hidden-links-in-cancer-cases/

Interesting sources published after the 2013 report (018)	
Dr Watson as a radiologist	http://www.mediuutiset.fi/uutisarkisto/peittoaako-konenako-radiologin-silmat-watson-analysoi-suomalaista-terveysdataa-jyvaskylassa-6638789
An AI learns to cook by watching videos	http://www.hs.fi/tiede/a1305914088246?jako=df300339f3cd69f898d367d247fe73ac&ref=fb-share
A diagnostic robot for X-rays, etc.	http://singularityhub.com/2016/01/18/digital-diagnosis-intelligent-machines-do-a-better-job-than-humans/
An application that warns about earthquakes	http://advances.sciencemag.org/content/2/2/e1501055.full
A computer predicts onset of psychosis with speech analysis	http://medicalxpress.com/news/2015-08-psychosis-automated-speech-analysis.html
CMU's AI wins against top players at Texas Hold'em	https://www.wired.com/2017/01/mystery-ai-just-crushed-best-human-players-poker/
Image to text, an online demo service	http://deeplearning.cs.toronto.edu/i2t
A robot lawyer has a success rate of 64% and has saved millions	http://www.refinery29.com/2016/06/115416/donotpay-bot-traffic-ticket-robot-lawyer
A diagnostic mirror (Wize Mirror)	http://www.smithsonianmag.com/innovation/look-into-this-smart-mirror-and-you-get-a-one-minute-medical-checkup-180956367/ - RzcrJM3cvh2IZBMQ.99
Quick identification of cancer cells in blood with 95% accuracy, microscope & AI	http://newsroom.ucla.edu/releases/microscope-uses-artificial-intelligence-to-find-cancer-cells-more-efficiently
Global monitoring of physical activity	http://activityinequality.stanford.edu/
300 million samples instead of 1 million – AI learned much more	https://www.wired.com/story/ai-and-enormous-data-could-make-tech-giants-harder-to-topple/
Adimec: Optical cancer assessment	http://info.adimec.com/blogposts/interview-with-fabrice-harms-at-lltech-about-high-full-well-capacity-camera-for-non-invasive-cancer-assessment-ffoct-systems
Parameterised design in the construction industry, etc.	https://www.youtube.com/watch?v=mghL4Wsi7vg
AI controls drifting Project Loon balloons	https://www.wired.com/2017/02/machine-learning-drifting-real-world-internet-balloons/
An AI for detecting cataracts	http://www.smithsonianmag.com/science-nature/eagle-eyed-ai-doctor-could-nip-cataracts-bud-180961993/
An AI solves quantum systems	https://www.newscientist.com/article/2120856-ai-learns-to-solve-quantum-state-of-many-particles-at-once/
Anticipation of strokes with AI	http://www.cnet.com/news/samsung-prototypes-brainwave-reading-wearable-stroke-detector/
Google's AI develops its own (go-between) language	https://www.facebook.com/techinasia/videos/1273081122730298/
Bioimage informatics – BioImageXD	https://www.doria.fi/handle/10024/97260
A smartphone can detect Parkinson's disease	https://www.ncbi.nlm.nih.gov/pubmed/25819808

Interesting sources published after the 2013 report (018)	
Sequedex quickly classifies sequenced DNA	http://www.computerworld.com/article/2854003/software-can-now-identify-dna-from-viruses-and-speed-up-diagnoses.html
Nvidia's 960 TFlops AI system for health care	https://www.anandtech.com/show/11824/nvidia-ships-first-volta-dgx-systems
Suicide risk is visible in MRI with 91% accuracy	https://www.nature.com/articles/s41562-017-0234-y
Musk's AI start-up beats the top player	http://profit.ndtv.com/news/tech-media-telecom/article-elon-musk-s-ai-startup-wins-against-world-s-best-dota-players-amazing-tweets-vishal-sikka-1737043
Viability of solar panels from a satellite image	http://www.iflscience.com/technology/should-you-get-solar-panels-ask-google

2.3 Digitalisation of sensory data and processing

The events in our environment are being digitalised more extensively and with more accurate equipment. The amount of recorded information doubles every two years and will become roughly hundred-fold between 2017 and the end of the following decade. This development is enabled by the continuous development of computer memory equipment and processing power.

The greatest effect of this development can be considered to be improved availability of data. When all available data is recorded in a digital format, it is easy to share. With processing power and presentation technology evolving rapidly, digital data will also be increasingly easy to find, identify and edit mechanically in the near future.

As a consequence of this development, decision-making will be less and less tied to any particular place. E-commerce will become easier, tourism may become virtual, and learning and research will increasingly take place in data networks, regardless of physical location. The compiling and combining of information will become increasingly common as an earnings model. It strongly involves economies of scale, crowdsourcing and a spirit of communal work. Efficient service easily gets citizens to provide their own data, and operators strengthen their market position by refining this data.

Digitalisation of the processing of observations	
ART-ID	**The ARTs in the group**
19	Smart glasses, AR glasses and augmented reality
20	VR glasses, MR glasses and virtual reality
21	Motion-based and haptic user interface
22	Fast and dense memory materials
23	Memristors and neural processors
24	Quantum computers and quantum communication

Digitalisation of the processing of observations	
25	New nanomaterials in electronics
26	Radical growth in computing power

2.3.19 Smart glasses, AR glasses and augmented reality (019) ****

Target area of the ART: Our senses, memory and knowledge are limited. The only easy ways for us to determine many things about our environment are by using measurement devices or data sources prepared by others. In addition to information, we may want to add artificial stimuli to our environment.

Smart glasses and AR glasses add elements to our field of vision that help or entertain us. These elements may comprise signage that guide us in the desired direction or a virtual pet. Smart glasses add information to our field of vision, while AR glasses make virtual objects look like a natural part of reality.

AR glasses resemble super senses when used in conjunction with various sensors. For example, a thermal image can be shown by colouring our natural field of vision according to thermal imaging or a surgeon performing an endoscopic surgery can be presented with a tomographic image as though the surgeon possesses X-ray vision. Augmented reality is not only limited to vision. The sense of touch is addressed elsewhere, in connection with haptic interfaces.

General description of the development: At its simplest, augmented reality is demonstrated by an application called Sky Map. When you look at the night sky with a smartphone covering part of your field of vision, the covered part of the sky is shown on your phone screen with all its stars and the names of each star. Pokémon GO is a similar application that has made the idea of augmented reality popular.

In addition to an augmented reality shown through smartphones, there is a great variety of smart glasses and AR glasses on the market. Smart glasses are particularly helpful when we need our hands for other tasks. For example, smart glasses are used in warehouse applications. However, despite their various features the smart glasses offered by Google and other manufacturers have not become widely popular.

AR glasses are technologically more sophisticated than smart glasses. In order to be able to place animated 3D objects in the user's environment in a natural way, they must first generate a 3D model of the environment. AR glasses placed on the market include HoloLens, Meta 2, ODG's R-9 and DAQRI, among others. The technology is for the time being limited with regard to both field of vision and depth of field. For now, environmental modelling is adequately successful only in favourable conditions, with the environment not being too complex. The development of AR glasses is likely to continue advancing rapidly, and the market is anticipated to grow to the scale of the smartphone market in the 2020s.

Three-dimensional holograms can be projected into the air with laser beams. Then the viewer does not need glasses or other terminal devices. These applications overlap with AR glasses, but the technology is still at an early stage of development. Research experiments include contact lenses that add information to our field of vision or adapt it to show a telescopic view or give us night vision, for example.

Resources and motive for development: Development has for the most part become company-driven, but academic research still has a clear impact, particularly on challenges relating to optics. One notable example of product development resourcing is Magic Leap, a company that carries out development work in this field. It has received almost $2 billion in financing from investors for product development and production before presenting even one product to the public. AR applications are being developed in a great number of sectors by a number of organisations.

Impact on value-producing networks, ART 19																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	5	5	10	0	0	10	3	5	0	5	0	3	3	5	10	5	3	3	0	****375

Progress since the previous report: The corresponding ART in the previous report was "2.22 Glasses of augmented reality," which ranked in the highest group. At the time, the top of the line was represented by Google Glass, which did not become a commercial success. There were no actual AR glasses on the market.

Development is advancing rapidly. The AR market is expected to grow to over $100 billion in a few years. Several relatively advanced AR glasses have joined smart glasses on the market, and the development of applications has become active. Many smartphones have been developed for AR applications. The most inexpensive AR glasses operating with a smartphone are available for $100.

Holograms have been successfully projected in the air and made tangible. Projectors have been used to achieve the appearance of an augmented reality on room surfaces. Elements of an augmented reality have been added to digital mirrors. For example, a mirror can show a person's intestines or a person wearing other clothes. Augmented reality visualises the soundwaves in an environment. Ball games can be played without an actual ball, and colour-blindness has been successfully corrected by adjusting the wavelengths entering the eyes.

Interesting sources published after the 2013 report (019)	
Short description of the link	**link**
Magic Leap has released a developer version of its AR glasses for 2018 delivery	https://www.rollingstone.com/glixel/features/lightwear-introducing-magic-leaps-mixed-reality-goggles-w514479
A video of holoportation by HoloLens	https://www.youtube.com/watch?v=7d59O6cfaM0
VR and AR will be worth $150 billion in 2020	http://www.fastcompany.com/3052209/tech-forecast/vr-and-augmented-reality-will-soon-be-worth-150-billion-here-are-the-major-pla

Interesting sources published after the 2013 report (019)	
Night vision lenses made of graphene	http://www.sciencealert.com/graphene-can-create-super-powerful-night-vision-lenses-that-are-just-one-atom-thick
$99 Mira Prism turns an iPhone into an AR headset	https://www.theverge.com/2017/7/18/15948700/mira-prism-iphone-augmented-reality-headset-hands-on-announce
The IoT & AR market will reach $7 trillion by 2027	http://www.prnewswire.com/news-releases/augmented-reality-market-iot-ar-to-reach-7-trillion-by-2027-595626251.html
A telescopic contact lens	https://www.facebook.com/RichardDawkinsFoundation/photos/a.496176595154.294030.8798180154/10151870994790155/?type=3&fref=nf
Meta 2 AR glasses and future prospects	https://www.youtube.com/watch?v=_cmPFsBOquk
VTT's display for smart glasses – Dispelix	http://dispelix.com/
A virtual mask with laser in real time	http://www.businessinsider.com/projection-mapping-like-digital-makeup-2014-8
The VR app Relumino compensates for vision problems	https://www.engadget.com/2017/08/20/samsung-relumino-vision-ar-app/
A mid-air hologram	http://www.bitrebels.com/technology/realview-mid-air-holography-station/
A Princess Leia hologram projector under development	http://www.zdnet.com/article/3d-printing-with-light-scientists-create-3d-holograms/
Glasses that give better colour vision	http://enchroma.com/technology/
A HoloLens review/introduction on YouTube	https://youtu.be/ihKUoZxNClA
Magic Leap looks for talent in Finland	https://techcrunch.com/2016/10/28/magic-leap-goes-to-finland-in-pursuit-of-nordic-vr-and-ar-talent/
A video demo of a mid-air 3D hologram, Holovect	https://www.facebook.com/mashablefutureshift/videos/10154557628434705/
A thermographic camera in a contact lens	http://www.extremetech.com/extreme/178593-graphene-smart-contact-lenses-could-give-you-thermal-infrared-and-uv-vision
Visualisation of wireless signals	http://www.theverge.com/2015/11/28/9811910/augmented-reality-app-lets-you-see-wireless-signals
Smart glasses (2D) from Kopin	http://venturebeat.com/2016/01/04/kopin-enables-augmented-reality-glasses-with-breakthroughs-in-display-speech-and-battery-tech/
A VR with projectors without glasses (MS RoomAlive)	https://www.fastcodesign.com/3036628/microsoft-can-now-turn-any-space-into-the-holodeck?partner=rss
Earbuds that modify the soundscape (Here)	http://gizmodo.com/what-its-like-to-wear-bionic-earbuds-1756802862
HoloLens technology explained	https://www.youtube.com/watch?v=-606oZKLa_s
QLEDs into contact lenses	http://www.cnet.com/news/bionic-eye-3d-printing-merges-contact-lens-and-qleds/

Interesting sources published after the 2013 report (019)	
AR-assisted table tennis	https://www.facebook.com/mymodernmet/?fref=nf
An artificial (super) lens for the eyes	http://www.collective-evolution.com/2015/06/19/the-8-minute-surgery-that-will-give-you-superhuman-vision-forever/
A scenario video of an augmented reality	https://vimeo.com/166807261
HoloLamp – AR without glasses, as a projection	http://hololamp.tech/faq/

2.3.20 VR glasses, MR glasses and virtual reality (020) ****

Target area of the ART: Television is an example of our desire to experience environments and conditions in which we are not personally present. However, even a movie theatre cannot create a deep sense of presence. In contrast, VR glasses offer a deceptively realistic impression of being somewhere else. The glasses cover the entire field of vision, so we cannot see our own natural environment. When we turn our head, we see our virtual environment as though we had turned our head in a natural environment. In addition to experiences, VR glasses are suitable for remote control. The user feels like he/she is part of the machine he/she controls.

VR glasses allows us to navigate virtual models similarly to reality. If we also simultaneously move in our own physical environment, this can easily lead to accidents. It is useful for the glasses to be able to integrate obstacles in our natural environment to a virtual world. This allows users to avoid bumping into objects in their physical environment.

MR glasses (mixed reality glasses) include a camera or several cameras and can combine elements of the physical reality with a virtual world seen by the viewer. MR glasses can be used to produce a similar experience to AR glasses, taking into account that the technical quality of the camera image is not yet up to par in quality with watching the natural environment directly through AR glasses.

General description of the development: VR glasses have long existed as prototypes and research equipment. Their release on the market has been obstructed by many problems. Low resolution spread across a field of vision has resulted in a mosaic-like image. Latency, i.e. the delay between the position of the head and change in the angle of view, has resulted in an unpleasant sensation and even nausea. The production of a virtual reality has also required an efficient computer. As consumer products, VR glasses are a very recent phenomenon.

The development of display devices and increase in processing power in mobile devices has made it possible for consumers to use virtual glasses. In practice, the most inexpensive glasses are a mobile phone holder equipped with lenses that is folded from carboard and placed on the head. A mobile phone produces a separate image for both eyes and a mobile phone application recognises the position of the head based on the position and movements of the mobile phone. This allows the image to conform to the head’s movements.

Independent VR glasses and VR glasses connected to a separate computer have also been released to the market. A great number of applications are available for glasses for the purposes of teaching, remote control, games, travel and other 3D experiences. For example, in 2015 the New York Times distributed a million VR glasses to its customers to let them enjoy the travel reports reported by the newspaper as 3D experiences.

Resources and motive for development: The development of VR glasses is almost fully market-based and based on perceived customer needs and anticipated rapid market growth. There is clearly competition on the market. The application market is developing quickly, and remote control will progress with the advancement of robotics.

Impact on value-producing networks, ART 20																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	3	3	5	0	0	0	5	3	5	3	10	1	3	3	5	10	1	3	10	5	****468

Progress since the previous report: This is a new category that was added after the previous report because of rapid development and a need for remote control that arose with robotics.

The development of VR glasses suitable for consumer use can be said to have begun in 2012, when Oculus applied for Kickstarter funding to VR glasses. The project received over $2 million in funding, and the actual consumer product was launched in 2016 after Facebook had first bought Oculus for roughly $2 billion. Google released its Cardboard glasses, folded from cardboard, for use together with a smartphone. It has delivered over 10 million of these glasses.

Google's new VR platform for Android phones is called Daydream. Together with Intel, Microsoft has released its own Windows 10 based VR development platform under the name Mixed Reality, and products have already been launched using this platform by HP, Acer, ASUS, Lenovo, Dell and Samsung, among others. VR glasses are being used to hold competitions for remote-controlled quadcopters, and the use of VR glasses in rehabilitation, therapy and training is being developed.

Game developers are developing products for users of VR glasses. Property viewings, trip introductions and movie experiences are also available for users of VR glasses. For example, the trench scene in the recent movie the Unknown Soldier can be experienced with 3D glasses. 360° videos are being shared on Facebook, for example. Latency is being improved, field of vision is being expanded and resolution is being improved in the focus area of our field of vision.

Interesting sources published after the 2013 report (020)	
Short description of the link	**link**
Intel expands to VR products, Project Alloy	http://www.bbc.com/news/technology-37098764
Quadcopter flight with VR glasses	http://www.youtube.com/CharpuFPV

Interesting sources published after the 2013 report (020)	
VR calms patients down during chemotherapy	https://www.facebook.com/ajplusenglish/videos/801983766609799/
VR promotes the rehabilitation of paraplegics	https://www.facebook.com/quartznews/videos/1247234775310222/
Nvidia, 1,700 Hz VR display, discussion about nausea	http://www.digitaltrends.com/virtual-reality/nvidia-1700hz-vr-display/
Google Earth VR available online	https://www.youtube.com/watch?v=SCrkZOx5Q1M
Oculus in remote control of a drone	http://mashable.com/2014/04/28/oculus-rift-flying-drone/
Virtual (CT) autopsy	https://www.youtube.com/watch?v=9usf3kJL7mc
Samsung Gear VR	http://www.pcworld.com/article/2986140/gadgets/samsungs-new-gearvr-virtual-reality-headset-only-costs-99.html
360° video Facebook/BBC	https://www.facebook.com/bbcearth/videos/1135051163195105/?fref=nf
Oculus VR in military use	http://www.itviikko.fi/uutiset/2014/05/06/panssarikuskit-suunnistavat-oculus-riftilla--vaikka-pahaa-tekisi/20146372/7
Examples of VR + robotics	http://www.youtube.com/watch?v=13JGGbB2ctM

2.3.21 Motion-based and haptic user interface (021) **

Target area of the ART: As information technology and telecommunication advance, the environment we operate in becomes increasingly abstract. We control things both near and far through telecommunication. However, controlling things through commands or levers is not natural or easy. For us, our hands are the most natural way to mould and move things and adjust or control devices, but what makes our hands particularly important is the fact that we recognise things with our hands and can perform many tasks without even seeing what we are doing, as long as our fingers can perceive the objects being handled by sense of touch.

Recognition of hand movements allows us to control a device flying far away so that it moves according to our hand movements, rather than requiring separate controls or keyboard commands. Naturally, this requires the controlled device to resemble our hands or otherwise interpret the movements of our hands into movements of the device in a sensible way. Natural interaction includes the ability of the person to feel what he/she is touching. A virtual sense of touch must be conveyed artificially to the hands controlling a device.

General description of the development: Many companies are developing data gloves. Their purpose is to detect the position of hands and fingers and where the hands are located. This can be done mechanically or electronically. The location of our hands can also be detected optically from 3D camera images by calculating the angles. The location of our hands can also be deduced from radar, sonar or LiDAR reflections.

When we handle a physical object, we can feel it as weight in our muscles and as pressure on our skin. Data gloves can generate a sensation of pressure and resistance mechanically or electronically. This sensation can also be achieved with airflow or as laser pulses. All of these methods have been tested. Haptic technologies have advanced slowly, and a breakthrough on the market is not yet in sight. Nevertheless, development efforts have not stopped. In addition to data gloves, the gaming industry has even experimented with full suits that generate a body response to experiences in a virtual world.

Resources and motive for development: Interfaces that are based on body movements, gestures and sensations are being developed by both IT companies and academic researchers. This area of research is not particularly heavily funded, and the demand on the market is not high, at least for the time being, but there appears to be continuous, motivated progress in any case.

Impact on value-producing networks, ART 21																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	5	3	0	0	0	3	0	5	0	5	3	3	0	3	5	1	0	0	0	**144

Progress since the previous report The corresponding ARTs in the previous report were "2.23 Interfaces based on feeling of touch," which ranked in the first group, and "2.21 Interfaces reacting on movements," which ranked in the second group. At the time, there was discussion about vibrating game controllers, generating Braille for people with visual disability and conveying sensations to fingertips. Since then, several data gloves that convey sensations have been released to the market, but they seem to still be relatively immature.

Many movement-based interfaces are still on their way to the market. A "micro-radar" that detects gestures has been integrated at the circuit level. It appears fast and precise in demonstrations. The tracking of eye movements has also improved. Oculus has released a touch controller related to its virtual glasses, while Myo has released an armband with versatile motion control and detection of gestures. The AR glasses of both Microsoft and Magic Leap also involve a feature that detects movement and gestures.

The touchability of mid-air holograms has been developed further. The detection of gestures and movements and haptic feedback are becoming increasingly important as VR and AR glasses become more common.

Interesting sources published after the 2013 report (021)	
Short description of the link	**link**
Touchable holograms with femtolasers	http://spectrum.ieee.org/tech-talk/consumer-electronics/audiovideo/femtosecond-lasers-create-3d-midair-plasma-displays-you-can-touch
UltraHaptics: multi-point mid-air haptic feedback with ultrasound	http://www.youtube.com/watch?v=2QkbVr4J7CM

Interesting sources published after the 2013 report (021)	
Soli – miniature radar, demo video	https://www.youtube.com/watch?v=H41A_IWZwZI
Finch: Light hand-tracking controller	https://www.daydreamdistrict.com/finch-demonstrates-new-hand-tracking-controller-for-mobile-vr/
A demo video of haptic VR gloves, Gloveone	https://www.facebook.com/virtuality/videos/977380659048733/
The eye-tracking “mouse” EYECAN+	http://www.theverge.com/2014/11/25/7279849/samsung-eyecan-plus-eye-mouse
Myo’s gesture-control armband	https://www.myo.com/
A gesture-based interface with ultrasound (Elliptic Labs)	http://www.cnet.com/news/elliptic-labs-ultrasonic-gestures-could-revolutionize-smartphone-interaction-next-year/

2.3.22 Fast and dense memory materials (022) ***

Target area of the ART: The cultural evolution of humanity has sped up since the invention of writing. The ability to record data on memory devices and share them with others has evolved in several stages, from cave paintings to online cloud services. Today, the data directly recorded and duplicated by people forms only a limited part of all need for memory devices.

Rapidly increasing numbers of machine observations are gathered on memory devices in order for machines to filter or compile them and learn something that is useful for people to know. Data is also stored in an increasing number of places to make them quickly and reliably available as needed.

Computers require a variety of memory devices. Great speed is required in the immediate vicinity of processors, while large density and permanence is required for archiving. Memory devices are also physically moved when their price and capacity offer more efficient and safer data transfer than telecommunication. Associative memory that mimics the human nervous system belongs to ART 23. This ART includes memory devices with a numerable address system.

General description of the development: Memory kept in the immediate vicinity of a processor is called main memory. The increasing number of mobile devices has led to a need for main memory that keeps its capacity with minimal energy consumption and is still adequately fast.

The density and speed of memory devices have increased continuously. USB memories and memory cards used by digital cameras have become an established physical way to transfer memory between machines when telecommunication is not used. In mass memories with large capacity, the aim is to get rid of mechanical, wearing elements.

In experimental memory materials, data is stored at the molecular level and even at the level of a single atom. DNA is one of the promising slow but dense memory materials. Spintronics offer efficient speed as a phenomenon. It involves manipulation of the intrinsic spin of elementary particles. The spinning direction can be detected, and a very fast change of direction only requires a small amount of energy. Dense, permanent memory structures have also been observed to be achievable by piling and editing three-dimensional crystalline structures.

Resources and motive for development: The electronics industry has a very strong motive for continuously improving memory technology. The greatest amount of effort is invested in incremental development of previous technologies or making improvements close to the mainstream. With just these measures, the annual improvements to features may rise to several dozen per cent. Academic research is important. It focuses on new phenomena and new materials that are used to try to more than double the capabilities of memory devices. Research is active and progresses in many different branches.

Impact on value-producing networks, ART 22																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	3	3	0	0	0	0	3	3	3	3	0	0	0	10	0	5	3	0	5	3	***308

Progress since the previous report: The corresponding section in the previous report was “2.35 Universal memory based on new materials and solutions.” It ranked in the third highest group. At the time, many theoretical opportunities were in sight. The research in these areas has progressed to a clearly more concrete stage. The products on the market, such as flash memory, have evolved, becoming dozens of times denser during the period examined. Intel has released an SSD memory module that is two times faster than flash memory and has a capacity of 1.5 Terabytes.

For main memory level DRAM circuits, density has only evolved at a level of 20% per year. We are quickly moving from mechanical magnetic discs and tapes to solid-state drives, but the former is also advancing. IBM and Sony have managed to store 330 Terabytes of data into a small tape cartridge.

Research progress has been rapid. Researchers have been able to use graphene to make a memory circuit that consumes very little energy. Data has been stored in a quartz crystal as a 3D structure. This has allowed a small, optically readable glass disc to fit 360 Terabytes of data. Researchers have achieved gigahertz speed with a multilayer structure in optic low-power read-write memories.

Spintronics research has advanced, and in storage density IBM has succeeded in fitting one bit of data on one atom. The development of IBM’s Racetrack memory is also advancing, and researchers estimate that it is five years away from production. At that time, the benefits may be too low compared to other technologies.

Interesting sources published after the 2013 report (022)	
Short description of the link	**link**
IBM data storage record of one bit on one atom	https://www.ibm.com/blogs/research/2017/03/meet-ibm-nanoscientists/
Fast memory processing with 128 GB of data stored per die	http://newsroom.intel.com/community/intel_newsroom/blog/2015/07/28/intel-and-micron-produce-breakthrough-memory-technology
IBM & Sony fit 330 TB into a tiny tape cartridge	https://arstechnica.com/information-technology/2017/08/ibm-and-sony-cram-up-to-330tb-into-tiny-tape-cartridge/
A 360 TB memory crystal has been made	http://phys.org/news/2016-02-eternal-5d-storage-history-humankind.html
Spintronics increases the energy efficiency of computers	http://www.natureworldnews.com/articles/6274/20140307/multiferroic-magnetic-materials-increase-power-efficiency-computers.htm
A fast, low-energy memory chip	http://news.stanford.edu/news/2015/october/graphene-memory-chips-102315.html
Intel: 1.5 TB SSD on a PCIe card to be released	https://arstechnica.com/information-technology/2017/03/intels-first-optane-ssd-375gb-that-you-can-also-use-as-ram/
An optical GST chip memory with gigahertz speed, permanent	http://www.kurzweilai.net/first-all-optical-chip-memory
500 Terabytes per square inch (slow read/write speed)	http://gizmodo.com/record-setting-hard-drive-writes-information-one-atom-a-1783740015
Flexible PRAM memory with a writing current of 20 uA	http://www.eurekalert.org/pub_releases/2015-06/tkai-akr061515.php
Graphene is made magnetic, memory	http://spectrum.ieee.org/nanoclast/semiconductors/materials/graphene-becomes-magnetic-and-electric-at-same-time
Racetrack memory progresses	http://www.electronicsweekly.com/news/glasgow-and-leeds-researchers-move-towards-racetrack-memory-2015-12/
IBM: Racetrack, fast mass memory 5 years away from production	http://www.computerweekly.com/news/450419357/Racetrack-Memory-products-in-five-years-says-IBM-fellow
MS has saved 200 MB into DNA	https://www.technologyreview.com/s/601851/microsoft-reports-a-big-leap-forward-for-dna-data-storage/

2.3.23 Memristors and neural processors (023) ***

Target area of the ART: In contrast to computers, the human brain is not divided into memory and a processor that reads it and makes decisions. In the brain, nerve cells form networks in which signals proceed in parallel between different nerve cells. The operation of a neural network depends on the connections between nerve cells and their ability to participate in activating other nerve cells. Processing, memory and skills cannot be separate from each other at this physical level.

The development of artificial intelligence has shown the functioning principle of the brain to be highly efficient in pattern recognition and deep learning. This is why AI systems mimic neural networks, but this must be done by simulating them with software, as computers do not have a structure similar to a nervous system. However, this simulation is not particularly fast or energy-efficient, which is why processors that simulate neural networks more efficiently and electronics that directly mimic neural networks have been developed for the needs of AI.

General description of the development: In recent years, graphics processors have been used in abundance to meet the needs of AI, as the computing required to show graphics is better suited for simulating neural networks than general processors are. Nvidia's efficient AI processors represent this trend. Google and IBM have developed various AI processors that are suited specifically for the computing required for their own AI systems.

Memristor has been a well-known concept in electronics for a long time. It means that we can set the electrical resistance and the memristor will remember it. The principle is well-known, but efficient ways to implement it have not been identified. In practice, the existing neural network processors are still based on traditional chip technology. Memristors and other new technologies could be used to develop chips in which the synapses between synthetic nerve cells are strengthened or weakened according to use. This type of electronics is currently being developed by many operators, although actual memristor chips are only being used in research. Leading developers include IBM, Intel, Qualcomm and HP.

The technology is being developed for the needs of AI-based cloud services of major computing centres on the one hand and consumer terminal devices, such as machine vision applications, on the other hand. For example, Apple has announced that it will be adding an AI processor to its smartphone.

Resources and motive for development: AI-related processor development and the development of associative memories has expanded from academic research to being an area of the electronics industry with extensive competition. However, these activities are to a large extent not yet aimed at meeting customer expectations, with the exception of Nvidia's processors. The developers believe in the market's rapid and extensive growth.

Development efforts aim for the next generation of information technology and to ensure the developers' own competitive positions in the next wave of artificial intelligence. Academic research still plays a major role in the pursuit of the energy-efficiency of the human nervous system with the envisioned memristors.

Impact on value-producing networks, ART 23																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	10	0	0	0		0	5	5	10	10	3	3	10	5	5	3	5	10	10	***291

Progress since the previous report: The closest corresponding section in the previous report was "2.36 Simulation and mapping of brain," which rose to the second most important group. Graphics processors and other special processors were not yet used in AI applications. The greatest neural network processor developed by researchers contained 128 neurons and 5,120 synapses.

The rate of development is illustrated by the fact that Intel has released the commercial Loihi processor, which contains 130,000 neurons and 130 million synapses. IBM has introduced a supercomputer with 16 chips that delivers 16 million neurons and 256 million synapses. Durable structures and materials have been identified for memristors, but they are still at the research stage.

Interesting sources published after the 2013 report (023)	
Short description of the link	**link**
An artificial synapse called a memristor learns autonomously	https://futurism.com/we-just-created-an-artificial-synapse-that-can-learn-autonomously/
IBM: A processor with 16 million neurons and 256 million synapses	http://nextbigfuture.com/2016/03/neuromorphic-supercomputer-has-16.html
HP: fast memory-driven computing, a conceptual prototype	https://news.hpe.com/hewlett-packard-enterprise-demonstrates-worlds-first-memory-driven-computing-architecture/
One million neurons on an IBM chip	http://www.bbc.com/news/science-environment-28688781
A digital neural interface under development (DARPA)	http://www.darpa.mil/news-events/2015-01-19
Intel's Loihi chip has 130,000 neurons and 130 million synapses	https://newsroom.intel.com/editorials/intels-new-self-learning-chip-promises-accelerate-artificial-intelligence/
Breakthroughs and prospects in neuromorphic computing	https://singularityhub.com/2018/02/07/brain-like-chips-now-beat-human-brain-in-speed-and-efficiency/
A memristor switches states in 50 ns, holds the state for 11 days without power	https://www.extremetech.com/extreme/258134-organic-memristor-sets-records-speed-durability
A memristor processor	http://fortune.com/2015/09/03/memristor-brain-like-chips/
The Knowm Memristor product family paves the way for memristors	http://knowm.org/memristors/
A new AI processor from Nvidia	http://europe.newsweek.com/miracle-computer-chip-gives-big-boost-artificial-intelligence-451366
Neurogrid – 1 million neurons and 7 billion synapses on a circuit board	http://www.cnet.com.au/brain-inspired-circuit-board-9000-times-faster-than-an-average-pc-339347168.htm
Google's TPU chips for its own AI use	https://cloudplatform.googleblog.com/2016/05/Google-supercharges-machine-learning-tasks-with-custom-chip.html
Background of memristors	http://edition.cnn.com/2015/02/26/tech/mci-eth-memristor/index.html
IBM's RPU speeds up neural networks	http://www.tomshardware.com/news/ibm-chip-30000x-ai-speedup,31484.html

Interesting sources published after the 2013 report (023)	
An inkjet printable memristor from Finland	http://yle.fi/uutiset/suomessa_kehitettiin_ainutlaatuista_painettua_alya__muistivastus_voidaan_tulostaa_vaikka_postipaketin_kylkeen/8494473
Low-power Eyeriss AI processor for smartphones	http://www.engadget.com/2016/02/07/low-power-neural-network-chip/
Apple Neural Engine for mobile devices	https://phys.org/news/2017-05-apple-mobile-ai-chip-intelligence.html
Neural processing units Qualcomm, IBM, Intel	http://readwrite.com/2013/10/25/neural-processing-unit
Whole brain emulation (IBM) (presentation by Modha)	http://www.youtube.com/watch?v=tqeINGOzIZo

2.3.24 Quantum computers and quantum communication (024) ***

Target area of the ART: For many demanding tasks, computing performed by computers is slow and energy-consuming. Researchers continuously seek to improve the speed and energy-efficiency of computing. Telecommunication is also slow for many needs, and data can be easily stolen or falsified. Ensuring data security so that no one is able to read or falsify any messages sent is a continuous race between those who encrypt messages and those who break the encryption. The former seek to prevent hacking across the lifespan of a message, which is why the easiest targets for hackers are old systems.

Quantum mechanics, with its many properties that mystify people, offers potential answers to future challenges, both in the good and the bad sense. In a quantum computer, the computing unit is a qubit, and for quantum mechanical reasons qubits can exist in several different states simultaneously. As the number of qubits increases, the number of superpositions grows exponentially, as does computing power. A quantum computer can quickly calculate an enormous number of alternatives and add them up. Qubits are not allowed to affect the outside world during this computing, as this would cause the superposition relating to the computing to collapse and the summation to occur prematurely.

Quantum computing poses a significant challenge to public-key encryption methods that are currently being used in telecommunication, as the most common methods can be cracked with a quantum computer comprising an adequate number of qubits. On the other hand, quantum mechanics offers a new alternative to the protection of telecommunication: quantum entanglement. This phenomenon has been known for a long time. It means that a change in one quantum simultaneously leads to a change in the state of another quantum entangled with it, even if they are far away from each other. The change in the state is immediate and does not follow the speed of light. Quantum entanglement can be used to ensure that no one else besides the intended recipient has read the message.

General description of the development: In quantum computing, separating qubits from their environment is key. Refrigeration and other experimental methods are used for this purpose. Increasing the number of qubits in a machine or ensuring their permanence during computing are demanding objectives. It is also difficult to develop algorithms on which quantum computing is based. In other words, instead of being faster than a normal computer in general, a quantum computer is only faster in algorithms that are suited for it.

The use of quantum entanglement in the encryption of communication requires entanglement between two quanta. After this, one of the two quanta is moved elsewhere without breaking the entanglement. Measuring the state of one quantum changes its state and simultaneously the state of another quantum entangled with it. Tests have been performed with photons, fibre connections and satellite connections.

Resources and motive for development: Research into quantum computers and quantum entanglement is primarily based on a scientific motive, but many companies also have long-term commercial motives for investing in their development.

Impact on value-producing networks, ART 24																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	3	0	0	0	0	3	10	10	0	0	0	0	10	0	0	20	5	3	5	***216

Progress since the previous report: The corresponding section in the previous report was “2.37. Quantum computers,” which ranked in the lowest group. D-Wave, which was then mentioned as being at the forefront of development, has not delivered as promised. It is a quantum computer, but one with comparatively low capabilities. Noise, qubit entanglement and the number of superpositions are key parameters in a quantum computer.

IBM has released its own 16-qubit quantum computer online for use by researchers and students. IBM has reported that it has achieved an operational 50-qubit quantum computer. Intel has delivered a 17-qubit chip to a customer and released a 49-qubit chip. Researchers have made a 4-qubit register stable, easily controllable by laser and readable. Many actors are already preparing for the advance of quantum technology and capability to crack passwords.

The record in quantum entanglement distribution is currently held by the Chinese with a total distance of over 10,000 km between China and Austria by satellite. Quantum cryptography has been shown to be possible, but the Zeno phenomenon has also been verified and it has even been proven in practice that it allows counterfactual quantum communication faster than light with the help of entanglement, but it is still uncertain whether data can be transferred faster than light.

Interesting sources published after the 2013 report (024)	
Short description of the link	**link**
Counterfactual quantum communication proven possible (Zeno effect)	http://www.electronicproducts.com/Sensors_and_Transducers/Sensors/World_39_s_first_direct_counterfactual_quantum_communication_proven_possible.aspx
The Zeno phenomenon verified	http://phys.org/news/2015-10-zeno-effect-verifiedatoms-wont.html

Interesting sources published after the 2013 report (024)	
Vortex beam quantum entanglement with kilometre distances	http://spectrum.ieee.org/telecom/security/two-steps-closer-to-a-quantum-internet
A quantum computer – a photon switch	http://www.scienceworldreport.com/articles/13946/20140410/new-atom-photon-switch-herald-breakthrough-quantum-computers.htm
A quantum-encrypted connection from China to Austria, 7,500 + 2,600 km	https://newatlas.com/micius-quantum-internet-encryption/53102/
Record entanglement distribution of over 1,200 km held by the Chinese	http://science.sciencemag.org/content/356/6343/1140
A quantum computer (Google) solves certain problems up to 100 million times faster	http://www.extremetech.com/extreme/219160-googles-quantum-computer-is-100-million-times-faster-than-a-conventional-system
Data security with quantum entanglement	http://phys.org/news/2014-12-fraud-proof-credit-cards-quantum-physics.html
Quantum communication between cities over fibre optic networks	http://blogs.discovermagazine.com/d-brief/2016/09/19/quantum-teleportation-enters-real-world/
IBM's 50-qubit quantum computer, quantum state preserved for 90 µs	https://www.technologyreview.com/s/609451/ibm-raises-the-bar-with-a-50-qubit-quantum-computer/
Quantum information of an electron spin transported to a photon in a silicon quantum chip	https://phys.org/news/2018-01-quantum-silicon-chip.html
A quantum computer bridge (chip) links quantum computers	https://www.eurekalert.org/pub_releases/2016-10/dnl-daf101416.php
Intel delivers 17-qubit chip to a customer	https://techcrunch.com/2017/10/10/intel-moves-towards-production-quantum-computing-with-new-17-qubit-chip/
A multi-channel quantum computing chip	https://www.eurekalert.org/pub_releases/2016-04/tos-rca042716.php
Refrigeration of a quantum computer solved at Aalto	http://www.aalto.fi/fi/current/news/2016-02-01-002/
A stable 4-qubit register	https://phys.org/news/2017-11-quantum.html
The Finnish BlueFors supplies cryogenics for quantum computers	http://www.bluefors.com/index.php/company
Aalto University is building a quantum computer	https://areena.yle.fi/1-4231529

2.3.25 New nanomaterials in electronics (025) **

Target area of the ART: Many new electromagnetically active materials have been identified. This ART includes the properties of new materials, particularly nanocarbons, in electronics, optoelectronics and electromechanics. These materials can influence the electrical and thermal conductivity, the speed, size, price, durability or sensitivity of devices as well as many other properties. Transistor materials are at the core of development, and speed or density are not the only objectives.

General description of the development: Nanocarbons are clearly the most important new material that affects electronics. Graphene and carbon nanotubes, both independently and together with other substances, offer a bafflingly large range of properties for researchers to study. Graphene consists of a single layer of carbon atoms arranged in a hexagonal lattice. Carbon nanotubes are cylindrical variations of graphene.

Electrons can move almost without resistance in graphene. Researchers have learned to make flexible, low-power and fast electronics components out of graphene. By piercing or otherwise fragmenting graphene chrystals, it is possible to generate piezoelectric and optical phenomena. These in turn can be used to implement transparent contact surfaces or photodetectors, for example. This development is still in its early stages in many areas.

Resources and motive for development: Many public bodies and companies have invested billions of euros in total in graphene research. The greatest focus is on materials used in the electronics industry. In several studies, there is a clear academic motive alongside long-term commercial benefits, but there are also a great number of product development projects aimed at satisfying direct commercial benefits and meeting customer demand.

Impact on value-producing networks, ART 25																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	3	3	0	3	3	3	0	0	3	0	10	10	10	0	3	3	0	0	0	**162

Progress since the previous report: This group was added because new materials are expected to influence the development of electronics materially by 2037. The potential impact of nanocarbon on electronics has been debated for several years, but significant results in electronics were not achieved until after the publication of the previous report. Graphene makes it possible to manipulate light within the IR to UV range. This enables transmitters, display devices, photodetectors and lenses as well as other applications of optoelectronics and components of optical computing.

Spintronics-based computing and memory chips have been proven to work with graphene. This type of computing is very energy-efficient. Researchers have successfully, with a variety of methods, implemented transistors that are more efficient, faster and take less space than circuit-based transistors. Graphene has also been used to implement flexible electronics on fabrics, the surface of the skin and plastics. The production methods of graphene-based electronics have also evolved.

Interesting sources published after the 2013 report (025)	
Short description of the link	**link**
Manipulation of light in the IR to UV range with graphene	http://newatlas.com/graphene-gallium-nitride-two-dimensional-penn-state/45144/
The electrons in graphene can be controlled with voltage	https://www.rdmag.com/article/2017/10/scientists-discover-how-control-electrons-graphene
Spin can be turned off, graphene/MoS2, memory & processing	https://phys.org/news/2017-07-graphene.html
1-nanometer transistor gate from carbon nanotube	http://phys.org/news/2016-10-materials-smallest-transistor-nanometer-carbon.html
N3XT 3D chip architecture uses carbon nanotubes	http://phys.org/news/2015-12-skyscraper-style-chip-boosts-fold.html
The flow of electrons in graphene is ballistic, almost free of resistance	https://phys.org/news/2017-08-electrons-liquid-graphene-physics.html
A carbon nanotube transistor is more efficient than a silicon-based transistor	http://spectrum.ieee.org/nanoclast/semiconductors/materials/carbon-nanotube-transistors-finally-outperform-silicon
A single-atom optical switch has been fabricated	http://spectrum.ieee.org/nanoclast/semiconductors/optoelectronics/worlds-first-singleatom-optical-switch-fabricated
A nanoscale diode, transistor	http://www.eurekalert.org/pub_releases/2015-07/dbnl-mth072915.php
Graphene electronic paper created by China	http://www.jagranjosh.com/current-affairs/china-developed-worlds-first-graphene-electronic-paper-1461921648-1
The first functional graphene transistor (FET)	http://www.extremetech.com/extreme/183653-the-first-fully-2d-wonder-material-graphene-molybdenite-transistor-could-be-the-future-of-fast-electronics
Printable Lightpaper	http://www.fastcompany.com/3038890/rohinnis-lightpaper-is-incredibly-thin-and-printable
Graphene/platinum – a sensitive photodetector and artificial leaves	https://phys.org/news/2018-01-proton-graphene-renewable-energy.html
Fast, flexible silicon-based transistors	http://www.eurekalert.org/pub_releases/2016-04/uow-wsp042016.php
A flat graphene speaker heats the air	http://spectrum.ieee.org/nanoclast/consumer-electronics/gadgets/graphene-enables-flat-speakers-for-mobile-audio-systems
A perovskite transistor	http://spectrum.ieee.org/nanoclast/semiconductors/materials/for-first-time-researchers-fabricate-a-transistor-out-of-perovskite
An exact method for nanocarbon electronics	https://www.sciencedaily.com/releases/2017/07/170725090138.htm
A very fast semiconductor made of 3D tin	http://www.gizmag.com/2d-semiconductor-tin-monoxide/41843/
A foldable, wearable electronics (MS)	http://www.neowin.net/news/microsoft-is-serious-about-foldable-and-printable-electronics
Low-power transistors	http://www.cam.ac.uk/research/news/engineers-design-ultralow-power-transistors-that-could-function-for-years-without-a-battery

Interesting sources published after the 2013 report (025)	
A graphene coating turns paper into a display	http://spectrum.ieee.org/nanoclast/semiconductors/optoelectronics/grapheneenabled-paper-makes-for-flexible-display
Challenges in the development of a transparent graphene solar cell	http://news.mit.edu/2017/mit-researchers-develop-graphene-based-transparent-flexible-solar-cells-0728
Chargeless electric current in graphene	http://www.natureworldnews.com/articles/9010/20140912/using-graphene-spin-electrons-new-directions.htm
Graphene-like surface that is easier to create precisely	https://phys.org/news/2017-12-artificial-graphene-nanofabricated-semiconductor.html
A radical improvement to the Shottky diode with graphene	https://phys.org/news/2017-02-diodes-graphene-interlayer.html
Transparent and stretchable transistors and conductors	http://advances.sciencemag.org/content/3/9/e1700159

2.3.26 Radical growth in computing power (026) ****

Target area of the ART: The clock rate of computers is difficult to increase above a few gigahertz by means of traditional electronics. However, as the computing requirements continue to grow, speed may increase in a variety of ways. Firstly, instruction sets can be optimised according to tasks, as is described elsewhere in connection with artificial intelligence and neural computing. Secondly, parallel computing can be increased with traditional means or by means of quantum computing, as described elsewhere. Thirdly, we can switch from computing that is based on electron transfer to other elementary particles and faster phenomena. This ART includes ordinary increasing of parallel computing as well as elementary particle phenomena faster than electronics.

General description of the development: Researchers seek to utilise the phenomena in photonics, quasiparticles and spintronics in accelerating computing. Plasmonics makes it possible to capture photons inside matter and utilize their movement. Plasmons and other quasiparticles, such as Weyl fermions, are massless, similarly to photons. Spintronics relies on a capability to detect and switch a quark's spin direction and use this to accomplish computing. This type of development may increase computing power, but for the time being it is at the level of basic research.

Processor density has increased continuously. Because researchers do not know how to increase complexity efficiently, increasing density increases parallelism. Parallelism changes applications and the ICT architecture. The buses between processors and joint memory become congested and slow down computing if the tasks being performed share a great deal of input and output data. These problems have been worked on since the 1970s and continue to be worked on with an increasing amount of resources and concrete goals.

Resources and motive for development: The main emphasis in research into quantum phenomena and their utilisation is academically motivated, and companies have a long-term interest in it. Parallel computing has expanded from academic research into becoming an object of direct interest among IT companies.

Impact on value-producing networks, ART 26																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	10	10	5	5	0	5	5	10	5	10	5	5	0	5	0	10	5	5	0	10	****440

Progress since the previous report: The closest corresponding ART in the previous report was "2.72 Extremely dense processors that take quantum phenomena into account," which ranked at the highest level. Development has continued, and new radical opportunities have opened up. Weyl fermions have been observed to transport a charge at a thousand-fold rate compared to electrons in ordinary conductors. The 245 THz frequency has been found to be possible with plasmonic tunnelling. Spintronics can be used to implement terahertz-level cascaded logic.

Designed for parallel computing, the Tardis structure significantly reduces the memory required for multi-core processors. Instead of increasing linearly, the amount of memory required only increases logarithmically, which is why the memory required by a device with 128 processors is reduced to one third. With the significance of parallel computing growing, Intel has decided to invest $16 billion in the development of massive parallel computing.

Interesting sources published after the 2013 report (026)	
Short description of the link	**link**
Circuit speed of 245 THz is possible with plasmonic tunnelling	http://www.gizmag.com/nanoelectronic-circuits-quantum-plasmonic-tunneling/31714/
Weyl fermions carry charge 1,000 times faster than electrons	http://www.sciencealert.com/scientists-have-finally-discovered-massless-particles-and-they-could-radically-speed-up-electronics
Cascaded all-carbon spin logic with terahertz frequency	https://www.nature.com/articles/ncomms15635
New opportunities with quasiparticles called exciton-polaritons	http://www.news.iastate.edu/news/2017/06/07/exciton-polaritons
Intel invests $16 billion into massively parallel computation (FPGA)	http://motherboard.vice.com/read/intel-bets-167-billion-on-the-massively-parallel-future
Tardis architecture reduces multi-core processors' need for memory	http://spectrum.ieee.org/tech-talk/computing/hardware/tardis-memory-could-enable-huge-multicore-computer-chips

2.4 Transport, mobility and logistics

Technological advancement affects transport and mobility in many ways. Transport is rapidly becoming robotised. For the time being, the impact has been visible in improved driving safety. Future development is anticipated to significantly affect the accessibility and costs of both passenger and freight transport. Autonomous freight transport allows the equipment and transport times to be optimised. In passenger transport, the decreasing price and improving availability of transport services allow us to relinquish our private cars, which reduces the overall need for cars and parking places.

The development of battery technology and electric motors guides us towards more extensive electrification of transport. In addition to electric cars, other types of light vehicles are rapidly becoming electrified. Electric aircraft are also under development, and they are considered to be a sensible alternative with the help of anticipated battery technology. Electricity is also increasingly being used in waterborne transport as a form of energy. Through technological advancement, quadcopters and other drones have become viable instruments in the distribution of goods.

The development of transport has wide-ranging effects on urban structures, how people use their time and even the status of cities. Many cities have been founded and grown thanks to sea transport. Container transport has also shaped the world for its part. The Hyperloop, travelling at 1,200 km/h, will change economic geography similarly.

In the future, mobility technology will affect the everyday life of many people with reduced mobility, restoring their independent functional ability. Transport-related technology will also make it increasingly easy for devices to reach outer space and other areas difficult to reach.

Transport, mobility and logistics	
ART-ID	**The ARTs in the group**
27	Walking robot and walking assists
28	Autonomous cars and trucks
29	Light passenger & cargo transport vehicles
30	Quadcopters and other flying drones
31	Personal VTOL and other light aircraft
32	Light continuously (24/7) flying aircraft
33	Radical waterborne traffic
34	Hyperloop and other tunnel technology
35	Easier access to space
36	Robotic insects & other biomimetics

2.4.27 Walking robot and walking assists (027) ***

Target area of the ART: The natural human environment is built for legs. Regardless of whether we are moving about indoors, within an urban environment or along forest trails, we can make the journey by foot unless distances or waterways require more efficient modes of transport. If our legs are weak or disabled, we start facing problems even in everyday life.

A wheelchair or rollator does not help us climb or descend stairs, neither do they elevate us to talk face-to-face with other people or reach for items on the top shelf in a shop. Wheeled robots easily face the same problems. Robotic legs are being developed so that both machines and people with low strength in their legs can easily move about everywhere a healthy person normally can.

General description of the development: Walking robots have been developed for a very long time. At first, machines walked on four or six legs in order to keep the walking constantly balanced. Surprising obstacles almost always caused these types of walkers to fall over.

Walking based on the dynamic model has solved many problems. In this model, a robot always assumes that it will fall and calculates where it should place its foot next to prevent itself from falling. This idea of walking is suitable for environments with uneven terrain and in which the firmness of the ground under our feet is difficult to assess due to slippery conditions or loose soil or rocks. The dynamic falling motion model enables a robot to run or dance. The best two-legged robot is now able to react to surprising situations, run, walk up and down stairs and jump, and it does not get confused over slipping.

Besides walking robots, and partly using the same technology, researchers have developed robotic legs for people with low strength in their legs, paralysed people and amputees. Robotic legs are wearable equipment that either assist the wearer in walking or walk on his/her behalf. In assistive walking, the robotic legs read signals originating from the human nervous system or muscles and strengthen them. In other words, this strengthens the function of the person's own legs.

It is not possible to receive the needed signals controlling legs from the muscles of a paralysed person or amputee, so in these cases the person must control the walking movements by indicating them with his/her hands, for example. Alternatively, the robot can be connected to the brain, which learns to give the robotic legs more detailed instructions on the direction of the movements.

Resources and motive for development: Trailblazing companies, such as Honda, have engaged in this development because of a long-term motive. Significant research work has also been carried out by universities and particularly in military medicine for assisting disabled soldiers. There has also been significant product development among start-up companies in the robotics business.

Impact on value-producing networks, ART 27																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	5	1	0	0	1	10	0	10	5	3	0	10	0	1	5	5	0	5	0	***330

Progress since the previous report: The closest ARTs in the previous report were "2.70 Robotic legs and the exoskeleton that reinforces movement" and "2.54 A walking robot with hands." Both rose to the highest group.

Cyberdyne's exoskeletons were already undergoing testing at the time the previous report was written, as was the Honda Walking Assist Device. Both products have now become commercialised, and there are newcomers to the market. A robotic exoskeleton with a light structure, weighing 12.5 kg and costing $40,000, is now available for paraplegics. The rental price of the Honda Walking Assist Device is now €331 per month, according to one available source.

Functional exoskeletons that assist both arms and legs are available for military use and heavy warehouse work. Artificial muscles have enabled the development and testing of soft walking assist devices. The walking of a two-legged robot has been demonstrated off road, for example on a forest trail. Four-legged robots can already walk smoothly on uneven terrain. There are several robots that can walk around built environments.

Honda's Asimo has demonstrated running motion and it stays upright despite being pushed. The warehouse robot of Boston Dynamics leaps over obstacles naturally. It moves fast on its two wheel-equipped legs, similarly to a roller skater. The device is able to lift and transport heavy objects.

Interesting sources published after the 2013 report (027)	
Short description of the link	**link**
A soft exoskeleton	http://www.technologyreview.com/news/530751/motorized-pants-to-help-soldiers-and-stroke-victims/
Honda will lease its Walking Assist Device for €331/month	https://www.autoevolution.com/news/honda-walking-assist-device-leasing-debuts-better-chances-for-recovering-riders-98106.html
The Atlas robot does backflips	https://www.wired.com/story/atlas-robot-does-backflips-now/
FDA approved robotic exoskeleton for paraplegics at $80,000	http://futurism.com/new-robotic-exoskeleton-paraplegics-way/
FDA approval for Cyberdyne's robotic legs (HAL)	https://spectrum.ieee.org/the-human-os/biomedical/devices/cyberdynes-medical-exoskeleton-strides-to-fda-approval
The SuitX exoskeleton for performers of heavy manual labour	https://www.facebook.com/businessinsider/videos/642649132609143/
Hyundai's exoskeleton goes on sale	https://www.wired.com/video/2016/12/hyundai-s-exo-skeleton-makes-everyone-an-iron-man/

Interesting sources published after the 2013 report (027)	
A robotic exoskeleton for paraplegic people, $40,000, 12.5 kg	https://www.technologyreview.com/s/546276/this-40000-robotic-exoskeleton-lets-the-paralyzed-walk/
DeepMind: an AI learns to walk in a simulated environment	https://deepmind.com/blog/producing-flexible-behaviours-simulated-environments/
An exoskeleton for lifting work (South Korea)	https://www.newscientist.com/article/mg22329803-900-robotic-suit-gives-shipyard-workers-super-strength/
Motion planning is a problem to be solved in robotics	http://spectrum.ieee.org/robotics/robotics-software/motionplanning-chip-speeds-robots
(Superflex) soft robotic legs/exoskeleton	https://www.technologyreview.com/s/601420/the-elderly-may-toss-their-walkers-for-this-robotic-suit/
Assist wear implemented with soft artificial muscles	https://www.sciencedaily.com/releases/2018/01/180110101016.htm
Soft assist wear (power suit?)	http://fashnerd.com/2017/01/smart-clothing-sensors-and-artificial-intelligence/
The small Minitaur robot walks on ice	http://spectrum.ieee.org/automaton/robotics/robotics-hardware/ghost-robotics-minitaur-demonstrates-impressive-new-skills
Robotic prosthetics – a stiffening and softening exoskeleton	http://www.ted.com/talks/hugh_herr_the_new_bionics_that_let_us_run_climb_and_dance
Two-legged robot SCHAFT	http://spectrum.ieee.org/automaton/robotics/humanoids/shaft-demos-new-bipedal-robot-in-japan
Remote-controlled robot bodies for paralysed people	https://www.newscientist.com/article/mg23230974-600-paralysed-people-inhabit-distant-robot-bodies-with-thought-alone
A two-legged robot takes a walk outdoors	http://venturebeat.com/2015/08/15/watch-a-boston-dynamics-humanoid-robot-wander-around-outside/
Exoskeleton, EksoBionics	http://gizmodo.com/wheelchair-bound-woman-walks-again-with-a-3d-printed-ex-1528719886
A feeling prosthetic leg	http://europe.newsweek.com/worlds-first-feeling-prosthetic-leg-revealed-328387
A spring-mass based robot that can walk on uneven terrain	http://www.sciencedaily.com/releases/2015/10/151027132928.htm
An exoskeleton that enlarges ranges of motion	https://www.facebook.com/groups/TuVRadikaalit/permalink/931819636935643/
A soft exosuit from Harvard	http://www.smithsonianmag.com/innovation/this-soft-exosuit-could-help-people-walk-farther-easier-180961893/

2.4.28 Autonomous cars and trucks (028) ****

Target area of the ART: Measured in the value of the national economy, a car is the most significant mode of transport in both passenger and freight transport. Roads that serve cars and the street network are included in the major investments of society. There are roughly three million cars in Finland, the majority of which are private cars used in passenger transport. The average utilisation rate of private cars is 4%. Roughly a billion hours are spent driving a car every year. The costs of maintenance and storage are also considerable.

If driving can be robotised, it will free up a billion person-hours per year for other purposes in Finland. Shared use may increase with cars autonomously moving from one user to another after being released. Passenger transport and freight transport will become materially more inexpensive when the cost of a driver is eliminated, and urban structures can be improved once the need for parking spaces decreases through increased shared use of cars.

Mechanical control does not pose a problem to the development of self-driving cars. Real-time perception of the environment in traffic that moves at great speeds requires sensor data and computing. Functional driving also requires artificial intelligence that is able to anticipate the actions of other road users. All this must be made to function reliably in different situations and conditions.

General description of the development: The development of a self-driving car is described as comprising five levels. Level 1 is driver assistance, with examples including park assist and lane departure warning. The driver is clearly involved in the driving. Level 2 refers to partial automation, in which a robot takes control of the gas pedal, for example, and adapts to the speed at which the line of cars proceeds on a motorway or congested road. Level 3 is conditional automation, in which a robot is in full control of driving in favourable conditions, but a human must be ready to take control if the driving situation changes. Level 4 is high automation under the right conditions. The car can, for example, drive independently on certain routes or within a certain neighbourhood and under the right weather conditions. This level also includes platooning, in which one human driver is followed by a group of self-driving cars under the supervision of this human driver. Level 5 refers to full, human-like automation that is functional everywhere and under all driving conditions.

The main focus of development is now on levels 4 and 5. In monitored experiments, the cars drive in many areas and routes almost on a routine basis. Researchers are simultaneously developing 3D map data, various sensors and AI systems for the needs of the vehicles to ensure that an increasing number of situations can be handled. Legislative development is also active with regard to both allowing autonomous transport and addressing liability issues. In addition to technology and legislation, development is also underway on new business models and changes in industrial structures that are made possible by autonomous transport.

Resources and motive for development: Academically motivated research has taken second place with the automotive industry, electronics industry and transport service providers competing over key places in the new value-producing networks that autonomous transport will generate. It has been calculated that more than $80 billion has been invested in development over the last few years. Academic research still plays a very important role in the development of sensors and technology required by AI.

Impact on value-producing networks, ART 28																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	20	20	0	3	5	0	10	10	5	10	5	0	10	5	0	5	20	3	3	0	****670

Progress since the previous report: The corresponding section in the previous report was "2.45 Self-driving car," which rose to the highest group. At the time, the forefront of development was represented by Google's (Waymo) self-driving car, which had driven almost a million kilometres autonomously, under supervision, primarily on the road. Level 1 automation had become available in many new model year vehicles.

Many clear steps have been taken in the anticipated direction since then. Waymo has launched a fully driverless service pilot in Phoenix. General Motors has announced that it will launch an autonomous taxi service in 2019. The demonstrations given by Waymo, General Motors and Ford of the capability of their self-driving cars to handle complex driving situations in urban environments decisively exceed the simple examples that were available at the time the previous report was published.

Tesla's standard model cars are now capable of level 3 automation, and they gather observation data about their driving for the needs of AI. Musk anticipated that autonomous driving would commence in 2018. Almost all notable car manufacturers have announced that they are seeking to launch a level 3–5 car on the market in the early 2020s. Several developers have begun testing self-driving cars under winter conditions.

Autonomous transport pilots are allowed to be conducted among normal traffic, and autonomous public transport is being piloted among other traffic in several countries. General Motors has announced that it has completed a production line that is able to manufacture hundreds of thousands of self-driving cars per year. The deliveries will begin once the company finishes its software and legislators approve the cars for road traffic. GM, Ford and several other car manufacturers have made an agreement with Lyft about a joint interface that can be used to call a robot taxi.

Interesting sources published after the 2013 report (028)	
Short description of the link	**link**
Nvidia: a new processor enables level 5 autonomous driving	https://www.theverge.com/2017/10/10/16449416/nvidia-pegasus-self-driving-car-ai-robotaxi
Waymo launches an autonomous ride-hailing service in Phoenix	https://www.wired.com/story/waymo-google-arizona-phoenix-driverless-self-driving-cars/
An autonomous vehicle for car sharing from Ford by 2021	https://media.ford.com/content/fordmedia/fna/us/en/news/2016/08/16/ford-targets-fully-autonomous-vehicle-for-ride-sharing-in-2021.html
GM's self-driving car drives skilfully on the streets of San Francisco	https://www.driverless.id/news/video-analysis-new-gm-cruise-self-driving-video-shows-more-mastery-sf-roads-time-with-pip-proof-0176178/
Waymo transports customers autonomously in Phoenix	https://medium.com/waymo/with-waymo-in-the-drivers-seat-fully-self-driving-vehicles-can-transform-the-way-we-get-around-75e9622e829a

Interesting sources published after the 2013 report (028)	
California allows fully driverless cars	http://www.dailymail.co.uk/sciencetech/article-3816278/Self-driving-cars-let-loose-California-Officials-sign-bill-lets-vehicles-travel-without-human-driver-inside.html
GM will launch a commercial robot taxi service in 2019	https://www.theverge.com/2017/11/30/16720776/gm-cruise-self-driving-taxi-launch-2019
GM + Lyft: a robot taxi service will be launched in 2017	http://www.computerworld.com/article/3066929/car-tech/lyft-gm-self-driving-electric-taxi-soon-itbwcw.html
Autonomous electric trucks will be launched in Sweden	https://www.kauppalehti.fi/uutiset/ruotsalaisyhtio-kehitti-ikkunattoman-sahkorekan---toimii-myos-kauko-ohjauksella/CnPguEHV
$80 billion has been invested in self-driving cars	http://thehill.com/policy/transportation/355696-driverless-car-investments-top-80-billion
GM is prepared to start mass producing self-driving cars	https://www.engadget.com/2017/09/11/gm-might-beat-competitors-to-driverless-car-production/
Autonomous transport and Here	http://360.here.com/2015/01/05/bmw-unveil-future-driving-ces/
BMW promises a self-driving car by 2021	http://nordic.businessinsider.com/bmw-to-rival-mercedes-with-level-5-driverless-car-in-2021-2017-3?r=US&IR=T
Tesla’s autopilot has a 40% lower accident rate	http://www.theverge.com/2017/1/19/14326258/teslas-crash-rate-dropped-40-percent-after-autopilot-was-installed-feds-say
19 developers of self-driving cars aim for the 2020s	http://nordic.businessinsider.com/companies-making-driverless-cars-by-2020-2016-10
A supercomputer for self-driving cars – deep learning	http://www.hpcwire.com/2016/01/06/nvidia-pascal-gpus-coming-to-automotive-supercomputer/
Simulation of the capacity of autonomous transport	http://www.forbes.com/sites/chunkamui/2014/04/17/mit-and-stanford-researchers-show-robotaxis-could-replace-private-cars-and-public-transit/
Uber orders 24,000 driverless Volvos	https://techcrunch.com/2017/11/20/uber-orders-24000-volvo-xc90s-for-driverless-fleet/
China’s Didi, similar to Uber, has obtained $19 billion in funding	https://www.wsj.com/articles/chinas-ride-sharing-app-didi-raises-4-billion-in-new-funding-1513820940
A robot taxi service in South Korea	http://www.uusisuomi.fi/autot/166221-video-nain-saadaan-taksikuskienkin-tyot-loppumaan
Autonomous driving in snow has been tested in Lapland	https://techcrunch.com/2017/12/15/finnish-autonomous-car-goes-for-a-leisurely-cruise-in-the-driving-snow/
GM invests $500 million in Lyft as part of a self-driving car strategy	http://www.wired.com/2016/01/gm-and-lyft-are-building-a-network-of-self-driving-cars/
Uber & Otto: a self-driving truck makes its 1st delivery	https://www.wired.com/2016/10/ubers-self-driving-truck-makes-first-delivery-50000-beers/
VW invests €34 billion in electric and self-driving cars by 2022	https://www.ft.com/content/6ed3b1d2-cbbb-11e7-aa33-c63fdc9b8c6c?segmentid=acee4131-99c2-09d3-a635-873e61754ec6
Autonomous tractors in farm work	https://www.youtube.com/watch?v=T7Os5Okf3OQ
Prototype of Nuro’s self-driving delivery vehicle announced	https://www.theverge.com/2018/1/30/16936548/nuro-self-driving-delivery-last-mile-google
Baidu values autonomous transport at $1 trillion	https://seekingalpha.com/article/4103658-driverless-technology-may-give-baidu-120-billion-annual-revenue-2021

Interesting sources published after the 2013 report (028)	
Estimate of the spread of self-driving cars	https://singularityhub.com/2017/02/05/what-happens-when-self-driving-is-as-common-as-cruise-control/

2.4.29 Light passenger & cargo transport vehicles (029) **

Target area of the ART: Cars are heavy and bulky modes of transport in many situations. A bicycle is the most common mode of passenger transport besides a car. In terms of numbers, wheelbarrows or other devices pulled or pushed with muscle power are the most common modes of transporting goods after cars.

A great number of light electric modes of transport have been developed that are quicker than walking and more convenient or effortless to use than bicycles. Electric bicycles are one of them. Autonomous modes of transport are at an experimental stage in the transport of goods on public routes. Robots have already been developed for controlling industrial and commercial flows of goods in closed areas. Armies also seek to use new technology for their logistics needs.

General description of the development: The development of battery technology has opened doors for electric modes of transport. Information technology allows devices to move dexterously on one or two wheels and keep their balance. Among other things, this enables a one-wheel vehicle that the passenger can stand on. It can be carried like a briefcase on modes of public transport and does not require juggling skills to use. There are several manufacturers of these one-wheel vehicles.

The first common self-balancing personal transporter is Segway. After Segway, development has progressed towards lighter, more efficient or one-seater devices. In addition to one-wheel vehicles, self-balancing scooters, electric kick scooters, electric mopeds and electric unicycles have also become available on the market. Many light-weight devices are foldable. Their typical speed is 20 km per hour, with one full charge enabling an hour of use.

Cargo transporting equipment recognise and learn their assigned route and are able to move along sideways, for example. There are several prototypes.

Resources and motive for development: Light-weight modes of transport are being developed for the needs of the market. Development utilises components created for other reasons, such as the latest batteries, radar, inertia devices, Lidar systems and machine vision applications. The development projects are not particularly extensive. This is why crowdfunding motivated by the need and interest of customers is a clear contributing factor to development. Academic research has a minor role. Robots play a growing role in controlling industrial and commercial flows of goods, which motivates industrial subcontractors to develop robotic carriers.

Impact on value-producing networks, ART 29																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	10	5	1	3	0	0	5	3	0	3	3	0	5	0	0	3	5	0	0	0	**184

Progress since the previous report: The corresponding section in the previous report was "2.46 1 or 2 wheeled vehicles for personal or good traffic," which ranked in the second group. At the time the report was written, the first self-balancing unicycles had been launched on the market. Their price has since then decreased from $1,795 to the highly competed level of $300.

Electric bicycles have rapidly become more common, and robotic cargo carriers are being tested. Finland has legalised controlled electric personal transport devices, while Estonia is considering allowing fully autonomous light-weight cargo carriers on sidewalks. Handle by Boston Dynamics has demonstrated its almost autonomous capability to move about in an industrial space on two wheels while lifting and transporting heavy loads. Handle is also able to jump over obstacles and stay balanced in uneven environments.

Interesting sources published after the 2013 report (029)	
Short description of the link	**link**
Handle – a 2-wheeled robot moves up and down stairs and carries items	https://www.youtube.com/watch?v=-7xvqQeoA8c
Estonia allows distribution robots on sidewalks	https://www.engadget.com/2017/06/15/estonia-welcomes-delivery-robots-to-sidewalks/
A smart 2-wheel cargo carrier (Piaggio)	https://www.technologyreview.com/s/603558/this-robot-will-carry-your-stuff-and-follow-you-around/
A small 6-wheel distribution robot	https://www.youtube.com/watch?v=lzwz1UsxYdk
A robot buggy	http://nextbigfuture.com/2015/11/skype-cofounders-make-ground-delivery.html
Urb-E, an electric scooter	http://techcrunch.com/2014/02/10/urb-e-the-fold-up-electric-scooter-goes-live-on-indiegogo/
Thyssen's cableless lift travels horizontally and vertically	https://www.facebook.com/FuturismEnergy/videos/168353087046984/
Electric personal transport devices legalised in Finland	http://valtioneuvosto.fi/artikkeli/-/asset_publisher/muutosta-aletaan-valmistella-kevyet-sahkokulkuneuvot-laillisiksi-liikennekaytossa
A radar for bicycles	http://www.techcentral.co.za/sa-made-radar-to-keep-cyclists-safe/50704/
A self-balancing scooter	http://www.dx.com/p/eyu-x1-2-wheel-self-balance-drifting-electric-vehicle-white-black-370426
A spherical robot in military testing	http://www.iflscience.com/technology/meet-guardbot-spherical-amphibious-robot

2.4.30 Quadcopters and other flying drones (030) ****

Target area of the ART: For a long time, cargo and measurement devices have been transported from place to place with a variety of aerial vehicles. With advancements made in battery technology and IT, all types of small-scale airborne transport have become easier. Motors have become simpler and devices have decreased in size. New small devices do not require an airport or heliport to operate.

Quadcopters and other similar devices can lift off and land vertically in a small area. A computer is able to keep them balanced and control them in the desired manner. The devices can be used for filming and measurement purposes, cargo transport and many physical measures. Passenger aircraft are addressed in ART 31.

General description of the development: Quadcopters and other robot helicopters are a relatively recent invention. The devices typically have four or a higher even number of rotary wings rotating in opposite directions. A computer uses sensors to monitor the devices' balance and adjusts the rotating speed of the rotary wings individually as needed. The desired height, direction and speed are selected through control measures.

A quadcopter consumes a relatively large amount of energy compared to its size when lifting off and also during flight. Some UAVs use fixed wings similar to planes during flight. These are typically referred to as drones. These technologies can be combined. A device can lift off like a helicopter and then turn in the air to continue flying with wings. After this, the rotors no longer push the device upwards but forwards.

In the development of quadcopters, the focus is no longer on their ability to stay airborne or fly in the desired direction. The algorithms for this are relatively mature and widely available. Increasing flight time and payload as well as the controllability of flight in different weather conditions are the focus areas of development, in addition to many similar applications. The air control required by the devices, in addition to their ability to stay on the assigned route independently and prevent collisions, are under development. The electronics used in self-driving cars is not as such suitable for small aircraft that are subject to weight and power limitations.

Resources and motive for development: Quadcopters and drones are primarily being developed for both military and civil use based on demand. Academic research plays an indirect role through the development of battery technology and machine vision. The necessary product development contributions are relatively limited and comprise combining achievements in other technologies. Development may also advance considerably through start-up companies and crowdsourced projects.

Impact on value-producing networks, ART 30																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	1	20	3	3	0	1	5	1	3	5	3	0	0	5	0	1	10	0	0	0	****427

Progress since the previous report: The corresponding section in the previous report was "2.47 Quadcopters," which ranked in the second group. At the time the report was being written, the basic technology was functional, and devices were being used for filming. Since then, development has been rapid, particularly with regard to application.

Many countries have amended their legislation to allow quadcopters and other drones. The distribution of packages is wide-scale in China, for example. Numerous creative ideas have been tested. Researchers have developed a quadcopter that transports a defibrillator next to a patient having a heart attack, a quadcopter for building a rope bridge and a quadcopter for transporting weapons. Amazon is promising to deliver any goods ordered to our homes within 30 minutes of the order being placed once it is licensed by the authorities to launch the service. This trial is underway in Great Britain.

Special processors that can recognise obstacles and plan routes have been developed for quadcopters to operate autonomously. Quadcopters have been demonstrated to fly without problems in the woods and among people. Quadcopters are also already being used in agriculture, forestry and rescue operations. Autonomous operation of quadcopters is being prepared at the level of both the USA and the EU, and an automated air control system is also being developed for the same purpose.

Interesting sources published after the 2013 report (030)	
Short description of the link	**link**
Wide-scale delivery operations with JD.com quadcopters	http://www.caixinglobal.com/2017-04-10/101076281.html
Amazon launches quadcopter deliveries in the UK	http://www.csmonitor.com/Technology/2016/0726/Amazon-begins-testing-delivery-drones-in-Britain
Pentagon: swarm intelligence in attack drones	https://www.weforum.org/agenda/2017/01/the-pentagon-is-testing-hundreds-of-miniature-attack-drones
Nokia develops UTM for UAV traffic management	https://unmannedcargoaircraftconference.com/drone/nokia-europes-drone-collaborate/
Autonomous quadcopters are undergoing rapid development	https://youtu.be/ZIHNM37maK0
Quadcopters and other drones in weaponised use	https://www.youtube.com/watch?v=9CO6M2HsoIA
The FAA approved a quadcopter for the delivery of medical supplies	http://www.ibtimes.co.uk/faa-approves-first-drone-delivery-service-amazon-prime-air-loses-race-medical-supply-firm-flirtey-1511175
The FAA reduces regulation of drone traffic (2016)	http://www.inc.com/yoram-solomon/with-one-rule-the-faa-just-created-an-82-billion-market-and-100000-new-jobs.html
A quadcopter flies for 2 hours with a fuel cell	http://www.geek.com/news/drone-can-fly-for-2-hours-thanks-to-hydrogen-fuel-cell-1650724/
Tracking of quadcopters with NASA/Verizon phone towers	https://wtvox.com/robotics/verizon-and-nasa-are-developing-a-system-to-track-drones/
Regulation of quadcopters in the USA	http://econ.st/1B4ywgh
A versatile agricultural drone	http://www.american-robotics.com/
A quadcopter in lifeguard operations	https://www.good.is/articles/chile-drones-lifeguards
Perching quadcopters for surveillance	http://spectrum.ieee.org/automaton/robotics/drones/microspines-make-it-easy-for-drones-to-perch-on-walls-and-ceilings
Amazon's quadcopter with a hybrid design	http://techcrunch.com/2015/11/29/amazon-shows-off-new-prime-air-drone-with-hybrid-design/

Interesting sources published after the 2013 report (030)	
Google to launch quadcopter deliveries in 2017	http://myfox8.com/2015/11/28/google-x-hopes-to-launch-drone-deliveries-by-2017/
EU regulation of RPAS (drones)	https://www.easa.europa.eu/sites/default/files/dfu/NPA%202014-09.pdf
Mercedes' vision of a delivery van + drones for local distribution	https://qz.com/879605/mercedes-made-a-crazy-van-with-built-in-drones-and-robot-arms-to-deliver-the-packages-of-tomorrow/
Reforestation with quadcopters – a 15% decrease in costs	http://www.iflscience.com/environment/drones-take-reforestation-new-heights/
Small, autonomous assassination drones	https://www.themaven.net/mishtalk/economics/micro-assassination-drones-fit-in-your-hand-IcoMKId1qUeR4hKnf11x9w
RumbleTools released autonomous robot drones	http://www.mtv.fi/uutiset/kotimaa/artikkeli/suomalaisinnovaatio-maailmanvalloitukseen-lentavia-robotteja-kohta-muurarin-apupoikana-ja-kauppahalleissa/6143508
A weaponised quadcopter	http://www.ibtimes.co.uk/drone-shoots-handgun-while-flying-alarming-video-raises-safety-concerns-1511294
Quadcopters in agriculture	http://www.bloomberg.com/news/articles/2015-03-16/what-the-french-know-about-drones-that-americans-don-t
The BVLOS cargo drone flies from Hanko to Haapsalu	https://www.hanko.fi/ajankohtaista/ajankohtaista/miehittamaton_ilma-aluslento_hangosta_haapsaluun_16.8..8870.news?7_o=60
Wal-Mart tests drones for home delivery	http://in.reuters.com/article/2015/10/27/wal-mart-stores-drones-idINKCN0SL0B120151027
Regulation of quadcopters by Trafi	http://www.trafi.fi/tietoa_trafista/ajankohtaista/3174/miehittamattomille_ilma-aluksille_erittain_liberaalia_saantelya
Platform for Unmanned Cargo Aircraft (PUCA) under development	http://www.platformuca.org/
An assault rifle works on a quadcopter with the right suspension	http://www.tekniikkatalous.fi/talous_uutiset/yritykset/rynnakkokivaari-saatiin-toimimaan-kauko-ohjattavassa-pienlennokissa-aseyhtio-ratkaisi-rekyyliongelman-6668482
Festo's robot bird	http://www.ted.com/talks/a_robot_that_flies_like_a_bird.html
Sports with quadcopters	https://www.facebook.com/nrklivsstil/videos/10154044139728619/
Droneboarding in the snow	https://www.facebook.com/verge/videos/1031743590195317/?fref=nf
A flying defibrillator	https://www.facebook.com/stjohnfirstaid/videos/857910784251727/
A quadcopter monitors the condition of the railroad in the USA	https://www.bloomberg.com/news/articles/2016-08-29/buffett-s-167-year-old-railroad-tests-skies-for-the-drone-age
A hydrogen-powered quadcopter stays in flight for 4 hours	https://edgylabs.com/hydrogen-powered-drone-hycopter-flight-4-hours
A drone delivery company for delivering goods	http://flirtey.com/
A microfilament drone flies at 150 m 24/7	http://phys.org/news/2015-11-parc-limit-flight-microfilament.html
A quadcopter for aerodynamic flight	https://www.youtube.com/watch?v=kXql26sF5uc

2.4.31 Personal VTOL and other light aircraft (031) *

Target area of the ART: Since ancient times, humans have been dreaming of flying from place to place. Flying has become common, but planes and helicopters do not make it possible for us to make short everyday trips by air. The difficult and dangerous nature of helicopters as well as the runway required by planes and the heavy bureaucracy involved in flying airplanes are examples of obstacles.

The development of battery technology and IT are opening up opportunities for autonomous light-weight devices that transport people. In the manner learned from quadcopters and drones, the device can fly itself without a pilot-trained person being required to accompany the passenger. This ART addresses light devices that are primarily intended for transporting one person by air.

General description of the development: Material technology allows the body of an aircraft to be made very light. For power sources, researchers have developed the Wankel engine, which has a high power-to-weight ratio, as well as light, efficient batteries and electric engines.

The development of battery technology plays a key role in electric machines. The space required by aircraft on the ground and their relocation from a storage place to somewhere they can lift off have been solved in many different ways in prototypes. Most developers have chosen vertical lift-off, similarly to how helicopters operate. The aircraft of some developers continue flying with rotors, while others transition to horizontal flight.

The design solutions materially affect flight speed and flight time. For example, the size and protection of rotors vary. Small, protected rotors are safe for any people nearby, which is why lift-off and landing require less safety measures. On the other hand, they require more power to lift off. In addition to a protected passenger cabin, devices resembling skateboards or electric bicycles have been developed for recreational purposes.

Resources and motive for development: The development of passenger aircraft has expanded from activity funded by start-ups to activity undertaken by major aviation companies and taxi companies. The funding for development has multiplied from what it was previously. There does not seem to be any relevant academic research relating to this theme.

Impact on value-producing networks, ART 31																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	5	0	0	0	0	0	3	0	0	3	1	3	0	0	0	1	3	1	0	0	*80

Progress since the previous report: The corresponding section in the previous report was "2.48 On-demand personal aviation services." It ranked in the fourth group. The production of the Finnish electric aircraft FlyNano has now been launched. The device weighs 70 kg, carries its pilot and lifts off from and lands in water. Moller, which uses Wankel engines and is the second company mentioned in the previous report and a forerunner in this field, is still seeking funding for producing its machine.

The prototypes of new companies operate with electric engines. Airbus is testing its flying car, Vahana. The German VTOL Lilium has also completed its first flight and is aiming to fly a distance of 300 km. Other prototypes include Hirobo Bit, Joby, SureFly and Ehang, among others. Uber has announced that it aims to launch a consumer-priced flying taxi service by 2020 in several cities using VTOLs.

Interesting sources published after the 2013 report (031)	
Short description of the link	**link**
Uber: a profitability forecast of air taxis	https://www.uber.com/info/elevate/summit/
Bloomberg: a review of the development of flying cars	http://www.bloomberg.com/news/articles/2016-06-09/welcome-to-larry-page-s-secret-flying-car-factories
Test flight of Lilium's flying car in Germany	http://www.theverge.com/2017/4/20/15369850/lilium-jet-flying-car-first-flight-vtol-aviation-munich
Dubai Autonomous Transport Strategy	https://www.linkedin.com/in/mohammedbinrashid
Airbus tests a flying car in 2017 (Vahana)	https://www.fastcompany.com/3067669/exclusive/airbus-is-about-to-build-a-self-flying-electric-robo-taxi/1
SureFly – a quadcopter for people, 1 hour flight time, testing in 2017	https://www.facebook.com/businessinsider/videos/10154850271619071/
Flying cars as Uber's goal	https://www.wired.com/2016/10/uber-flying-cars-elevate-plan/
Dubai to test passenger drones in traffic	http://www.bbc.com/news/technology-38967235
Intel and Toyota to fund Joby's flying taxi	https://www.digitaltrends.com/cool-tech/electric-flying-taxi-joby-aviation/
A video of Lilium's test flight	https://www.google.fi/amp/s/techcrunch.com/2017/04/20/watch-liliums-successful-test-flight-of-the-worlds-first-electric-vtol-jet/amp/
Joby's eVTOL vehicle	http://www.jobyaviation.com/S2/
Uber's flying taxis in Dubai, LA and Dallas by 2020	https://www.engadget.com/2017/11/08/uber-works-with-nasa-to-get-flying-taxis-ready-for-2020/
Personal helicopter Hirobo Bit	https://www.facebook.com/groups/TuVRadikaalit/permalink/851170468333894/
Larry Page invests in flying cars	https://www.vox.com/new-money/2016/12/30/14105960/flying-car-future-explained
Zapata Ezfly, a commercial aerial Segway, flight time 3 min	https://newatlas.com/zapata-ezfly-flying-segway/53044/
A hoverboard with 10 min of flight time	http://zapata-racing.com/flyboardair-en/

2.4.32 Light continuously (24/7) flying aircraft (032) **

Target area of the ART: There are many reasons why aircraft should stay airborne for a long time and manage with low energy. Distances may be long, or devices, such as measurement and IT devices, carried by aircraft need to stay airborne for a long time.

Long-lasting flight can be achieved in the atmosphere with light, wide wing structures and by successfully utilising air currents. Structures lighter than air, such as balloons filled with hydrogen or helium, are another method used. Light solar panels may help an aircraft collect energy needed to prolong the flight during the flight.

General description of the development: Light, sturdy structures, efficient solar panels based on thin-film technology, light electric engines and light high-capacity batteries are methods used in seeking longer flight times. This type of aircraft could stay airborne without needing to land for any reason other than maintenance work or loading and unloading cargo. Continuous flight is particularly interesting because of telecommunication and air control, in which respect existing solutions are inadequate in different ways.

Airships from a hundred years ago or slightly younger than that are obtaining their modern equivalents. Material technology is producing increasingly sturdy, light structures and simultaneously increasingly dense, sturdy surface materials.

The aim is to implement an airship using as little helium as possible or in a way that ensures the safety of hydrogen. Lift-off and landing should then be handled by varying gas pressure, without leaking out the gas. This solution would give a highly energy-efficient form of transport to many kinds of loads.

Resources and motive for development: The development of continuously flying aircraft is motivated by challenges in telecommunication, military technology and logistics. Academic interest in this subject area seems to be limited, but the indirect benefit from academic research is great.

Impact on value-producing networks, ART 32																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	3	0	0	0	3	3	3	3	3	1	0	0	10	0	0	5	0	0	0	**148

Progress since the previous report: The corresponding section in the previous report was "2.52 Light continuously flying equipments," which rose to the second highest group. At the moment the report was written, the solar-powered aircraft Solar Impulse was the most advanced device. Headway has been made in reaching the goal, and many actors, such as Google and Facebook, have made considerable investments in this development. However, Google has discontinued its Titan project after the failure of the drone's first flight. The first flight of Facebook's corresponding prototype was a success, and the project has been expanded under the name Project Aquila.

Balloons have been developed for the purpose of providing Internet coverage in areas that do not have base stations for various reasons. Google's Loon balloons are controlled in air currents with AI, and the project has been expanded. Lockheed and several other operators have developed modern airships that are suitable for transporting considerable loads. A test flight of Lockheed's airship is planned for 2018. Its cargo capacity is over 20 tonnes, and it travels at a speed of 70 miles per hour. The travelling distance with one refuelling is around the world.

Interesting sources published after the 2013 report (032)	
Short description of the link	**link**
An airship for cargo transport from Lockheed	http://hybridhe.com/
Successful test flight of Facebook's relay station drone	https://www.facebook.com/facebook/videos/10154835146021729/
A solar-powered aircraft for flying around the world	http://www.solarimpulse.com/
SUNSTAR, a solar-powered aircraft for the HALE mission, is under development	http://www.solar-flight.com/projects/sunseeker-duo/
An 81-hour flight by a solar-powered aircraft	http://www.suasnews.com/2015/07/37499/solar-powered-81-hours-flight-successful-a-new-endurance-world-record/
Aquila advances, FB's system of atmospheric satellites	https://code.facebook.com/posts/348442828901047/aquila-what-s-next-for-high-altitude-connectivity-/
Lockheed: A hybrid airship to fly in 2018	https://www.circa.com/story/2017/09/18/science/lockheed-martins-hybrid-airship-is-taking-off-next-year-we-got-a-sneak-peak
Atmospheric satellite aircraft Solara undergoes testing (Skybender)	http://www.theguardian.com/technology/2016/jan/29/project-skybender-google-drone-tests-internet-spaceport-virgin-galactic
Google Loon to India	http://fossbytes.com/googles-project-loon-gets-indian-govt-in-principle-nod/
Google Loon around the world in 22 days	http://www.techtimes.com/articles/5216/20140405/googles-loon-balloon-circles-globe-in-just-22-days-internet-for-all-remains-goal.htm
PWC: Lifting 500 million people out of poverty with floating Internet base stations	https://www.theguardian.com/technology/2016/may/17/connecting-everyone-to-internet-global-economy-poverty
A drone stays airborne for a day with solar energy	http://youtu.be/rMkPjBf6dNQ
DARPA: flying platforms for aircraft	http://sploid.gizmodo.com/call-the-avengers-the-pentagon-wants-to-make-helicarri-1656968348
24-h hybrid drone Airstrato	http://nextbigfuture.com/2015/12/stratospheric-solar-electric-and-hybrid.html

2.4.33 Radical waterborne traffic (033) **

Target area of the ART: The challenges in waterborne traffic are partly the same as those faced in land traffic. Navigation in waterborne traffic requires more positioning and knowledge of the environment than land traffic. Technologies resembling those used with self-driving cars make waterborne traffic less tied to people.

We are able to influence the draught and surface shapes of ships with new technologies. Draught determines the amount of energy consumed when the ship displaces water. Energy consumption depends on the weight of the ship and its cargo, the design, surface structure and shapes of the hull as well as the travelling speed.

Draught is a more decisive factor for a ship's efficiency in inland waters than in maritime traffic. The economy of inland waterway transport and its development as a replacement for road transport depend on loading and unloading capabilities, the automated docking of ships to both piers and locks as well as the special requirements for ballast in both inland waters and icebreaking. Clearance (bridges) is also limited in inland water conditions.

General description of the development: Due to the increasing sizes of ships, European ports along the Atlantic Ocean have become transport hubs also for the Baltic Sea region.

Development is underway to make ships self-guided, and another aim is to make ship structures lighter. Because the environments that ships navigate, particularly oceans, do not provide relevant data for positioning purposes, positioning relies more on satellite data and data on the ships' previous movements and direction. On coastlines, potential ways to supplement GIS data include sonars that map the seabed as well as observations of the coastline or radio beacons.

In addition to its location, an autonomous ship also needs information and observations about other waterborne traffic and mapped routes. Otherwise waterborne traffic would be simpler to automate than motoring, for example, but verifying location data is difficult if satellite data is falsified.

Many expensive structures can be left out of unmanned vessels and particularly ships powered by electricity. This allows them to carry more cargo. The elimination of crew costs also facilitates the reduction of speed, which leads to considerable energy savings.

An unmanned ship is not particularly susceptible to piracy. An autonomous solar-powered ship can study sea conditions or recover plastic waste practically without causing any other costs besides capital costs.

The hull materials of ships can be made lighter and even buoyant. This is particularly beneficial in inland waters, in which draughts are not high. A lighter vessel can be made to carry a larger load or it can travel routes that other vessels cannot operate as efficiently. New composite materials, such as aluminium–steel composite metal foam, enable very light hull structures.

Foiling technology developed for passenger transport in inland waters considerably reduces the amount of energy required for fast waterborne transport, also generating less waves. The advancement of information technology facilitates the optimisation and continuous position adjustment of the hydrofoils. In maritime transport, energy efficiency is also affected by sails, solar panels, windmills and kite energy, each of which are being developed.

Replacing road transport with inland water transport requires the technology of conventional ships to be altered and logistics structures to be developed.

Resources and motive for development: The development of waterborne transport is not an academically active field. Maritime transport is primarily developed by companies and commercial research institutes and for the needs of companies engaging in maritime transport. Crowdsourcing and start-up funding can be significant in the development of small, robotised vessels. The EU seeks to favour the replacement of road transport with rail and inland water transport, so a social motive exists, or at least one has been publicly expressed.

Impact on value-producing networks, ART 33																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	3	5	0	0	3	1	1	1	1	3	1	0	0	1	0	3	3	0	0	0	**130

Progress since the previous report: This is a new category that was added because of its rapid development. Since the previous report, Rolls-Royce and VTT have presented the benefits and development prospects of unmanned ship transport and progress made in this area, in addition to publishing a white paper.

Lighter ship structures have been approved in regulations, Yara has started building an unmanned cargo ship for ocean transport, unmanned ferries have been developed and an ultralight inland water vessel has been introduced. The SeaOrbiter is crowdfunded. It is a slowly drifting marine research vessel that generates its own energy and food. Foiling is spreading as a new hydrofoil technology, providing windsurfing boards, sailboats and other waterborne vessels with considerable speed and energy efficiency.

Interesting sources published after the 2013 report (033)	
Short description of the link	**link**
Foiling	http://edition.cnn.com/videos/tv/2015/03/11/spc-mainsail-design-special-a.cnn
Autonomous electric cargo barges to be launched in inland waterways in 2018	https://www.theguardian.com/environment/2018/jan/24/worlds-first-electric-container-barges-to-sail-from-european-ports-this-summer
An ultralight inland waterway vessel does not require deep waterways	http://docplayer.fi/3182488-Biolaivat-ky-uutta-suomalaista-innovatiivista-varustamotoimintaa.html
RR: An autonomous ship under development in Finland	https://www.youtube.com/watch?v=vg0A9Ve7SxE&feature=youtu.be
Yara's autonomous, electric container ship	https://www.wsj.com/articles/norway-takes-lead-in-race-to-build-autonomous-cargo-ships-1500721202

Interesting sources published after the 2013 report (033)	
The SeaOrbiter is crowdfunded, set to begin construction	http://inhabitat.com/the-seaorbiter-futuristic-marine-research-vessel-reaches-crowdfunding-goal-nears-construction-start/
RR & VTT: A white paper on autonomous vessels	http://www.rolls-royce.com/products-and-services/marine/services/ship-intelligence/remote-and-autonomous-operations.aspx
Lighter ship structures in regulations	http://www.e-lass.eu/

2.4.34 Hyperloop and other tunnel technology (034) **

Target area of the ART: Travelling between city centres or through cities is often difficult. Airports are located far away and their operation is inflexible. Trains' reliance on schedules makes travelling difficult even if the trains usually arrive in city centres. Road traffic is often slow and congested.

The speed of traffic can be increased with magnetically floating cars and pods travelling in sealed tubes. Shortening travelling times between city centres to seven minutes per every one hundred kilometres seems possible. Cities that are located hundreds of kilometres apart would form a uniform commuting and services area.

General description of the development: Superfast maglev trains have long been using magnetic levitation instead of wheels. The magnetic field is achieved with superconductors, and the technology has been both expensive and demanding. The magnetic materials have now improved, and we have learned to use them better.

A passive maglev refers to a technology in which permanent magnets are attached in arrays to the underside of a train car or pod rather than the track. When passing by, they induce electric currents in the coils of wire attached to the track, which in turn generate an electromagnetic field that repels the arrays. In other words, a track does not have to be equipped with magnets, only coils. The moving train car is lifted on the tracks and moves forward without friction.

When a train car or pod is placed in a tube, there is no need to worry about interference from outside the tube. Air can be evacuated from the tube to reduce resistance. The device moves with magnets, and most of the kinetic energy returns with magnetic braking. It is estimated that this technology can achieve almost the speed of sound, but projects have also been proposed to achieve many times the speed of sound.

Short test tracks have been completed and longer ones are being designed. Several companies are developing this technology, and there are government actors interested in these projects in many countries. Passenger transport is not the only aim. For example, researchers believe that this technology can potentially be used to relocate ports and terminals farther away from cities' valuable shore areas. A port could be located at sea, with a terminal connected to it via a Hyperloop located inland.

In addition to cargo transport, transport of passenger cars on similar magnetic skates beneath cities is under development. According to the developer's estimate, the speed in the tunnel, with normal pressure, could be 200 km/h.

Resources and motive for development: The Hyperloop has progressed to practical tests with the help of start-up funding. Research communities and engineers interested in the subject have widely participated in the development of ideas and simulations. Major potential user organisations, ranging from states to cities and companies providing transport services, have contributed funding.

Impact on value-producing networks, ART 34																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	10	5	0	0	0	0	10	3	0	0	3	0	0	0	0	1	3	3	3	5	**184

Progress since the previous report: The corresponding section in the previous report was "2.49 Vactrains," which ranked in the fourth group. At the time the report was written, Elon Musk had just published his Hyperloop concept, which initiated the current rapid phase of development. After this, several companies were founded to develop practical products. Of these, Hyperloop One has made the most progress.

A speed of 310 km/h has been achieved on an almost kilometre-long test track, and Hyperloop One estimates that it requires a two-kilometre long test track to reach full speed. The company has signed several letters of intent regarding trials and practical implementation with the government of Dubai, for example. The company has formed a strategic partnership with Richard Branson's Virgin Group and is now one of the companies in the Virgin Group.

Elon Musk's companies have become active in digging tunnels, with test tracks being planned for fast transport of cars on skates through cities and for the implementation of a Hyperloop connection between major American cities. HTT is also carrying out active investigation in order to launch such projects.

Interesting sources published after the 2013 report (034)	
Short description of the link	**link**
The Boring Company introduces tunnel skates	https://www.facebook.com/techinsider/videos/750382231826802/
Hyperloop One – 1st test of the Hyperloop Pod a success, 310 km/h	https://www.engadget.com/2017/08/02/hyperloop-one-first-pod-xp1-test/
KPMG: A Hyperloop between Helsinki and Stockholm is viable	http://gizmodo.com/hyperloop-connecting-helsinki-and-stockholm-turns-300-m-1783135650
A passive maglev – magnets only on the underside of train cars	https://web.archive.org/web/20050309204941/http://www.skytran.net/press/sciam02.htm
The Boring Company has offered a high-speed loop connection for an airport	https://www.engadget.com/2017/11/30/elon-musk-boring-company-chicago-airport-transit/

Interesting sources published after the 2013 report (034)	
2 Hyperloop projects between Abu Dhabi and Dubai	http://mobile.reuters.com/article/idUSKBN1411AI
Hyperloop One as part of Virgin Group, Branson joins the board	https://hyperloop-one.com/introducing-virgin-hyperloop-one
A Hyperloop between Helsinki and Stockholm?	http://www.mtv.fi/uutiset/kotimaa/artikkeli/junalla-helsingista-tukholmaan-tulevaisuuden-junafirma-kiinnostui-tunnelihankkeesta/5573288
The Boring Company – a tunnel demonstration	http://insideevs.com/elon-musk-reveals-electric-sled-boring-company-tunnel/
Letters of intent regarding Hyperloops with Finland, the Netherlands and Dubai	http://www.cnbc.com/2016/11/10/hyperloop-one-finland-netherlands-dubai-setting-up-high-speed-transport-system.html
1st stage of SpaceX's Hyperloop Pod Competition	http://hyperloop.tamu.edu/news-release-january-30-2016/
Slovakia's Hyperloop project	http://www.engadget.com/2016/03/10/hyperloop-transportation-technologies-slovakia-contract/
A Chinese company's plan to build a 4,000 km/h Hyperloop	http://shanghaiist.com/2017/08/30/hyperloop.php
HTT will build the first commissioned Hyperloop pod	https://techcrunch.com/2017/03/21/hyperloop-transportation-technologies-starts-building-its-first-full-size-passenger-pod/

2.4.35 Easier access to space (035) ***

Target area of the ART: Space has always evoked interest and wonder in people. At first, we sought to go to space to satisfy our curiosity. Rational motives entered the picture later. The study of space has resulted in capability for intercontinental missiles, nonsticking materials such as Teflon (PTFE) and many other steps forward.

Space research produces many direct benefits. Satellites orbiting Earth relay telecommunication. They can be used to monitor the orbits of asteroids and comets and measure phenomena on the ground and in the atmosphere. Weightless space and vacuum can be used to manufacture material structures that are either impossible or materially more difficult on the ground.

The space near Earth contains a great number of asteroids and meteoroids, some of which would be priceless on Earth due to the rare metals they contain. Space allows continuous generation of solar energy, and it is a notable experience as a tourist destination. The space beyond the atmosphere also allows high-speed travel from place to place.

General description of the development: For the time being, access to space has required three-stage rockets that require an enormous amount of fuel to get a reasonably low payload into orbit or to outer space. The largest parts of rockets, the stages of a launch vehicle, have been abandoned after use and they have been destroyed upon returning to Earth. In recent years, significant development efforts have focused on enhancing fuels and making launch vehicles reusable. Researchers have also sought to develop planes that rise to the upper parts of the atmosphere and serve as launch pads.

Satellites are being developed to be increasingly light and smaller in size. Their dimensions have also been standardised so that the satellites of different developers would fit efficiently into the rockets of companies that provide transport services. Researchers have sought to develop new power sources for satellites travelling in space, such as solar sails and engines based on quantum phenomena. The efficiency of launch vehicles has also been improved with new engine solutions.

It has been long thought that a rocket is not the only way to reach space. A meteorite in orbit could provide a counterbalance from which a rope could be lowered to serve as a lift. The lift could extend from a geostationary orbit to the boundary of the upper atmosphere or all the way to the ground. Material technology already knows substances that could theoretically be used to achieve sufficient rope strength, but these space lifts are for the time being only being designed at the conceptual level.

Resources and motive for development: Since World War II, rockets have been developed for military purposes. Space research has since become commercialised due to telecommunication needs. Commercialisation has been expedited by NASA's decision to outsource the space travel required by its research activity to commercial subcontractors. Both traditional major companies and new companies funded with venture capital are investing in making space more easily accessible. Commercial short and long-term benefits, people's fascination with space and academic research all play important roles.

Impact on value-producing networks, ART 35																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	0	0	1	0	0	5	1	5	5	3	3	0	0	3	0	1	1	1	3	1	***198

Progress since the previous report: The corresponding section in the previous report was "2.51 CubeSat and other minisatellites." It ranked in the third group. A standard had been created for nanosatellites in order to enhance commercial broadcast activity. A new commercial operator, SpaceX, had made its first deliveries to the International Space Station in 2012. After the report, SpaceX began testing the landing of launch vehicles, and it is now reusing the same launch vehicles in its flights.

Several other matters have also progressed. Rocket engines and carbo fibre outer shells of rockets have been 3D printed. Ramjets and ionic thrusters have been tested. Branson's Virgin Group has joined the competition in the space industry. Several operators are planning to launch thousands of telecommunication satellites. WiFi connections are being developed for nanosatellites. THz connections are also being tested between space and Earth. The revolutionary propellant-free EmDrive has gained scientific support but not absolute affirmation. At the conceptual level, there is talk about half-hour travel times around the world through space. A journey to Mars is being seriously planned by several operators.

Interesting sources published after the 2013 report (035)	
Short description of the link	**link**
An ionic thruster for light aircraft	http://newsoffice.mit.edu/2013/ionic-thrusters-0403
Successful landing by SpaceX's rocket booster	http://www.space.com/32525-president-obama-hails-spacex-rocket-landing.html
Falcon Heavy: A Tesla to the asteroid belt	https://www.nytimes.com/2018/02/06/science/falcon-heavy-spacex-launch.html
Rocket Lab – 3D printed carbon fibre rocket, payload 150 kg	https://www.rocketlabusa.com
Bank of America: the space industry will be worth $3 trillion in 30 years	https://www.cnbc.com/2017/10/31/the-space-industry-will-be-worth-nearly-3-trillion-in-30-years-bank-of-america-predicts.html
Lunar XPRIZE, five teams try to land on the Moon in 2017	http://www.theverge.com/2017/1/24/14360574/google-lunar-x-contest-moon-landing-2017
Caltech: $17.5 million in funding for a solar power system of 2,500 modules	http://www.caltech.edu/news/space-based-solar-power-project-funded-46644
Metallic hydrogen will enable single-stage-to-orbit rockets if stable	https://www.livescience.com/57645-elusive-metallic-hydrogen-created.html
Inexpensive satellite launch, Branson	https://www.facebook.com/RichardBranson/photos/a.10150152138395872.292541.31325960871/10152552306725872/?type=3
Ramjet – Mach 4 supersonic cruise missiles	http://nextbigfuture.com/2015/08/russia-shows-off-supersonic-combusting.html
6 different experiments back EmDrive functionality	https://www.technologyreview.com/s/601299/the-curious-link-between-the-fly-by-anomaly-and-the-impossible-emdrive-thruster/
Musk's Internet network of 4,000 satellites, plan	http://www.cnet.com/news/elon-musk-is-trying-to-bring-the-internet-to-space/
A paper on the EmDrive to be published after peer review	http://arc.aiaa.org/doi/full/10.2514/1.B36120
Musk promises long-distance travel by rocket in under an hour	https://www.theverge.com/2017/9/29/16383048/elon-musk-spacex-rocket-transport-earth-travel
A WiFi connection with cubesats	http://www.ibtimes.com/introducing-outernet-free-worldwide-wi-fi-access-beamed-space-1556016
Successful test landing of a commercial spaceplane released from a helicopter	https://www.theverge.com/2017/11/13/16643094/sierra-nevada-corporation-dream-chaser-nasa-commercial-cargo-program-free-flight
A microsatellite is launched into orbit with 10 m, 3 t rocket	https://gizmodo.com/watch-the-japanese-space-agency-set-a-record-for-smalle-1822700556
The pilot wave and other EmDrive theories, an overview	http://emdrive.com/faq.html
An air-breathing rocket engine under development	http://tiedetuubi.fi/tekniikka/mullistava-rakettimoottori-sai-rahoituksen-ja-lupaa-mullistusta-avaruusliikenteessa
Hypersonic scramjets for launching satellites?	http://www.bbc.com/future/story/20161117-australias-hypersonic-spaceplane-for-a-new-space-race

Interesting sources published after the 2013 report (035)	
50 nano-spacecraft to explore 300 asteroids	http://www.popularmechanics.com/space/solar-system/a28265/finnish-scientists-push-for-50-nano-spacecraft-to-explore-300-asteroids/
The U.S. Commercial Space Launch Competitiveness Act	http://www.planetaryresources.com/2015/11/president-obama-signs-bill-recognizing-asteroid-resource-property-rights-into-law/
Ion rocket engine	http://nextbigfuture.com/2015/09/new-ion-drive-achieves-14600-isp-which.html

2.4.36 Robotic insects & other biomimetics (036) *

Target area of the ART: Animals possess a great number of characteristics and skills that are useful for humans to copy in their machines. For example, study of wall-climbing lizards led to the invention of adhesive glueless tape. Insects, birds and bats fly more easily and with less energy than machines developed by humans. Other animal movements are also worth mimicking. This ART includes all machines that mimic the movements of insects and other animals, with the exception of walking, which is discussed in another group. The common denominator is the research method: biomimetics.

General description of the development: Insects are small. The use of small machines is worth pursuing in congested disaster areas that are difficult to traverse and when monitoring targets that we do not want to disturb. Applications can also be found in agriculture, research, monitoring, espionage, rescue services and military use.

Various magnetic and piezoelectric phenomena and memory materials are being researched for making robotic insects mobile. The aim is to use minimal energy to make the limbs or wings of an insect move. Ordinary engines and power transfer mechanisms can be used in the size class of birds and bats. In order to make batteries lighter, research has been carried out on recovering energy from a device’s environment.

Resources and motive for development: The main motive of research is academic. Commercial interest in the biomimetics of mobility is limited, and it above all applies to all human-like walking which is described elsewhere. Because the movements of animals are energy-efficient and suited to their environment, motivation can be presumed to increase as the development of artificial muscles progresses, as it would place a variety of practical applications within reach.

Impact on value-producing networks, ART 36																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	0	3	0	0	1	0	3	3	0	0	0	5	0	3	5	0	0	0	*69

Progress since the previous report: The corresponding section in the previous report was “2.55 The cyber insect,” which ranked in the fourth group. The development of tiny robots has progressed, but very slowly. The flight of these insects has been extended from air to water. Flexible robots that are the size of a cockroach and move like them between low structures have been developed. A robot that flies like a bat and weighs 93 grams has been developed.

Interesting sources published after the 2013 report (036)	
Short description of the link	**link**
The flying Bat Bot, 93 g	http://www.theverge.com/circuitbreaker/2017/2/2/14483116/bat-bot-robot-drone-biomimicry
Insect drones	http://www.popsci.com/article/technology/rise-insect-drones
A flexible cockroach-inspired robot	http://www.abc.net.au/news/2016-02-09/cockroach-inspired-robot-could-help-save-disaster-victims/7149426
A flying and swimming minirobot	http://www.smithsonianmag.com/innovation/robobees-can-fly-and-swim-whats-next-laser-vision-180957308

2.5 Production of products and services

The most significant trend concerning products is efficient decentralisation of manufacturing, achieved with flexible robotisation. Centralisation is supported by increasingly efficient logistics. Things continue to be created by traditional, inflexible automation that is difficult to decentralise. Inflexibility of automation has typically increased economies of scale, regional specialisation and global exchange. An important characteristic of robotisation and new manufacturing methods is flexibility. Flexible production lines can manufacture small product batches and a variety of products with the help of information technology. At the forefront of development, a 3D printer or handy robot can manufacture a very large number of different products, even customising them. The greatest effect of this development may be the decentralisation of manufacturing to be increasingly close to the market, and for simple products, manufacturing may even take place at home.

Logistics has played an even more important role in service production than in the manufacturing of tangible products, with the exception of fully intangible telephone services, for example. Usually either the customer or service provider has travelled to the other's location. With virtual reality, an increasing number of services is becoming intangible.

Robotisation enables the automated production of physical services. A service may be fully automated or personally remote controlled. Telepresence saves travelling time and allows us to avoid some of the pressure involved in social encounters. For example, snowploughing can be performed through remote control, with only the machine that will physically perform the service travelling to the customer's location.

The transition in the production of products and services affects the nature of work tasks, the location of work, the need for work and skill requirements. Robotisation and digitalisation will have a radical impact on jobs over the next twenty years.

Production of products and services	
ART-ID	**The ARTs in the group**
37	Sensitive robotic fingers and arms
38	3D printing of things
39	3D printing of buildings and constructs
40	Self-organising and swarm intelligence
41	Ubiquitous environment and Internet of Things
42	New robotised services
43	New methods for manipulating materials/substances
44	Robotic tailor

2.5.37 Sensitive robotic fingers and arms (037) ***

Target area of the ART: Human arms and hands are better suited for the general use, transfer and combining of goods and substances than any machine humans have so far invented. This is understandable, as many goods and devices are used by humans and specifically designed to be handled by humans.

One of the key aims of robotics is to mimic the functionality of human arms and hands. Hands allow machines to handle the human environment and goods. For humans, robotic hands offer both a natural user interface and a familiar tool for handling things through remote control. In hand function, soft touch and sense of feeling are essential, in addition to natural movement. Robotic prosthetics are also important for those who have lost one or both of their hands. Sense of feeling in the robotic hand and natural control are key in such situations.

General description of the development: Robots' gripping devices usually resemble mechanical tools used by people, such as pliers, clamps or suction cups. With robots transitioning from factories to the human environment, development is focused on more sensitive and general-purpose devices. Lifting a raw egg without breaking it is a test that general-purpose robotic hands should pass.

Traditional mechatronic and hydraulic solutions are still being used in strength adjustment in robotic hands. Artificial muscles have yet to deliver on promises other than in special cases. The fineness of movements is important in strength adjustment, as is the ability to adjust and feel the strength of a grip.

The skin on robotic hands or other sensitive sense of feeling in the fingers in particular is key. Humans do not control their hands so much by sight as with the help of feedback from muscles and skin. Materials have evolved, enabling a sense of feeling in robotic fingers and prosthetics that is better than in human fingers. The softness and durability of skin are also essential and being developed.

Robotic hands may also be equipped with senses that humans do not naturally possess. For example, micro-radars, sonars and electromagnetic sensors placed in fingers may be useful in many tasks.

Resources and motive for development: The research motive is great in medicine, which is developing prosthetics for people who were born without hands or have lost one or both hands. The academic motive is highlighted in the linking of prosthetics directly to the brain of paralysed or handless persons.

For the time being, commercial development has produced relatively limited and, compared to humans, primitive gripping devices for industrial robotics, in which the tasks performed are repetitive and usually focus on one type of product.

The market for robots with hands or avatars has not yet opened up on a wide scale, which is why commercial development of human-like robotic hands is motivated by a more long-term goal and pioneer funding. Crowdfunding and amateur robotics play an important role at this stage of development.

Impact on value-producing networks, ART 37																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	5	5	5	0	0	3	0	3	10	5	0	1	0	0	5	3	3	3	0	***204

Progress since the previous report: The closest corresponding section in the previous report was "2.54 A walking robot with hands," which ranked in the first group and has now been divided into two sections.

Robotic arms have been developed as prosthetics in many new ways. They can be controlled with thoughts or arm nerves, depending on the nature of the disability. The sense of feeling in separate robotic arms used in remote work can also be linked so that a human can sense it. Tools that accurately recognise the position of the human arm and hand and convey the sense of feeling in robotic fingers to human fingers have been developed for remote controlling robotic arms. Artificial muscles have been tested, and flexible materials in fingers facilitate gripping.

Robotic arms installed in a kitchen have been demonstrated to be able to cook efficiently, otherwise using the same methods and tools used by humans. A walking robot equipped with arms has been demonstrated to be able to perform simple household tasks. Smooth walking and dexterous hands are being developed in separate projects, and robotisation is not yet mature enough with regard to interfaces so as to allow the best features to be combined without problems.

Interesting sources published after the 2013 report (037)	
Short description of the link	**link**
A robot chef from Moley Robotics (high-quality arms)	https://www.facebook.com/thisisinsider/videos/1502461713394555/
The future of robotic surgery (flexible arms)	https://www.facebook.com/TheScienceExplorer/videos/1530664270285974/
Sensitive robotic fingers with artificial muscles	http://europe.newsweek.com/robotic-fingers-use-artificial-muscles-lift-eggs-without-breaking-them-421701?rm=eu
A sensitive robotic hand suitable for remote work	https://www.shadowrobot.com/products/dexterous-hand/
Restoring sense of touch to a paralysed person through a prosthetic robotic arm	https://www.nationalgeographic.com/magazine/2017/09/explore-health-robotic-arm-senses-touch/
A robotic hand communicates sense of touch to the user via a brain implant	http://edition.cnn.com/2015/09/15/health/prosthetic-hand-senses-touch/index.html
A smart spoon for patients with Parkinson’s disease	http://thescienceexplorer.com/brain-and-body/smart-spoon-could-change-lives-parkinson-s-sufferers
Johns Hopkins: modular robotic arms to an amputee	https://www.facebook.com/viralinusa/videos/517223481970893/
Soft Robotics – sensitive robotic hands demonstrated	https://techcrunch.com/2017/04/01/soft-robotics-grippers/
Synthetic skin with a sense of touch	http://www.cnet.com/news/prosthetic-smart-skin-can-feel-all-of-the-things/
The robotic glove Exo-Glove Poly restores hand functions	https://youtu.be/QUUM_DUIU8c?list=PLKfWL8IXgKBte4TfD53pLaHONfSYCX0RH
A robot performs soft-tissue surgery	http://www.popularmechanics.com/science/health/a20718/first-autonomous-soft-tissue-surgery/
Ford: EksoVest, an upper body exoskeleton for industrial work	https://www.cnet.com/roadshow/news/fords-exoskeleton-could-help-factory-workers-in-a-big-way/
Warmth improves a robot’s sense of touch	http://spectrum.ieee.org/automaton/robotics/robotics-hardware/robots-with-warm-skin-know-what-theyre-touching

2.5.38 3D printing of things (038) ****

Target area of the ART: There is no need to explain the need for manufacturing goods. The features are determined by the materials, manufacturing processes and tools. Machines melt and squeeze a substance into a mould, break pieces into parts, join pieces together and coat them. Industrial structures are complex. Factories can specialise in materials, components made of these materials, assembly or finishing. Both subcontracting chains and distribution chains can be long.

The aim in 3D printing things is to produce pieces directly based on a computer model, without a mould. Another aim is to produce shapes and structures that would otherwise require assembly or are impractical because of their difficulty. Using 3D printing can materially shorten both subcontracting and distribution chains and reduce stocks.

General description of the development: The most important principles of 3D printing have been known relatively well since the 1990s. The patenting of the easiest techniques and the weakness of forerunner companies slowed down development until the start of the 2010s. Development has only sped up after the most important patents expired. The main 3D printing technologies are plastic extrusion, curing of photocurable liquid resin, fusing powder grains together with a laser or electron beam, and gluing and possibly fusing powder grains together with heat. Ultrasound has also been used.

In extrusion technology, the trend is towards increasingly diverse thermoplastics and plastic composites, increasingly inexpensive or precise devices and e.g. extrusion of carbon fibres, food, ceramics or biomaterials. New devices are able to print several different materials into the same object and mix them.

With regard to photocurable resins, the quality of the materials, printing speed and precision have been developed. The technology is precise, but the material properties are difficult to develop and the raw materials are valuable compared to thermoplastics. The most common technology allows the use of only one material, but there are also devices on the market that spray the liquid directly on the object it is intended to be attached to. These devices allow several types of photocurable resins to be attached to the same object.

In powder-based devices, the material may be plastic, metal or a composite. Powder-based devices are technically more complicated than the printers mentioned above and have higher asking prices. Devices that are intended for professional use typically cost several hundred thousand euros. Plastic printers are more inexpensive and considerably faster on average than metal printers.

Resources and motive for development: This technology is being developed by hobbyists, crowdfunded or investor-funded start-ups and major listed companies. The development motives include the expected rapid growth of the industry, customer demand and significant development potential. Academic research is significant, at least in the printing of biomaterials, optics and precision mechanics and the development of metal technologies.

Impact on value-producing networks, ART 38																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	1	5	20	0	0	3	3	3	3	5	5	0	1	0	5	3	3	3	3	1	****469

Progress since the previous report: The corresponding section in the previous report was “2.56 3D printing of goods,” which ranked in the highest group. The number of 3D printers and the turnover in the industry have multiplied since then.

Hewlett-Packard and several other well-funded operators have entered the market. New printing methods are both radically faster and more precise than previous methods. Several new methods now make it possible to combine different material properties in the same printed product. The quality of the printed products is materially better than it was before.

The aircraft industry is adopting 3D printing as a production method, and Airbus has flown a fully 3D printed small aircraft. Adidas has started 3D printing the soles of shoes, and Michelin is testing the 3D printing of airless tyres. Local Motors is bringing the first 3D printed car to the market. High-quality optics has been successfully 3D printed. The market for 3D printers is predicted to continue multiplying in size.

Interesting sources published after the 2013 report (038)	
Short description of the link	**link**
3D printing of ceramics (strong, precise, heat-resistant)	http://www.popularmechanics.com/science/a18801/3d-printed-wonder-ceramics-wont-shatter/
Fast, inexpensive 3D printing of metal (furnace)	https://techxplore.com/news/2017-08-company-focused-metal-d-faster.html
A fast 3D printer, SLA (Carbon 3D)	http://www.bloomberg.com/news/articles/2016-04-01/this-company-does-3d-printing-at-a-speed-no-one-else-can-match
Local Motors builds a factory in Europe	https://3dprint.com/159726/local-motors-berlin-microfactory/
3D printing of lenses	http://www.azom.com/article.aspx?ArticleID=11129
Adidas intends to sell 100,000 pairs of 3D printed shoes	http://www.cnbc.com/2017/04/07/adidas-3d-printed-trainers-futurecraft-4d.html
Airbus has flown a fully 3D printed plane	http://qz.com/707849/watch-airbus-made-a-completely-3d-printed-plane-that-actually-flies/
Aerosint: a 3D powder bed printer combines different materials	https://3dprint.com/190661/aerosint-multi-material-3dp/
3D printing of light graphene aerogel	http://www.eurekalert.org/pub_releases/2016-03/uab-tst030316.php
HP Multi Jet Fusion 3D Printer unveiled	https://3dprint.com/133713/hp-mjf-3d-printer-unveiled/
3D printing based on holography and photocuring – fast, freer geometry	https://techcrunch.com/2017/12/08/holography-based-3d-printing-produces-objects-in-seconds-instead-of-hours/
5,000 times faster nanoscale 3D printing with an electron beam	http://spectrum.ieee.org/nanoclast/semiconductors/nanotechnology/electron-beam-nanofabrication-made-up-to-five-thousand-times-faster
3D printing of metals with extrusion & furnace	http://www.eurekalert.org/pub_releases/2016-01/nu-anw011116.php
3D printing with cellulose acetate	http://news.mit.edu/2017/3-d-printing-cellulose-0303
Miniaturising hydraulics (robot) with 3D printing	http://www.technologyreview.com/view/544766/how-to-3-d-print-a-hydraulic-powered-robot/
Inkjet printable graphene	http://horizon2020projects.com/il-advanced-materials-manufacturing-processing/researchers-develop-printable-graphene-inks/
3D printing of micrometre-scale copper structures	http://phys.org/news/2016-01-copper-deposition-fabricate-tiny-3d.html
3D printing of cars (EDAG)	http://www.wired.com/autopia/2014/03/edag-3-d-printed-car/

Interesting sources published after the 2013 report (038)	
3D printing of biomimetics for aircraft design	http://www.aamulehti.fi/raha/luuta-lumpeenlehtia-ja-sienia-lentokoneisiin-etsitaan-uusia-ominaisuuksia-luonnosta/
3D printing of cellulose, a review of different methods	http://www.aalto.fi/fi/current/news/2015-11-05-007/
Progress made in the printing of metals – 10 times faster	http://3dprint.com/116276/nvbots-launches-nvlabs/
Michelin's airless 3D printed tyres	https://www.facebook.com/futurism/videos/800477063464828/
3D printed magnets	http://www.economist.com/news/science-and-technology/21710233-3d-printers-promise-better-cheaper-and-more-powerful-magnets-magnetic-moments
Customisable 3D printed products from Amazon	http://www.cnet.com/news/amazon-launches-store-to-sell-3d-printed-products/
3D printing of high-strength aluminium	https://www.youtube.com/watch?v=8YwlenA4bdg&app=desktop
Inexpensive 3D printing for aligning our own teeth	http://www.sciencealert.com/a-college-student-has-3d-printed-his-own-braces-for-less-than-60
A hydraulic 3D printed robot	http://news.mit.edu/2016/first-3d-printed-robots-made-of-both-solids-and-liquids-0406
3D printing of electronics	http://www.geek.com/chips/voxel8-3d-printer-can-print-a-complete-quadcopter-including-the-electronics-1613166/
Growth of the 3D printer market	http://usfinancepost.com/3d-printer-market-is-about-go-grow-tenfold-in-next-four-years-11511.html
Printing a fully functional speaker	http://gizmodo.com/you-can-now-3d-print-a-fully-functional-speaker-1484084187
A 3D printed titanium bicycle	http://www.gizmag.com/3d-printed-titanium-bicycle-frame/30760/
A method for colouring 3D printed objects	http://www.eurekalert.org/pub_releases/2015-05/cuso-nct052215.php

2.5.39 3D printing of buildings and constructs (039) *

Target area of the ART: Concrete construction is usually carried out by first making a mould using boards or plates, reinforcing the mould from the inside and casting concrete in the mould, after which the concrete solidifies as it dries and the mould can then be dismantled. An alternative method is to produce the frame structure by joining prefabricated elements, laying bricks or fastening block, wood or steel structures in a manner suitable for each material.

Construction can be enhanced by means of 3D printing and robotisation. These new methods can simultaneously be used to achieve customisation, varied shapes and cost-effective manufacture. This ART includes all robotised technology that enables customised construction.

General description of the development: From a construction technology perspective, the 3D printing of concrete entails slip casting. The concrete is cast without a fixed mould.

The concrete is mixed with an accelerator at the extrusion stage, allowing it to harden layer by layer before the next layer is cast. The challenges in the development of this technology are related to iron reinforcements, insulation, surface quality and the sensitivity of the process in relation to grain size of the sands used and humidity.

Non-load-bearing walls can be printed with 3D printers from plaster, for example, or a bricklaying robot can be used to put up a brick cladding. The latter is currently under development, as are robots that weld steel structures according to a model.

Robots are able to manufacture bricks, transport them to the construction site and lay a brick wall. Bricklaying robots are being tested in buildings. Robots are also being used in the manufacture of roof trusses and other building components and the construction of building foundations.

Resources and motive for development: The development of robotisation in construction is in the hands of relatively few companies or research units with low funding. The construction industry is very conservative, and the procedures are slow to change. The motive for development is related to the aesthetic and financial potential of new technology and expectations that the technology will mature and become usable in the construction industry.

Impact on value-producing networks, ART 39																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	1	0	0	3	1	10	1	0	3	1	0	0	0	0	5	0	0	1	0	*116

Progress since the previous report: The corresponding section in the previous report was "2.57 3D printing of buildings," which ranked in the third group. At the time, development was research and academically oriented. Since then, the number of developers has increased, and activities have expanded to rely in part on commercial companies and start-up funding.

The Chinese company WinSun has 3D printed the elements of a multi-storey building using concrete. The Finnish company Fimatec has published the first 3D printer for prefabricated walls, which is not only able to prefabricate external and internal walls but also coat the walls, automatically reinforce them and add thermal insulation according to building regulations.

A room has been 3D printed with a statuesque interior. Small offices have been printed in Dubai. A round house has been printed in Russia. Unsupported steel structures have been printed. Bricklaying robots have been introduced. Robotised manufacture of roof trusses has been launched.

Interesting sources published after the 2013 report (039)	
Short description of the link	**link**
Fimatec's 3D printer for prefabricated elements has been unveiled	http://yle.fi/uutiset/3-9596469
A 3D printed room – interior	http://www.youtube.com/watch?v=BV_6QUXFnuE
3D printing of houses in China (WinSun)	http://gizmodo.com/how-a-chinese-company-3d-printed-ten-houses-in-a-single-1557613229
Fimatec's concrete 3D printer development project	http://www.hs.fi/kotimaa/a1435029017846
A small office building has been 3D printed in Dubai	http://www.architectmagazine.com/technology/gensler-designs-the-worlds-first-3d-printed-office-building-in-dubai_o
A bricklaying robot	https://www.facebook.com/techinsider/videos/594897617375265/
A 3D printed steel bridge (the Netherlands)	https://www.facebook.com/Vocativ/videos/1020304231315145/
A round house has been printed in Russia	http://mashable.com/2017/03/03/3d-house-24-hours/
Supportless multi axis 3D printing in metal, MX3D	https://www.youtube.com/watch?v=NFF0QQIQDXE
Apis Cor, which 3D prints buildings, receives $6 million in funding	https://readwrite.com/2017/10/09/apis-cor-international-expansion/
Automatic roof truss production line	http://www.trussmatic.fi/

2.5.40 Self-organising and swarm intelligence (040) *

Target area of the ART: The living world comprises self-organising structures. Our cells recognise the environment they are in and function accordingly. The same applies to animals, organisms and communities. Each layer has its own autonomy and self-regulating homeostasis. In each layer, cooperation creates an emergent entity. For example, no one orders neural cells to take on the role of a brain or assembles them as such, but as a group, they form a brain.

The design of emergent structures is challenging. The entity manifests as the systemic combined effect of its simple parts. Evolution has had hundreds of millions of years to test, select and evolve emergent, layered structures.

Swarm intelligence is a powerful concept. It can be used to achieve fault tolerance, self-repair and adaptability in changing situations. Rather than repair, a better description would perhaps be healing, even in technical systems, and rather than construction and reprogramming, we should perhaps talk about adapting or growing. This ART covers self-organisation and self-repair in structures similar to swarm intelligence, which is why it is very abstract.

General description of the development: Research into self-organisation and swarm intelligence is young within engineering science and organisation science. In natural science, the same research dates back to Darwin. In information technology, the first common concept of self-organisation, “plug & play,” was received well and became common.

Many devices recognise their environment and adapt to it. Devices are also capable of detecting their own software failures and rectify them as well as repel viruses and balance themselves or the conditions.

Physical self-repair is for the time being a rare ability in technical systems, as is independent grouping to create an emergent entity without a pre-prepared model, which is characteristic of biology.

Resources and motive for development: Research into emergence, layered homeostasis and swarm intelligence is for the time being primarily academically motivated. Some companies and platform economy developers are studying the subject within the context of marketing, but this is for the time being not being done in the contexts of construction, assembly and maintenance.

Impact on value-producing networks, ART 40																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	5	5	5	0	3	5	5	0	5	1	0	0	0	0	1	0	0	0	3	*114

Progress since the previous report: This subject is new and was added on the list due to increasing research interest and miniaturisation of robotics. Recent scientific studies on swarm intelligence have been published within the contexts of pickup, mapping, assembly and organisation. For example, warehouse robots pick up products and assist each other. Modular robots adapt to the desired assemblies. Robots end up with shared views about the overall entity and they build entities. Robots have also been developed to have self-repair capabilities. Self-organisation can also in good conscience be considered to apply to waste collection robots operating in urban environments and modular housing, which allows a house to be easily relocated somewhere else. Concrete practical examples of progress are still few in number.

Interesting sources published after the 2013 report (040)	
Short description of the link	**link**
A self-folding robot / memory material	http://gizmodo.com/this-tiny-self-folding-robot-will-destroy-itself-when-i-1707655885
Robots equipped with self-repair capability	http://cacm.acm.org/magazines/2016/2/197416-self-repair-techniques-point-to-robots-that-design-themselves/fulltext
Waste-collecting robot (Volvo ROAR)	http://www.theverge.com/2015/9/16/9336229/volvos-robots-roar-trash-collection
The portable tiny house Koda	https://asunnot.oikotie.fi/kotiin/artikkeli/asuntomarkkinat/rakentaminen_ja_asuntomessut/pieni_alytalo_nimelta_koda

Interesting sources published after the 2013 report (040)	
A self-assembling robot structure (HyperCells)	https://www.facebook.com/futurism/videos/564265797085957/
Robot swarms in rescue operations	http://www.newsweek.com/zebro-swarm-robot-insect-network-ready-mass-production-686787

2.5.41 Ubiquitous environment and Internet of Things (041) ****

Target area of the ART: In cars, we adjust the seat to the most suitable position for us. If we have a broken product, we may look for the warranty certificate or information about where we bought the product. Objects involve a great deal of adjustment and remembering.

As the amount of information technology increases, our devices and other objects can become smarter so that a bench will remember us and automatically adjust itself to our preferred position, or an object may look for the information we need in its own databases. The word ubiquitous describes an environment that automatically, by means of information technology, adapts to our needs.

The Internet of Things (IoT) is an Internet-related concept in the field described above. This ART includes spaces and goods that are smart in an interactive manner. The ART also includes services that handle interaction in a smart, unique manner on behalf of objects with a known identity. These types of objects can be considered to be virtually smart even if they themselves do not possess actual intelligence or telecommunication capability.

General description of the development: A thermostat is one example of the first steps towards a smart environment. When a presence sensor is added to a thermostat and ventilation, the system is more clearly at the level of a ubiquitous environment. The simplest elements in a smart environment are lamps and escalators that sense presence. Automation is gradually increasing in construction, particularly in the construction of new buildings.

Today, products are equipped with codes that allow smartphones to show the product's details. The labels added to packaging for logistics purposes are unique, allowing us to find details about the packages' history, location and destination in data systems. A unique label is added to many products in the manufacturing stage. A car is the most familiar example of this, besides banknotes. This practice is even becoming common in ordinary traded goods. For the time being, unique labels are primarily specific to the type of good, and the data related to them is scattered and accessible through various applications and terminal devices.

The miniaturisation of information technology and spread of smartphones have made it practical to equip increasingly simple devices with smart features. Children's toys recognise presence, tyres can tell their own air pressure, construction beams can tell their strain or walls can alert us to any moisture within them.

An IoT computer that communicates with the Internet or smartphones and can be embedded in goods can be bought for a few euros. Many sensors only costs cents. A small display or electric engine can be bought for a few euros. Functionality can be achieved inexpensively. This is visible in the growth of the ubiquitous environment. Waste bins alert us when they are full, tooth brushes alert us about their lack of use, and the apartments in nursing homes alert us when an elderly person has fallen over or another unusual phenomenon has occurred.

Resources and motive for development: The academic motive for development in this field is comparatively low, with the exception of miniaturisation. Within the electronics industry development is continuously carried out, motivated by customer demand and in the hope of new product areas. New business models also motivate crowdfunded and investor-funded start-ups. Investments by service companies and the trade sector in IoT development are increasing for the purpose of collecting customer data and due to logistics needs.

Impact on value-producing networks, ART 41																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	10	10	5	0	3	10	10	5	5	3	3	0	10	0	5	5	5	3	3	****392

Progress since the previous report: This is a new ART. It was added because a smart environment will take on an increasingly active role as the number of smartphones and AR glasses increases. Examples of new developments include the decreasing of the price of Arduino controllers to a few euros, the adoption of new street lights that detect movement in urban environments, a strong increase in IoT-related discussion and projects for standardising the unique identification of objects and utilising cloud services in the interaction between people and goods as well as between goods and devices. Several new technologies, such as NFC, enable simple interaction with devices in our immediate environment.

Interesting sources published after the 2013 report (041)	
Short description of the link	**link**
A €10 Arduino IoT controller	https://www.olimex.com/Products/IoT/ESP8266-EVB/open-source-hardware
Cloud intelligence for dumb goods, Thing2Data	http://www.tivi.fi/Kaikki_uutiset/tavaroiden-uber-tuo-alyn-tyhmillekin-tavaroille-suurhanke-alkaa-6540964
A WiFi-connected IoT device without a power source	https://www.engadget.com/2017/12/05/researchers-3d-print-wifi-connected-objects-no-power/
An artificial feeling surface made from paper	http://spectrum.ieee.org/tech-talk/biomedical/devices/paper-skin-mimics-the-real-thing
An NFC-based user interface (IoT)	http://vimeo.com/96316406

Interesting sources published after the 2013 report (041)	
Battery-free, remote sensing, graphene RFID sensors	https://phys.org/news/2018-01-scientists-graphene-sensors-revolutionise-internet.html
Versatile home automation in a doll house	https://www.facebook.com/R29Beauty/videos/1433672733328910/
Smart street lighting, motion sensor, etc.	http://www.tekniikkatalous.fi/innovaatiot/90+miljoonaa+katuvaloa++suomalainen+startup+aikoo+valloittaa+ne+kaikki/a1028485
IoT – general description/background	https://www.linkedin.com/pulse/article/20140925043829-1409028-what-is-internet-of-things?trk=object-photo

2.5.42 New robotised services (042) ***

Target area of the ART: We humans serve each other both for work and for social reasons. We require services either due to being busy or having functional shortcomings, and expertise arising from specialisation is often important. Trade and services are gradually transitioning towards self-service. We pick up products from shops by ourselves and fill in forms. Instead of live music, we listen to recordings. Many previous services have become industrial mass products, and we find the most suitable ones for us from among them.

Robotisation promises to turn the trend from self-service towards both robotised and robot-assisted, humane services. Instead of self-service, a robot has the time and ability to help us in a personalised manner. In addition to fully robotised service, robots can also function as avatars. A service offered by another person can be brought close to us without any time needed for travel. This ART does not include autonomous transport, which is addressed in ART 28.

General description of the development: Remote services previously referred to telephone services or e-mail and self-service with the help of Internet forms. Video calls are gradually becoming more common. Health care services and many other online services provide an opportunity to chat with customer service personnel as well as verbots and chatbots, which are described in ART 15 of this report.

Avatars, i.e. robots developed for telepresence, are a recent addition to remote services, particularly in institutional environments and home care of elderly persons. A physician or nurse can see the patient or elderly person through an avatar. The avatar moves to the person being treated with remote control. In addition to conveying conversation and a sense of presence, a remote-controlled avatar robot can also perform simple measurements, procedures and independent monitoring.

Telepresence or artificial intelligence can be used to perform a variety of tasks relating to environmental care or cleaning. Robots are also able to provide assistance in numerous other tasks relating to moving objects and handling matter, in addition to the transport tasks addressed elsewhere in this report.

Resources and motive for development: The simplest service robots are already available on the market. The development motive is clearly related to customer expectations and competition. Development is motivated by investor-funded start-ups and robotics units of major companies pursuing new business models. Academic research plays an important role in the development of the general capabilities of robots.

Impact on value-producing networks, ART 42																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	0	3	3	1	1	10	5	10	5	5	0	3	3	0	10	3	0	0	5	***280

Progress since the previous report: This is a new ART that was created due to the anticipated strong growth of the service robotics market. The difference between production robotics and service robotics may be difficult to see in the future, as the manufacture of goods is at least in part returning from being provided by industry to being provided by the service sector.

In recent years, research into robotics has included research into self-assembling robots, waste sorting robots, vertical parking robots, robot cooks, waiter robots and numerous other robots related to services and manufacture. A fully robotised Japanese hotel is planning to expand to a hundred new locations.

A robot cook can cook a hundred different meals, the planned selling price is $75,000. Intestinal surgery has been 60% robotised in trials, and blood sampling can be fully robotised. Medical ultrasound can be performed remotely via a robot. Domestic robot prototypes are mobile and can move tableware and other objects and play games.

Interesting sources published after the 2013 report (042)	
Short description of the link	**link**
A robotic chef can cook over 100 meals	http://www.forbes.com/sites/eustaciahuen/2016/10/31/the-worlds-first-home-robotic-chef-can-cook-over-100-meals/
A 60% robotised intestinal surgery	http://spectrum.ieee.org/the-human-os/robotics/medical-robots/autonomous-robot-surgeon-bests-human-surgeons-in-world-first
A Japanese robot hotel intends to open 100 new hotels	https://www.curbed.com/2017/8/25/16201928/robot-hotel-japan-henn-na
LG's 3 service robots for hotels, etc.	https://www.cnbc.com/2018/01/04/south-koreas-lg-electronics-to-introduce-new-robots-at-ces-2018.html
Advancement in robotic kitchens, estimated price $75,000	https://www.facebook.com/futurism/videos/580578375454699/
A surgical microscope	http://www.scienceworldreport.com/articles/12903/20140214/next-gen-surgical-microscopes-see-tumor-cells-in-real-time.htm
A domestic robot prototype from Boston Dynamics	https://www.youtube.com/watch?v=tf7IEVTDjng
Boston Dynamics: A four-legged robot opens a door	https://techxplore.com/news/2018-02-boston-dynamics-robot-claw-arm-door.html

Interesting sources published after the 2013 report (042)	
The blood-drawing robot Veebot	https://www.facebook.com/futurism/videos/674588682720334/
A domestic robot from Halodi	http://halodi.com/
Saudi Arabia is developing a robot (service) city	https://www.bloomberg.com/graphics/2017-neom-saudi-mega-city/
Ultrasound technology with a haptically-enabled avatar robot	http://www.universityherald.com/articles/30622/20160521/robotics-news-deakin-university-telstra-invent-remote-ultrasound-technology-distant.htm
A table tennis robot, Omron – demo	https://m.youtube.com/watch?v=0PCJ2X7Dz7E
Foodini – a 3D printer for food	http://www.cnn.com/2014/11/06/tech/innovation/foodini-machine-print-food/index.html
A quickly constructed vertical parking robot	https://www.youtube.com/watch?v=XNZ3G2w5VVs

2.5.43 New methods for manipulating materials/substances (043) *

Target area of the ART: This ART includes the moving of objects by means of industrial assembly, with mechanical lifting equipment, conveyor belts and manual labour. Many new methods have been developed for assembly and the moving of objects in relation to assembly. Equipment used in actual cargo transport are not examined in regard to this ART.

General description of the development: Industrial manufacture and logistics have pursued economies of scale and the increase of batch sizes in repetitive work. The objects being assembled move along a conveyor, on which they are then processed or connected to parts or other matter. Each work phase normally uses automatic equipment that is either programmed to repeat the work phase or operates mechanically.

With the advancement of robotisation, we have begun talking about flexible production lines. They make it possible to change the direction of production and even add unique qualities to products. However, it typically still refers to the proceeding of products along a conveyor belt. A conveyor belt is often replaced by a lifting machine, such as a beam crane, which is used to move the object from one work phase to the next.

Mobile robots make it possible to keep the objects being assembled in place, while the robots handling them move from object to object. On the other hand, the replacing of conveyor belts with flying or otherwise moving robots in moving components is evolving at a fast pace, particularly in construction technology, but also on a wider scale in trials. Large warehouses are already using robots that assemble loads and move packages as part of their warehouse logistics. Warehouse logistics is also being automated in smaller specialised shops.

Product transfer platforms are being developed based on magnetism, soundwaves, electromechanics and hydraulics. The aim is to make them generic and flexible. Objects are also increasingly being moved to their place of assembly as structures that take little work to open up into their operational condition. The aim is to minimise the amount of space required for transport and the amount of assembly work required on site.

Resources and motive for development: Flexible industrial robotics, as well as warehouse logistics, are being developed by companies. This is a competitive field, and the development motive is commercial. More versatile robot mobility and their swarm and flight-based operation are being developed by start-ups funded by venture capitalists. Manipulation methods based on new techniques rely on academic research, which particularly focuses on miniaturisation and the nanoscale.

Impact on value-producing networks, ART 43																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	1	5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*27

Progress since the previous report: This is a new area. Since the previous report, Konecranes has unveiled a warehouse robot called Agilon, which can be tasked with taking objects into storage or picking something up from storage. ABB has unveiled a production robot called YuMi, which is able to move, combine and handle goods while being careful of any people in its vicinity.

A move-in ready 30-storey building was built in China in 15 days based on prefabrication at a factory. Swarm intelligent quadcopters have built a rope bridge. Small components have been moved with a tractor beam, sound waves and magnetically. Very high levels of precision have been achieved in magnetic transfer.

Interesting sources published after the 2013 report (043)	
Short description of the link	**link**
A motorised 3D table top by MIT	http://www.dezeen.com/2014/04/16/mit-media-lab-transform-table-technology-milan-2014/
Fast-paced construction	https://www.youtube.com/watch?v=rwvmru5JmXk
A maglev with nanometre-scale precision and 3D motion for transport	https://phys.org/news/2017-05-precisely-movement-levitating-applications.html
Quadcopters build a rope bridge, swarm intelligence in the assembly	http://www.bbc.co.uk/news/technology-34327364
Deloitte/Autodesk: A review of future manufacturing methods	http://www.autodesk.com/industry/manufacturing/resources/mechanical-engineer/future-of-manufacturing-report
Manipulation of materials with sound waves	http://futurism.com/links/new-class-of-sound-wave/
Acoustic manipulation possible for larger objects	https://www.sciencedaily.com/releases/2018/01/180121221627.htm
Production robot YuMi	http://new.abb.com/products/robotics/yumi
Graphene tweezers for grabbing biomolecules	https://phys.org/news/2017-12-graphene-nano-tweezers-individual-biomolecules.html
A water-based “tractor beam”	http://www.sciencealert.com.au/news/20141108-26002.html

2.5.44 Robotic tailor (044) *

Target area of the ART: Sewing clothes involves a great deal of manual labour that is now primarily performed in countries with inexpensive labour. Despite the manual labour, this primarily comprises mass production for clothing shops and online shops, from which customers buy their ready-made clothes. Purchasing customised clothing is usually an expensive service that requires several fittings.

Close 3D measurement and modelling of the body can be carried out in a routine manner with new technologies. Fully automated production of customised clothing seems to be an achievable goal as artificial intelligence and robotisation advance. This ART includes 3D measurement of the body, customised design of the cut of clothes and mechanical production.

General description of the development: For the time being, only imaging, i.e. automatic measurement of the human body, has been achieved of the envisioned operating method of a robotic tailor. Fitting rooms that measure and create a 3D model of a person for the manufacturing of clothes are coming to the market.

Customised clothes can be printed with 3D printers from artificial fibres, but this method is slow and expensive. Personalised two-dimensional knitwear can be produced with comparatively inexpensive machines. Simpler textiles, such as linen, can already be produced fully by machine.

It has proven to be very challenging for robots to perceive fabric in its different shapes and handle it smoothly in the manner required for sewing. The development of AI and robotic arms facilitate the efforts to solve this problem, but for the time being the challenges in development have exceeded the attempts to find a solution, with the exception of simple pieces of clothing.

Resources and motive for development: There are many different reasons for modelling the human body. The commercial and academic motives are strong and extensive. Computer modelling of clothing design is for the most part driven by commercial motives of the clothing industry. The development of robotic tailors is advancing based on commercial motivation and the interests of the clothing industry, and customised clothing is, for the time being, not a competitive field that the clothing industry has embraced.

Impact on value-producing networks, ART 44																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	10	0	0	0	0	5	3	5	0	0	0	0	0	5	0	0	3	0	*93

Progress since the previous report: The corresponding section in the previous report was "2.62 Robo-tailoring," which ranked in the fourth group. Since the report, precise measurement of the body has advanced to a routine level in terms of technology, and products are available for this purpose. 3D modelling of clothing has reached a routine level.

Robotic manufacturing has advanced. A Chinese company has announced that it will be establishing 21 fully automated production lines in the United States, each of which will manufacture a million T-shirts per year. A robotic production line is also able to produce a pair of jeans that is almost finished but requires some work phases to be performed manually. Customised clothing produced with Objet 3D printers have been presented in fashion shows. The prices of digital flat knitting machines have decreased.

Interesting sources published after the 2013 report (044)	
Short description of the link	**link**
A robotic production line produces a million T-shirts, 21 lines to be built in the USA	https://www.fastcompany.com/40454692/this-t-shirt-sewing-robot-could-radically-shift-the-apparel-industry
Two developers of robotic tailors in the USA	https://www.economist.com/news/science-and-technology/21727058-robot-tailors-are-their-way-sewing-clothes-still-needs-human-hands-how
An inexpensive digital knitting machine (flat)	http://www.theverge.com/circuitbreaker/2017/4/3/15162846/kniterate-digital-knitting-machine-3d-print-design-stitches-kickstarter
A 3D scanner takes body measurements for clothing	https://www.youtube.com/watch?v=A6fLH4F0DPU

2.6 Material technology

Nanotechnology is advancing rapidly at the research level. Nanomaterials are already available on the market as a variety of coatings that make objects frictionless, dirt-repellent or electronically and optically active. We have also learned to produce many nanomaterials as three-dimensional structures with sufficiently cost-effective means, allowing the applications to expand to objects that require mechanical durability or other special properties. Nanomaterials are also being used as composites. In the development of nanomaterials, simulation radically speeds up the testing and development of product features.

In the future, new materials will materially affect electronics, optics, electromechanics and other mechanics, construction, chemical and biological processes as well as a great number of product-specific features. The development of separation techniques and circular economy create new opportunities and needs for both choices of material and processing of raw materials. Carbon neutrality sets requirements, particularly for materials used in the construction industry.

The major change in material technology will lead to the industry needing to change its processes, product design and product features. According to an estimate, the change in the production of goods will be as substantial as the change brought on by the spread of iron or plastics.

Material technology	
ART-ID	**The ARTs in the group**
45	Frictionless surfaces and levitation
46	Light and strong or insulating materials
47	3D printing of metamaterials and compounds
48	Nanomaterials as fibres, fabrics and reinforcement
49	Production of nanomaterials
50	New separation techniques & circular economy
51	Antibacterial and repellent surfaces
52	Structural materials replacing concrete
53	Artificial muscle and artificial skin
54	Fresh water production
55	Smart materials and their simulation techniques

2.6.45 Frictionless surfaces and levitation (045) *

Target area of the ART: Friction is an obstacle to mobility. It occurs when materials slide or roll against each other, regardless of whether the materials are solid, liquid or gaseous. Friction is caused by phenomena at the atom and quantum levels, and the energy spent to overcome it turns into normal heat.

Friction can be reduced in many different ways. Improving wheels and bearings and decreasing the resistance of the surfaces and shapes of boats, cars, rails, windmills, skis and aircraft are all examples of both the potential and benefits of reducing friction.

General description of the development: In rotational movement, friction is caused by surfaces touching each other and changing shape as they are subjected to forces. Air and liquid resistance is caused partly by the fact that the moving object must displace them and partly by surface phenomena. These also cause friction when solid objects slide forward pressed against each other.

The loss of energy resulting from the transformation can be reduced by stiffening the materials or improving their elasticity and recovering transformation energy. The energy spent to displace gases and water is reduced by changing the shapes of the object so that the vibration created by its movement is as low energy as possible. The friction related to touch can be reduced by developing the surface shapes and composition.

Due to quantum-level phenomena, certain nanometre-scale shapes of surfaces cause repellence and reduce friction. Surface structures can also retain gases or other substances that facilitate sliding on the surface. On the other hand, friction can be reduced with the help of magnetic and quantum level levitation.

In practice, this development is divided into a few clear branches. Researchers seek aerodynamic shapes. Material technology is used to seek slippery surfaces and lubricants as well as pursue the recovery of kinetic energy spent in transformations. Magnetic levitation and its energy efficiency are being researched.

Resources and motive for development: There are strong academic and commercial development motives for overcoming friction in various ways. Research is conducted continuously in all areas.

Impact on value-producing networks, ART 45																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	5	3	3	1	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	*72

Progress since the previous report: The corresponding sections in the previous report were “2.50 Magnetic or superconductor based levitation” and “2.79 Materials that levitate on nanolevel,” both of which ranked in the fourth group. Levitation based on the magnetic locking ability of superconductors has not advanced to any significant degree. Cuprates have been used to achieve superconductivity at room temperature, but there are no practical applications for this yet.

Levitation based on permanent magnets has progressed. Halbach array technology has been successfully applied on Hyperloop test tracks, and variations of it are also being developed for industrial manufacture. Links to these sources are included in the relevant ARTs 34 and 43. Significant progress has taken place in the development of frictionless surfaces through a better understanding of nanoscale phenomena and simulation models. The friction properties of graphene and nanodiamonds have been found to be very low.

Interesting sources published after the 2013 report (045)	
Short description of the link	**link**
Cuprate superconductors in room temperature	https://www.nextbigfuture.com/2017/02/recipe-for-room-temperature.html
Trilayer graphene is a magnetic material	https://www.sciencedaily.com/releases/2017/02/170223114729.htm
Customised magnets	https://youtu.be/IANBoybVApQ?t=5m51s

Interesting sources published after the 2013 report (045)	
A frictionless nanodiamond ball bearing with a graphene surface	http://www.rsc.org/chemistryworld/2015/05/graphene-wrapped-diamond-ball-bearings-cut-friction-nothing
A monopole magnet	http://yle.fi/uutiset/suomalaistutkija_loysi_kauan_etsityn_yksinapaisen_magneetin/7059297
A frictionless material	http://www.sciencedaily.com/releases/2015/07/150721194001.htm

2.6.46 Light and strong or insulating materials (046) **

Target area of the ART: We need both load-bearing and insulating structures for various purposes. The weight of the necessary structure depends on the density and geometry of the materials as well as its strength and insulating capacity. Weight plays a particularly important role in flying machines, but also in tall buildings and long bridges. Weight and size are also very important in portable equipment and modes of transport as well as land and waterborne traffic.

The thickness of insulation and load-bearing capacity of structures are important questions in almost all machines and the built environment. Note that when referring to insulation, we are talking about several different types of insulation, such as the insulation of heat, electricity, moisture or gases. All of these types of insulation are required often.

General description of the development: Aerogels are the lightest known strong materials. They may even be lighter than air. The technologies for producing aerogel have evolved. Aerogels have been found to be excellent thermal and sound insulation materials even when their layers are half as thick as those of traditional insulation materials.

When talking about strength, it must be noted that this concept is not a simple one. Tensile strength and compressive strength must be understood as different properties, as must shear stability, bendability and other mechanical and chemical properties relating to strain tolerance.

Light and sturdy materials enable more energy-efficient flying or floating devices. By foaming metals, researchers have, for example, made aluminium foam, which is a sufficiently strong material for the hulls of ships and lighter than water. Researchers have developed a material with double the strength of steel in terms of weight using magnesium alloy.

Researchers have learned to 3D print and solidify carbon fibre with electricity. Welded seams have been made materially stronger, enabling lighter steel structures. A strong glue has been developed for metals. Researchers consider it to be possible for new materials to be used to build a 20-kilometre high tower, with more inexpensive space flights departing from the top of the building.

Resources and motive for development: Research into strong and light materials is for the most part driven by an academic motive. Product development by companies typically only becomes active after inventions have been verified and production methods have been invented. In addition to aerogels used as insulation, metal foams and carbon fibre production methods have also clearly progressed to the level of competitive, commercial motivation for product development.

Impact on value-producing networks, ART 46																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	5	5	5	3	1	3	10	0	0	0	0	0	3	1	0	3	1	0	0	0	**160

Progress since the previous report: The corresponding section in the previous report was "2.80 Ultralight and strong materials," which ranked in the second highest group. Progress has continued to be fast-paced. Researchers have successfully made 3D printed graphene that is as strong as steel and weighs as much as polystyrene. Researchers have made aluminium that is clearly transparent. Light, impact-resistant metal foams have been found to stop radiation. Researchers have made an aluminium-steel alloy that is as strong as titanium.

ABL made of lignin is twice as strong as ABS plastic. A light, flexible graphene aerogel retains 85% of its strength after being squeezed a thousand times. Light insulation that weighs less than a kilogramme per square metre has been used to achieve 45 dB soundproofing at low frequencies. The market for silica aerogel is expected to increase to billions.

Interesting sources published after the 2013 report (046)	
Short description of the link	**link**
3D printed graphene is 10 times stronger than steel, only 5% of its weight	http://www.nextbigfuture.com/2017/01/mit-makes-compressed-graphene-sponge.html
Silica aerogel is a light insulation material with record efficiency	https://www.worldbuild365.com/news/sycw8j1a0/industry-news/4-futuristic-building-materials-to-look-out-for-in-2017
Light, impact-resistant metal foams block radiation	http://www.eurekalert.org/pub_releases/2015-07/ncsu-sfm071715.php
An alloy of five metals that is as light as aluminium and as strong as titanium	https://www.nextbigfuture.com/2014/12/new-alloy-is-as-light-as-aluminum-as.html
A light, soundproof metamaterial	http://scitation.aip.org/content/aip/journal/apl/106/17/10.1063/1.4919235
A plastic made with lignin (ABL) is 10 times stronger than ABS	http://www.eurekalert.org/pub_releases/2016-03/drnl-ori032216.php
An aluminium-steel alloy is as strong as titanium but 10 times cheaper	http://www.roadandtrack.com/new-cars/car-technology/a24939/new-steel-alloy-titanium/
A strong, light nanolattice made with pyrolysis	http://www.nature.com/nmat/journal/vaop/ncurrent/full/nmat4561.html

Interesting sources published after the 2013 report (046)	
Metal foam is very heat-resistant	http://www.eurekalert.org/pub_releases/2016-03/ncsu-sfm032816.php
A light, strong magnesium alloy	http://www.eurekalert.org/pub_releases/2015-12/uoc--urc122315.php
A strong, sandwich-like aluminium foam structure for train cars	http://www.wired.com/2014/12/aluminum-foam-trains/
The lightness/strength of natural materials achieved with freeze-casting	http://www.eurekalert.org/pub_releases/2015-12/dbnl-tam121115.php
Light 3D printed graphene is stronger than steel	https://www.computerworld.com/article/3155102/emerging-technology/mit-creates-3d-printed-graphene-thats-lighter-than-air-10x-stronger-than-steel.html
Transparent aluminium	http://www.nrl.navy.mil/media/news-releases/2015/transparent-armor-from-nrl-spinel-could-also-ruggedize-your-smart-phone
Elastic graphene aerogel retains 85% of its strength after being squeezed 1,000 times	http://cen.acs.org/articles/95/i29/Plant-inspire-exceptionally-strong-elastic.html
The lightest 3D printed structure (graphene)	http://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/15209/Least-Dense-3D-Printed-Graphene-Structure-Enabled-by-New-Technique.aspx
A nacre-like aluminium structure is 2–3 times stronger	http://nanotechweb.org/cws/article/tech/70151
Solidifying carbon fibre with electricity	http://www.eurekalert.org/pub_releases/2015-04/miot-tam041415.php
Helmets inspired by hedgehog quills	https://www.inverse.com/article/25760-hedgehog-spine-quills-hedgemon-helmet-concussion
Gallium nitride is almost as wear-resistant as diamonds	https://www.eurekalert.org/pub_releases/2016-10/lu-rsa102816.php
A 20-km high tower	http://nextbigfuture.com/2015/08/canadian-inflated-tower-would-be-20.html
A wooden skyscraper to be built in Vienna	http://www.popsci.com/next-futuristic-building-material-wood
A metallic glue for electronics	http://phys.org/news/2016-01-metallic-soldering-welding.html
Q-carbon, harder than diamond	http://phys.org/news/2015-11-phase-carbon-diamond-room-temperature.html
Aerogel as thermal insulation	http://www.tekniikkatalous.fi/tekniikka/kemia/2012-02-02/Halpa-aerogeeli-on-tulevaisuuden-supereriste-3307075.html
A strong weld	http://www.eurekalert.org/pub_releases/2015-10/osu-mco102915.php
Cubic boron nitride coating harder than diamond, for processing steel	http://www.eurekalert.org/pub_releases/2016-03/tpu-cf031616.php

2.6.47 3D printing of metamaterials and compounds (047) *

Target area of the ART: Traditional methods that we use to produce materials that we need for goods, chemicals or structures are based on separation techniques, alloy, heat treatment and other treatment methods used in the process industry as well as joining surfaces created with these methods to each other. We also use a great amount of materials created by treating biological raw materials. These methods are insufficient for producing all material found in nature or theoretically modelled materials.

3D printing enables many materials produced at the nanoscale and microscale in which a honeycomb structure or interaction between the layers of material offer useful properties. When a material's nature changes without chemical reactions, it can be referred to as a metamaterial. This ART also includes potential chemical reactions, but excludes DNA printing, which is described elsewhere. In other words, this ART describes additive techniques used for the purpose of producing material properties, rather than completed objects.

General description of the development: There are many 3D printing techniques. They are discussed elsewhere. When talking about printing material structures and compositions, it is obvious that their scale is small. Printing is carried out by conveying a substance to the desired spots in a way that attaches it to a larger entity. Printing techniques allow several substances to be combined either by mixing them during the printing process or by printing them into different spots.

At the most precise level, 3D printing of materials is used to pursue chemical bonds that could otherwise not be achieved. For example, it is possible to use nanocarbon to print whole honeycomb structures that are very light and sturdy. It is also possible to pursue porosity in battery materials or hydrogen storage.

More complex materials can be used in printing to pursue surface structures with optical or electrochemical properties that make them excellent catalysts. Examples of this include the use of MOF materials for transforming solar energy into fuels and nanoscale shapes that eliminate gravity as a result of quantum level phenomena. Surface structures such as tissue and nacre have also been researched.

When the printed materials have mechanical post-printing properties, similarly to memory materials, it is referred to as 4D printing. For example, the printed material may transform due to the effect of an electric current. Researchers are pursuing a robot that can walk out of the printer after being printed as well as a self-assembling robot.

Resources and motive for development: The 3D printing of materials is an important tool for academic research in the study of the properties of new nanomaterials. Many of the results described elsewhere in this report have been achieved by 3D printing nanomaterials. 3D printing has progressed to being used in production, at least in medicine and the electronics industry. The aim in production is usually to find faster production techniques.

Impact on value-producing networks, ART 47																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	3	0	5	5	0	3	1	5	0	0	0	0	0	1	0	0	0	0	*69

Progress since the previous report: The corresponding subject in the previous report was "2.58 3D and 4D printing of material." It ended up in the third group. There has been clear progress made in the 3D printing of medications. Craig Venter's team has printed medical proteins. The FDA has approved a method for printing customised medicine capsules with adjustable content and absorption rate.

Electrically, optically and chemically active material structures have been printed, and they are described in their own functionality-based groups in this report. Transforming materials have been printed, and printing techniques that mix materials in many ways during the printing process have been unveiled for powder bed 3D printing technology, in addition to the previously known Objet printer that was limited to photocurable resin.

Interesting sources published after the 2013 report (047)	
Short description of the link	**link**
Venter's protein printer progresses, a detailed description	https://motherboard.vice.com/en_us/article/59zj9b/craig-venters-digital-to-biological-converter-is-real
3D printing of protein-based drugs (Venter)	http://www.theguardian.com/science/2013/oct/13/craig-ventner-mars
Synthesis of drugs with a portable device	http://news.mit.edu/2016/portable-device-produces-biopharmaceuticals-on-demand-0729
3D printing a drug manufacturing device – pharmaceuticals on-demand	https://motherboard.vice.com/en_us/article/wjpygw/new-reactionware-3d-printing-system-spits-out-pharmaceuticals-on-demand
LLNL: nanoscale 3D printing with two-photon lithography	https://3dprint.com/199184/llnl-nanoscale-3d-printing/
3D printed drugs/FDA	http://www.washingtonpost.com/news/to-your-health/wp/2015/08/04/fdas-approval-of-first-3-d-printed-pill-opens-up-endless-possibilities-for-personalized-medicine/
Programmable nanorobots for building molecules	http://www.manchester.ac.uk/discover/news/scientists-create-worlds-first-molecular-robot-capable-of-building-molecules/
Printing of graphene structures at the nanoscale	http://3dprint.com/27324/graphene-nano-3d-print/

2.6.48 Nanomaterials as fibres, fabrics and reinforcement (048) *

Target area of the ART: Fibres are materials that comprise long molecules and have a good tensile strength. They are primarily used in yarn and fabrics in which tensile strength is the most important determinant. Paper is another example of fibre-based materials. Fibres are added to substances when we want to add flexibility and tensile strength to the mix. Many are familiar with fibreglass boats and carbon fibre objects, and the adding of fibre to construction materials is well known among those who are familiar with old techniques.

Nanotechnology was previously only considered to be surface technology, but it is quickly becoming a notable research area in the manufacturing of fibres. Significant benefits can be achieved with nanofibres compared to traditional fibres. This ART includes synthetic fibres. Plant and animal fibres, including nanocellulose, are discussed in ART 68.

General description of the development: Progress is continuously being made in the spinning of carbon nanofibres. In practice, the fibres are still far from the potential strength that is made possible by the theoretical structure of graphene or carbon nanotubes. Additionally, they are still behind traditional carbon fibres with regard to their practical properties. The production methods are also still immature and expensive. However, in light of research goals it seems probable that nanocarbons will draw closer to their theoretical potential in the future, gradually surpassing traditional materials in many applications.

Synthetic fibres are being added to electronics, fabrics and structural materials. Fibres improve the strength properties of materials in many ways.

Resources and motive for development: The use of nanocarbons in fibres and reinforcement is for the time being progressing primarily based on an academic research motive. Nanocarbons are still too valuable for most practical applications, and the development of production processes is incomplete, with the properties falling many times below their theoretical values.

Nanocarbon has already found its place in the electronics industry. Printing materials mixed with nanocarbon in 3D printing are being offered for use, and their versatile commercial availability has led to product and market experiments being conducted by start-up-funded companies. As the production costs of nanomaterials decrease, researchers have started testing them as reinforcement for materials used in the process industry, such as plastic, concrete and asphalt.

Impact on value-producing networks, ART 48																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	1	5	0	0	20	5	0	0	0	0	0	0	0	0	3	5	0	0	0	*126

Progress since the previous report: The closest corresponding sections in the previous report were “2.75 Carbon nanotube yarn or thread” and “2.77 Nanocarbon as a reinforcement or as functional surface,” both of which ranked in the third group. Swedish researchers have succeeded in producing continuous, kilometre-long threads of synthetic spider silk. Nanofibres have been successfully produced with several different methods, both magnetically and with laser. A flexible conductor has been made of boron nitride. Graphene yarn has been tested as an electrical conductor. The durability of asphalt has been materially improved with graphene.

Interesting sources published after the 2013 report (048)	
Short description of the link	**link**
An extensive review of carbon nanofibres	http://www.sciencedirect.com/science/article/pii/S1369702115002084
Kilometre-long fibres, synthetic spider silk	http://www.slu.se/en/ew-news/2017/1/spinning-spider-silk-is-now-possible/
Production of strong spider silk is anticipated	https://www.livescience.com/57645-elusive-metallic-hydrogen-created.html
Very strong polyethylene fibres – an easy process	https://www.eurekalert.org/pub_releases/2018-01/miot-ufh010518.php
An electrical conductor made of graphene yarn	http://www.gizmag.com/stretchable-graphene-yarn/32657/
Graphene materially improves the durability of asphalt	https://newatlas.com/graphene-additive-asphalt-roads-eco-pave/52337/
A flexible conductor made of boron nitride	http://www.eurekalert.org/pub_releases/2015-08/ps-fdp080615.php - .VcY_8kTWhuo.facebook
Nanofibres through magnetospinning – quality, energy consumption	http://www.eurekalert.org/pub_releases/2015-05/uog-rdn052015.php
Growing nanowire lasers	http://www.eurekalert.org/pub_releases/2015-04/uow-snm041015.php

2.6.49 Production of nanomaterials (049) *

Target area of the ART: Nanomaterials have been found to have numerous special properties, many of which are useful. For example, nanocarbons could replace almost all of the most important applications of fourteen scarce metals, with the exception of gold jewellery.

Many properties of nanomaterials are superior, but their production methods are immature. This results in the materials being expensive and having poor quality. This ART includes the production methods and applications of graphene and other useful nanomaterials.

General description of the development: The properties of nanomaterials are tied to the structures of the materials, the size of continuous surfaces, the integrity of threads or the flawlessness of a surface. Additives, laminates and other molecules combined with a nanomaterial surface materially affect the properties.

The price of a flawless graphene crystal is rapidly decreasing, and increasingly large touch interfaces can be made of graphene. Production methods are evolving at a fast pace, enabling new properties as well as financially sensible use of nanocarbons in an increasing number of applications.

Graphene is the most important well-known nanomaterial. The quality of graphene materially affects its applications. In terms of material technology, we can talk about individual pure crystals on top of a surface, smaller flakes comprising several layers or mixed structures of varying sizes that are attached to each other. The word graphene is also used when referring to graphene oxide or layered surfaces formed by graphene and some other material. All of these can have different applications, production methods and properties. The value of the graphene market is estimated to grow to $1 billion by 2025.

Graphene is produced from graphite by separating its thin layers from each other. Graphene can also be produced by reducing carbon dioxide on a copper or glass surface, for example, by using heat and electricity. In the LIG (laser-induced graphene) method, a laser is used to burn off and separate all elements other than carbon from hydrocarbon or cellulose, leaving a film of graphene. A great number of methods has been developed for the production of graphene, with varying graphene quality and costs.

Resources and motive for development: Graphene research is to a significant extent academically motivated, but the commercial market for graphene has grown to such a large scale that development efforts can now be partly covered with income from sales. The anticipated fast pace of growth will also lead to venture capital investments and companies investing in new, potential product areas.

Impact on value-producing networks, ART 49																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	3	3	5	0	5	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	*120

Progress since the previous report: This ART is new. It was established due to the rapid development and increasing importance of the production of nanomaterials. Researchers have succeeded in increasing the production rate of single-crystal graphene to 60 micrometres per second in roll-to-roll processing. AMI's graphene production increased to 1,000 metric tonnes in 2016. VTT's process produces several kilos of nanometals per day with a test device. Silicon dioxide can be produced at room temperature. LIG graphene suitable for batteries and hydrogen production has been produced from wood. Porous 3D graphene material suitable for supercapacitors has been produced with sodium.

Interesting sources published after the 2013 report (049)	
Short description of the link	**link**
13/14 scarce metals can be replaced with nanocarbons	https://phys.org/news/2017-09-graphene-carbon-nanomaterials-scarce-metals.html
Most of the production of graphene in China	http://www.nanotech-now.com/columns/?article=1136

Interesting sources published after the 2013 report (049)	
100 times faster roll-to-roll growing of single-crystal graphene	http://spectrum.ieee.org/nanoclast/semiconductors/materials/singlecrystal-graphene-films-grown-two-orders-of-magnitude-faster-than-previous-methods
CNT, graphene and optical transistors	http://www.eurekalert.org/pub_releases/2015-09/nu-rcn090815.php
The graphene market may exceed 1 billion by 2025	https://www.prnewswire.com/news-releases/global-graphene-market-2017---a-1-billion-market-by-2025-300561732.html
Laser-induced graphene from wood for batteries, hydrogen production, etc.	https://phys.org/news/2017-07-chemists-laser-induced-graphene-wood.html - nRlv
Flawless graphene inexpensively	https://www.delta.tudelft.nl/article/making-graphene-affordable
Sodium & CO2 -> porous graphene for supercapacitors	https://phys.org/news/2017-08-greenhouse-gas-d-surface-microporous-graphene.html
A lithium-sulphur battery with graphene, several pieces of graphene news	http://phys.org/news/2014-12-future-batteries-lithium-sulfur-graphene-wrapper.html
VTT's nanometal process, kilos per day with a test device	http://www.tekniikkatalous.fi/innovaatiot/3+000+grammaa+paivassa++vtt+puskee+metallinanohiukkasia/a1053682
A high-quality graphene surface on SLG for electronics applications	http://phys.org/news/2016-02-scientists-common-glass-optimize-graphene.html
Graphene boosts the thermal conductivity of PET	http://physicsworld.com/cws/article/news/2014/oct/28/graphene-boosts-thermal-conductivity-of-popular-plastic
AMI's graphene production reaches 1,000 tonnes per year in 2016	http://www.nanotech-now.com/news.cgi?story_id=52605
Silicon dioxide at room temperature	http://www.eurekalert.org/pub_releases/2015-04/uog-ucs042315.php
Laser-induced graphene – producing graphene out of polymer with a laser	http://spectrum.ieee.org/nanoclast/semiconductors/nanotechnology/graphenebased-supercapacitors-enable-wearable-electronics

2.6.50 New separation techniques and circular economy (050) ***

Target area of the ART: Many types of raw material are required for production. In addition to materials found in nature or produced by agriculture, forestry and fishing, industrial byproducts and household waste also contain raw materials. All of these most commonly exist as compounds and mixtures or pieces attached together.

The separation of useful raw materials has traditionally been referred to as processing. The methods used are often referred to as separation techniques. A circular economy is an economy in which disposed commodities or other waste are used as raw material, with the aim of minimising the consumption of fresh natural resources. This ART includes material processing technologies that are aimed at as careful utilisation and recycling of natural materials as possible. The availability of fresh water is discussed in ART 54.

General description of the development: Nanocarbons are the most recent great promise in separation technique. Porous nanocarbon or a honeycombed nanocarbon surface are selective with regard to which atoms or molecules they let through and which ones they block or take in. Separation characteristics are also relatively easy to adjust, and the separation precision is in many cases better than that of traditional techniques.

In biological separation, bacteria or other small organisms are made to collect or separate the chosen particles. DNA-based nanomachines or multicellular organisms can be harnessed to serve separation techniques.

The most important phenomenon of a circular economy, the utilisation of carbon dioxide, is discussed in ART 78. A good example of this is the collection of landfill waste and plastic waste floating in the seas with robots. New methods are continuously being developed for the reuse of plastic waste, waste paper and other waste.

Resources and motive for development: Separation techniques are being developed within the process industry in particular. New types of separation techniques draw significant academic interest. The subject extends beyond chemistry, biology and physics to information technology and mechatronics, even partly at the same scale. Many processes may use methods from several disciplines. This research area is challenging, but IT simulations speed up trials. In the future, simulations will also open up this area to crowdsourcing.

Impact on value-producing networks, ART 50																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	5	5	5	3	5	3	5	0	3	0	3	0	1	0	0	0	0	3	3	***220

Progress since the previous report: The closest corresponding section in the previous report was "2.76 Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons," which ranked in the fourth group. The production of fresh water has been moved to group 54, and more weight has been placed on recycling.

Graphene has been successfully tested in filtering nuclear waste and various gases. Graphene filters have been found to easily penetrate solvents but block small particles. In one demonstration, whisky was stripped of its colour. Researchers have succeeded in developing a type of diode for separating liquid, with part of the liquids only flowing in one direction. Precious metals in recycled electronics are now being processed. A caterpillar that eats plastic, use of microbes in treating water, a DNA robot that sorts molecules, and a new porous liquid that dissolves gases are examples of recent advances made in this area.

Interesting sources published after the 2013 report (050)	
Short description of the link	**link**
Building blocks made of recycled plastic	https://www.facebook.com/DavidAvocadoWolfe/videos/10153603640636512/
A report on the sufficiency of resources	http://www.mckinsey.com/insights/energy_resources_materials/reverse_the_curse_maximizing_the_potential_of_resource_driven_economies
Helium in nanochannels, promotes fusion energy, etc.	https://phys.org/news/2017-11-fusion-energy.html
The Row-bot treats water by eating the microbes in it to power itself	http://www.dogonews.com/2016/1/7/ingenious-row-bot-devours-microbes-from-polluted-water-to-fuel-itself
A useful material out of PE + iPP waste	http://science.sciencemag.org/content/355/6327/814
A graphene oxide filter lets solvents through, filters out nanoscale particles	https://www.theengineer.co.uk/graphene-based-filters-slash-cost-chemical-separation-purification/
A diode for fluids	http://physics.aps.org/synopsis-for/10.1103/PhysRevLett.115.134503
Precious metals in recycled electronics	http://www.bbc.com/future/story/20161220-the-scientist-mining-mobile-phones
Separation of minerals with the help of bacteria	http://bt-isotopes.com/
A porous liquid	http://www.eurekalert.org/pub_releases/2015-11/qub-qub111115.php
A DNA robot moves and sorts molecules	http://science.sciencemag.org/content/357/6356/eaan6558
Industrial symbiotic relationships	http://www.sitra.fi/talous/teolliset-symbioosit
Examples of a circular economy	http://www.maaseuduntulevaisuus.fi/ymp%C3%A4rist%C3%B6/sitra-kotimaista-h%C3%A4rk%C3%A4papua-tuontisoijan-tilalle-1.126302
A technique for separating uranium from seawater continues to advance	https://www.forbes.com/sites/jamesconca/2016/07/01/uranium-seawater-extraction-makes-nuclear-power-completely-renewable/
A graphene filter for nuclear waste	http://spectrum.ieee.org/nanoclast/semiconductors/materials/graphene-filter-offers-a-tenfold-reduction-in-energy-requrements-for-cleaning-nuclear-waste
Laser as a rust removal method	https://www.youtube.com/watch?v=WgiecR6LzwA
Making paper out of waste paper at the office	https://www.facebook.com/ScienceNaturePage/videos/765132843618976/
A new filtering method for heavy metals	http://www.eurekalert.org/pub_releases/2016-01/ez-heh012216.php
A caterpillar that eats plastic, recycling biodegradable waste	https://www.forbes.com/sites/grrlscientist/2017/04/24/these-caterpillars-can-eat-your-plastic-trash/

2.6.51 Antibacterial and repellent surfaces (051) **

Target area of the ART: Our goods and the built environment become dirty. Hazardous materials easily accumulate on surfaces and may potentially cause diseases, spoilage or corrosion or impair aesthetic appearances. New surface materials can reduce problems or prevent them entirely. In addition to the surfaces of goods, this ART also includes the packaging materials containing goods and substances.

General description of the development: Antibacterial and dirt-repellent surfaces are being developed from nanomaterials in particular. For example, nanocarbon coating has been found to prevent an aircraft's wings from freezing over, and both silver and copper are known to kill bacteria. Frictionless surfaces repel dirt and moisture.

A surface may have special characteristics that prevent the product it is protecting from rusting, losing its colour, being exposed to UV light or moisture or warming up. These needs may be related to a variety of goods and structures.

Several antibacterial surfaces are based on the use of silver or titanium oxide. A surface treatment provides protection from microbes, mould or dirt in general, depending on the method of treatment, and this type of treatment is beneficial for medical instruments, dosing instruments, containers, treated surfaces, structures, textiles and equipment used in the food industry, chemical industry and agriculture.

Resources and motive for development: The development of protective surfaces is part of companies' continuous product development. With regard to nanomaterials and other special materials and phenomena, there is a notable academic motive.

Impact on value-producing networks, ART 51																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	5	3	5	3	3	3	3	3	0	3	0	1	0	0	0	0	0	1	0	0	**132

Progress since the previous report: The corresponding section in the previous report was "2.74 Antibacterial and other dirt repellent materials and surfaces." It ranked in the highest group. A self-cleaning, self-repairing painted surface and the use of copper as a material in antibacterial surfaces are new research findings made after the previous report.

Graphene has been used to improve the water resistance of plastic film by a million-fold. The accumulation of ice on aircraft wings has been prevented with a graphene coating. Researchers have developed a translucent plastic film that cools the surface it is covering. A nanofabric reflects light and allows IR to escape. A self-cleaning, hydrophobic paint has been developed, and the durability of objects has been materially improved with strong and resilient paint.

Interesting sources published after the 2013 report (051)	
Short description of the link	link
A million times more water resistant plastic film with graphene	http://www.plasticstoday.com/packaging/graphene-infused-packaging-improves-lifespan-moisture-sensitive-products/109717355624929
A graphene coating keeps wings ice-free	http://www.eurekalert.org/pub_releases/2016-01/ru-gcm012516.php
A cooling nanofabric (reflects light, allows IR to escape)	http://spectrum.ieee.org/nanoclast/semiconductors/materials/nanomaterial-offers-first-fabric-that-can-keep-us-cool
A cooling, translucent plastic film	http://www.sciencemag.org/news/2017/02/cheap-plastic-film-cools-whatever-it-touches-10-c
An amazing video demo of "miracle materials"	https://www.facebook.com/ScienceNaturePage/videos/896390947159831/
A self-cleaning, hydrophobic paint	http://www.scienceworldreport.com/articles/23182/20150310/new-tough-paint-super-water-repellent-self-cleans-video.htm
A passive radiator in cooling	http://spectrum.ieee.org/tech-talk/green-tech/solar/passive-radiators-cool-by-sending-heat-straight-to-outer-space
UV LED lighting for disinfection from Salo	http://ledtailor.fi/fi/fotonidesinfiointi/
Antibacterial surfaces – copper destroys viruses	http://www.eurekalert.org/pub_releases/2015-11/uos-uct110915.php

2.6.52 Structural materials replacing concrete (052) *

Target area of the ART: Steel and concrete play a major role in the built environment. Both of them cause considerable amounts of carbon dioxide emissions and their production has high energy cost. Furthermore, the durability of traditional materials is limited, with ageing and consumption causing considerable maintenance costs. Replacements have been developed for concrete, and several options are progressing to the commercialisation phase.

Concrete has excellent compressive strength, but its other strength properties are modest, which is why iron reinforcements have been necessary. Replacing the expensive iron reinforcement phase with less expensive methods is one of the objectives.

General description of the development: The replacement of reinforced concrete with new compounds is being researched with the help of wood fibres, ash, plastics and nanocellulose in particular. Quickly hardening concrete that is suitable for slip casting and 3D printing, as well as fibre-based reinforcements that reduce the need for iron reinforcements, are among the objectives.

New fillers are used in pursuit of better concrete quality and durability in salty and wet conditions. Carbon neutrality is one of the objectives. At present, the manufacturing of cement contributes a great amount of global carbon dioxide emissions. By changing the production method and composition, researchers are trying to make cement capable of storing carbon dioxide.

Resources and motive for development: The construction industry engages in wide-scale activity on a global level, and reinforced concrete is one of its key raw materials. However, rather than improving the quality of concrete, customer demand focuses on increasingly inexpensive construction. This is why the development of material technology relies largely on research institutes and the product development of subcontractors that are developing new methods, such as the chemical industry.

Impact on value-producing networks, ART 52																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	0	0	0	10	10	0	0	3	0	0	0	0	0	0	3	0	0	0	*104

Progress since the previous report: The corresponding section in the previous report was “2.73 New building materials that replace reinforced concrete,” which ranked in the fourth group. The durability of Roman concrete has now been determined more accurately. New types of porous concrete have been developed. Several new carbon-neutral types of cement and cement manufacturing processes have been introduced. Bricks and concrete blocks can now be hardened at room temperature with the help of bacteria, and this process can be implemented on an industrial scale.

Interesting sources published after the 2013 report (052)	
Short description of the link	**link**
Bricks harden at room temperature with bacteria	http://www.inc.com/kevin-j-ryan/best-industries-2016-sustainable-building-materials.html
Carbon-neutral cement / emissions from limestone	http://nextbigfuture.com/2015/09/carbon-neutral-cement-manufacturing.html
The durability of Roman concrete has been solved	https://www.theguardian.com/science/2017/jul/04/why-roman-concrete-still-stands-strong-while-modern-version-decays
An emission-free replacement for concrete	http://www.pbs.org/newshour/bb/cement-alternative-absorbs-carbon-dioxide-like-sponge/
Porous concrete from Lafarge Tarmac	https://www.facebook.com/techinsider/videos/419013808296981/
Flue gas into concrete	http://phys.org/news/2016-03-carbon-dioxide-sustainable-concrete.html

2.6.53 Artificial muscle and artificial skin (053) **

Target area of the ART: Machines and organisms create their momentum differently from each other. Steam engines, internal combustion engines and electric engines are all clunky devices compared to animal muscles. With artificial muscles, machines will also be able to move similarly to animals without separate, hard engines and complex power transfer mechanisms. Artificial, touch-sensitive and self-healing skin would complement the opportunities.

This ART includes technologies that allow operation that mimics the limbs of animals to be implemented as efficiently as possible. In addition to robotics, this development can be valuable to medicine.

General description of the development: Memory materials are raw material of artificial muscles. They change their state, mainly by bending or contracting when environmental factors change. A muscle can be activated by moisture, heat, a chemical stimulus or an electric current, for example.

Artificial muscles may be several times stronger than a human muscular fibre of the same size. However, there are several development stage problems in various technologies. For example, the chemicals used in artificial muscles may be harmful, and the voltages or temperatures required may be high. The muscles may be slow to stiffen or relax, and they may wear quickly. The manufacturing technology may be complicated or require expensive materials. Development efforts seek to solve these problems.

The most essential property of skin is that it covers the things underneath it without disturbing them, adapts to muscles or the movements of the skeleton and endures wear. Touch or pressure sensors integrated into the skin are necessary for many tasks. A sense of touch is being developed for both robotic arms and prosthetics, and it is also a useful surface property in general. Self-healing is a useful property in some applications, regardless of a sense of touch and muscles.

Resources and motive for development: The most important motive for researching artificial muscles is academic. For many commercial companies, the goal is simply too distant. After scientific breakthroughs have been made, this situation is likely to change rapidly, as general-purpose artificial muscles have great potential commercial added value. The technology is already mature for narrow commercial segments, which is why development carried out by start-ups seems possible.

Impact on value-producing networks, ART 53																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	5	3	3	3	5	3	0	5	10	0	0	5	1	0	5	0	0	5	0	**159

Progress since the previous report: The corresponding sections in the previous report were "2.65 Artificial muscles" and "2.66 Artificial, self-renewing skin." They ranked in the third and fourth groups, respectively.

Development has been extensive and multifaceted. A sensitive robotic arm has been successfully made of memory material that contracts like muscles. Memory metal has been proven to endure millions of transformations in tests. Synthetic muscles have been made 100–1,000 times stronger than human muscles. A synthetic muscle that functions slowly with a low voltage has been made of silicone with 3D printing.

Researchers from IBM have developed a polymer that is stronger than bone, recyclable, lightweight, corrosion-resistant and self-healing. The Smithsonian has developed a material that heals itself quickly when exposed to oxygen, and Belgian researchers have produced skin that heals itself with "fever."

Interesting sources published after the 2013 report (053)	
Short description of the link	**link**
Fluid-driven, origami-inspired muscles are fast, durable and strong	http://www.pnas.org/content/early/2017/11/21/1713450114.full
A self-healing, fast, soft muscle costs 10 cents to make	http://www.newsweek.com/soft-robotics-self-healing-actuators-muscles-hasel-771612
Artificial muscles are 100 times stronger than natural ones	http://science.sciencemag.org/content/343/6173/868
Dielectric elastomers – artificial muscles	http://www.seas.harvard.edu/news/2016/07/artificial-muscle-for-soft-robotics-low-voltage-high-hopes
Robot skin heals itself with "fever"	https://www.wired.com/story/the-robots-will-be-soft-and-cuddly-and-heal-their-own-wounds/
A soft, inexpensive, slow, electric (8 V, 1 A) artificial muscle	https://phys.org/news/2017-09-soft-robotics-self-contained-actuator-stronger.html
Artificial muscles – a humanoid hand	http://iopscience.iop.org/article/10.1088/1748-3190/aa52f8/meta
A bio-bot / muscle from rat heart cells	https://www.youtube.com/watch?v=skCzl7FlM34
A liquid metal that changes shape as programmed	http://www.sussex.ac.uk/broadcast/read/42158
Micro-muscles from vanadium dioxide 1,000 times stronger than human muscles	http://nextbigfuture.com/2013/12/a-micro-muscular-break-through-1000.html
An elastic, self-healing material	http://www.sciencemag.org/news/2016/04/artificial-muscle-can-heal-itself
Durable, sensitive artificial skin from recycled materials	http://advances.sciencemag.org/content/4/2/eaaq0508.full
A demo video of a robot with artificial muscles	https://www.facebook.com/humansofthefuture/videos/653454958145520/
Artificial muscles, polyurethane foam & wax	http://mashable.com/2014/07/14/shape-shifting-robot/
Self-healing polymer	http://www.gizmag.com/ibm-polymer-discovery-plastic/32088/

Interesting sources published after the 2013 report (053)	
Shapeshifting materials from carbon fibre	http://spectrum.ieee.org/tech-talk/computing/hardware/4d-printing-turns-carbon-fiber-wood-into-shapeshifting-programmable-materials
A polymer robot that moves with UV light	http://www.nature.com/articles/ncomms13260
Soft robots	http://www.kurzweilai.net/robotic-fabric-could-bring-active-clothing-wearable-robots
Artificial muscles powered by evaporating water	http://qz.com/429309/these-machines-can-capture-a-new-source-of-clean-energy-evaporating-water/
A LIG graphene oxide surface facilitates bone regeneration	http://nanotechweb.org/cws/article/tech/70740
A self-healing plastic for space ships, etc.	http://www.smithsonianmag.com/innovation/this-plastic-heals-itself-180956495/
A memory metal – millions of transformations	http://www.popularmechanics.com/technology/a15773/shape-shifting-metal-alloy/
A muscle grown in a Petri dish	http://www.eurekalert.org/pub_releases/2015-01/du-fch011315.php
Elastic, electroluminescent skin/fabric	http://www.eurekalert.org/pub_releases/2016-03/cu-see022916.php
A material that changes shape and volume	http://www.eurekalert.org/pub_releases/2016-03/hjap-afm030816.php

2.6.54 Fresh water production (054) *

Target area of the ART: Water is a necessity for all life. In areas with no water, life withers away. In addition to vital functions, we also use water for washing, recreational purposes and industrial processes. The water used for these purposes is almost always fresh water, which does not contain harmful amounts of microorganisms or salts. The water economy involves many heavy investments by society that are normally divided into the supply of fresh water and treatment of wastewater.

Fresh water is produced by treating natural water, wastewater or sea water into tap water. The dirtier or saltier the water from which the tap water must be obtained, the greater the challenge. Today, we also often seek to treat wastewater, even if we discharge it into the sea. Both mechanical and chemical separation techniques are used for treating wastewater.

Access to water is a significant problem in areas with low rainfall. Desalinating sea water requires a great amount of both space and energy with the commonly used methods. Easier access to fresh water would make many deserts fertile and habitable.

General description of the development: New methods are continuously being developed for making water drinkable or suitable for agriculture and collecting water from air humidity. The fastest to advance have been electric condensation and separation methods. The continuous decrease in the price of solar energy promotes methods that are based on electricity.

The use of graphene in treating water is based on low-resistance filters that are slow to become blocked. Graphene is a strong but very thin material, and it is this thinness that makes durability a challenge in this method.

MOF materials consisting of metal ions and organic substances may enable efficient collection of water from air humidity. As a result of alternation between heat and cold, the MOF material is first saturated with water drawn from the air, and the water then drains into a container.

Resources and motive for development: Water purification methods are being developed within industrial operations and academic research in the field. Start-up companies launched by venture capitalists and crowdfunding are also active.

The challenges in the water economy will grow unless technology advances, as climate change, diminishing geological water reservoirs and population growth are already increasing the water shortage in many areas. The development motive is largely societal.

Impact on value-producing networks, ART 54																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	1	10	1	5	1	1	0	0	5	5	0	0	0	3	3	0	3	5	*129

Progress since the previous report: The closest corresponding ARTs in the previous report were "2.63 Nanosurfaces that convert air moisture to water," and "2.76 Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons," both of which ranked in the fourth group. The use of graphene in the production of water was a radical idea at the time the previous report was written. Progress has been fast since then. Several projects have reported successful outcomes in experiments on methods that save electricity and use solar energy. Without using electricity in the filtering process, researchers have been able to remove 85% of the salt in sea water.

The XPRIZE Foundation has announced a competition in which the objective is to produce water out of air for 2 cents per litre. With a kilogramme of MOF material, researchers have been able to produce 3 litres of water out of air without electricity. Dialysis methods have become much more efficient than before, and the use of pressure differences in treating well water has been demonstrated.

Interesting sources published after the 2013 report (054)	
Short description of the link	**link**
A graphene sieve makes sea water drinkable	https://phys.org/news/2017-04-graphene-sieve-seawater.html
An inexpensive water purifier based on pressure differences from India	http://economictimes.indiatimes.com/small-biz/startups/this-device-will-kill-99-of-microbes-in-water-and-end-waterborne-diseases/articleshow/59905197.cms
3 l of water from air with 1 kg of MOF material and solar power over 12 h	https://phys.org/news/2017-04-device-air-powered-sun.html

Interesting sources published after the 2013 report (054)	
1 l of water from air with 2 cents worth of electricity, Water-Gen	http://timesofindia.indiatimes.com/home/science/Now-a-machine-that-makes-drinking-water-from-thin-air/articleshow/34332827.cms
The Water Abundance XPRIZE (2 cents/litre)	http://www.theverge.com/2016/10/24/13358120/xprize-competition-water-abundance-womens-safety
Nitrates from agricultural runoff into water and nitrogen with catalysts	https://www.eurekalert.org/pub_releases/2018-01/ru-ruo010418.php
Electricity-free 85% desalination of sea water with graphene	https://phys.org/news/2017-09-smart-graphene-membrane-desalinate.html
Desalination of water with battery technology	http://www.eurekalert.org/pub_releases/2016-02/uoia-btc020416.php
Desalination of water based on electrodialysis	http://spectrum.ieee.org/energywise/energy/environment/shocking-trick-to-desalinate-water
Purification of mining water with an electric charge	http://www.eurekalert.org/pub_releases/2015-12/uof-qcn121015.php
Water purification with graphene	http://phys.org/news/2014-02-graphene-affair.html

2.6.55 Smart materials and their simulation techniques (055) **

Target area of the ART: Material technology is advancing rapidly. New opportunities are opening up through physics, chemistry and biology. Thanks to faster information technology, these can be simulated and observed virtually. Simulation accelerates the identification of new material properties and reduces laborious laboratory experiments that would prove to be fruitless. This ART includes functionally interesting new materials and their virtual research methods. Excluded from this ART are the materials described elsewhere in this report.

General description of the development: Smart materials may have many different properties. They may be shape-shifting, electromechanical, electrochemical, optically active, photoelectric, thermoelectric, magnetic or catalytic in nature. They may be smart materials that are active with regard to molecules, polymers and acidity or other properties.

Smart materials can also be used in sensors, actuators, structures, optical devices, robots, energy storage and recovery, biomimetics, insulation, textiles and the food and process industries, for example.

Today, new materials are being developed by simulating phenomena relating to molecules and their structures with computational models. When promising structures are identified, researchers seek to implement them in reality and measure whether their actual properties correspond to the modelled ones.

Resources and motive for development: Material research is largely academically motivated. Industry is an active contributor in solving key problems in each field and particularly with regard to areas that produce short-term benefits. Many major successes in material research are achieved in basic research.

Impact on value-producing networks, ART 55																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	5	0	3	5	0	0	0	0	0	0	0	5	10	3	3	1	0	0	**140

Progress since the previous report: This group is new. It was founded because the development of material technology is accelerating considerably as a result of atom-level simulation techniques. This report includes a great many examples. This section lists recent research news that do not belong in any other group.

Bullet-proof, transparent polyurethane has been invented. It absorbs kinetic energy by becoming temporarily liquefied. Concrete has been made self-healing with the help of bacteria. Water has been found to be in a solid state inside carbon nanotubes at room temperature. The electrons in 2D electride material have been successfully transformed into a gaseous state. This finding is expected to find a multitude of applications, ranging from transparent conductors to chemical catalysts.

Hydrogen has been transformed into a metallic state in a laboratory. A new state of matter, time crystals, has been successfully implemented. Time crystals are atomic structures that consistently change their state. Live cells have been used in fabrics to increase breathability. Graphene has been used as an emitter in a radiator, and the electromagnetic insulation of conductors has been improved.

Interesting sources published after the 2013 report (055)	
Short description of the link	**link**
New materials, a summary of the 6 most important	http://www.businessinsider.com/futuristic-construction-materials-2014-4
Hydrogen into a metallic state in a laboratory	https://phys.org/news/2017-01-metallic-hydrogen-theory-reality.html
A functional model: CNT as a replacement for platinum in fuel cells	https://phys.org/news/2018-01-optimize-nanomaterials-fuel-cell-cathodes.html
An inexpensive, efficient lithium-iron-oxide battery has been modelled	https://www.theregister.co.uk/2018/01/05/battery_whizzes_use_iron_and_oxygen_to_improve_battery_design/
Water is solid in carbon nanotubes at room temperature	http://www.deepstuff.org/researchers-discover-astonishing-behavior-water-confined-carbon-nanotubes/
Time crystals – a new state of matter	http://www.sciencealert.com/it-s-official-time-crystals-are-a-new-crazy-state-of-matter-and-now-we-can-create-them
2D electride – an electron gas material	https://m.phys.org/news/2017-01-scientists-d-electride.html

Interesting sources published after the 2013 report (055)	
Better conductor insulation with carbon	http://www.nyteknik.se/nyheter/energi_miljo/vindkraft/article3879035.ece
A graphene heating system	http://spectrum.ieee.org/nanoclast/green-tech/conservation/graphene-heating-system-dramatically-reduces-home-energy-costs
Live cells in a shirt regulate ventilation	http://news.mit.edu/2017/moisture-responsive-workout-suit-0519
Critical metals and security of supply in Finland	https://www.huoltovarmuuskeskus.fi/kriittiset-metallit-huoltovarmuus-selvitys-julkaistu/

2.7 Biotechnology and pharmacology

Genetic manipulation has become considerably more precise and common. There has been a radical change since the previous report. The massive increase in genetic data at the same time as sequencing becomes easier is influencing both pharmaceutical development and bioproduction.

Treatment with medicine based on genetic data is increasingly precise. In the future, medicine will be easier to produce. Radical opportunities will be unlocked by the all the time more probable solving of the mystery of ageing, for example. In addition to artificial lengthening of healthy life expectancy, we can expect the causes of many serious diseases to be identified and new treatment methods to be found. For example, the use of RNA interference in medicine will open completely new treatment opportunities. Control of the body's own mechanisms, such as the immune system, will also provide efficient means for health care.

Important steps forward have been taken in the regrowth of organs, cell culture and the development of prosthetics that repair the body's functional ability. Radical milestones have also been reached in the production of biomaterials and food.

Biotechnology and pharmacology	
ART-ID	**The ARTs in the group**
56	Cyborgs uniting biology and mechatronics
57	Radical longevity
58	Nanoparticles and microbots in mammal body
59	GMO producing substances and organs
60	Genetic editing techniques, CRISPR/Cas9
61	Simulating living cells, artificial cell
62	Microbiome, metabolism and genetics of cells
63	Repair of organs, cell culture
64	3D printing of organs and biomaterials
65	Curing and preventing dementia

Biotechnology and pharmacology	
66	Biotechnical meat and meat imitations
67	LED farming, robotic farming
68	Plant and animal fibres, nanocellulose
69	Cryogenics of biomaterials

2.7.56 Cyborgs uniting biology and mechatronics (056) ***

Target area of the ART: The functional ability of humans and other organisms can be changed artificially. Glasses, hearing aids and pacemakers are all familiar examples to us. Prosthetics are used to replace deficiencies in the body, but it is also possible to improve functional ability beyond the organism's own natural level with devices permanently linked to the body.

General linking to the brain is discussed in ART 1 of this report. This ART includes cyborg-like functionality achieved with the help of a device connected as an organ to a human or other organism.

General description of the development: Prosthetics and artificial organs for humans are being developed for many different purposes. The prosthetics made for people who have lost limbs have become sensitive and can now be controlled directly by the person's brain. Neural pathways and internal organs are being replaced with artificial devices. Artificial eyes are also evolving.

Prosthetics are now partly better than their natural equivalents. For example, artificial eyes can replace night-vision goggles or distinguish between materials and see far away. An artificial pancreas can adjust insulin levels better than a natural one.

Technology can change the properties of plants and microorganisms in surprising ways. Organisms can be programmed to grow into the desired shapes. They can also be made to produce complex materials and structures either inside them or externally. Plants can produce light or electricity and grow other electronic functionalities inside them.

Researchers are already able to combine digital devices and biology, e.g. animal muscle cells can be used to move a robot. On the other hand, the self-control of an entire organism can be replaced with digital technology. It is also increasingly possible to use artificial environments, such as an artificial womb, for procreation. One important branch of research is formed by energy supply to digital implants.

Resources and motive for development: Development in this area is first and foremost based on an academic and medical motive. It is to be expected that the electronics industry will become a more active participant in the future, and the role of start-ups launched with the help of investors and crowdsourcing will grow.

Impact on value-producing networks, ART 56																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	0	3	5	5	0	0	1	3	3	10	20	5	1	5	5	0	0	5	***213

Progress since the previous report: The closest corresponding sections in the previous report were "2.08 Brain implants that restore or develop brain functions" and "2.64 Biobots," which ranked in the third and fourth groups, respectively.

Progress has been fast since then. Increasingly good eye implants have been tested. An infrared light powered retina implant is under development, and a light-sensitive artificial retina successfully functions without an external energy source. Neural disorders have been treated with neural prostheses. The Neuralink project seeks to standardise neural links.

Bacteria have been used to add electromagnetic properties to biofilm. A biofuel cell implantable into the body has been developed. Body heat has been turned into electricity. Biocompatible transmission of electricity has been implemented using ions instead of electrons. A spinal cord injury in monkeys has been bypassed with a spinal cord implant.

A cockroach carrying a miniature camera and wireless radio connection can be remote controlled with passable precision. Locusts have also been remote controlled. A robot that swims like a stingray has been built using rat heart cells. Electric conductors and electronics, including a transistor and a logic gate, have been introduced into a plant through its stem. A glow-in-the-dark GMO plant has borne fruit.

Interesting sources published after the 2013 report (056)	
Short description of the link	**link**
An artificial womb has been tested on lambs	https://www.theguardian.com/science/2017/apr/25/artificial-womb-for-premature-babies-successful-in-animal-trials-biobag
AI-controlled brain implants for treating mental illness	https://www.nature.com/news/ai-controlled-brain-implants-for-mood-disorders-tested-in-people-1.23031
A brain implant improves memory by 15%	https://www.nytimes.com/2018/02/06/health/brain-implant-memory.html
Remote-controllable dragonflies (cyborg)	http://www.smithsonianmag.com/innovation/turning-dragonflies-drones-180962097/
DARPA: A bionic hand, thought-controlled	https://singularityhub.com/2016/02/18/this-remarkable-robot-hand-is-worthy-of-luke-skywalker/
Cyborg Olympics – several prosthetics	https://www.facebook.com/quartznews/videos/1144632095570491/
Monkeys implanted with brain implants that bypass spinal cord pathways	http://www.smithsonianmag.com/science-nature/wireless-brain-computer-network-helps-paralyzed-monkeys-walk-humans-could-be-next-180961049/
A cyborg stingray made of rat heart cells	http://spectrum.ieee.org/automaton/robotics/robotics-hardware/a-cyborg-stingray-made-of-rat-muscles-and-gold
A biofuel cell suited for implants	http://www.rdmag.com/article/2016/11/researchers-develop-biofuel-cell-energy-storage

Interesting sources published after the 2013 report (056)	
A spinal cord implant restores ability to walk	http://gizmodo.com/watch-this-spinal-cord-implant-revive-the-legs-of-a-par-1560697896
Remote control of a camera-carrying cockroach	https://www.theguardian.com/science/2015/mar/04/cockroach-robots-not-nightmare-fantasy-but-science-lab-reality
Body heat into electricity	http://newatlas.com/ncsu-wearable-thermoelectric-generator/45389/
8 words per minute with a brain implant	http://spectrum.ieee.org/the-human-os/biomedical/bionics/new-record-for-typing-by-brain-paralyzed-man-uses-brain-implant-to-type-8-words-per-minute
Electronics into a cyborg plant	http://gizmodo.com/scientists-have-created-a-cyborg-rose-1743933339
A paralysed man feels a robotic arm through a brain implant	https://www.washingtonpost.com/news/to-your-health/wp/2016/10/13/in-a-medical-first-brain-implant-allows-paralyzed-man-to-feel-again/
Electromagnetic properties into biofilm with bacteria	http://www.natureworldnews.com/articles/6420/20140324/mit-researchers-develop-living-material-using-e-coli.htm
A prosthetic arm detects spinal nerve signals	http://www.rdmag.com/news/2017/02/prosthetic-arm-technology-detects-spinal-nerve-signals
Remote-controlled locusts for sniffing out bombs	https://www.washingtonpost.com/news/morning-mix/wp/2016/07/06/navy-grants-750000-to-develop-cyborg-locusts-to-sniff-out-bombs/
A battery that transmits electricity with biocompatible ions	https://www.nature.com/articles/ncomms15609
A human fitted with an artificial eye	http://bionicvision.org.au/eye
A watch that powers itself with body heat	http://spectrum.ieee.org/view-from-the-valley/consumer-electronics/gadgets/this-smart-watch-will-charge-itself-using-the-heat-of-your-skin
Pentagon's AI prosthetics to go on sale	https://phys.org/news/2017-06-advanced-prosthetic-arms-pentagon-sale.html
A magnetic artificial sense for humans	http://www.smithsonianmag.com/innovation/artificial-sixth-sense-helps-humans-orient-themselves-world-180961822/
Treating neuropsychiatric disorders with neuroprosthetics	http://www.npr.org/sections/health-shots/2014/05/27/316129491/military-plans-to-test-brain-implants-to-fight-mental-disorders
Seeds of glow-in-the-dark plants bear fruit	http://www.smh.com.au/technology/sci-tech/glowinthedark-plants-a-step-closer-as-avatars-seeds-bear-fruit-20140117-30zhe.html
A spinal implant	http://www.telegraph.co.uk/news/science/science-news/11333719/Cyborg-spinal-implant-could-help-paralysed-walk-again.html
Artificial muscles help the heart	https://www.wired.com/2017/01/robots-coming-heart/
A light-sensitive artificial retina without an external energy source	http://www.medicalnewstoday.com/articles/286352.php
Electricity and telecommunication wirelessly transmitted to a soft contact lens	http://advances.sciencemag.org/content/4/1/eaap9841

Interesting sources published after the 2013 report (056)	
A summary of the expansion of human abilities in sports	http://www.wired.co.uk/article/sport-science-technology-human-performance
Neural implants in restoring motor nerves – a demo video	https://www.facebook.com/ScienceNaturePage/videos/810586075740319/
Musk announces his Neuralink project	https://futurism.com/dont-edit-elon-musk-just-outlined-how-hell-merge-the-human-brain-and-ai/
Bacteria that "eat" electricity	http://www.tekniikkatalous.fi/kemia/tallaista+elamaa+ei+pitanyt+olla+olemassakaan++sahkoa+syovat+bakteerit+laittavat+oppikirjat+uusiksi/a1044302
Augmented humans – a summary of prosthetics	https://www.facebook.com/futurism/videos/520599168119287/
A bionic eye for a blind person	https://www.theguardian.com/science/2016/dec/22/blind-nhs-patients-to-be-fitted-with-pioneering-bionic-eye

2.7.57 Radical longevity (057) ***

Target area of the ART: Humans and other mammals have a period of old age during which the body's regeneration slows down or stops while degeneration speeds up. Old age does not manifest in the same way in every fish or reptile species. For example, a turtle population appears to become healthier on average as it ages.

The mechanisms of ageing are on the verge of being identified on many levels. Old age and age-related diseases can be postponed in many test animals. Healthy life expectancy can be lengthened in several different ways, and some of these methods have progressed to human trials.

General description of the development: Several companies funded by venture capitalists have been founded for researching artificial lengthening of humans' healthy life expectancy. Research into age-related diseases is also extensive. The majority of studies is conducted on mice due to their easy procreation and short life expectancy. In the studies, researchers assume that mice and humans have a similar ageing mechanism. The healthy life expectancy of mice has been successfully lengthened by roughly 30% with various techniques.

Ageing is affected by the degeneration of cells as a result of accumulating toxins and self-destructive activity starting in mitochondria. Factors that affect the life expectancy and degeneration of cells have been identified at the levels of the body, organs and cells themselves. The SIRT1 gene and proteins related to it have been found to have effects relating to the ageing of cells. One apparent cause of ageing is the shortening of telomeres, which prevent cancer, in stem cells.

Several proteins used for transmitting signals between cells or organs seem to affect life expectancy, as does the efficient removal of senescent cells from the body. The significance of signal transmission supports the assumption that the body itself speeds up its ageing after the best reproductive period, and this self-destructive activity is activated by one of the body's own organs, most likely the hypothalamus. In tests conducted on mice, researchers have succeeded in healing symptoms and diseases relating to skin, muscles, the heart and the brain. Researchers have succeeded not only in slowing down ageing but also rejuvenating the body and healing age-related memory disorders.

Resources and motive for development: Research into lengthening life expectancy is not particularly academically active for some reason. Results have been achieved by comparatively small research teams and activists in this research area. A large part of the funding originates either from millionaires and billionaires who are afraid of ageing or pharmaceutical companies that are looking for methods to cure age-related diseases.

Impact on value-producing networks, ART 57																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	0	3	0	0	3	1	0	3	5	20	5	0	5	5	3	0	10	5	***204

Progress since the previous report: The corresponding section in the previous report was "2.06 Longer life time and slower aging processes," which ranked in the third group. The first official human trials were launched after the previous report. Researchers have identified an on/off switch in telomerase. The blood of a young mouse rejuvenates an old mouse, as does the reprogramming of cells.

Trials on mice have succeeded in rejuvenating the skin, muscles, the liver and the heart. The role of mitochondria and the SirT1 gene in ageing has been strengthened in several studies. Methylene blue has been found to prevent progeria, i.e. premature ageing, and it is believed to also affect normal ageing. HEL-1/FOXO affects the regulation of ageing.

Interesting sources published after the 2013 report (057)	
Short description of the link	**link**
Cellular reprogramming rejuvenates (mice)	http://medicalxpress.com/news/2016-12-scientists-reverse-aging.html
ADG says that robust mouse rejuvenation is 5–7 years away	https://www.nextbigfuture.com/2017/12/aubrey-de-grey-interviewed-by-nextbigfuture-on-agex-and-progress-to-radical-life-extension.html
SirT1 prevents metabolic stress, ageing	http://phys.org/news/2014-01-protein-sirt1.html
Young blood rejuvenates an old mouse	http://www.nature.com/news/young-blood-anti-ageing-mechanism-called-into-question-1.17583
Rejuvenation of muscle cells – NAD/mitochondria	http://www.bbc.co.uk/news/health-25445748
Prevention of ageing (progeria research, methylene blue)	http://cmns.umd.edu/news-events/features/3352

Interesting sources published after the 2013 report (057)	
Stopping ageing (skin), elimination of Granzyme B, experiment on mice	http://www.geek.com/science/scientists-accidentally-stop-skin-aging-in-mice-1611888/
Results that support the role of mitochondria in delaying ageing	https://futurism.com/researchers-have-found-a-way-to-delay-aging/
Rejuvenation with blood	http://www.theguardian.com/science/2015/aug/04/can-we-reverse-ageing-process-young-blood-older-people
Cardiac stem cells made old mice able to exercise 20% more	http://edition.cnn.com/2017/08/14/health/cardiac-stem-cells-make-rats-younger-study/index.html
Delaying ageing by killing old cells	http://onlinelibrary.wiley.com/doi/10.1111/acel.12344/abstract
Prolonging life with HEL-1/FOXO, experiment on worms	http://www.pnas.org/content/early/2015/07/16/1505451112
The genetics of ageing is being studied	http://www.sciencedaily.com/releases/2015/12/151201113917.htm
Slowing down the ageing of liver tissue by manipulating mitochondria	http://emboj.embopress.org/content/early/2016/02/02/embj.201592862
Reversing ageing – pharmaceutical trials begin	http://www.iflscience.com/health-and-medicine/preliminary-results-early-human-trials-anti-aging-formulas-reveal-no-adverse
An on/off switch found in telomerase	http://www.sciencealert.com.au/news/20142409-26223.html
Human Longevity, Inc. (HLI)	http://www.humanlongevity.com/

2.7.58 Nanoparticles and microbots in mammal body (058) **

Target area of the ART: We are used to taking medication and also feeding them to sick animals in our care. We perform measurements and surgical operations on the body. Miniaturisation makes it possible for us to swallow or insert into our veins independently operating devices.

The best-known device placed under the skin, the pacemaker, is relatively large in size. Miniaturised devices can perform measurements or targeted and scheduled administration of medication, for example. This ART also includes nanomachines, i.e. molecular level biomechanical structures designed for certain purposes that are injected into the body or swallowed. Their goal may be to destroy cancer cells, for example.

General description of the development: The challenges in miniaturisation are clear, and they have been researched widely within the areas of electronics and material technology. Biocompatibility means that particles placed within the body do not cause any adverse reactions in the body. Biodegradability is important if the device is only needed for a short period of time. A biodegradable device does not need to be surgically removed from the body.

A microbot can travel through the body in a natural way, carried by the flows caused by vital functions. The controllability of the microbot can also be developed with the help of a magnetic field or an independent power source and movement, for example. A self-controlled microbot should possess the necessary route information. External control requires electromagnetic or chemical communication through the body. If a microbot consumes more energy that it is able to store, it must obtain energy from its environment.

Nanomachines, which are smaller than microbots, are usually designed to disperse around the body in great numbers. Essential research is related to how they recognise their target, such as a cancer cell, and how they are able to invade it.

Resources and motive for development: The research motives in this area are partly academic and partly medical. With opportunities increasing, it seems apparent that the electronics industry and venture capitalists will have an increased interest in this area.

Impact on value-producing networks, ART 58																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	0	5	0	3	0	0	1	0	0	10	3	3	0	0	3	0	0	5	**132

Progress since the previous report: The corresponding section in the previous report was "2.05 Nanorobots (nanobots) in the health promotion," which ranked in the fourth group. The development of capsules intended to be swallowed or travel through the bloodstream has been fast-paced since then.

A swallowable camera that uses the body's energy, motorised nanoscale robots that move within a cell, nanoscale administration of medicine inside the body, remote-controlled and biodegradable medical implants and other remote-controlled subcutaneous medical chips, cancer-seeking nanobots and activation of paralysed limbs with neural implants are all advancements announced after the previous report. Researchers have now also tried controlling nanobots with DNA, tested microbatteries and telecommunication within the body, and tried to kill cancer with microbots and nanomachines.

Interesting sources published after the 2013 report (058)	
Short description of the link	**link**
A microchip powered by cell energy	http://www.ecnmag.com/news/2015/12/columbia-engineers-build-biologically-powered-chip
A remote-controlled medical implant, contraception on/off	http://www.technologyreview.com/news/528121/a-contraceptive-implant-with-remote-control/
A device communicates wirelessly from inside the body	http://eecs.umich.edu/eecs/about/articles/2016/Injectable-Computers-Can-Broadcast-from-Inside-the-Body.html
Treating leukaemia with nanobots	http://nextbigfuture.com/2015/03/ido-bachelet-dna-nanobots-summary-with.html

Interesting sources published after the 2013 report (058)	
DNA-based nanorobots for treating cancer	http://cacm.acm.org/magazines/2015/4/184703-molecular-moonshots/fulltext
A programmable medical chip implanted under the skin	http://www.cnet.com/news/remote-controlled-chip-implant-could-be-the-future-of-contraceptives/
Nanoparticles clean blood vessels	https://www.sciencenews.org/article/nanoparticles-beat-back-atherosclerosis
Nanobots that compute with DNA	http://www.popsci.com/article/science/nano-robots-compute-dna-installed-living-cockroach
A biodegradable implant	https://www.facebook.com/photo.php?fbid=10152824561419909&set=gm.672970076153935&type=3
A graphene antenna & electronics under the skin	http://phys.org/news/2015-12-graphene-wearable-devices.html
Nanobot micromotors deliver medication inside a mouse	http://www.gizmag.com/nanobot-micromotors-deliver-nanoparticles-living-creature/35700/
Nanomotors controlled inside a cell	http://www.scienceworldreport.com/articles/12786/20140210/first-nanomotors-ever-controlled-inside-living-cells.htm
A microbattery the size of a grain of rice for biotelemetry	http://spectrum.ieee.org/nanoclast/biomedical/devices/graphene based-microbattery-ushers-in-new-age-for-biotelemetry
Nanoparticles controlled by magnets inside the body	http://www.theverge.com/2014/10/28/7085023/google-wants-to-flood-your-body-with-tiny-magnets-to-search-for
Nanocapsules kill cancer cells	http://gemini.no/en/2014/09/killing-cancer-cells-with-super-glue/
Bacteria as power sources for small devices	https://phys.org/news/2016-07-scientists-simulate-tiny-bacteria-powered-windfarm.html
A pill sends a message when swallowed, FDA approved	https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm584933.htm
Medication delivered by micromotors healed an ulcer	https://www.newscientist.com/article/2144050-tiny-robots-crawl-through-mouses-stomach-to-heal-ulcers/
Nanomachines have been tested against cancer	http://www.sciencemag.org/news/2017/08/nanomachines-drill-holes-cancer-cells
Cancer-targeting nanorobots	https://www.scientificamerican.com/video/south-korea-develops-worlds-first-c2014-01-05/
Nanoparticle sensors inside the body – branched bottlebrush polymer	http://www.engadget.com/2014/11/19/mit-polymer-medicine-nanotech/
A swallowable camera, the Smithsonian	https://www.smithsonianchannel.com/videos/a-pill-that-takes-up-to-50000-photos-of-your-insides/33935
Nanoscale drug delivery, biocompatible Halloysite	http://www.rdmag.com/news/2015/10/halloysite-finally-promising-natural-nanomaterial?et_cid=4898946
A programming language for building DNA	http://www.washington.edu/news/2013/09/30/uw-engineers-invent-programming-language-to-build-synthetic-dna/

2.7.59 GMO producing substances and organs (059) **

Target area of the ART: All the raw materials in our food and a large part of the raw materials in our goods are organic. In addition to these, a considerable part of other substances used by humans are produced by plants, animals and other organisms. We have tamed and bred organisms in order to make them produce raw materials that are suitable for us. Compared to breeding, genetic engineering offers almost limitless potential for developing new organic materials and products.

General description of the development: Genes control protein production. By editing the genes of organisms, we can make them produce the desired proteins and, through them, other substances that the organisms in question would not normally produce to the same extent or at all. The simplest things to edit are bacteria and moulds as well as viruses that affect the functioning of organisms. They have been used to produce a variety of materials, ranging from medications to nacre-like structures.

By genetically engineering plants, we can make them more productive or improve their tolerance of environmental stresses. Plants can also be developed to be better suited for indoor farming or the changing climate, for example. Genetic engineering is also used to study the production of artificial organs.

Genetic engineering can be used to turn normal cells into stem cells. This is currently being used to research whether procreation is possible without sperm or egg cells. When normal cells are turned into stem cells, cell culture can be applied at the scale of food production, in addition to medicine.

Genetic engineering of cells allows human bodies to be made to function in a medicinal way. By modifying microbes, we can affect the soil or biofilms. Bacteria can be controlled to produce batteries, solar panels and many other structures in a Petri dish.

Resources and motive for development: The research motive is largely academic. With regard to the cultivation of GMOs, the motive is commercial and partly societal, which is the case for food production in China and India, for example. The medical, therapeutic motive is significant.

Impact on value-producing networks, ART 59																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	3	10	3	5	1	3	0	0	0	5	3	0	0	3	5	0	0	0	**164

Progress since the previous report: The closest corresponding sections in the previous report were “2.04 Drugs based on genetically modified organisms” and “2.71 Genetically modified organisms as producers of multi-use materials,” both of which ranked in the second highest group. After the writing of the report, researchers have succeeded in producing a mouse egg cell from the stem cell of an adult mouse outside the body. Genetic manipulation has also been used to produce a virus that kills cancer. Cancer and HIV have been contained with gene therapy and by modifying the body’s immune system. A stem cell treatment has been successfully used to treat Parkinson’s disease.

Bacteria have been made to produce medication through genetic manipulation. The photosynthesis properties of genetically engineered rice have been improved, and rice has been successfully grown in saline water. Genetically engineered bacteria have been used to produce biofilm with nanoscale electric conductors assembled from gold particles. Human organs have been grown inside the body of a genetically modified pig. A DNA-based growing computer has been shown to be possible.

Interesting sources published after the 2013 report (059)	
Short description of the link	**link**
17 leukaemia patients treated with modified T cells	http://ascopubs.org/doi/10.1200/JCO.2017.72.8519
Mouse eggs from adults' stem cells	http://www.nature.com/nature/journal/vaop/ncurrent/full/nature20104.html
Genetically engineered microbes fertilise plants	http://www.sciencemag.org/news/2017/04/genetically-engineered-microbes-make-their-own-fertilizer-could-feed-world-s-poorest
A general concept for treating many cancers	http://www.sciencecodex.com/new_general_concept_for_the_treatment_of_cancer-131015
A robust vaccine against caries, effective in many cases	https://www.nature.com/articles/s41598-017-10247-8
Fat cells in the stem cell treatment of other tissue	http://www.sciencealert.com/new-stem-cell-treatment-using-fat-cells-could-repair-any-tissue-in-the-body
Engineered cells grow to the desired 3D shapes	https://phys.org/news/2017-12-hack-cell-biology-d-tissue.html
A growing DNA computer is possible	https://phys.org/news/2017-03-scientists-reveal-super-fast.html
A universal flu vaccine	http://www.bbc.co.uk/news/health-24175030
Human organs grown inside a pig	http://www.bbc.com/news/health-36437428
The photosynthetic potential of genetically engineered rice	http://longnow.org/seminars/02016/mar/14/radical-ag-c4-rice-and-beyond/
Reprogramming bacteria to produce protein	http://www.scienceworldreport.com/articles/9855/20131001/scientists-uncover-hidden-feature-genetic-code-control-protein-production.htm
Quick production of vaccines	http://www.eurekalert.org/pub_releases/2015-11/byu-ceh111815.php
Clinical trials of anti-CD47 cancer treatment begin	https://med.stanford.edu/stemcell/CD47.html
A new type of rice invented in China grows in saline water	https://nextshark.com/china-invents-rice-can-grow-salt-water-can-feed-200-million-people/
A low-gluten wheat has been produced by gene editing	http://www.independent.co.uk/news/science/low-gluten-wheat-coeliacs-genetic-engineering-eaten-safe-ge-foods-a8078866.html
CRISPR-Cas9 expedites the production of biomaterials	http://phys.org/news/2016-01-crispr-cas9-tool-production-biofuel-precursors.html
Procreation without egg cells is being researched	http://www.iflscience.com/health-and-medicine/creating-babies-without-eggs-may-one-day-be-possible-thanks-to-groundbreaking-new-research/
A virus-based treatment for Ebola	http://www.eurekalert.org/pub_releases/2016-02/uop-nsh021216.php

2.7.60 Genetic editing techniques, CRISPR/Cas9 (060) **

Target area of the ART: There are many reasons for editing the genome of humans and other organisms, ranging from healing illnesses to improving properties and producing material. Materials produced with genetic editing and artificial life are discussed in ARTs 59 and 61. This ART includes the actual new techniques of genetic editing as well as their therapeutic use in repairing genetic errors and the type of editing that is not conducted for the purpose of material production.

General description of the development: Genetic editing has been practiced for a long time. At first, it was based on radiation that causes random mutations or cytotoxins. The vectors that cause changes have gradually been adjusted more and more precisely. The technique used today is based on the defence mechanism of bacteria. The CRISPR/Cas technique originates from the pursuit of bacteria to prevent bacteriophages and plasmids from affecting their own genome.

There are several CRISPR/Cas variations. The ease and reliability of the techniques used in them vary. At its simplest, we are talking about a “garage level” laboratory that uses supplies that are sold to enthusiastic hobbyists at a very cheap price. The necessary materials cost dozens or hundreds of euros, and handbooks on genetic editing are freely available.

The most recent techniques are so precise that they allow dozens of genetic factors to be changed at the same time, while ensuring the success of these changes. There are also techniques that can efficiently and extensively repair an error caused by a single mutation in the whole body of an adult human.

Resources and motive for development: The development motive is for the most part product development related to the food industry, medicine or biotechnology or a deep amateur interest. Development funded for terrorist or military purposes is difficult to exclude. Research is advancing rapidly and on a wide scale.

Impact on value-producing networks, ART 60																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	0	0	5	0	3	0	0	5	0	0	10	5	0	0	3	5	0	3	0	**195

Progress since the previous report: Genetic editing techniques are a new category. It was created because use of the methods is expanding, and they are evolving rapidly. The CRISPR-Cas9 method has become a widely marketed, inexpensive, comparatively precise and easy method to use. At the time this report was written, it had already been shared tens of thousands of times among researchers. The recently invented CRISPR-Cif1, CRISPR/Cas13 and CRISPR/Cas 3 technologies are reported to be even more precise.

Researchers have synthesised a whole yeast chromosome and placed it back into yeast, after which it has multiplied. A cell has successfully been changed into another type of cell. A hereditary heart condition has been edited out of an embryo in the USA, and a similar condition has been removed from an embryo in China. A hereditary condition has been removed from the system of an adult human. The functioning of a walker performing DNA editing can be imaged. CRISPR has been proven to be a potential solution to the health care crisis caused by antibiotic resistance.

Interesting sources published after the 2013 report (060)	
Short description of the link	**link**
More precise CRISPR-Cas13 editing of DNA	https://www.wired.com/story/new-science-could-sharpen-crisprs-gene-editing-scalpel/
CRISPR edits the genome at the level of a single letter of DNA	http://www.theverge.com/2016/4/20/11450262/crispr-base-editing-single-nucleotides-dna-gene-liu-harvard
A hereditary heart condition edited out of an embryo in the USA	https://www.nytimes.com/2017/08/02/science/gene-editing-human-embryos.html?_r=0
Converting cells to a new type of cell with the CRISPR technique	http://naturalsciencenews.com/2016/08/13/modified-crispr-technique-shows-great-promise-for-gene-therapy-applications/
Electronic control of gene expression in E.Coli	http://www.nature.com/articles/ncomms14030
A hereditary disease removed from a human embryo in China	http://www.bbc.com/news/health-41386849
DNA walkers and nanoscale imaging	https://phys.org/news/2017-02-super-resolution-reveals-mechanics-tiny-dna.html
CRISPR modification prevents unwanted mutations	https://www.researchgate.net/blog/post/crispr-modification-overcomes-major-hurdle-to-human-treatments
Epigenetic CRISPR therapy advances rapidly	https://gizmodo.com/a-modified-crispr-could-treat-common-diseases-without-e-1821067896
CRISPR to solve resistance to antibiotics?	https://www.technologyreview.com/s/604126/edible-crispr-could-replace-antibiotics/?set=604202
CRISPR-Cas3 to solve the antibiotics crisis?	https://techcrunch.com/2016/12/21/move-over-cas9-crispr-cas3-might-hold-the-key-to-solving-the-antibiotics-crisis/
Treating haemophilia B with gene therapy	http://www.nejm.org/doi/full/10.1056/NEJMoa1708538
CRISPR-Cas9 & customisation and regulation of the genome	https://www.washingtonpost.com/news/speaking-of-science/wp/2015/12/01/historic-summit-on-gene-editing-and-designer-babies-convenes-in-washington/
CRISPR-Cas9 – anyone can edit genes with mail-order kits	https://www.scientificamerican.com/article/mail-order-crispr-kits-allow-absolutely-anyone-to-hack-dna/
A programming language for cells	http://phys.org/news/2016-03-language-cells.html
Broad visions for CRISPR applications	http://www.newyorker.com/magazine/2017/01/02/rewriting-the-code-of-life
Current status of CRISPR (a review by TED)	http://www.ted.com/talks/ellen_jorgensen_what_you_need_to_know_about_crispr
Human embryos CRISPR modified at Karolinska Institutet	http://www.sciencealert.com/a-swedish-scientist-is-using-crispr-to-genetically-modify-healthy-human-embryos
CRISPR-Cas9 applications	http://www.nature.com/news/hiv-overcomes-crispr-gene-editing-attack-1.19712
An inexpensive online shop for CRISPR/Cas materials	https://www.genscript.com/crispr-products.html?src=pullmenu

Interesting sources published after the 2013 report (060)	
The CRISPR-Cas3 method progresses	https://www.sciencedaily.com/releases/2017/06/170629142850.htm
Cells edited with CRISPR-Cas9 to treat cancer in humans	https://www.scientificamerican.com/article/crispr-gene-editing-tested-in-a-person-for-the-first-time/?WT.mc_id=SA_FB_HLTH_NEWS
An eBook on CRISPR/Cas9 editing	http://powered.synthego.com/how-to-conduct-successful-crispr-experiments-ebook

2.7.61 Simulating living cells, artificial cell (061) **

Target area of the ART: Nature continues to be a mystery to humans in many ways. Most medical research is a shot in the dark. Experiments conducted on test animals often fail when repeated on humans, and sometimes a substance developed to treat a heart condition unexpectedly becomes a medication for treating impotence. Information technology is making development easier to control.

The functioning of cells can be simulated with computer models. For example, simulation can be used to test the effect of medications on cells corresponding to a person's genome and separately on each cell type. On the other hand, cell imaging and simulation provide an opportunity to engineer and test genetically modified organisms before their actual development. This also opens up an efficient route for the creation of fully synthetic life and even virtual life.

General description of the development: Understanding of cell biology has increased continuously. Cell metabolism and signalling, as well as the functioning of the genome, are now understood so well that researchers are able to model a considerable part of the interactions that are essential to the functioning of cells. It is not yet possible to simulate human cells at a level that is useful for pharmaceutical testing, but researchers consider it possible that this goal will be reached by 2025.

Cell simulation models are being used for engineering artificial cells. Such cells have already been produced for several different purposes. Among other things, researchers have created a cell that they believe is similar to early cells in Earth's prehistory, and they have succeeded in making it reproduce autonomously. Artificial cells can perform a variety of tasks, such as prevent pollution, produce raw materials for energy or other raw materials and goods.

Resources and motive for development: The primary research motive is academic.

Impact on value-producing networks, ART 61																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	1	5	1	10	0	0	0	1	0	5	0	5	5	1	3	3	3	5	**144

Progress since the previous report: The corresponding section in the previous report was "2.68 Artificial cell and simulating life on cell level." It ranked at the second highest level. Recent advancements include replacing 30% of a yeast genome with synthetic chromosomes. A synthetic organism with 6-letter DNA has proven to be stable. A synthetic bacterium is functional with 473 genes. The cell simulation model and open source synthetic biology are progressing. An RNA-based biocomputer has been developed at the Wyss Institute.

Interesting sources published after the 2013 report (061)	
Short description of the link	**link**
Synthetic (30%) yeast has been produced, Sc2.0	https://www.washingtonpost.com/news/speaking-of-science/wp/2017/03/09/scientists-create-designer-yeast-in-major-step-toward-synthetic-life/
A semisynthetic organism is stable with a 6-letter DNA	http://www.pnas.org/content/114/6/1317.abstract
Open source lessons for synthetic biology, problems	http://radar.oreilly.com/2015/10/open-source-lessons-for-synthetic-biology.html
A synthetic bacterium with 473 genes	http://gizmodo.com/mad-scientists-created-synthetic-bacteria-with-only-473-1766686722
A cell simulation model	http://www.scientificamerican.com/article.cfm?id=scientists-successfully-model-a-living-cell-with-software&WT.mc_id=SA_Facebook
An RNA-based biocomputer at the Wyss Institute	http://www.kurzweilai.net/a-living-programmable-biocomputing-device-based-on-rna

2.7.62 Microbiome, metabolism and genetics of cells (062) **

Target area of the ART: Significant advancements are continuously being made in medicine, particularly cell biology. Cell metabolism, signalling between cells and the functioning of organs form an important entity, particularly in the context of growth, well-being and illnesses.

In addition to the environment, the functioning of cells is also affected by the genetics of cells and epigenetics. Their combined effect causes many illnesses and other functional disorders. This ART includes findings in cell metabolism and the genetics of diseases. The most important environment for humans' own cells is the microbiome within the body, i.e. the numerous microorganisms living in our bodies.

General description of the development: The functioning of cells has been studied, and increasingly precise models have been developed for simulation, as described earlier in this report. Study of the genome has become routine. Epigenetics, i.e. the regulation mechanism related to gene expression, is a rising area of research.

In addition to the human genome, researchers can also gather information about the human microbiome. This refers to the microbes, i.e. microorganisms, living in our bodies that may represent different types of organisms, such as bacteria, archaea, moulds, yeasts and algae. These exist in abundance in mammal bodies, with some being beneficial and others being harmful.

Extensive access to information on the genome, epigenetics, cell metabolism and microbiomes, combined with lifestyle information and well-being, enable new medical findings. Returned to the individual level, this information also provides opportunities for personalised medicine, in which the treatment methods are closely connected to the individual's environment, lifestyle and genome.

Resources and motive for development: Research is primarily academically motivated in the fields of medicine and cell biology, but interest is increasing within the pharmaceutical and food industries.

Impact on value-producing networks, ART 62																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	0	5	0	0	0	3	0	0	0	20	10	3	0	0	0	0	0	0	**164

Progress since the previous report: This is a new ART that was added because of rapid advancements in medicine. Recent steps forward include the following: Two new versions of the human protein map have been published. They contain roughly 20,000 proteins, of which almost 200 were previously unknown. Any protein can be destroyed in a cell without changing the genome.

The link between the brain and immune system has been identified. The genetics of schizophrenia have been studied more precisely than before, as have the genetics of the MS disease. Bacterial activity can be prevented with liposomes. A virus has been observed to trigger celiac disease. Increasingly accurate understanding of the metabolism is widely helpful in both diagnosing and treating difficult diseases.

Microbiome treatment has been used to save an endangered plant species, and its use in the treatment of cancer, ageing and HIV patients is being studied.

Interesting sources published after the 2013 report (062)	
Short description of the link	**link**
Any protein in a cell can be destroyed easily	https://phys-org.cdn.ampproject.org/c/s/phys.org/news/2017-11-scientists-method-rapidly-protein-kind.amp
Psychobiotics in treating depression, etc.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5102282/
Activating T cells kills tumours and metastases in mice	http://med.stanford.edu/news/all-news/2018/01/cancer-vaccine-eliminates-tumors-in-mice.html
Blood tests found 70% of cancer types, less than 1% false positives	http://time.com/5111157/blood-test-for-cancer/
Life expectancy estimated for free online with 18 blood test results and a facial photo	http://bigthink.com/robby-berman/an-ai-algorithm-predicts-your-expiration-date

Interesting sources published after the 2013 report (062)	
Utilising the microbiome in cancer treatment	https://www.reuters.com/article/us-health-cancer-microbiome/biotech-firms-race-to-recruit-good-bugs-in-war-on-cancer-idUSKBN1DE1D2
Bacteria against oxygen radicals	http://www.oulu.fi/yliopisto/node/37748
The human proteome	http://www.iflscience.com/health-and-medicine/first-complete-mapping-human-proteome-discovers-193-new-proteins
A virus triggers celiac disease	https://news.uchicago.edu/article/2017/04/06/seemingly-innocuous-virus-can-trigger-celiac-disease
The health impacts of spruce resin	http://www.uusisuomi.fi/tiede-ja-ymparisto/59304-tutkija-osoitti-perimatiedon-todeksi-suomen-metsissa-kasvaa
A malaria vaccine in experiments on mice	http://news.sciencemag.org/health/2014/05/new-malaria-vaccine-shows-promise-mice
A microbiome transplant saved an endangered plant	https://phys.org/news/2017-11-microbiome-transplants-disease-resistance-critically-endangered.html
The genetics of schizophrenia are a touch clearer	https://www.washingtonpost.com/news/speaking-of-science/wp/2016/01/27/scientists-open-the-black-box-of-schizophrenia-with-dramatic-genetic-finding/
A vaccine against high cholesterol	http://news.unm.edu/news/unm-nih-researchers-develop-vaccine-to-treat-high-cholesterol
The genetic origin of multiple sclerosis has been discovered	http://www.genengnews.com/gen-news-highlights/genetic-origin-of-multiple-sclerosis-discovered/81252785
An antibiotic that is effective against MRSA	http://yle.fi/uutiset/tutkijat_uskovat_loytaneensa_mullistavan_antibiootin__oli_kaivettuna_maahan_takapihalle/7724435
Fighting bacteria with liposomes	http://www.tekniikkatalous.fi/innovaatiot/rasvalla+tulehdusten+kimppuun+antibioottien+sijaan++kokeet+ihmispotilailla+alkavat+ensi+vuonna/a1027451
Destroying cancer cells with red light	https://www.eurekalert.org/pub_releases/2016-12/unio-gss121216.php
The microbiome affects the clinical picture of a patient with AIDS	https://www.specialtypharmacytimes.com/news/how-the-gut-microbiome-affects-outcomes-in-hiv
The link between the brain and the immune system	http://www.sciencedaily.com/releases/2015/06/150601122445.htm

2.7.63 Repair of organs, cell culture (063) **

Target area of the ART: Many diseases and accidents can damage our organs. Organ damage may also be due to a birth defect. Repairing this damage with biological and mechanical means or other methods of healing organs are included in this ART. Cell culture technique is also included in this ART, although processing cultures into food and 3D printing of cultured cells into artificial organs and food is discussed elsewhere.

General description of the development: Cell culture is based on stem cells that are able to produce other cells. Today, researchers are able to produce stem cells from other cells. They are able to control the stem cells' specialisation and choose the cell types that each stem cell produces. Researchers have noticed that specialised cells, such as heart cells, can be injected into a damaged heart. New cells replace damaged ones and start functioning in the appropriate way in their new environment.

If the genome of cells is modified and new, modified stem cells are injected into a human, the function determined by the new genome spreads to the tissue created by these stem cells. Specialised human stem cells can be placed into animals or the person him/herself. This makes it possible to grow human cells and even an organ that may, under certain conditions, be suitable for an organ transplant. It is also possible to change another animal's genome so that its organs are suitable to be transplanted into a human.

Mechanical repair and replacement of organs with synthetic materials progresses as material technology evolves. Development is particularly fast in relation to the musculoskeletal system, bones and cartilage.

Resources and motive for development: Research is for the most part academically and medically motivated. The motive of the pharmaceutical industry is growing rapidly as many societies approve forms of treatment relating to this technology.

Impact on value-producing networks, ART 63																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	0	3	5	0	5	0	0	0	3	1	5	3	0	0	3	0	0	0	0	**140

Progress since the previous report: The corresponding sections in the previous report were "2.10 Repairing and regrowing of human organs, (stem) cell cultivation" and "2.11 Synthetic cartilage in human joints." They ranked in the third and fourth groups, respectively. Progress has been very extensive and fast since the breakthroughs described in the previous report.

Technology suitable for stem cell dental implants has been developed. Synthetic cartilage has progressed to clinical trials, and the regeneration of cartilage is being developed. Type 1 diabetes in mice has been treated with cultured stem cells. 90% of terminal patients with leukaemia have gone into remission with the help of genetically modified T cells. An efficient method has been developed for producing blood from stem cells. Skin cells have been reprogrammed into blood vessels.

Insulin-producing beta cells have been created in large quantities. 60 genes in a pig have been edited to make pig organs viable for transplantation into humans. Nerves have been successfully regenerated. The immune system has been "trained" to treat celiac disease. A kidney has been grown in a lab and several other organs have been 3D printed. Breathable artificial skin has been used to remove age-related wrinkles.

Interesting sources published after the 2013 report (063)	
Short description of the link	**link**
Reprogramming skin cells into blood vessels	http://www.theregister.co.uk/2017/08/08/cellular_reprogramming_with_people_rather_than_phones/

Interesting sources published after the 2013 report (063)	
A 44-year-old man's hereditary disease may have been removed from his body	http://edition.cnn.com/2017/11/15/health/first-in-body-edit-dna/index.html
Artificial blood from factories – a development project	http://www.telegraph.co.uk/health/healthnews/10765132/Artificial-blood-will-be-manufactured-in-factories.html
Cell culture (blood)	http://medicalxpress.com/news/2015-10-gene-lab-based-red-blood-cell.html
Complex CRISPR editing of a pig for organs transplantable into humans	http://www.iflscience.com/health-and-medicine/scientists-break-gene-editing-record-create-animal-organs-human-transplantation
A lab-grown kidney	http://www.sciencealert.com/lab-grown-kidneys-shown-to-be-fully-functional-in-animal-recipients
Insulin-producing beta cells created in large quantities	http://www.webmd.com/diabetes/news/20141009/stem-cell-success-raises-hopes-of-type-1-diabetes-cure
Type 1 diabetes in mice treated with cultured stem cells	http://gizmodo.com/stem-cell-breakthrough-could-put-an-end-to-daily-insuli-1754981810
Human cells grown in sheep embryos	https://www.theguardian.com/science/2018/feb/17/breakthrough-as-scientists-grow-sheep-embryos-containing-human-cells
A review of the growing of artificial organs	http://discovermagazine.com/2014/jan-feb/05-stem-cell-future
Artificial cartilage tested on a patient	http://www.foxnews.com/health/2015/03/12/artificial-cartilage-implants-may-reduce-need-for-knee-replacement-surgery.html
Removing wrinkles with breathable artificial skin	http://www.nytimes.com/2016/05/10/health/second-skin-aging-wrinkles.html?_r=0
The FDA approved a gene therapy for treating childhood leukaemia	https://www.usnews.com/news/business/articles/2017-08-30/us-clears-first-living-drug-for-tough-childhood-leukemia
Regeneration of nerves with the help of carbon nanotubes	http://phys.org/news/2016-07-bridge-carbon-nerve-tissues.html
Regeneration of a knee joint	https://www.facebook.com/techinsider/videos/491774337687594/
90% of terminal patients with leukaemia went into remission	http://www.bbc.com/news/health-35586834
A full-sized human heart grown from stem cells in a laboratory	http://www.popsci.com/scientists-grow-transplantable-hearts-with-stem-cells
A spongy material for repairing cartilage	http://www.eurekalert.org/pub_releases/2016-03/acs-smh021916.php
Cultured heart cells	http://www.sciencedaily.com/releases/2015/07/150714124129.htm
Cartilage grown from stem cells into the shape of a hip joint	http://www.livescience.com/55444-stem-cells-could-replace-hip-replacements.html
Iron particles make immune cells attack cancer	http://phys.org/news/2016-09-iron-nanoparticles-immune-cells-cancer.html
Stem cell dental implants	http://worldtruth.tv/stem-cell-dental-implants-grow-new-teeth-in-your-mouth/
Noses and ears grown from stem cells	http://www.cbsnews.com/news/ears-noses-grown-from-stem-cells-in-petri-dishes/

Interesting sources published after the 2013 report (063)	
Nerve regeneration	http://factor-tech.com/3d-printing/19785-complex-damaged-nerves-re-grown-for-first-time-using-3d-printed-guide/

2.7.64 3D printing of organs and biomaterials (064) *

Target area of the ART: This ART includes 3D printed artificial organs and 3D printing of food and other biomaterials.

Life consists of biological tissue. Animals need it as food. The tastiness of tissue depends not only on cells but also the structure they form, i.e. their texture. 3D printing a cell culture allows the texture and composition to be adjusted as desired.

New organs are required to replace damaged ones. With suitable 3D printers, cultured cells can be printed into tissue and structures without damage to the printed cells. Artificial organs based on live tissue may be used for organ transplantation or research purposes.

General description of the development: In order for foodstuffs to be 3D printed, we must first solve the hygiene issues. Food materials cannot be processed in a way that impairs their taste. The most common 3D printing method suited for food is extrusion. It allows us to make food in unusual shapes or with an unusual structure, without ruining the taste. This method may be used for the purposes of customisation, healthiness, tastiness and aesthetics or production efficiency.

The 3D printing of live cells involves a number of problems besides hygiene. The cells must stay alive both during and after the printing process. Printing with the extrusion method can succeed under suitable conditions if the tissue is simple. Printing complicated ducts and capillaries within other cells is a significant challenge. For example, researchers have for the time being only succeeded in producing capillaries with the help of biological cultivation. However, researchers have succeeded in keeping the places of veins free and cells alive during printing by printing a material absorbed into the cells during the printing of organs.

Resources and motive for development: The research motive is for the most part academic. The pharmaceutical and food industries have shown emerging interest.

Impact on value-producing networks, ART 64																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	3	5	0	3	0	0	3	5	3	5	0	3	0	3	0	0	0	0	*99

Progress since the previous report: The corresponding section in the previous report was “2.59 3D printing of organs,” which ranked in the fourth group. This field has advanced rapidly. 3D printers specialising in printing biomaterials have been launched on the market. Several different organs have been printed in experiments, and researchers have improved the functionality of 3D printed bone, cartilage, joints, skin, livers, kidneys, bladders, blood vessels, ovaries, brains and other parts of the nervous system, among other things.

Printing a heart is estimated to be possible within 10 years. The technique for growing capillaries facilitates the 3D printing of organs. Spinach leaves have also been used as blood vessels in artificial organs, and printable artificial veins are being developed. Printing of tissue samples into matrices is becoming routine.

Interesting sources published after the 2013 report (064)	
Short description of the link	**link**
Growing capillaries in a lab facilitates 3D printing of organs	https://www.digitaltrends.com/cool-tech/artificial-capillaries-3d-printing/
Veins with biomaterial that grows into the desired shape	http://www.eurekalert.org/pub_releases/2015-09/qmuo-smt092415.php
A heart to be 3D printed within 10 years	http://www.wired.co.uk/news/archive/2013-11/21/3d-printed-whole-heart
3D printing bone and tissue	http://3dprint.com/37745/bone-and-tissue-bioprinting/
3D printed mouse ovaries work	https://news.northwestern.edu/stories/2017/may/3-d-printed-ovaries-offspring/
3D printed artificial cartilage	http://www.iflscience.com/health-and-medicine/made-order-cartilage-could-combat-osteoarthritis
Spinach leaves into blood vessels for an artificial organ	http://news.nationalgeographic.com/2017/03/human-heart-spinach-leaf-medicine-science/
3D printing models of human tissues for tests, DPAC	http://www.ucsf.edu/news/2015/08/131431/dna-guided-3-d-printing-human-tissue-unveiled
Fast cell-level printing of biomaterials with in-air microfluidics	https://www.sciencedaily.com/releases/2018/02/180201092233.htm
3D printing of blood vessels	http://www.iflscience.com/health-and-medicine/scientists-use-3d-printing-produce-blood-vessels
3D printed tissue found to work	http://www.nature.com/nbt/journal/vaop/ncurrent/full/nbt.3413.html
Tumour, cultured & 3D printed	http://phys.org/news/2014-04-breakthrough-cancer-tumors-3d-printer.html
3D printing organs in gel	http://www.vocativ.com/235846/3d-printing-in-gel-could-bring-us-closer-to-replacement-organs/index.html
Soft 3D printed tissue as scaffolds for artificial organs	https://www.livescience.com/61416-3d-printed-brain.html
3D printed rhino horn	http://www.digitaljournal.com/news/environment/biotech-firm-creates-fake-rhino-horn-to-help-save-real-rhinos/article/436325
Goods from biomaterial	http://www.hs.fi/tiede/a1398344570326
Mini-brains produced for research purposes	http://hub.jhu.edu/2016/02/12/mini-brains-drug-testing

2.7.65 Curing and preventing dementia (065) **

Target area of the ART: Memory disorders are one of the great problems in society. In the serious phase of these disorders, the patient requires constant care. This period is taxing on both the patient and his/her immediate circle. As we age, a large part of the population encounters memory disorders, and the underlying cause of these disorders and a proper cure have yet to be identified.

General description of the development: Alzheimer's disease, Parkinson's disease and other diseases that cause dementia are subjects of continuous research because they cause wide-scale suffering and great costs. Research into Alzheimer's disease has also focused on the formation of beta-amyloid plaque and preventing it. Other areas of research include the mechanism behind the disease, anticipation and predisposition to the disease, reduction of symptoms, slowing down the progress of the disease and curing it completely.

Parkinson's disease is a disorder caused by brain degeneration that starts with motor problems and progresses to memory problems in later stages. Research goals are largely the same as with Alzheimer's disease and rare brain diseases, such as Huntington's disease.

Resources and motive for development: The research motive is medical, social and academic due to the large scale of the problem. The relatives and friends of persons with a memory disorder are also individually motivated to fund research, as demonstrated by the recent example of Bill Gates providing $100 million for research into Alzheimer's disease.

Impact on value-producing networks, ART 65																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	1	0	0	0	0	0	0	0	0	0	0	20	0	1	3	3	3	3	10	0	**132

Progress since the previous report: The corresponding section in the previous report was "2.9 Drugs that prevent dementia," which ranked in the highest group.

Researchers have developed an ultrasound method that cures 70% of Alzheimer cases in mice. Alzheimer patients have already been treated with ultrasound at Turku University Hospital. A daily dose of IL-33 protein has cured Alzheimer's disease in mice and prevented it from recurring. The KLOTHO gene, which provides considerable protection from dementia, has been identified. The significance of the amyloid and tau proteins and the link of NCAM2 to the onset of Alzheimer's have been studied, and virgin oil has been found to reduce the incidence of Alzheimer's.

Researchers have been able to curb Huntington's disease in mice with "zinc finger" gene therapy. Gene therapy and stem cell treatments have been developed for treating Parkinson's disease. Electric stimulation of the brain to prevent symptoms has been used increasingly and in earlier stages of the disease. Its use is now also being studied in other diseases of the mind.

Interesting sources published after the 2013 report (065)	
Short description of the link	**link**
The IL-33 protein reversed Alzheimer's symptoms in mice	http://www.sciencealert.com/new-protein-injection-reverses-alzheimer-s-symptoms-in-mice-in-just-one-week
The memory function was restored in 75% of mice with ultrasound	http://www.sciencealert.com/new-alzheimer-s-treatment-fully-restores-memory-function
A treatment for Alzheimer's disease reduced symptoms	https://www.sciencedaily.com/releases/2016/06/160616071933.htm
Treating memory disorders with a brain implant	https://news.usc.edu/86658/new-device-aims-to-help-people-struggling-with-memory-loss/
The KLOTHO gene protects from Alzheimer's and improves intelligence	http://www.ucsf.edu/news/2014/05/114196/better-cognition-seen-gene-variant
Huntington's curbed with zinc finger gene therapy in mice	http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_9-9-2016-13-13-26
Deep brain stimulation recommended earlier in the course of Parkinson's disease	https://shakeitup.org.au/latest-news-deep-brain-stimulation/
An Alzheimer's drug destroys plaques in tests	http://www.bbc.com/news/health-37222863
Alzheimer's research – tau vs amyloid	http://www.scienceworldreport.com/articles/23679/20150325/tau-protein-not-amyloid-now-thought-to-be-responsible-for-alzheimers.htm
Ultrasound treatment of Alzheimer's at Turku University Hospital	https://www.facebook.com/photo.php?fbid=10153660903485735&set=a.96587095734.91338.728060734&type=3
New insight into the brain's memory storage	http://gizmodo.com/our-brains-can-store-10-times-more-information-than-we-1754255335
Treating Parkinson's with gene therapy	https://geneticliteracyproject.org/2016/08/23/gene-therapy-breaking-ground-treating-parkinsons-disease/
Alzheimer's research, link to NCAM2	http://www.nature.com/ncomms/2015/151127/ncomms9836/full/ncomms9836.html
Virgin oil prevents Alzheimer's in mice	http://www.newsweek.com/extra-virgin-olive-oil-prevents-alzheimers-mediterranean-diet-627851

2.7.66 Biotechnical meat and meat imitations (066) ***

Target area of the ART: We all know that humans need a variety of amino acids to live. The body itself can produce eleven of the necessary twenty proteins, and the other nine we need to get from food. The most natural source of protein for humans is animal meat. Many plants contain great amounts of protein, but only animal products contain the suitable protein composition for humans.

Vegetarians must choose their food carefully in order to obtain an adequate amount of all the necessary amino acids. While animal husbandry and fish farming more easily produce an amino acid composition that meets our needs, they also cause a greater environmental load than other agriculture. The objective of meat-like plant proteins and farmed or biotechnical meat is to replace animal husbandry with more efficient methods without losing the nutritional values of meat while adapting to the tastes and preferences of those who eat meat.

General description of the development: Stem cell techniques allow cells of animal origin to be cultured in nutrient solution. As a technique, cell culture and printing into tissues resembles the growing of artificial organs, which is discussed elsewhere in this report. Another challenge besides cost-effectiveness is getting the end product's structure and taste to an acceptable level. Development efforts are being funded with the help of rarities and experiences, as the genome of the grown meat can originate from rare or even extinct animals. Cells can also be genetically modified, and completely new but healthy and tasty meat can be grown.

Researchers have been developing plant-based meats for a long time. The primary focus is on protein content, structure and taste. Tastiness and structure continue to be a challenge to researchers, as does balanced protein composition. The majority of people continue to eat animal products rather than plant-based products because these issues have not been solved in a way that satisfies them.

Insect-based protein production is becoming more common. It is already at a good level in terms of productivity and nutritiousness, but taste preferences continue to pose a challenge, particularly in plant-based meats. The latest new technology is protein produced from electricity, carbon dioxide, water and other limited nutrients with the help of single-celled organisms. For the time being, the greatest problem in this experimental method is its low efficiency ratio.

Resources and motive for development: Some of the research is academically motivated, but the development efforts are largely motivated by the needs of the food industry and vegetarians as well as the pursuit of new product areas by venture capitalists and start-ups based on these needs.

Impact on value-producing networks, ART 66																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	5	0	20	0	0	5	0	3	3	0	5	0	0	0	5	3	0	10	0	***295

Progress since the previous report: The corresponding section in the previous report was "2.69 In-vitro meat and meat-like plant protein," which ranked in the fourth group. The production cost of synthetic meat has decreased very rapidly. Plant-based eggs now correspond to real chicken eggs in quality. An ingredient that mimics the taste of blood has been found in the roots of legume plants for use in plant-based meats.

Artificial meat has obtained a considerable amount of funding and is becoming commercialised. China has ordered $300 million worth of products based on cultured meat from Israeli companies. The EU is about to allow the sale of insects as food, and the growing of insects for food is becoming productised. VTT has succeeded in producing proteins in a water solution with the help of a one-cell organism, electricity and carbon dioxide.

Interesting sources published after the 2013 report (066)	
Short description of the link	**link**
Protein from carbon dioxide, water and electricity	http://www.vttresearch.com/media/news/protein-produced-with-electricity-to-alleviate-world-hunger
China buys $300 million worth of lab-grown meat from Israel	http://www.independent.co.uk/news/world/asia/china-israel-trade-deal-lab-grown-meat-veganism-vegetarianism-a7950901.html
Synthetic meat becomes cheaper	http://www.sciencealert.com/lab-grown-burger-patty-cost-drops-from-325-000-to-12
Eating fish considerably improves sleep quality and cognition	https://www.nature.com/articles/s41598-017-17520-w
CellPod – a plant cell incubator for home use	http://www.biotalous.fi/cellpod-kasvattaa-tulevaisuuden-avaruusruokaa-kotonasi/
Cultured meat and milk progress, who regulates	http://www.sciencemag.org/news/2016/08/lab-grown-meat-inches-closer-us-market-industry-wonders-who-will-regulate
A plant-based egg, Beyond Eggs	https://www.facebook.com/garytvcom/videos/892932674095315/
The EU allows the sale of insects as food	https://www.facebook.com/ajplusenglish/videos/854038361404339/
A veggie patty tastes likes meat, leghaemoglobin protein	http://www.sciencealert.com/news/20140910-26310.html
Artificial meat and its funding	https://www.facebook.com/garytvcom/videos/855040404551209/
$17 million in funding for Memphis Meats' lab-grown meat	http://www.xconomy.com/san-francisco/2017/08/23/memphis-meats-cooks-up-17m-funding-round-for-lab-grown-meat/
Modular insect farms from the Finnish company EntoCube	http://arcticstartup.com/article/wins-e50000-investment/

2.7.67 LED farming, robotic farming (067) ****

Target area of the ART: Almost all of our food production is based on cultivating plants to feed either people or animals. Agriculture has many harmful effects due to soil erosion, emissions from fertilisers and pesticides, plant diseases and space requirements. Food production can be automated to increase productivity and reduce harmful effects. Relocating production to indoor spaces, in which food is cultivated in vertical stacked layers, is another new opportunity as the efficiency of artificial light continues to develop.

General description of the development: Plants require light and nutrients. The continuous decrease in the price of LED lights, adjusting the wavelengths to be suitable for plants and improving efficiency are increasing the profitability of indoor farming. Cultivation in stacked layers under artificial light can be continued as a closed cycle all year round, protected from weather and free from emissions. The development of suitable cultivars, the position and timing of light as well as nutrient content are among the essential areas of development. Indoor farming can be implemented in a decentralised way in urban areas. The need for logistics and storage is low.

Both outdoor and indoor farming benefit from robotics. In addition to reducing personnel costs, robots are able to handle planting, watering, fertilisation and harvesting very meticulously. For example, in cultivating fields a robot is able to identify the soil nutrient content or weeds, fertilise the plants and eliminate weeds as necessary.

Resources and motive for development: The development motive is partly academic but for the most part commercial and dictated by customer needs. New opportunities also motivate technology developers, venture capitalists and start-ups to participate both in the development and looking for new business models.

Impact on value-producing networks, ART 67																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	0	5		20	5	3	5	3	3	3	3	3	0	0	0	3	3	0	5	0	****384

Progress since the previous report: This is a new ART that was added because LED farming and robotisation of agriculture are both progressing rapidly and linked to each other. In Japan, a farm that produces 10,000 heads of lettuce per day has been set up inside an old factory building. Similar farms have also been set up elsewhere, such as basements in London, on a large scale. In Finland, Silmusalaatti was the first company to adopt commercial LED farming. Fujitsu has announced that it is setting up an experimental plant factory in Finland.

Container-sized automatic farming facilities and farming equipment intended for households have quickly arrived on the market. Productised container farms are available for rent at €20,000 per year. Both indoor and outdoor farming robots have been developed for many types of plant. Tomatoes are being farmed in the desert with sea water and solar energy. Researchers have succeeded in fully robotising the planting and harvesting of barley.

Interesting sources published after the 2013 report (067)	
Short description of the link	**link**
Productised container farms at €20,000/year	https://www.facebook.com/HuffingtonPost/videos/10153593374106130/
Growing tomatoes with sea water and solar power in a desert	http://qz.com/803646/a-desert-farm-is-growing-tomatoes-on-seawater-and-solar-power/
An indoor farming robot	https://www.facebook.com/techinsider/videos/543055419226152/
Fujitsu’s plant factory in Finland	http://www.fujitsu.com/global/about/resources/news/press-releases/2016/1128-01.html
The total insect biomass has decreased by 76% in Germany within 27 years	https://www.theguardian.com/environment/2017/oct/18/warning-of-ecological-armageddon-after-dramatic-plunge-in-insect-numbers

Interesting sources published after the 2013 report (067)	
Indoor farming with LED lighting (Japan)	http://upriser.com/posts/largest-indoor-farm-100x-more-productive-99-less-water-40-less-power-80-less-waste
LED farming by Silmusalaatti	http://www.hs.fi/tiede/a1439520997977?jako=65a7ada6a9f2a41fd8d132dbdfb3863e&ref=tw-share
Plenty: A hectare-sized LED farm in Seattle, yield 2 million kg/year	http://nordic.businessinsider.com/vertical-farming-company-plenty-investment-second-farm-seattle-2017-11?r=US&IR=T
A potato mine (LED farming) in Pyhäsalmi	http://www.maaseuduntulevaisuus.fi/maatalous/pyh%C3%A4j%C3%A4rvelle-perustetaan-perunakaivos-1.174395
Indoor farming, hemp	http://www.mielleyhtyma.com/wp/there-no-business-like-business/kivi-paperi-hamppu/
Speeding up plant growth with plasma technology	http://spectrum.ieee.org/tech-talk/energy/environment/a-blast-of-plasma-makes-plants-grow-faster
Jellyfish: Concept based on aquaculture, water purification, solar energy	http://www.trueactivist.com/magnificent-jelly-fish-gardens-purify-the-water-and-grow-food-watch/
Fully robotised planting and harvesting of barley	https://www.digitaltrends.com/cool-tech/robot-farmers-harvest-barley/
A robotised LED farm in Tampere	http://www.aamulehti.fi/raha/tamperelainen-keksinto-voi-mullistaa-maailman-kasvihuoneet-ei-tarvita-tyontekijoita-eika-aurinkoa-24148440/
MIT invests in LED/vertical farming	http://spectrum.ieee.org/computing/embedded-systems/mits-food-computer-the-future-of-urban-agriculture
Indoor farming in grocery stores	https://techcrunch.com/2017/06/26/infarm/
Underground farming with LED lighting in London	https://youtu.be/FecuxU0tMmE
A farming experiment on the Moon	http://newswatch.nationalgeographic.com/2013/12/05/nasa-may-test-its-lunar-green-thumb/
Communication within fungal networks	http://www.bbc.com/earth/story/20141111-plants-have-a-hidden-internet
Container farming with LED lighting, K. Musk	http://squarerootsgrow.com/
A LED farm for the kitchen, Plantui	http://plantui.com/fi/smart-gardens/plantui-6-smart-garden/
Aeroponic farming of potatoes in Tyrnävä	http://www.maaseuduntulevaisuus.fi/maatalous/nasan-esimerkki-innosti-kasvattamaan-perunoita-ilmassa-tyrn%C3%A4v%C3%A4ll%C3%A4-1.146632

2.7.68 Plant and animal fibres, nanocellulose (068) *

Target area of the ART: Both plants and animals are used to produce fibres. Fibres are used in fabrics, as additives that increase tensile strength and in food. Fibres are also used as insulation and packaging material for a variety of purposes. This ART features organic fibres, including wood. Synthetic fibres are discussed in ART 48.

General description of the development: The most common natural fibre available is cellulose. It is a structural component in almost all plants. Pure cellulose is produced by separating hemicellulose and lignin from a plant, such as a tree. The most important products made of cellulose are paper and cardboard.

When the structure of cellulose is altered, it is referred to as regenerated fibre. When chopped into cellulose microfibres or nanocellulose, its properties change. It can be used in fabric, plastic or as an edible substance suited for food. The structure of nanocellulose affects its properties. Its production methods and product properties and applications are continuously being developed.

Traditional fibres, such as silk, and many plant fibres, such as cotton, also continue to be developed. Materials that were previously only used rarely, such as mycelium and spider silk, are being researched. The objective is to achieve new types of properties, efficient production processes and commercial applications. The end products may be construction materials, packaging, clothing and various consumer products. In terms of their properties, they may be very strong, transparent, porous or dense, for example.

Resources and motive for development: Product development is carried out on a wide scale. The motivates are both academic and industrial. Researchers particularly seek to increase the value of byproducts and recyclability. Depending on the stage of development and how new the method is, the objectives may also be directly commercial.

Impact on value-producing networks, ART 68																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	3	0	0	10	3	0	0	0	0	0	0	0	0	3	0	0	0	0	*76

Progress since the previous report: The closest corresponding section in the previous report was “2.78 Cellulose nanofiber and microfiber,” which ranked in the highest group. A recent market survey anticipates that the nanocellulose market will grow by more than 20%, reaching almost €300 million by 2020. An aerogel developed from nanocellulose is a flame-retardant super insulation. Nanocellulose can be made efficiently from potatoes, for example.

Researchers have made transparent wood. Wood strength has been increased tenfold. Edible packaging has been made from milk protein. Silk retains the freshness of fruit. Spider web and silk become twice as strong when silkworms or spiders are fed carbon nanotubes.

Interesting sources published after the 2013 report (068)	
Short description of the link	**link**
An aerogel made of nanocellulose is a flame-retardant super insulation material	http://www.mdpi.com/1996-1944/10/3/311/pdf
Tenfold increase in the strength of processed, compressed wood	https://www.nature.com/articles/nature25476

Interesting sources published after the 2013 report (068)	
A review of the development of cellulose nanofibre (CNF)	http://asia.nikkei.com/magazine/20170209/Tech-Science/Move-over-carbon-fiber-here-comes-cellulose-nanofiber
A fungi will replace polystyrene (biodegradable)	http://news.nationalpost.com/news/world/ikea-fungus-mushrooms-for-packaging
Spider web can hold a human when spiders are fed carbon nanotubes	http://www.smh.com.au/technology/sci-tech/nanotech-super-spiderwebs-are-here-20170822-gy1blp.html
Efficient manufacturing of nanocellulose from potatoes	http://www.maaseuduntulevaisuus.fi/tiede-tekniikka/nanosellua-ei-kannatakaan-tehd%C3%A4-puusta-vaan-perunasta-ja-juurikkaasta-suomalaisyritys-aikoo-vallata-40-miljardin-markkinat-1.168494
Applications of nanocellulose (VTT)	http://www.vttresearch.com/services/bioeconomy/biobased-materials/nanocellulose-tailoring
Silk keeps fruit fresh	http://www.eurekalert.org/pub_releases/2016-05/tu-skf050516.php
The Ioncell method for processing wood fibres	https://phys.org/news/2017-04-upcycling-fast-fashion-pollution.html
Recycling cotton textiles	http://www.vtt.fi/medialle/uutiset/vtt-n-poistopuuvillan-kuiduttamiskokeet-toteutetaan-kes%C3%A4ll%C3%A4
Optically transparent wood	http://pubs.acs.org/doi/abs/10.1021/acs.biomac.6b00145
A low-cost method for making nanocellulose	http://www.fstjournal.org/news/new-low-cost-process-make-nanocellulose/670
Marimekko & Spinnova to develop yarn from wood	https://www.hs.fi/talous/art-2000005436951.html
The market for nanocellulose is small but growing	https://globenewswire.com/news-release/2016/01/29/805894/0/en/Global-Nanocellulose-Market-Analysis-Trends-Report-2016-2020-Industry-Forecasts-for-the-295-Million-Industry.html
Edible packaging made from milk protein	http://www.eurekalert.org/pub_releases/2016-08/acs-efp072116.php

2.7.69 Cryogenics of biomaterials (069) *

Target area of the ART: Freezing is a well-known technique for preserving biomaterials. When freezing is carried out sufficiently quickly, the ice crystals that form do not grow large enough to break the cell structures. This improves the preservation of nutrients and the feeling of freshness in food products. In the breeding of plants and animals as well as organ transplantation, cryogenics can be used to keep the live tissue fit for transplantation. It is also considered to be possible for humans to be frozen cryogenically and revived, or at least for their memory to be preserved.

General description of the development: The development of refrigeration with the help of better insulation and more efficient refrigeration equipment is steering the food industry towards frozen foods. It is essential to pursue freezing techniques that preserve nutritional values and taste. The key factor in this pursuit is the refrigeration rate.

In medicine, reproductive cells have been frozen in cases in which patients wish to have offspring after an illness or treatment has destroyed their reproductive cells. The genome of many rare species has also been frozen for the purpose of fostering biodiversity. Humans are known to have been frozen in the hopes of being brought back to life, but for the time being only the first mammal has been successfully brought back after being cryogenically frozen.

Trauma patients may die before they can be treated. The FDA has approved severely injured patients to be cooled for the duration of the preparations for surgery. One potential benefit of freezing the brain cryogenically is that we will be able to read the person's memories if the brain's structure is undamaged.

Resources and motive for development: Cryogenics is being widely developed for research purposes. For example, this technology is important for superconductors and quantum computers. However, the most extensive area of application for cryogenics is food production, for which purpose technology is being developed. The cryogenic freezing and revival of humans are difficult areas of research, but the private motive for it is clear and preparatory research is also being conducted for this purpose.

Impact on value-producing networks, ART 69																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	3	0	3	0	0	0	3	0	3	0	3	3	5	0	0	0	0	3	0	*104

Progress since the previous report: This ART is new. Recent observations include the following: The cooling of trauma patients and suspension of their vital functions are being tested for the purpose of buying time for treatment. A rabbit's brain has been frozen without damaging its structure.

Interesting sources published after the 2013 report (069)	
Short description of the link	**link**
Cooling trauma patients (hibernation)	http://io9.com/humanity-is-now-officially-ready-for-suspended-animatio-1581727874
Humans are already being cryogenically frozen with the expectation of being revived	https://www.express.co.uk/news/science/844464/cryogenically-frozen-REVIVED-cryonics
Suspension of vital functions is being tested in humans	http://www.extremetech.com/extreme/179296-humans-will-be-kept-between-life-and-death-in-the-first-suspended-animation-trials
A rabbit's brain has been frozen without damaging its structure	http://www.sciencealert.com/a-mammal-s-brain-has-been-cryonically-frozen-and-recovered-for-the-first-time

2.8 Energy technology

Energy technology is one of the fastest evolving areas included in this report. Climate change is one of the clearest drivers of change. Consumerisation of solar energy is a major trend in many countries. Together with the development of battery technology and fuel cells, it is e.g. anticipated to become profitable for one in two households to separate from the electricity grid in Australia by 2020.

The increase in solar energy and wind energy will increase fluctuation in energy prices. Decentralised production of energy for our own needs will reduce the use of the electricity grid while increasing the unit costs of electricity transmission. Increasing price fluctuations will improve the profitability of energy stores and increase the significance of heat stores, particularly in northern conditions.

The development of battery technology supports the electrification of transport. Electrification of air transport is also within sight. Combined with the production of synthetic fuels with solar and wind energy, the development of fuel cells and micro-turbines gives us the opportunity to benefit from solar and wind energy during all seasons, even in the north.

Nuclear energy may be at the cusp of new breakthroughs. Small mass-produced nuclear power plants, fusion energy and even nuclear reactions achieved with laser technology in room temperature seem to be realistic scenarios. In addition to the new coming of nuclear energy, we are also reminded of themes in old science fiction comics by ray guns and wireless electricity transfer, both of which are about to enter the field of technology that can be taken seriously.

Energy technology	
ART-ID	**The ARTs in the group**
70	Rapid development of photovoltaics
71	Capturing/storing solar heat, heat to electricity
72	Grid-level energy storage
73	Transportable batteries and supercapacitors
74	Artificial leaf and synthetic fuels
75	Cheap small fuel cell and micro-turbine CHP
76	Cheap efficient storage of hydrogen
77	Off-grid and microgrid solutions
78	Carbon capture and CO2 usage as raw material
79	Small fusion and fission plants
80	Recovery/harvesting of kinetic energy
81	Power lasers, ray guns, railguns
82	Wireless electricity transfer
83	New power sources for vehicles

2.8.70 Rapid development of photovoltaics (070) ****

Target area of the ART: According to the figures of Motiva, an average of 1,000 kWh of radiation energy falls on each horizontal square metre in southern Finland per year. In terms of the price of electricity normally paid by households, this corresponds to an amount of energy worth roughly €100 if it could be fully used to replace purchased electricity. In an area spanning a hectare, this would amount to €1 million. A more realistic calculation that is adjusted with the electricity production cost of roughly €0.03/kWh and 20% efficiency still leads to the considerable level of €60,000. This can be compared to sustainable average sales revenue from forests. It is less than one hundredth of the yield of solar panels, only €200–300/ha.

Solar energy provides an opportunity to reduce the consumption of fossil energy and our dependency on the electricity grid. Solar panels are believed to have a significant impact on light aircraft of the future, for example, and they are in practice the only significant source of energy for satellites in space.

General description of the development: The price of installed solar energy has decreased by 7–15% per year over a long period of time. According to studies, this decrease in price may continue for a long time. Thin film technology allows solar panels to be made flexible, lightweight and easy to integrate into other structures. They require less and less valuable materials. The challenge in thin film technology has been its low efficiency, but this problem is quickly being remedied.

The sustainability and raw material composition of the films have been developed. Perovskite and nanocarbon are being researched particularly actively as promising materials for the purpose of replacing raw materials that are valuable or problematic with regard to the manufacturing process and the environment. In addition to sustainability, low price and efficiency, the materials are also being developed to be suitable for efficient roll-to-roll processing. The objective is to make materials that are suitable for coating normal roof tiles, sheeting and exterior wall cladding.

Solar panels are also being planned to cover road surfaces. Panels that allow visible light to pass through as necessary are being planned for window surfaces. In several countries, the price of solar energy is calculated to have already fallen below the parity with electricity supplied by the electricity grid, and the payback periods are continuously getting shorter. Investments in solar power are continuously increasing at the global level.

Resources and motive for development: The development motive behind radical technologies is academic and societal in nature, but development is driven by customer demand and commercial competition in technologies that are nearing commercialisation. Development is extensive, well-resourced and diverse.

Impact on value-producing networks, ART 70																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	5	5	10	5	20	5	10	1	3	3	3	0	0	3	0	0	5	3	3	0	****588

Progress since the previous report: The corresponding sections in the previous report were "2.82 Rapidly cheapening solar energy" and "2.83 Efficient and light solar panels," which ranked in the first and third groups, respectively.

The efficiency of commercial thin films has increased from 5% to 14%. At the laboratory level, thin films have exceeded 20% efficiency with panels that are nearing the goal in terms of their service life. The numbers of solar panels installed globally have continued increasing rapidly. Many products in which solar panels are integrated into other construction materials have become common.

Laboratory-level solar cells have exceeded 40% efficiency. A flexible graphene film has achieved 15.6% efficiency. A perovskite cell with 11% efficiency has lasted for 10,000 hours, and the efficiency record of thin film perovskite cells is approaching 20%. An experimental solar panel intended for windows turns transparent when cooled and, conversely, dark and photovoltaic when exposed to sunlight. The price of solar energy is anticipated to continue decreasing considerably in the 2020s, and efficiency is anticipated to improve.

Interesting sources published after the 2013 report (070)	
Short description of the link	**link**
R2R printing of PV panels $10/m2	https://www.newcastle.edu.au/newsroom/featured-news/the-clever-electronic-inks-rewriting-our-energy-future
Concentrator PV panels made from GaSb, 44.5% efficiency	http://wallstreetpit.com/113806-new-solar-cell-capture-suns-energy/
Flexible graphene PV panels, 15.6%	http://www.gizmag.com/graphene-solar-cell-record-efficiency/30466/
A perovskite solar cell stable for 10,000 hours with 11% efficiency	http://www.eenewseurope.com/news/low-cost-perovskite-solar-cell-achieves-10000-hour-stability-0
A perovskite PV panel stable for 1,000 hours with 19% efficiency	https://phys.org/news/2017-12-guanidinium-stabilizes-perovskite-solar-cells.html
Transparent/darkening glass, a solar panel with 11% power conversion efficiency	https://www.nature.com/articles/s41467-017-01842-4
FS: an efficient thin film PV panel by 2017	https://cleantechnica.com/2015/12/30/first-solar-panels-likely-surpass-p-type-crystalline-panels-performance-2017/
1 km of 800kW photovoltaic road surface in China, charges cars	http://www.moneycontrol.com/news/technology/china-tests-its-first-solar-powered-highway-that-can-charge-electric-cars-2472605.html
Saudi Arabia receives an offer of €0.015/kWh for solar energy	https://www.bloomberg.com/news/articles/2017-10-03/saudi-arabia-gets-cheapest-ever-bids-for-solar-power-in-auction
IRENA: Solar energy generation to grow sixfold by 2030, prices to decrease by 59%	http://cleantechnica.com/2016/06/23/solar-power-account-13-world-electricity-generation-2030-says-irena/
Batteries and PV panels on fabric	http://spectrum.ieee.org/nanoclast/semiconductors/materials/back-to-the-future-serves-as-inspiration-for-clothing-with-a-solarpowered-battery

Interesting sources published after the 2013 report (070)	
Tesla: Solar roofs and Powerwall 2	http://www.theverge.com/2016/10/28/13463236/tesla-solar-roof-battery-new-elon-musk
Solar energy becomes the cheapest form of electricity	http://fortune.com/2016/12/15/solar-electricity-energy-generation-cost-cheap/
Record PV panel efficiency with lab techniques – a map	https://www.nrel.gov/pv/assets/images/efficiency-chart.png
Fraunhofer: a comprehensive review of solar energy	https://www.ise.fraunhofer.de/en/downloads-englisch/pdf-files-englisch/photovoltaics-report-slides.pdf
A perovskite thin-film solar module with 17.8% efficiency	https://www.eurekalert.org/pub_releases/2016-10/kift-rfp100616.php
Solar energy in the USA at $0.028/kWh, including storage costs	https://electrek.co/2016/10/16/us-based-solar-power-storage-at-0-028kwh/
Trials of solar panel paved roads expand	https://www.facebook.com/qznews/videos/371889156523828/
Spray-cast perovskite solar cells produced	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5554192/
Multiple electrons from a photon with graphene (PV)	http://spectrum.ieee.org/nanoclast/green-tech/solar/graphene-gets-another-boost-in-high-conversion-efficiency-photovoltaics
A solar absorber withstands 1000C	http://news.mit.edu/2014/perfect-solar-cell-0929
A micrometre-thin, flexible solar cell	http://www.sciencedirect.com/science/article/pii/S1566119916300222
An organic thin-film PV cell with 13% efficiency	http://www.electronics-eetimes.com/en/heliatek-claims-opv-world-record-efficiency-of-13.2-percent.html?cmp_id=7&news_id=222927415
Virte Solar roofing has a PV surface	http://www.aamulehti.fi/kotimaa/suomalaisyritys-keksi-kattopellin-joka-toimii-samalla-aurinkovoimalana/
Coloured solar cells with 35% efficiency	http://www.economist.com/news/science-and-technology/21596924-way-double-efficiency-solar-cells-about-go-mainstream-stacking
SunPower's 24.1% PV efficiency	https://www.forbes.com/sites/michaelkanellos/2016/06/27/sunpowers-24-1-efficiency-mark-are-we-near-the-ceiling/
Perovskite can "recycle" photons	http://www.businessinsider.com/scientist-have-found-a-way-to-recycle-sunlight-2016-3?IR=T
Rectenna from carbon nanotubes, potential estimated	https://wattsupwiththat.com/2016/10/20/forget-solar-panels-optical-rectenna-converts-light-directly-to-electricity/
PV efficiency may exceed the Shockley-Queisser limit	http://drexel.edu/now/archive/2016/august/bulkpve/

2.8.71 Capturing/storing solar heat, heat to electricity (071) *

Target area of the ART: At Helsinki's latitude, solar radiation heats every square metre of non-reflective surface by 1,000 kWh per year. In warm countries, tap water is routinely heated with solar thermal collectors. Solar heat can also be used for other heating. However, in northern conditions the availability of solar heat is at its lowest when the need for heating is at its greatest. Northern areas seek to store summertime solar heat for wintertime. This ART also includes the direct conversion of temperature differences into heat.

General description of the development: Researchers are developing the efficiency of solar thermal systems. Usually, the liquid circulating in a solar thermal collector cell passes through the water being heated. If the water is already warm enough, the extra heat can be discharged in the soil to prevent overheating. Heating the soil with the help of the piping of a geothermal system is beneficial as is, as the soil retains the heat for a long time. Warm soil enhances the operation of geothermal heating. Another aim is to store heat in specifically built heat storages, i.e. insulated materials that store heat.

Concentrated solar power systems use mirrors to concentrate sunlight onto PV panels or thermophotovoltaic TPV panels. Some of the temperature difference is not turned into electricity. When stored as heat, it can also be utilised and developed.

The conversion of condensation heat into electricity is being researched extensively. This involves the Seebeck effect, in which a temperature difference is converted into electricity. This phenomenon is contrary to refrigerators, which convert electricity into a temperature difference. This effect can be used to improve the efficiency of heat-generating processes. Thermoelements that convert temperature differences into electricity are being developed to reduce the temperature difference required, improve efficiency and lower the production costs of materials.

Resources and motive for development: Solar thermal systems and heat storages are being improved for commercial reasons. In entirely new types of solutions, the research motive is either academic in nature or a long-term commercial goal. The development is relatively extensive and involves start-ups.

Impact on value-producing networks, ART 71																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	0	3	0	3	3	5	3	0	0	1	0	0	0	0	0	1	0	3	0	*88

Progress since the previous report: The closest corresponding ART in the previous report was “2.91 Solar heat and long-term storage of heat,” which ranked in the second highest group. Several Finnish products and product concepts have been published for the recovery and storage of solar heat, including PolarSol, Solixi and AHOOD. A geothermal power plant is being constructed in Espoo. IBM has unveiled a solar thermal and concentrated photovoltaic system with a combined efficiency of 75%. It produces electricity, heat and clean water. The storage of solar heat is being researched based on a phase transition. Solar heat storage solutions are being launched on the market, and solutions are evolving relatively quickly.

Interesting sources published after the 2013 report (071)	
Short description of the link	**link**
A 200 MW cold energy storage plant	http://www.bbc.com/news/science-environment-37902773
Recovering waste heat with the spin Seebeck effect	https://www.rdmag.com/article/2017/01/device-converts-heat-electricity
IBM's 80% solar electricity generator	http://www.theguardian.com/environment/2014/sep/28/solar-energy-sunflower-ibm-airlight-electricity
Vanadium dioxide conducts electricity but not heat	http://newscenter.lbl.gov/2017/01/26/electricity-not-heat-flows-in-vanadium-dioxide/
Heat recovery, AHOOD	http://koti.ts.fi/rakenna/aktiivivaippa-nappaa-ilmaislammon-talteen
Sand stores solar heat	https://news.masdar.ac.ae/explore-news/stories-by-type/transformation/item/8888-masdar-institute-research-successfully-proves-uae-desert-sand-can-store-solar-energy-up-to-1000-c.html
IBM's Sunflower progresses, combined efficiency 75%	http://www.sciencedirect.com/science/article/pii/S0038092X17304942
Storage of solar heat, phase transition	http://www.google.com/patents/US8231804
A supercondenser charged by the sun, Linköping	http://phys.org/news/2016-03-supercondenser-sun.html

2.8.72 Grid-level energy storage (072) **

Target area of the ART: Society uses a great amount of energy on heating, transport and a variety of industrial processes. As both the need for energy and production capacity vary, energy production requires adjustability or the ability to store energy. This variation depends on the time of day, season and weather conditions, for example. Due to the broad spectrum of needs and capabilities, the optimal solutions vary.

In this ART, energy storages are not considered to include normal oil tanks or coal piles. Instead, this ART focuses on energy storages that convert electrical energy into an easily stored form and later converts it back into electricity. Batteries intended for mobile devices and other small batteries are discussed in ART 73.

General description of the development: Several forms of energy are utilised in energy storage. Potential energy is used in pumped storage plants. Water is pumped into reservoirs, high towers, mine shafts or spheres on seabeds. Energy is also stored with pumps in pressurised spheres, caves and on seabeds. Potential energy is also stored as a mechanical mass in cars pulled up a mountainside, for example. Kinetic energy is mostly stored as flywheel energy.

Electrochemical phenomena convert electrical, photovoltaic or thermal energy into a form from which the energy can be recovered later with another reaction. Researchers are looking for materials for these reactions that are as long-lasting and inexpensive as possible.

With high capacity batteries, we are talking about the amount of energy stored, the charge and discharge power, the electricity-to-electricity efficiency and the number of charge cycles that determine battery life. Some of the batteries only work when hot. If a battery has a low efficiency, it should be noted that it also heats up easily. This type of battery must be cooled during use. The price of capacity and energy must be estimated separately for several high capacity batteries, as the relationship between them varies greatly depending on the technique used.

Reservoirs are still the most massive solutions used for energy storage. Other current method to compensate for variation in production or consumption is by activating or deactivating plants that provide load-following capacity as necessary. With increased need for load-following capacity due to the volatility inherent in renewable energy and also advancements made in technology, battery-like energy storages have started to become more common and their development is anticipated to increase rapidly.

Resources and motive for development: The academic motive is still strong in the development of large energy stores, but commercial and competitive motives will gain strength as a result of rapid market growth.

Impact on value-producing networks, ART 72																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	0	3	0	20	0	0	5	0	0	0	0	0	0	0	0	1	0	0	0	**145

Progress since the previous report: The corresponding section in the previous report was "2.90 Massive storage of energy in high capacity batteries," which ranked in the second group. Several of the technologies that were promising at the time have progressed to production, and development is now considerably more extensive in all areas.

According to one estimate, annual energy storage capacity additions will increase by several dozen times by 2026, and energy storage costs will decrease by 70% by 2030. Tesla has unveiled a high capacity LI battery as backup power for properties and for the electricity grid's load balancing needs. It has also launched the production of its $5 billion Gigafactory. EOS has unveiled its $160/kWh zinc hybrid cathode batteries under the name Aurora and has committed to lower the price to $95/kWh in 2022.

The material cost of a flow battery under development is $20–30/kWh, and its current working life is 1,500 hours. An aluminium battery, a sodium-magnesium battery, a zinc-manganese battery and many other battery materials are progressing towards long-lasting structures. Wind turbines have been combined with pumped storage plants in several different ways.

Interesting sources published after the 2013 report (072)	
Short description of the link	**link**
MIT: Flow battery costs $20–30/kWh, working life now 1,500 h	https://newatlas.com/air-breathing-battery/51720/
Annual energy storage capacity additions to exceed 50 GW by 2026	https://cleantechnica.com/2017/07/24/global-annual-utility-scale-distributed-energy-storage-capacity-additions-exceed-50-gw-2026/
EOS is taking orders, price to decrease to $95/kWh in 2022, now $160	http://www.businesswire.com/news/home/20170418005284/en/Eos-Energy-Storage-Orders-95kWh-Eos-Aurora%C2%AE
A pumped storage plant in the sea, competitive	http://www.renewableenergyworld.com/articles/2016/09/storing-energy-in-the-sea-a-new-design-for-marine-energy-storage.html
Low-cost battery materials: aluminium, urea, graphite, 100% Faraday efficiency	http://news.stanford.edu/2017/02/07/stanford-engineers-create-low-cost-battery-storing-renewable-energy/
A sodium-magnesium battery, promising test results	http://pubs.acs.org/doi/abs/10.1021/acs.chemmater.5b03531?journalCode=cmatex&
An aluminium battery that stands 7,500 charge-discharge cycles	https://energy.stanford.edu/news/aluminum-battery-stanford-offers-safe-alternative-conventional-batteries
Wind turbines with built-in hydroelectric batteries	http://qz.com/823054/germany-wind-turbine-hydroelectric-batteries/
Tesla's Gigafactory, $5 billion	https://www.bloomberg.com/news/articles/2016-07-26/tesla-opens-gigafactory-to-expand-battery-production-sales
A zinc-manganese oxide battery, 285 Ah/kg over 5,000 cycles	http://www.pnnl.gov/news/release.aspx?id=4269
Status of battery technology development (grid-scale), ARPA-E	http://www.sandia.gov/ess/docs/events_news/2nd_12_projects_9-17-10.pdf
Alphabet – salt-based thermal energy storage	https://www.bloomberg.com/news/articles/2017-07-31/alphabet-wants-to-fix-renewable-energy-s-storage-problem-with-salt
Long lifetime, 99% Faraday efficient, flow battery	http://pubs.acs.org/doi/abs/10.1021/acsenergylett.7b00019
Tesla: A 129 MWh lithium-ion battery in Australia in 100 days	https://www.theguardian.com/australia-news/2017/jul/07/tesla-to-build-worlds-biggest-lithium-ion-battery-in-south-australia
Sweden intends to support residential energy stores	http://www.renewableenergyworld.com/articles/2016/10/sweden-set-to-launch-residential-energy-storage-scheme.html
A flow battery from inexpensive materials	http://jes.ecsdl.org/content/161/9/A1371.full?sid=e4be8ba7-839f-4669-9a85-5b9c42d73289
Testing of wind turbines' 85% compressed air energy storage	http://www.offshorewind.biz/2016/11/14/german-researchers-start-testing-offshore-wind-energy-storage-system/
Energy storage costs down by 70% by 2030	https://www.worldenergy.org/publications/2016/e-storage-shifting-from-cost-to-value-2016/
A market forecast for energy storage	http://cleantechnica.com/2014/06/09/solar-energy-storage-system-market-germany-approaching-boom/
A flow battery from safe materials for use at home	http://www.eurekalert.org/pub_releases/2015-09/hu-gsf091715.php
Undersea energy storage, compressed air	http://dspace.mit.edu/handle/1721.1/78934

Interesting sources published after the 2013 report (072)	
Inexpensive battery materials fool's gold, sodium, magnesium	http://www.gizmag.com/fools-gold-replace-lithium-batteries/40404/
An aftermarket for electric vehicle batteries	https://ark-invest.com/research/ev-batteries-value
Underwater energy storage (pressure)	http://www.greentechmedia.com/articles/read/fraunhofer-races-hydrostor-for-underwater-storage
A liquid metal battery under development in Norway, sodium-zinc	http://www.eenewseurope.com/news/new-liquid-metal-battery-may-solve-renewable-energy-storage-problem-0
Improved energy density in a sugar battery	http://phys.org/news/2014-01-energy-dense-sugar-battery.html
Battery storage payback period 5 years in the USA	http://www.greentechmedia.com/articles/read/battery-storage-pays-back-in-less-than-five-years-sc-finds
A flux capacitor with nanoscale interdigital electrodes, 2 Wh/kg	http://advances.sciencemag.org/content/advances/1/9/e1500605.full.pdf
A flow battery €240/kWh	https://cleantechnica.com/2014/12/01/us-navy-pushes-solar-energy-storage-solution/

2.8.73 Transportable batteries and supercapacitors (073) ****

Target area of the ART: Mobile machines and portable electronics devices require an independent power source. Internal combustion engines, solar panels and other solutions that use primary energy are often impractical alternatives compared to batteries.

The increase in the number of electric engines, portable electronics devices and robots that move outside the reach of the electricity grid has rapidly increased the demand for lightweight, energy-dense and quickly charged batteries. Energy stores used for load balancing in the electricity grid are discussed in ART 72.

General description of the development: Batteries have five important characteristics: energy density specifies the amount of energy stored per kilogramme or litre. Power capability specifies how much energy can be extracted from a battery per a unit of time. Efficiency specifies the proportion of energy that can be utilised while the rest mainly warms up the battery. Battery life specifies how many charge-discharge cycles a battery can endure without a material decrease in performance. Charging speed specifies the time it takes to fully charge a battery. All of these characteristics should be at an acceptable level in order for the use of the battery to be sensible.

Other important characteristics besides those mentioned above include the low cost of the battery materials, efficiency of the manufacturing process and safety of the end product. Several studies report the peak value of an individual characteristic even if the battery as a whole is unusable. In battery technology, reading research publications is more challenging than in many other research areas as a sensible battery comprises many factors that affect each other.

There is an abundance of promising development projects. As the mainstream technology, lithium-ion batteries have held their ground for two reasons First of all, their current generation contains a great number of incremental and production-related innovations. Secondly, economies of scale are on their side as a result of large production volumes. A competing technology should be decisively better in order for major investments in automating production and in other economies of scale to be worthwhile. There are signs that new technologies are about to exceed these limits.

Instead of chemistry-based batteries, capacitors are devices based on the capacitance of electrons. Capacitance is based on a very wide surface on which electrons can travel. Charging and discharging speeds are usually high, while wear is inexistent. Capacitors are used for fast storage and discharging needs, but they are also used similarly to batteries if they have an adequate energy density. The development of capacitors has sped up with improved understanding of nanomaterials and thin surfaces in particular.

Resources and motive for development: Research is progressing at a considerable speed as a result of academic motivation, competitive reasons of major manufacturers and start-ups funded by venture capitalists.

Impact on value-producing networks, ART 73																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	20	10	0	0	5	0	5	0	3	5	0	0	5	5	0	10	3	0	0	0	****497

Progress since the previous report: The corresponding ART in the previous report was "2.89 Rapidly charging light batteries and supercapacitors." It ranked in the highest group. Progress has continued to be fast-paced. Companies have developed several methods that considerably improve the energy density, charging speed and lifetime of lithium-ion batteries. Challenger technologies have achieved significant performance values in laboratories. StoreDot batteries and Toshiba's SCiB battery can be charged within five minutes. BroadBit is also developing its own sodium battery that can be charged within five minutes.

A nanowire-based, quickly recharged battery developed by the University of California can be recharged over 200,000 times without loss of performance. The development of lithium-air batteries is progressing with the goal of achieving a power-to-weight ratio equivalent to liquid fuels. The energy density of a lithium-sulphur battery is ten times higher than current lithium-ion batteries, but researchers have for the time being only achieved a version that can endure 50 charge-discharge cycles. BioSolar anticipates a price of $54/kWh and energy density of 1 kWh/kg for a polymer battery under development. Researchers are using cellulose and graphene to develop supercapacitors with a capacity that is nearing that of existing batteries, but their charging speed and number of charge cycles are higher.

Interesting sources published after the 2013 report (073)	
Short description of the link	**link**
Functional lithium-air batteries with minor deterioration and loss	http://www.nature.com/articles/nenergy2016111
A water-bearing lithium-ion battery, 10,000 cycles, 2 min charging time	https://phys.org/news/2017-12-road-fast-stable-batteries.html
Lithium-ion battery capacity to 500 Wh/kg with graphene, 98%/400	https://arstechnica.com/science/2017/07/lithiumgraphene-foil-makes-for-a-great-battery-electrode/
A battery with fast recharging and a long lifetime, 200,000 cycles	http://www.techtimes.com/articles/152383/20160422/nanowire-based-battery-with-off-the-charts-charging-power-is-this-the-future-of-electronics.htm
Some problems in lithium-oxygen batteries solved	http://news.mit.edu/2016/new-lithium-oxygen-battery-greatly-improves-energy-efficiency-longevity-0725
Rice: An asphalt-lithium metal battery 500 cycles at peak values	http://news.rice.edu/2017/10/02/asphalt-helps-lithium-batteries-charge-faster-2/
A StoreDot battery charged in 5 min, lasts for 300 miles	https://www.engadget.com/2017/05/12/storedot-ev-battery-demo/
Toshiba's SCiB battery is charged within minutes, withstands freezing temperatures	http://www.scib.jp/en/about/index.htm
A fast-charging battery, ample funding, Samsung, StoreDot	http://www.bbc.com/news/technology-30708945
Low-cost, efficient sodium batteries in testing, BroadBit	http://www.broadbit.com/
A lithium-sulphur battery with high energy density, active development	http://www.extremetech.com/extreme/200255-glass-coated-sulfur-particles-could-improve-battery-life-1000-percent
A supercapacitor from plastic with the LIG process	http://spectrum.ieee.org/nanoclast/semiconductors/materials/laserinduced-graphene-looks-to-diplace-batteries-with-supercapacitors
A research publication of Braga & Goodenough's high-capacity battery	https://news.utexas.edu/2017/02/28/goodenough-introduces-new-battery-technology
A lithium-air battery under development	http://spectrum.ieee.org/transportation/advanced-cars/an-electric-car-battery-that-will-get-you-from-paris-to-brussels-and-back
BroadBit's sodium batteries strongly linked to Finland	http://www.insinoori-lehti.fi/natriumakut-valtaavat-s%C3%A4hk%C3%B6py%C3%B6r%C3%A4t
Supercapacitors from cellulose	http://www.nanotech-now.com/news.cgi?story_id=49290
Tesla has doubled the lifetime of batteries	https://electrek.co/2017/05/09/tesla-battery-lifetime-double/
Lithium-metal batteries becoming commercialised	https://techxplore.com/news/2016-08-lithium-metal-batteries-smartphones-drones.html
Bill Joy's polymer battery, 400 cycles, 3 years to production	https://www.wired.com/story/bill-joy-finds-the-jesus-battery/?mbid=social_fb
Samsung: a lithium-ion battery with graphene balls, charged within minutes	https://www.nature.com/articles/s41467-017-01823-7
BioSolar is developing a $54/kWh, 1,000 Wh/kg polymer battery	http://cleantechnica.com/2016/02/26/new-energy-storage-solution-could-hit-magic-54-mark/

Interesting sources published after the 2013 report (073)	
A fast, inexpensive aluminium battery, 7,500 cycles	http://www.nature.com/nature/journal/v520/n7547/abs/nature14340.html
A supercapacitor easily from hemp, 12 Wh/kg	http://www.acs.org/content/acs/en/pressroom/newsreleases/2014/august/could-hemp-nanosheets-topple-graphene-for-making-the-ideal-supercapacitor.html
Bosch promises an inexpensive 400 Wh/kg battery by 2020	http://nextbigfuture.com/2015/09/bosch-claims-they-will-commercialize.html
Daimler's funding for fast-charging StoreDot batteries	https://www.bloomberg.com/news/articles/2017-09-14/daimler-trucks-backs-storedot-fast-charging-battery-startup
A long-lasting experimental battery (400 years)	http://www.myamazingearth.com/2016/09/student-accidentally-creates.html
A lithium-titanate hybrid battery is fast and stable, 10,000 cycles	https://www.nature.com/articles/s41467-017-00574-9
A production technique for graphene-sulphur-lithium battery material invented	https://techxplore.com/news/2017-12-graphene-lithium-sulfur-batteries.html
Supercapacitors from cellulose	http://www.sciencedaily.com/releases/2015/12/151203111337.htm

2.8.74 Artificial leaf and synthetic fuels (074) *

Target area of the ART: The use of fossil fuels generates carbon dioxide emissions that cause climate change. In the pursuit of a carbon-neutral society, all the carbon burned should be recovered from escaped carbon dioxide and reduced back to carbon or other compounds. Carbon dioxide and water can be converted into liquid fuels with the help of solar and wind energy, for example. Photosynthesis is a biological method for this purpose, and it should be mimicked efficiently.

Synthetic fuels may have several benefits compared to fossil fuels. For example, purity or another type of composition can facilitate their use. Synthetisation of liquid fuel is also a way to make energy into an easily stored form.

General description of the development: The simplest way to produce synthetic liquid fuel is based on breaking down water into hydrogen and oxygen with electricity. Hydrogen itself is a product worth seeking, although it is difficult to store. It can be converted into methane with carbon dioxide to make it easier to store. The necessary chemical reactions are facilitated with the help of catalysts and separation techniques to minimise the amount of energy used. Instead of hydrogen, the objective can be to make liquid formic acid or more complex liquid hydrocarbons, the storage and use of which in internal combustion engines and fuel cells is simpler than that of gas.

Instead of electricity, it is possible to use catalysts that help photons perform the task. The effect of light causes water and carbon dioxide to combine directly into hydrocarbons and release oxygen, similarly to plants. If the catalytic materials are synthetic, this is referred to as artificial photosynthesis. It is also possible to use genetically modified bacteria for the same purpose. The low cost, efficiency and durability of the necessary materials are characteristics sought by research.

Resources and motive for development: The development motive is primarily academic in nature or the long-term goal of companies. There is a clear societal motive, but it manifests above all as researchers' personal interest in the research area. Funding from society does not correspond to the scope of the problem that researchers are seeking to solve.

Impact on value-producing networks, ART 74																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	3	0	0	10	0	10	5	0	0	3	0	0	0	0	0	5	0	3	0	*126

Progress since the previous report: The corresponding section in the previous report was "2.84 Artificial leaf and synthetic fuel from the sunlight and carbon dioxide," which ranked in the fourth group. Development has progressed rapidly towards more efficient and long-lasting experimental devices.

At the laboratory level, researchers have reached an efficiency of over 20% in converting solar energy into hydrogen. A duration of 40 hours has been achieved with 14% efficiency. Hydrogen has been produced from electricity with an efficiency of over 80%, and efficiency has exceeded 50% in the production of methane. MOF materials are being developed for the production of synthetic liquid fuels. Genetically modified bacteria have been used to convert sunlight into acetic acid with 80% efficiency. A nanocatalyst that lasts for 100 hours has reduced carbon dioxide into carbon monoxide by using sunlight. The production of ethanol with an electrocatalyst is also undergoing continuous development, with researchers achieving over 50% Faraday efficiency. A method has been found for producing propane by using genetically modified bacteria. Researchers have succeeded in making algae produce electricity.

Interesting sources published after the 2013 report (074)	
Short description of the link	**link**
Isobutanol from sunlight with 10% efficiency	http://news.harvard.edu/gazette/story/2016/06/bionic-leaf-turns-sunlight-into-liquid-fuel/
LIG splits water into hydrogen on one side and oxygen on the other	https://phys.org/news/2017-08-lab-dual-surface-graphene-electrode-hydrogen.html
Concentrated solar power and nickel as a catalyst, 22% captured as hydrogen	http://www.techtimes.com/articles/77142/20150818/this-artificial-leaf-could-be-humanitys-lifeline-when-fossil-fuels-are-out.htm
Hydrogen from sunlight, 14%, stable for 40 h, goal 1,000 h	http://phys.org/news/2015-09-efficiency-solar-hydrogen-production-percent.html
Hydrogen from visible light (65% quantum efficiency)	http://www.kurzweilai.net/making-hydrogen-fuel-from-water-and-visible-light-at-100-times-higher-efficiency

Interesting sources published after the 2013 report (074)	
Acetic acid from sunlight with cyborg bacteria, 80% efficiency	https://phys.org/news/2017-08-cyborg-bacteria-outperform-sunlight-compounds.html
MOF -> CO_2 into liquid fuel (formate, etc.) with blue light	https://phys.org/news/2017-04-scientist-trigger-artificial-photosynthesis-air.html
Hydrogen from air with graphene	http://phys.org/news/2014-11-protons-fuel-graphene-prospects.html
Plant CO_2 -> 25% improvement to the Calvin cycle	http://www.popularmechanics.com/science/energy/a23938/fix-carbon-dioxide-useful-products/
CO_2 -> acetic acid, formic acid with nickel & carbon catalyst	http://advances.sciencemag.org/content/3/7/e1700921.full
CO_2 -> CO with sunlight, the nanocatalyst lasts for 100 h	https://www.sciencedaily.com/releases/2016/07/160730154602.htm
Soletair: liquid fuel from CO_2 and the sun with a portable device	http://newatlas.com/carbon-dioxide-fuel-pilot-plant-finland-kit-ineratec/46362/
CO_2 into ethanol with a nanotechnology-based catalyst, 63% yield	https://phys.org/news/2016-10-nano-spike-catalysts-carbon-dioxide-ethanol.html
CO_2 & H_2O into liquid fuel with sunlight and heat	http://www.eurekalert.org/pub_releases/2016-02/uota-pop022216.php
An efficient iron-nickel catalyst for hydrogen production	https://www.sciencedaily.com/releases/2018/02/180201141512.htm
An efficient, durable catalyst for separating hydrogen from water	http://www.pnas.org.ezproxy.grifols.com/content/114/22/5607.full
Ammonia from dinitrogen with sunlight	http://www.eurekalert.org/pub_releases/2016-04/drel-ndl042616.php
Hydrogen + CO_2 into methane in a biogas plant with biomethanation	http://www.biotalous.fi/qvidja-kraftin-biometanointi-mullistaa-bioenergian-tehokkuuden-ja-varastoinnin/
Hydrogen from water with more than 82% efficiency	http://news.stanford.edu/news/2015/june/water-splitter-catalyst-062315.html
Prototype of a scalable artificial leaf, 3.9% efficiency	http://www.nature.com/ncomms/2016/160907/ncomms12681/full/ncomms12681.html
Hydrogen with a mass-produced three-layer film, 1.55 V	http://www.sciencedirect.com/science/article/pii/S221128551730441X
CO_2 efficiently into soda ash	https://qz.com/878674/two-indian-engineers-have-drastically-reduced-the-cost-of-capturing-carbon-dioxide-emissions/
A nickel-iron battery produces hydrogen gas when charged	http://www.energyharvestingjournal.com/articles/10431/electricity-storage-and-hydrogen-production-in-a-single-system
Diesel from water and carbon dioxide at Audi's pilot plant	http://www.sciencealert.com/audi-have-successfully-made-diesel-fuel-from-air-and-water

Interesting sources published after the 2013 report (074)	
Algae into an energy source	http://www.eurekalert.org/pub_releases/2015-10/ws-mpp100215.php
E.coli made to produce propane	http://www.utu.fi/fi/Ajankohtaista/Uutiset/Sivut/Mikrobit-saatiin-tuottamaan-propaania.aspx
CO2 into methane with UV light + rhodium	https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/13671/ncomms14542.pdf?sequence=1
Infrared releases hydrogen from water using ruthenium	https://www.sciencedaily.com/releases/2017/11/171117103742.htm
CO2 -> formic acid with a non-degenerating iridium-based catalyst	https://phys.org/news/2016-06-chemists-greenhouse-gas-hydrogen-fuel.html
Methane from electricity, 50%	http://www.rdmag.com/news/2015/08/milestone-achieved-hybrid-artificial-photosynthesis
Ethanol from CO at room temperature, 57% Faraday efficiency	http://news.stanford.edu/news/2014/april/ethanol-without-plants-040914.html
A molecular system for artificial photosynthesis	http://www.sciencealert.com/new-research-has-made-synthetic-photosynthesis-possible
CO2 methanation with an MOF catalyst	http://pubs.rsc.org/en/content/articlelanding/2017/ta/c7ta00958e
Methanol from methane with a manganese catalyst	http://www.eurekalert.org/pub_releases/2016-01/uosd-hto012816.php
Hydrogen peroxide from seawater for fuel cells, 0.3% efficiency	http://phys.org/news/2016-05-electricity-seawater-method-efficiently-hydrogen.html

2.8.75 Cheap small fuel cell and micro-turbine CHP (075) **

Target area of the ART: Local energy production is comparatively simple with an internal combustion engine if mechanical energy is required. Combustion is also simple if thermal energy is required. However, electricity production is comparatively ineffective with these methods. The availability of other methods, such as solar energy or wind energy, varies in northern conditions, and long-lasting and high-capacity energy storage at the grid level carries a high cost.

Fuel cells offer a better solution for decentralised back up and load-balancing energy production than aggregate diesel, for example. It is a noiseless and non-polluting device that converts fuel directly into electricity and heat. In addition to fuel cells, this ART includes micro-CHP solutions such as devices based on micro-turbines.

General description of the development: The market for fuel cells has grown several dozen times larger in the 2000s. The various devices use hydrogen, methane, alcohol or sugar, among other things as their fuel. Fuel cells were originally developed for the energy needs of space research and other demanding conditions. Now they are being used to produce back-up power for computing centres, electricity and heat for buildings, and electricity for many sites outside the reach of the electricity grid as well as for hydrogen vehicles.

Fuel cells operate with the help of catalytic materials so that some of the energy released during the oxidation of fuel is converted directly into an electric current while the rest is converted into heat. A fuel cell may require a minimum temperature that has to be reached before the start of electricity generation. Impurities easily block catalysts, and fuel cells may also otherwise have a limited lifetime. Separate fuel cells have been designed for each fuel.

Micro-turbines have also evolved rapidly for the needs of back-up power and the combined generation of electricity and heat. The proportion of electricity will not rise to the level of fuel cells, but the technology is more mature and the combined efficiency is high.

Resources and motive for development: The development of fuel cells is accelerated by academic motives as well as product development by companies and customer demand. Micro-turbines are being developed as a normal part of business operations.

Impact on value-producing networks, ART 75																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	3	3	0	0	10	0	5	3	0	0	0	0	0	0	0	0	3	0	0	0	**135

Progress since the previous report: This is a new ART that was established because of the advancement and presumed importance of the area. The efficiency of fuel cells has clearly exceeded that of aggregate diesel, even without taking heat generation into account. Redox Cube is a natural gas fuelled 25 kW device one cubic metre in size that promises over 54% efficiency in electricity generation and over 80% efficiency in the combined generation of electricity and heat. GE estimates that it will reach up to 95% energy efficiency by combining the generation of electricity and heat. Microbial fuel cells use E. coli bacteria and sugar. Electricity has been produced from methane with the help of archaea. Platinum has been replaced with nickel in a fuel cell. Toyota has made thousands of fuel cell patents available. The market for micro-turbines is clearly growing in micro-CHP systems.

Interesting sources published after the 2013 report (075)	
Short description of the link	**link**
GE: fuel cells with 95% efficiency, heat + electricity, 65% of natural gas into electricity	http://spectrum.ieee.org/energywise/green-tech/fuel-cells/ge-claims-fuel-cell-breakthrough-starts-pilot-production
Small fuel cells, a natural gas fuelled 25 kW, 1m3 system	http://www.redoxpowersystems.com/products/
IEA: a vision for fuel cells to 2050	https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapHydrogenandFuelCells.pdf
A household fuel cell with over 80% efficiency, heat + electricity	https://www.viessmann.co.uk/en/residential-buildings/combined-heat-and-power-generation/micro-chp-unit-based-on-a-fuel-cell/vitovalor-300p.html

Interesting sources published after the 2013 report (075)	
Feasibility calculation of micro-CHP fuel cells	http://enefield.eu/wp-content/uploads/2017/12/LCC_modelling_report_Public-Summary-ene.field_.pdf
Over 5,000 fuel cell patents made available by Toyota	http://www.geekwire.com/2015/toyota-gives-away-patents-build-game-changing-car-future/
A sugar-fuelled microbial fuel cell, E. coli, etc.	http://www.businessinsider.com/chinese-students-sugar-powered-battery-microbial-fuel-cell-2015-11
A Swedish hydrogen fuel cell company	http://www.powercell.se/
A fuel cell for a smart microgrid in Marjamäki	http://www.decentralized-energy.com/articles/2018/02/fuel-cell-chp-planned-for-finnish-district-energy-smart-grid.html
A review of the development of fuel cells	https://www.greentechmedia.com/articles/read/fuel-cells-in-2017-are-where-solar-was-in-2002
Nickel replaces platinum in fuel cells	http://www.eurekalert.org/pub_releases/2016-01/uod-fca011416.php
Off-grid housing, PV -> hydrogen -> fuel cell	http://inhabitat.com/worlds-first-solar-powered-hydrogen-development-takes-homes-100-off-grid/
Microbial fuel cells, background	https://en.wikipedia.org/wiki/Microbial_fuel_cell
A Capstone turbine, micro-CHP, combined heat and power efficiency 90%	https://www.capstoneturbine.com/products/c30
EnerTwin micro-CHP 3 kW electricity + 15 kW heat	http://www.enertwin.com/
Biomass combustion without emissions	http://www.vtt.fi/medialle/uutiset/vtt-kehitt%C3%A4%C3%A4-biomassan-polttoteknologiaa-%E2%80%93-tavoitteena-negatiiviset-p%C3%A4%C3%A4st%C3%B6t
Electricity from methane with archaea	http://phys.org/news/2015-10-microorganisms-sea-power-nanowire-cables.html

2.8.76 Cheap efficient storage of hydrogen (076) *

Target area of the ART: Hydrogen can be separated from water without much of the energy being wasted as heat. It can also be utilised as a source of electricity, heat and mechanical energy with simple equipment. The use of hydrogen is limited by the fact that it is difficult to store. At atmospheric pressure, hydrogen takes a great amount of space. It requires a sturdy container when compressed and a very low temperature when in liquid form. Hydrogen will become more usable if a safe and inexpensive solution is found for storing it.

General description of the development: The storage of hydrogen is currently primarily being developed for the needs of hydrogen vehicles. Compressed hydrogen tanks leak, and refuelling with hydrogen is demanding in terms of connection technology. Development is underway on porous or chemical materials to which hydrogen bonds and from which it is released easily for use. These materials can be nanostructures and ducts or chemicals.

Resources and motive for development: The research motive is both academic in nature and a long-term industrial goal relating to opening a new market.

Impact on value-producing networks, ART 76																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	5	5	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*60

Progress since the previous report: The closest corresponding ART in the previous report was "2.92 Inexpensive storage of hydrogen in nanostructures," which ranked in the fourth group. The storage of hydrogen in toluene, ammonia and benzene has taken promising steps forwards. Hydrogen has been stored in benzene by utilising sunlight. Researchers have made a nanomaterial that can store 12% of its weight in hydrogen at room temperature as well as a metal structure that can store the same amount of hydrogen at 200 bar that normally requires 700 bar.

Interesting sources published after the 2013 report (076)	
Short description of the link	**link**
Storing hydrogen in toluene	https://www.chiyodacorp.com/en/media/2013/post-77.html
Dense storage of hydrogen in a tank at 200 bar	https://www.eurekalert.org/pub_releases/2016-12/fsu-fpd120116.php
Storing hydrogen in ammonia and using it in cars	http://phys.org/news/2014-06-hydrogen-breakthrough-game-changer-future-car.html
Storing hydrogen in benzene with sunlight	http://phys.org/news/2015-06-simple-hydrogen-storage-solution-powered.html
Graphene-nanotube stores 12% of its weight in hydrogen at room temperature	http://spectrum.ieee.org/nanoclast/green-tech/fuel-cells/graphenenanotube-combo-exceeds-benchmarks-for-hydrogen-storage-in-fuel-cells

2.8.77 Off-Grid and Micro-Grid solutions (077) *

Target area of the ART: Societies have built infrastructure for the purposes of transport, water supply, telecommunication and energy needs. Many new technologies are now reducing the need for physical infrastructure. Advanced living comforts are possible outside the reach of the electricity grid, water supply network and road network. These types of entities are described by the term "off-grid," while "micro-grid" refers to small village-specific structures in electricity generation and distribution. This ART discusses overall entities within this area and their independence from centralised electricity generation.

General description of the development: Separation from the electricity grid is becoming increasingly easy as local production and storage evolve. The majority of people in the world live in areas in which a reasonable amount of daylight is available all year round and batteries suffice to balance daily variation in production and consumption. At northern latitudes, fuel cells and their fuel stores, as well as heat storages, may offer a solution.

It is estimated that as many as 50% of all households in Australia could separate from the electricity grid by 2020 on financial grounds. In addition to fully independent solutions, village-specific solutions have also been developed, as have solutions for independent food production and manufacture of goods. Additionally, solutions for waste management, clean water and transport in roadless areas are constantly evolving, as is wireless telecommunication.

Resources and motive for development: The development motive for components required for off-grid housing is industrial in nature and arises partly from other needs. The research motive for this whole area is societal and academic in nature and is based on personal interest. Development is steered by the needs of developing countries.

Impact on value-producing networks, ART 77																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	0	0	3	5	0	3	1	1	0	1	0	0	0	0	0	1	0	3	3	*96

Progress since the previous report: This ART is new. Ecocapsule is a prototype of an easily transported dwelling that generates the energy it needs, gathers and purifies rainwater for domestic use and treats sewage waste. A wooden city is being built in China based on the off-grid concept. Local micro-grid solutions are becoming common in Australia. Houses intended for maritime usage have been developed. Various elements relating to the area are progressing rapidly, and they are described in this report in connection with the relevant technologies.

Interesting sources published after the 2013 report (077)	
Short description of the link	**link**
Off-grid housing – Ecocapsule	http://www.huffingtonpost.com/2015/05/26/tiny-house_n_7443744.html
A wooden off-grid city in China	https://futurism.com/china-has-officially-started-construction-on-the-worlds-first-forest-city/
An off-grid decision in court (district heating)	http://www.tekniikkatalous.fi/tekniikka/energia/onko-kaupungin-kaukolampoa-pakko-kayttaa-kho-ratkaisi-riidan-porvoolaispariskunnan-hyvaksi-6648788
A local electricity grid as a solution in Australia	http://cleantechnica.com/2015/10/14/the-future-of-energy-in-australia-may-be-renewable-micro-grids/
Half of Australian households to have PV + battery storage	http://www.telegraph.co.uk/news/worldnews/australiaandthepacific/australia/11945075/Half-of-Australian-homes-to-adopt-solar-power-and-move-off-grid-from-2018.html
A floating off-grid house	https://electrek.co/2017/11/10/solar-and-battery-technology-power-a-novel-hurricane-resistant-floating-electric-house-boat/

2.8.78 Carbon capture and CO2 usage as raw material (078) *

Target area of the ART: Climate change is, unfortunately, a topic we are all familiar with. The use of fossil fuels is a generally accepted cause of carbon dioxide emissions. Improving energy efficiency and use of an alternative carbon-neutral method of generating energy will solve some of the problems. Additionally, processes are being developed in which carbon dioxide, rather than being released, is bound in some shape that can be stored or processed further. This ART includes the development of existing processes that release carbon dioxide to be carbon dioxide neutral as well as new processes that use atmospheric carbon dioxide or carbon dioxide produced as byproduct as their raw material.

General description of the development: Climate warming has led to global actions, ranging from emission standards to a carbon dioxide tax and emissions trading. New methods are continuously being invented to remove carbon dioxide from the combustion gases of processes, the atmosphere and seawater. The most promising methods are ones that convert carbon dioxide into useful materials or ones in which the process is not energy-intensive.

Biological carbon dioxide removal methods include genetically modified bacteria, plants and synthetic photosynthesis. Carbon dioxide is also used as a raw material for liquid fuel and methane. The purpose is to use extra solar and wind energy in the production of synthetic fuel.

The most interesting radical technologies include pumping air through molten salt and a charged catalyst. This process consumes little electricity and reduces carbon into usable and valuable nanocarbon. With this process, the production cost of nanocarbon may decrease at least by an order of magnitude compared to a material of similar quality. In theory, the method seems to be scalable to purify the atmosphere entirely of extra carbon dioxide in an economically viable way.

Resources and motive for development: The recovery of carbon dioxide is a significant societal objective. Emission standards and carbon emission trading motivate development in various organisations. Industry is developing solutions to reduce its emissions, and the academic motive is significant.

Impact on value-producing networks, ART 78																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	3	3	3	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*81

Progress since the previous report: This is a new ART that was established because of research being increasingly diversely focused on carbon dioxide as a raw material rather than only its separation and storage.

Progress has been made in several areas, including the following: Anaerobic bacteria and nanowires have been used to produce several types of hydrocarbons with a high efficiency from carbon dioxide and water. Promising processes have produced methanol, formate and ethylene from carbon dioxide, water and sunlight.

Micromotors have produced calcium carbonate from carbon dioxide in water. The production of nanocarbon from carbon dioxide is progressing in a promising way. The carbon recovery processes used by power plants are becoming increasingly efficient. Researchers have noticed that carbon dioxide hinders cognition even at normal concentrations in poorly ventilated indoor air.

Interesting sources published after the 2013 report (078)	
Short description of the link	**link**
Nanowires/anaerobic bacteria, CO2 + H2O + the sun -> tailored hydrocarbons	http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.5b01254?journalCode=nalefd
Production of carbon nanotubes from CO2 emissions advances	https://phys.org/news/2016-06-power-co2-emissions-carbon-nanotubes.html
CO2 efficiently into formate with a thin nanomaterial surface	http://www.sciencealert.com/new-material-converts-co2-into-clean-fuel-with-unprecedented-efficiency
Elevated CO2 levels have a significant negative impact on cognition	https://thinkprogress.org/exclusive-elevated-co2-levels-directly-affect-human-cognition-new-harvard-study-shows-2748e7378941
CO2 into ethylene with a copper nanoparticle catalyst	http://www.eurekalert.org/pub_releases/2016-04/bu-ccm040716.php
Carbon capture and storage in Iceland (basalt + CO2 -> limestone)	https://www.theguardian.com/environment/2016/jun/09/co2-turned-into-stone-in-iceland-in-climate-change-breakthrough
CO2 emissions down by 90% in electric self-driving cars	http://www.popsci.com/green-argument-driverless-cars
Seaweed lowers methane emissions from cows	http://www.abc.net.au/news/2016-10-19/environmental-concerns-cows-eating-seaweed/7946630?pfmredir=sm
IEA's vision to 2050	http://www.iea.org/etp/explore/
CO2 into calcium carbonate in sea water with micromotors	http://www.jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=1817
CO2 recovery at a natural gas-fired pilot plant	http://www.sciencemag.org/news/2017/05/goodbye-smokestacks-startup-invents-zero-emission-fossil-fuel-power
Methanol from hydrogen and carbon dioxide in the air	http://phys.org/news/2016-01-carbon-dioxide-captured-air-methanol.html
Hydrogen from methane without carbon emissions, graphite as a byproduct	https://arstechnica.co.uk/science/2017/11/converting-natural-gas-to-hydrogen-without-any-carbon-emissions/
An efficient CO2 separation technique with small temperature swings	http://www.nature.com/nature/journal/v519/n7543/full/nature14327.html
Carbon Xprize, semi-finalists chosen	https://www.engadget.com/2016/10/17/carbon-xprize-semi-finals/
An overview of 17 new energy technologies	http://www.businessinsider.com/17-emerging-energy-technologies-2014-4
Laser-equipped satellites in mitigating climate change	http://motherboard.vice.com/read/scientists-propose-using-lasers-to-fight-global-warming-from-space
CO2 capture by power plants, CO2 Memzyme	http://climatenewsnetwork.net/new-patent-boosts-co2-capture-hopes/

Interesting sources published after the 2013 report (078)	
Fast-growing genetically modified trees	http://www.manchester.ac.uk/discover/news/article/?id=14313
Uruguay shifts to 95% renewable energy	https://www.theguardian.com/environment/2015/dec/03/uruguay-makes-dramatic-shift-to-nearly-95-clean-energy
Capturing carbon in a fuel cell, Exxon	https://www.technologyreview.com/s/601402/exxon-has-a-clever-way-to-capture-carbon-if-it-works
Laser ignition improves the efficiency of engines by 27%	http://spectrum.ieee.org/energywise/energy/fossil-fuels/lasers-could-boost-engine-efficiency-by-27
Capturing carbon into biochar in soil with pyrolysis	http://www.news.cornell.edu/stories/2016/10/new-model-suggests-scrubbing-co2-atmosphere
A freeze-dried substance absorbs and releases CO2 like a sponge	https://newatlas.com/freeze-dried-foam-co2-sponge/50932/
CO2 from industry into baking soda/chalk with deep-sea bacteria	http://www.eurekalert.org/pub_releases/2015-10/uof-dbc_1102215.php

2.8.79 Small fusion and fission plants (079) *

Target area of the ART: Nuclear energy is one of the potential solutions for reducing carbon dioxide emissions, which contribute to climate change. A nuclear power plant creates the conditions for continuous nuclear reactions, with atom structures breaking apart or uniting and releasing a part of their mass as energy. Creating the conditions required for continuous nuclear reactions is difficult for many reasons. The reactions also cause hazardous substances and high temperatures as manageable risks. Of the reactions known to be possible, only a small part has been successfully harnessed for energy generation.

Large power plant projects are problematic due to their manageability and permit practices. Small mass-produced power plants could bypass many of these problems. As the acquisition of raw material and activity of waste also pose a problem in fission-based power plants, and as some of the raw materials are suited for making nuclear weapons, some have placed their hopes and focused their development efforts on fusion energy. Fusion energy uses hydrogen as its raw material. The challenge in known processes is achieving sufficient pressure and heat. Another type of challenge is posed by the partial inexplicability of even theoretical operating principles of low-temperature phenomena.

General description of the development: Fusion energy is being developed in many significant and well-funded projects. New projects aim for small-scale power plants, and their development cycle is estimated to be materially faster than the development of large-scale power plants. The scientific basis of small fusion power plants has been verified. Interest in novel fission reactors, thorium reactors and other new types of reactors, such as the TWR reactor, has also increased, particularly in China.

LENR (cold fusion) stimulates continuous discussion, and several independent groups have produced promising research results, but they do not fulfil the scientific criteria with regard to independence and openness, with the exception of the observation that the subject of research and claims is an actual new phenomenon.

The development of femtolasers has led to the ability to subject atoms to brief petawatt-class pulses to achieve a nuclear reaction. Researchers are now able to produce nuclear reactions without high temperatures or pressure. Harnessing these observations in energy production is being researched.

Resources and motive for development: The research motive is to a large extent both academic and social in nature. Both fusion and fission energy are being researched and developed in public research as well as projects funded by venture capitalists.

Impact on value-producing networks, ART 79																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	0	3	3	10	3	5	0	0	0	0	0	0	0	0	0	3	0	0	0	*81

Progress since the previous report: The corresponding section in the previous report was “2.88 Serial production of small nuclear reactors, fission and fusion,” which ranked in the fourth group. Development has progressed rapidly since then. In Canada, a company has applied for a licence for a molten salt reactor that is claimed to be considerably less expensive than a light-water reactor. China is building a TWR reactor in collaboration with Bill Gates. In Finland, STUK is tentatively talking about the possible permit practices of mass-produced small nuclear power plants.

MIT has reported a 15% increase in plasma pressure at its fusion energy pilot plant, in addition to introducing a concept for a compact tokamak project based on the increased efficiency of magnets. Tri Alpha Energy’s (TAE) fusion reactor project has received $500 million in additional funding, and pilot projects have progressed. Lockheed’s fusion reactor project has reported progress.

A report published by NASA shows that a low-energy (2 MeV) photon beam causes a nuclear reaction and changes in atomic composition in a material composed of several metals and heavy hydrogen, with measurements showing over 10 MeV of free neutrons. This finding indicates that low-temperature nuclear reactions are an interesting area of scientific study. A fusion of hydrogen and boron is considered to be possible with a petawatt-class laser beam.

LENR research has yet to produce undisputable evidence that a manageable method usable in energy generation has been found.

Interesting sources published after the 2013 report (079)	
Short description of the link	**link**
Bill Gates and China’s joint venture to build a TWR reactor	http://terrapower.com/updates/terrapower-establishes-joint-venture-with-cnnc-for-twr-co-development/
Hydrogen-boron fusion possible with a 30 petawatt femtolaser	http://www.laserfocusworld.com/articles/2017/12/laser-initiated-hydrogen-boron-fusion-now-leading-contender-for-energy-source.html
A 2 MeV beam creates a nuclear reaction in heavy hydrogen	https://arxiv.org/abs/1704.00694

Interesting sources published after the 2013 report (079)	
MIT: a 15% increase in plasma pressure in a fusion reactor	http://www.sciencealert.com/new-fusion-world-record-lifts-the-bar-for-clean-energy-potential
Lockheed's fusion project progresses	http://fusion4freedom.us/pdfs/McGuireAPS.pdf
$500 million in funding to Tri Alpha Energy's fusion reactor	http://www.dailymail.co.uk/sciencetech/article-4140888/The-commercial-fusion-reactor-ready-2027.html
Several fusion projects funded by venture capitalists advance	https://www.geekwire.com/2018/commercial-fusion-ventures-learn-lessons-engineering-expectations/
Several funded fusion projects	http://www.bbc.com/future/story/20160428-the-secretive-billionaire-backed-plans-to-harness-fusion
A compact tokamak under development by MIT	http://news.mit.edu/2015/small-modular-efficient-fusion-plant-0810
STUK is considering the permit practice for mass-produced nuclear power plants	https://yle.fi/uutiset/3-9857325
A review of radical nuclear power development, $1 billion for R&D	http://thirdway.org/report/advanced-nuclear-101
Licence is being sought for an Integral Molten Salt Reactor (IMSR) in Canada	https://www.forbes.com/sites/rodadams/2017/04/05/terrestrial-energy-describes-progress-towards-commercializing-advanced-small-modular-reactor
Tokamak Energy, a small-scale tokamak project	http://physicsworld.com/cws/article/news/2015/feb/16/smaller-fusion-reactors-could-deliver-big-gains
A fusion reactor (high-beta), UW dynomak	http://www.washington.edu/news/2014/10/08/uw-fusion-reactor-concept-could-be-cheaper-than-coal/
A patent for LENR	http://fcnp.com/2015/08/27/the-peak-oil-crisis-cold-fusion-gets-a-u-s-patent/
Fusion pilot device Wendelstein 7-X now in operation, Stellator	http://www.ipp.mpg.de/3984226/12_15
Critique of LENR	https://medium.com/starts-with-a-bang/the-e-cat-cold-fusion-or-scientific-fraud-624f15676f96
The compact breeder reactor PRISM	http://en.wikipedia.org/wiki/PRISM_%28reactor%29
Nature: a hypothesis of nuclear reactions in Earth's inner core	https://www.nature.com/articles/srep37740
A theory for the LENR phenomenon, Sweden	http://animpossibleinvention.com/2015/10/15/swedish-scientists-claim-lenr-explanation-break-through/

2.8.80 Recovery/harvesting of kinetic energy (080) *

Target area of the ART: Kinetic energy can be found in atmospheric flows, water currents and waves as well as the movements of machines and matter. Wind power is already an important source of primary energy, and wave power is also anticipated to become one. Regenerative braking in vehicles and the recovery of robots' kinetic energy lengthen battery life and improve energy efficiency.

General description of the development: Wind power is being developed continuously. Wind strength increases the higher up we go from ground level. Continuous goals of development include increasing the height of towers, making the blades lighter and improving efficiency. The Windside wind turbine is an example of designs in which the blades or foils rotate around the axis, and bladeless wind turbines have also been developed. Wind power is also collected with kites or gliders tethered to the ground with a cable. They generate energy with a generator used by the propellers or kite cable.

Wave power is first converted into mechanical movement and then into electricity. This can occur with the help of buoys that rise and fall with the surface of the water or with currents generated by waves, for example. Flowing or evaporating charged saline water also generates electrical energy that can be directly recovered. Peculiar methods of generating energy include materials that generate electricity from bending. More common development is represented by brakes that function similarly to dynamos. They are intended to replace friction-based brakes.

Resources and motive for development: Traditional wind power is primarily being developed as part of companies' own product development. Both academic motivation and start-ups funded by venture capitalists are active contributors to the development of radically novel wind power technologies. Materials that recover kinetic energy and wave power are for the most part progressing in academically motivated research. The development of the recovery of braking energy is motivated by industrial competition.

Impact on value-producing networks, ART 80																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	3	0	0	5	3	3	0	0	0	5	0	0	0	0	0	0	0		0	*88

Progress since the previous report: The corresponding sections in the previous report were "2.86 Flying wind power and other new ways to produce wind energy" and "2.87 Piezoelectrical energy sources, harvesting of kinetic energy," both of which ranked in the third group.

Windside wind turbines have continued evolving. The development of kite power has continued, utilising several principles. Google's Makani has started testing a 600 kW kite and is rapidly increasing its staff. KPS and AWELabs are also actively developing kite power. A wave power plant has been tested with many methods. The principle of a convection power plant has been introduced. Ricoh has launched a rubber that generates electricity from kinetic energy. Galfenol, an alloy consisting of gallium and iron, is able to convert 70% of kinetic energy into electricity. Brownian motion has been converted into electricity on a graphene surface. Based on this finding, it seems possible to produce electricity from heat without an actual temperature difference. This result is contradictory to the second law of thermodynamics, and it should be taken with a grain of salt.

Interesting sources published after the 2013 report (080)	
Short description of the link	**link**
Brownian motion into electricity with graphene, eternal batteries possible	https://newatlas.com/graphene-motion-limitless-energy/52319/
Airborne wind power with a quadcopter	http://www.skywindpower.com/
Kite power, AWELabs – a generator on the ground	http://www.awelabs.com/awelabs-awecs-proposal/
£5 million in funding for kite power (KPS)	http://www.pbo.co.uk/news/potential-game-changer-wind-energy-market-46500
Testing the WaveRoller wave power device	http://yle.fi/uutiset/suomalaisen_aaltovoimalan_testituloksia_julki__erittain_rohkaisevaa/7073948
Wave power with buoys	https://www.facebook.com/HuffPost/videos/10153808267231130/
Flowing salt water over graphene generates electricity	http://arstechnica.com/science/2014/04/flowing-salt-water-over-graphene-generates-electricity/
A rubber that generates electricity from movement (Ricoh)	http://ricoh.com/release/2015/0518_1.html
Mechanical energy into magnetic energy with galfenol	http://nextbigfuture.com/2015/09/galfenol-can-convert-70-percent-of.html
A convection power plant in the desert, a concept	https://www.fastcompany.com/3030110/this-giant-tower-in-the-desert-could-generate-as-much-power-as-the-hoover-dam
Wind power technology from Vortex Bladeless	http://www.vortexbladeless.com/
KNBNNO harvests energy from light, heat and motion	http://www.oulu.fi/university/node/46702
Vertical-axis wind turbines	http://earthtechling.com/2011/07/vertical-turbines-packed-tight-boost-power/
A ship that utilises wind power, the hull as a sail	http://www.tekniikkatalous.fi/Liikenne/rahtialus+liikkuu+tuulen+voimalla++automaattiohjaus+loytaa+energiapiheimman+purjehdusreitin/a1043105
Wind power in Mexico $0.0177/kWh	https://electrek.co/2017/11/16/cheapest-electricity-on-the-planet-mexican-solar-power/
A 100 m tall Windside wind turbine	http://yle.fi/uutiset/windside_virittelee_sadan_metrin_tuuliruuvia_valkeakoskelle/7989676

2.8.81 Power lasers, ray guns, railguns (081) *

Target area of the ART: When light is emitted with a consistent wavelength, phase and direction, this is referred to as a laser beam. A laser beam retains its strength over a long distance without dispersing, unlike normal light. The strength of a laser beam can be momentarily high, which is referred to as pulses. Strong and brief pulses that hit a very narrow area cause the material structure to break down due to the energy not having time to settle in the structures and spread out as heat, for example.

Laser beams are used for numerous different purposes, and this topic is discussed in ART 10 of this report. This ART is limited to high-power lasers that are used for the purpose of cutting or welding metal, for example. There is a great number of applications for it in both the manufacturing industry and weapons technology. In addition to lasers, this ART also includes other ray guns and railguns.

General description of the development: Researchers are constantly seeking to increase the power of laser beams. The properties of the beams depend on the wavelength, which is why both the phase of the beam and increase of power must be solved for each waveband. The adequacy of the power source is one of the challenges in the pursuit of highly efficient lasers. The easiest solution is to shorten the laser pulses. The simplest way to do so is by charging a capacitor with electricity. The charge in a capacitor can be discharged quickly into a laser, which results in a much higher momentary power than an actual power source.

Another problem arises if we want a laser to emit a more efficient pulse than it is capable of. A peculiar and interesting method has been identified for this problem. The pulse is shortened optically by taking the first half of the pulse to the target through a longer path than the second half. The first and second halves can also travel along paths with different light speeds. When the second half of the pulse makes it to the level of the first half, the two signals combine, doubling the efficiency of the resulting pulse. The difference in distance must be several times longer than the wavelength in order for this to be possible. This operation can be performed several times in a row, doubling the power of the pulse in each phase.

Weapons technology is also developing other beams besides laser weapons. The most peculiar of these is an electromagnetic pulse that destroys unprotected electronic devices. The weaponised use of EMP pulses is limited by them not having been directional. For example, a nuclear explosion creates an EMP pulse that spreads in all directions around the site of the explosion.

Railguns are among the more recent inventions in weapons technology. With an efficient electromagnet and electric energy, a railgun can launch iron projectiles at high velocity in a way that does not wear out the weapons or waste much energy.

Resources and motive for development: Development is partly motivated by academic interest and partly by the development of commercial industrial tools. The arms industry's motivation is based on normal product development and governmental customer demand.

Impact on value-producing networks, ART 81																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	1	5	0	5	3	3	0	0	3	0	0	0	0	0	0	5	0	0	0	*125

Progress since the previous report: The corresponding section in the previous report was "2.94. High-performance lasers, wireless power transfer, laser weapons," which ranked in the fourth group. Since then, development has continued in several areas.

The USA has adopted a laser weapon it previously tested and is now testing the possibility of expanding its use from the Navy to the Army and Air Force. A high-power laser can be used to destroy an unarmoured vehicle being driven towards it. A laser and a neutralising anti-laser have been combined in the same device. Several directed-energy weapons have been developed for repelling drone attacks.

A Russian company has reported that it is developing a directed EMP weapon. The directed Bofors HMP BLACKOUT is able to turn off electric devices. Energy weapons that cause pain have also been developed extensively. A new magnetic railgun has a range of almost 200 kilometres.

Interesting sources published after the 2013 report (081)	
Short description of the link	**link**
A laser weapon can stop a car	http://www.engadget.com/2015/03/04/lockheed-martin-laser-athena-test/
A magnetic railgun has a range of almost 200 km	http://newatlas.com/us-navy-electromagnetic-railgun-field-deomnstrations/50631/
Adoption of a laser weapon (USA)	http://www.uusisuomi.fi/teknologia/75325-usan-armeija-otti-juuri-kayttoon-1-laseraseen-047-eu-laukaus
Pest control with laser technology, funded by the EU	http://birdcontrolgroup.com/life-laser-fence-rodenticide-use/
A laser and anti-laser in the same device	https://www.eurekalert.org/pub_releases/2016-11/dbnl-wgh110316.php
The Bofors HMP and other directed-energy weapons	http://www.miltechmag.com/2014/03/todays-directed-energy-weapons-meeting.html
A laser with almost 5 PW peak power for femtoseconds	https://www.osapublishing.org/ol/abstract.cfm?uri=ol-42-10-2014
A Russian directed EMP cannon introduced	http://yle.fi/uutiset/venaja_esittelee_mikroaaltokanuunan__tuhoaa_lentokoneiden_ja_lennokkien_elektroniikan/8075687
Lockheed develops a laser weapon for fighter aircraft	http://news.lockheedmartin.com/2017-11-06-Lockheed-Martin-Receives-Contract-to-Develop-Compact-Airborne-High-Energy-Laser-Capabilities
Development projects of the US Navy	http://news.yahoo.com/blogs/power-players-abc-news/technologies-once-available-only-in-movies-are-now-a-reality-for-the-us-navy-225652354.html
An anti-UAV, a British radio gun	http://www.theguardian.com/technology/2015/oct/07/drone-death-ray-device-liteye-auds?CMP=twt_a-technology_b-gdntech

2.8.82 Wireless electricity transfer (082) *

Target area of the ART: Nikola Tesla pursued a method that would allow considerable electrical power to be transferred over long distances without electricity grids. Radio waves contain energy, so at least small-scale energy transfer is unproblematic. Electronics enthusiasts may have built a radio out of a diode and a crystal earpiece in their youth. To operate, this radio only needs the energy it receives in the earpiece from the antenna.

Energy is transmitted and received wirelessly as electromagnetic radiation. This is the case for radio waves and e.g. a laser beam that transmits its energy illuminating a distant solar panel which in turn converts the light back into electricity. In other words, we transfer energy wirelessly. If we learn how to transfer larger volumes of energy with inexpensive devices and minimal loss, without danger and at reasonable distances, it will reduce our need for plugs, power cords, sockets and batteries.

General description of the development: The simplest way to implement wireless electricity transfer is to place two coils near each other and feed an alternating current to one of them. The current generates a magnetic field, and a change in the current causes a change in the magnetic field, which in turn generates a voltage in both coils placed near each other and a current corresponding to the voltage to also be generated in the other coil. This straightforward method used in transformers works when the coils are very close to each other.

When energy is transferred over longer distances, it must be transmitted as electromagnetic vibration that is only loaded by the recipient or as directed radiation that reaches the recipient to a large extent. The electromagnetic spectrum is very wide, and different methods can easily be used in different wavebands. Some of these methods work with a distance of a few metres, whereas others can potentially be tested between space and ground.

Resources and motive for development: Most development efforts are academically motivated or are part of companies' long-term pursuit of new products. Crowdsourced start-ups and start-ups funded by venture capitalists have pursued wireless charging in consumer electronics. In the automotive industry, wireless charging is a subject of competitive development, particularly in city bus transport. This is motivated by customer demand for electrification and is accelerated by the societal goal of being emission-free.

Impact on value-producing networks, ART 82																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	3	5	3	0	3	0	5	0	0	3	0	3	3	3	0	0	0	0	0	0	*93

Progress since the previous report: The closest corresponding section in the previous report was "2.93 Wireless electricity transmission (magnetism) for electric cars and other electrical devices," which ranked in the third group. Progress has been rapid since then. Duke University is developing a lens that focuses magnetic fields. Disney has demonstrated wireless charging in a room, transferring as much as 1.9 kW of power to multiple devices with 40–95% efficiency, depending on the distance.

The University of Washington has been developing passive WiFi technology and harvesting of energy from surrounding radio waves. WiTricity has launched a system for wirelessly charging a car. Wi-Charge transfers power with directed infrared radiation. Ossia has demonstrated its Cota technology, which can charge 30 devices within a 10-metre range. Among other devices, a modified AA battery has been demonstrated as a wirelessly rechargeable device. Several operators have launched chargers that operate at close distances with the help of induction.

Interesting sources published after the 2013 report (082)	
Short description of the link	**link**
Disney: Wireless charging in a room, 1.9 kW with 40–95% efficiency	http://www.iflscience.com/technology/disney-researchers-make-wireless-power-transfer-breakthrough/
Wireless charging with infrared laser	http://spectrum.ieee.org/tech-talk/consumer-electronics/portable-devices/wicharge-promises-phone-charging-by-infrared-laser
The FDA approves Wi-Charge's wireless IR charging within a 10-m range	https://www.businesswire.com/news/home/20180110006324/en/Wi-Charge-Wins-CES-2018-Innovation-Award
Wireless charging of a car, etc.	http://witricity.com/
A battery-free mobile phone, energy from the surroundings	http://www.smart2zero.com/news/battery-free-cell-phone-prototype-unveiled
Wireless power transfer with a lens that focuses magnetic fields	http://www.scienceworldreport.com/articles/12112/20140110/wireless-power-transfer-range-vastly-extended-with-superlens.htm
Advancements in wireless charging, WiTricity and Ossia on different tracks	https://www.computerworld.com/article/3235176/mobile-wireless/wireless-charging-explained-what-is-it-and-how-does-it-work.html?page=2

2.8.83 New power sources for vehicles (083) ***

Target area of the ART: The most common power source in vehicles is an internal combustion engine. For cars, it is a piston engine, and for planes, a turbine. At least two paths are available to us in our pursuit of a carbon-neutral society. On the one hand, we can generate carbon-free electricity, compressed air or other secondary energy and us it in vehicles. On the other hand, we can generate synthetic fuels and use them in internal combustion engines and fuel cells. Internal combustion engines have a relatively low efficiency. This ART examines challengers to internal combustion engines as power sources for vehicles.

General description of the development: Electric cars are rapidly becoming more common. They can be regular hybrid electric vehicles, plug-in hybrid vehicles or all-electric vehicles. Electric motors are inexpensive, long-lasting and efficient. The bottleneck for the spread of electric cars has been the development of battery technology. Batteries are examined elsewhere in this report, but their price is continuously decreasing and their characteristics are improving. It is only a matter of time before electric cars are in practice better than cars with internal combustion engines in every way.

The first commercial electric trucks have been introduced. Electric waterborne transport is also expanding from small devices to increasingly large ones. Electric aircraft will also become worth considering as the energy density of batteries continues to increase. Electric aircraft will start with short distances and special aircraft, but there are already significant plans for electrifying passenger aircraft.

In addition to electric modes of transport, researchers are developing modes of transport that utilise compressed air, fuel cells and micro-turbines. Besides batteries, solar panels are also being tested in slower or energy-efficient devices with a large surface, such as aircraft, ships and trains.

Resources and motive for development: Research in this area has largely become normal product development for industry that manufactures modes of transport. The motivation is clearly competitive, particularly as we transition to electric cars, and development is focused on products of the future with regard to electric aircraft. Start-ups have a noticeable influence on small electric aircraft.

Impact on value-producing networks, ART 83																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	10	10	0	0	5	3	3	0	0	0	0	3	0	0	0	0	0	0	0	0	***204

Progress since the previous report: This is a new ART that was established because of the rapid development of new power sources for modes of transport. The following examples demonstrate this rapid development. Tesla has unveiled an all-electric truck. Nikola has unveiled a hybrid electric truck and Renault an all-electric truck. The maximum driving distance of the new Tesla with a single charge is 800 km. Sweden is testing electric trolley trucks, and its government has announced that it intends to invest over SEK 1 billion into the electrification of transport.

Volvo has announced that all its new car models will be either all-electric or hybrids starting from 2019. Several countries intend to ban the sale of vehicles with internal combustion engines. AIRPod, a car powered by compressed air, has a driving distance of 200 km. Citroen Cactus Airflow has a hybrid gas and compressed air engine. Airbus and NASA are planning an electric aircraft. Boeing is also investing in an electric aircraft.

Interesting sources published after the 2013 report (083)	
Short description of the link	**link**
Volvo: new car models to be all-electric or hybrids from 2019 onwards	https://www.theverge.com/2017/7/5/15921208/volvo-all-electric-by-2019
Tesla's all-electric truck may be more efficient than railroads	https://www.youtube.com/watch?v=h_SjAcQeU1A&feature=youtu.be&t=12m49s
The electric plane Solar Stratos to fly at an altitude of 24 km	https://www.facebook.com/futurism/videos/675719135940622/
Several countries intend to ban new vehicles with internal combustion engines	https://www.theguardian.com/business/2017/jul/06/france-ban-petrol-diesel-cars-2040-emmanuel-macron-volvo

Interesting sources published after the 2013 report (083)	
Airbus, RR and Siemens team up in electric aircraft	http://www.airbus.com/newsroom/press-releases/en/2017/11/airbus--rolls-royce--and-siemens-team-up-for-electric-future-par.html
Boeing invested in an electric aircraft start-up	http://www.businessinsider.com/boeing-jetblue-invest-zunum-electric-jet-startup-2017-4?r=US&IR=T
London–Paris electric commercial flights in 10 years	http://www.bbc.com/news/technology-39350058
A more efficient electric engine for urban driving	http://hyperloop.tamu.edu/news-release-january-30-2016/
Germany intends to mandate a transition to electric cars by 2030	http://electrek.co/2016/06/14/all-new-cars-mandated-electric-germany-2030/
Walmart pre-orders 15 of Tesla's new autonomous electric trucks	https://www.ft.com/content/5880bdf6-e746-34d6-a9d7-2956c2c19ea6
Citroen Cactus Airflow, a hybrid gas & compressed air engine	http://www.engadget.com/2014/10/03/citroen-airflow-2l-concept-hands-on/
A top-efficiency electric motor for aircraft	http://www.siemens.com/press/en/feature/2015/corporate/2015-03-electromotor.php
AIRPod, a compressed air-powered car, 200 km driving distance	http://zeropollutionmotors.us/
A plan for a fleet of plug-in hybrid ships in Norway	http://cleantechnica.com/2015/10/26/norway-plans-to-construct-a-fleet-of-plug-in-hybrid-ships/
A battery-powered tractor and other heavy equipment	https://www.facebook.com/groups/TuVRadikaalit/permalink/1211803945603876/
Nikola unveils an efficient hybrid electric truck	https://robertscribbler.com/2016/06/15/al-gores-revenge-internal-combustion-engines-stink-and-this-ridiculously-powerful-electric-turbine-truck-proves-it/
Ampaire, an efficient, electric, fixed-wing aircraft	https://www.ampaire.com/
WV: electric cars to be less expensive than vehicles with internal combustion engines by early 2020	http://www.iltasanomat.fi/taloussanomat/art-2000001940713.html
An all-electric truck from Renault	http://cleantechnica.com/2015/12/07/renault-brings-2-clean-energy-trucks-cop21/
The Chinese electric car Nio is based on swappable batteries	https://www.theverge.com/2017/12/18/16790920/nio-es8-electric-suv-price-specs-china
More charging spots than gas stations in Japan	https://transportevolved.com/2015/02/17/official-japan-now-electric-car-charging-spots-gas-stations/
Sweden to invest SEK 1 billion in the electrification of transport	https://www.aftonbladet.se/senastenytt/ttnyheter/inrikes/article25878152.ab

2.9 Digital crowdsourcing platforms

The uberisation of work is being talked about increasingly seriously at the global level. Software and the global data network allow the interface of work events, work quality control, trust, commissions and payment traffic to be automated. This lowers administrative costs and enables dynamic, flexible organisations. Typically, workers own the resources they use or provide and are not in a fixed employment relationship.

Platform companies open up channels for a sharing economy in which we provide a residence, car or unnecessary items we own for others to use on a temporary or more permanent basis. Crowdsourcing can also be related to funding, gathering of information in connection with use or other activities in which we make our funds or expertise available to others through a shared platform. Such a platform can be owned by a company or the third sector.

The impact of crowdsourcing platforms on the reorganisation of work is growing greatly. Platforms are lowering the hierarchy of organisations and changing some previously paid work to be voluntary. Wikipedia is a good example of this phenomenon, which may replace business operations entirely in some fields or shrink them to a shadow of themselves while still offering users superior quality and availability compared to the services provided by previous companies. A platform company may employ a considerable number of people. For example, the 7-year-old Uber employs over a million drivers in 64 different countries and forwards their services. A platform company has practically complete power over the operation of the platform and, because platforms function as cloud services, any changes affect the services directly.

Digital crowdsourcing platforms	
ART-ID	**The ARTs in the group**
84	Gamification of collaboration and society
85	Cryptocurrencies/exchange media bypassing banks
86	Crowdfunding and microfinancing
87	Flipped learning and proficiency demonstrations
88	Robotised physical remote work, AI as superior
89	Encrypted and anonymous telecommunication
90	Platforms for local sharing & collaboration
91	Commercial platforms for sharing economy

2.9.84 Gamification of collaboration and society (084) ***

Target area of the ART: As the old saying goes: you get what you measure! Some dogs stay behind the fence to beg for a treat even though they could circle around the fence. This is because they are unable to distance themselves from the treat in front of them even for a while.

Gamification involves measuring performance in a way that guides us to proportion our immediate performance to long-term goals. For example, equipping cars with instantaneous and average fuel economy meters has taught many people to use the gas pedal sparingly.

Gamification includes the idea of instant feedback and accumulation. This ART includes techniques and innovative examples that contribute to gamification and demonstrate its power in improving the work performance and everyday decisions of individuals and organisations.

General description of the development: Organisations are used to measuring the performance of their units and employees. The same applies to schools. In our everyday lives, we might measure our sports performance or weight. Only rarely do these methods lead to as efficient learning as is the norm when playing computer games. In games, learning is often very fast. This has drawn attention from researchers and organisational developers.

Gamification is now being talked about as a special operating model. The immediate feedback it involves does not indicate good or bad as such. Neither are actions caused by such feedback considered to be right or wrong as such. Instead, it might be a case of making a sensible sacrifice to reach a greater goal. This initially leads to a small negative feedback, but the subsequent performances result in positive feedback and growing accumulation. Humans are naturally good at understanding this type of feedback, and it efficiently motivates them to develop operations at the level of everyday behaviour.

Gamification is being developed to assist the management and self-organisation of organisations. For example, a gamified management model has completely replaced many supervisors in platform companies. Gamification also efficiently leads to a healthy lifestyle and other personal life management.

As a learning event, gamification includes indicators as well as simulated situations and problem solving. In all the environments mentioned, it may include the possibility of comparing our own performance to other people's actions.

Resources and motive for development: Gamification is being researched academically, although this research is not particularly extensive. Organisational developers are continuously adding gamified elements to their data systems. This development is particularly advanced in platform companies, for which gamification is an important competitive factor. In institutionalised teaching, simulation and gamification are progressing slowly.

Impact on value-producing networks, ART 84																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	1	0	3	3	1	1	3	0	0	5	5	1	3	10	3	0	10	5	5	***248

Progress since the previous report: The corresponding ART in the previous report was "2.20 Gamification," which ranked in the first group. This area was new at the time, but it had already been tested in the fields of life management and teaching. Gamification has clearly advanced in the trust-building structures of platform companies, such as Uber. Buurtzorg is a fast-growing, low-hierarchy health care organisation that is led with digital and gamified methods. Zappos is a leaderless company of 1,500 people, organised with the help of gamified teachings.

In advertising, ad tech business is based on gamified elements and targeting of advertising using these elements. Artificial intelligence and new personal measurement devices improve the conditions for gamification. For example, an AI is able to predict from CT scans whether a person will die within the next five years with 69% accuracy.

Interesting sources published after the 2013 report (084)	
Short description of the link	**link**
An AI predicts lifetime expectancy from CT scans with 69% accuracy	https://www.engadget.com/2017/06/05/ai-can-predict-if-youll-die-soon-by-examining-your-organs/
Ad tech business – transformation of advertising media, several links	http://www.macrumors.com/2016/01/13/apple-automated-iad-platform/
Buurtzorg, a digital organisation	http://www.buurtzorgnederland.com/
A summary of the digitalisation of health care	https://www.cbinsights.com/blog/digital-health-medicine-market-map-company-list/
China is developing a system for rating the trustworthiness of its citizens	http://www.wired.co.uk/article/chinese-government-social-credit-score-privacy-invasion
The ideology of gamification matures	https://en.wikipedia.org/wiki/Gamification
Leaderless organisations, such as Zappos, are becoming common	http://www.washingtonpost.com/blogs/on-leadership/wp/2014/01/03/zappos-gets-rid-of-all-managers/

2.9.85 Cryptocurrencies/exchange media bypassing banks (085) **

Target area of the ART: Money has a long history, and there are many interpretations of its phenomena. Money is, with good reason, understood to be either decentralised accountancy of delayed exchange or a fully gratuitous security. The value of money depends on how valuable people are willing to consider it.

Exchange has never constituted simple trade. In present-day society, exchange occurs as a multilateral and delayed series of transactions. It is impossible to agree upon such transactions between the parties. This is why humans engage in trade using certain commodities, such as precious metals or securities entitling us to such precious metals, as well as documents that are issued in limited numbers and not fixed to any specific value.

Supply and demand meet when a suitable number of mediums of exchange that are accepted as payment for a sale price and can be easily recognised as such is in circulation. People become used to considering money to be valuable when they trust that it is always accepted as a means of payment. This ART includes new mediums of exchange that are independent from money issued by governments.

General description of the development: Time bank systems are based on social trust. For every hour of work performed, members of such a system earn a time credit which they can redeem for work by another member, assuming that the members accept time credits as compensation for their work.

Cryptocurrencies are expanding the sphere of trust so that there is no need to trust any centralised data controller and we can trade globally. Furthermore, instead of being tied to a specific amount of work, the exchange value of cryptocurrencies is determined through free pricing.

Cryptocurrencies are a rapidly growing global and Internet-wide means of payment. The transactions related to currency are validated in a shared manner online. All transactions are encrypted into a chain that starts from the creation of each unit of currency and the data is shared to the nodes of the network. Anyone can participate in this computing of transactions, also known as cryptocurrency mining. As a reward for this work, every participant is provided with new currency.

The blockchain-based cryptocurrency Bitcoin played its first significant role during the worst phase of Greece's debt crisis. Since then, exchange of Bitcoin has more than doubled per year. The value of the exchange was at a daily level of $1 billion towards the end of 2015 and at the level of $20 billion in early 2018. Exchange of other cryptocurrencies has likewise increased to a daily level of billions of US dollars.

Some people have installed a Bitcoin wallet under their skin, a protocol is being developed for distributing Bitcoin over the radio, and Bitcoin is being accused of being a pyramid scheme. Weaknesses are being pointed out in the system's operating principles, and a successor is anticipated. Debate is widespread and continuous. The most significant piece of criticism pertains to the electricity consumption caused by transactions. Because it is possible to earn cryptocurrency from mining, increasingly efficient special processors are being developed for this purpose. Bitcoin miners utilise the idle time of computers and periods of inexpensive electricity.

Resources and motive for development: The primary motive of the developers of time bank systems is social in nature or related to platform economy. The development may be carried out as communal work. Cryptocurrencies are being developed by independent programmers and their communities as well as financial institutions, IT companies and states. The motives include creating issuable currency from scratch and increasing its value or making it cost-effective but also ensuring its anonymity to protect criminals or political activity. The motives are partly typical start-up motives and partly motives of notable financial operators.

Impact on value-producing networks, ART 85																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	0	1	0	0	1	0	1	5	3	0	1	0	0	0	0	0	3	3	1	3	**132

Progress since the previous report: The corresponding section in the previous report was "2.99 Electronic money, time banks," which ranked in the highest group. Electronic money, which is based on normal bank money, is excluded from this ART. At the time the previous report was written, Bitcoin was practically the only cryptocurrency. The market value of the issued Bitcoins was a fraction of its current value, being $1 billion.

The total market value of all cryptocurrencies issued exceeded $800 billion in January 2018. A Singapore-based company's VISA card is compatible with Bitcoin. A hacker has stolen $31 million worth of Ethereum wallets. In their present form, Bitcoin transactions are highly energy-inefficient. Through mobile phone payments, electronic money has become very important in Africa, and transferring money easily from one account to another with mobile phone applications is a countermove by banks to cryptocurrency. Time banks have not advanced in any significant way.

Interesting sources published after the 2013 report (085)	
Short description of the link	**link**
A Singapore-based company's VISA is compatible with Bitcoin	https://www.bloomberg.com/news/articles/2017-07-23/singapore-startup-counts-on-visa-to-take-bitcoin-into-real-world
A hacker stole $31 million worth of Ethereum	https://medium.freecodecamp.org/a-hacker-stole-31m-of-ether-how-it-happened-and-what-it-means-for-ethereum-9e5dc29e33ce
Validation of Bitcoin transactions is very energy-inefficient	https://www.weforum.org/agenda/2017/10/the-electricity-required-for-a-single-bitcoin-trade-could-power-a-house-for-a-whole-month
Impacts of Bitcoin/blockchain	http://www.telegraph.co.uk/technology/news/10881213/The-coming-digital-anarchy.html?fb
MIT: More efficient solutions than blockchains under development	https://www.technologyreview.com/s/609771/a-cryptocurrency-without-a-blockchain-has-been-built-to-outperform-bitcoin/amp/
Nordea bans its employees from trading Bitcoin	https://www.bloomberg.com/news/articles/2018-01-22/nordea-bans-employees-from-trading-bitcoin-spokeswoman-says
Bitcoin trade over radio	http://kryptoradio.koodilehto.fi/
Paypal/Bitcoin during the euro crisis	https://www.cryptocoinsnews.com/paypal-shuts-greece-bitcoin-still-operates/
A Bitcoin wallet under the skin	http://www.slideshare.net/PekkoVehvilinen/worlds-first-bitcoin-transfer-into-a-human-this-is-how-we-did-it
Criticism of Bitcoin	https://www.washingtonpost.com/news/innovations/wp/2016/01/19/r-i-p-bitcoin-its-time-to-move-on/

2.9.86 Crowdfunding and microfinancing (086) ***

Target area of the ART: Many ideas require a great amount of resources to be realised. The traditional method for carrying out large-scale projects is to organise communal work. The monetary economy established organisations such as banks that lend the amount of money needed for a project or procurement against interest. The borrowed money is used to hire employees and purchase raw materials for performing the task. The loan is paid back with the profit from the completed project. This mechanism fails to achieve many of the benefits inherent in communal work.

The benefits of communal work are often divided between the participants. If the benefit is one-sided, the organiser of the work is left indebted to many people. This debt is paid back or forward by participating in communal projects organised by others. Social pressure to pay back a debt is greater in this instance than it is when owing a debt to a private party. Other forms of funding have been established as replacements for communal work. It is typical for them to have many financers even in small projects or for the benefit to be divided among many people.

General description of the development: As a prerequisite for microfinancing, the one who needs the loan describes his/her project and situation. A great number of lenders assesses the risks and, if they want, they each make their offers for the amount they are willing to lend and the interest with which they are prepared to participate in the lending. In other words, the lenders share the risks, and in practice they each end up participating in projects the background of which they think they are able to evaluate. The best lenders set the correct price tag on risks and are able to expand their operations. The debtor typically owes a small debt to many people and is very motivated to pay back this debt.

The oldest form of crowdfunding is equity saving, in which the financer receives a part of the company he/she finances. Modern crowdfunding provides the financers with the first completed products in return. In other words, it involves a pre-order and pre-payment. Crowdfunding is also used to promote charity and recreational interests. The output of the promised project may therefore more broadly benefit an area of development that is important to the financer. In this respect, crowdfunding corresponds to fundraising combined with clear goal orientation and modern global monitoring.

Resources and motive for development: The development of crowdfunding relies primarily on the activity of start-ups and crowdfunders as well as those who apply for crowdfunding. This is a phenomenon that trusts in the power of crowdsourcing.

Impact on value-producing networks, ART 86																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	1	1	3	0	1	0	0	3	0	0	3	0	1	0	3	0	0	5	3	10	***204

Progress since the previous report: The corresponding ART in the previous report was "2.18. Crowdfunding and micro finance," which ranked in the third group.

Kickstarter continues to be a significant crowdfunding platform, but several other crowdfunding systems have been established alongside it. The amounts of funding for individual projects have increased. A simple invention related to beekeeping amassed over $13 million in crowdfunding through Indiegogo. A Finnish space application raised €2 million in crowdfunding. The programming guidebook Hello Ruby by Linda Liukas raised $380,000 in funding from more than 9,000 backers.

Crowdfunding platforms have established themselves as significant early-phase funding and marketing channels for new product ideas. Indiegogo is also planning to offer its services to medium-sized and large companies. The role of crowdfunding in the transformation of the economy and bypassing intermediaries that rigidify structures will probably continue to grow.

Interesting sources published after the 2013 report (086)	
Short description of the link	**link**
€2 million in crowdfunding for a Finnish space app	https://thenextweb.com/apps/2017/02/13/winner-astronaut-training-game-to-space/
An AI hedge fund from 7,500 anonymous coders	https://www.wired.com/2016/12/7500-faceless-coders-paid-bitcoin-built-hedge-funds-brain/
Digital crowdsourcing platforms for larger companies	http://www.fastcompany.com/3055223/fast-feed/indiegogo-courts-big-businesses-with-enterprise-crowdfunding
Linda Liukas' Kickstarter project	http://www.theguardian.com/technology/2014/jan/27/hello-ruby-kids-coding-book-kickstarter
An example of crowdfunding – beekeeping	https://www.indiegogo.com/projects/flow-hive-honey-on-tap-directly-from-your-beehive

2.9.87 Flipped learning and proficiency demonstrations (087) ***

Target area of the ART: Traditional learning is led by teachers. A teacher explains the topic, assigns tasks and checks them. In most cases, we still demonstrate our skills with a diploma granted by an educational institution when we apply for work. Completing a degree or qualification requires us to keep up with teaching and be admitted to an educational institution.

Increasingly often, teaching is faced with the challenges of the teacher's knowledge being outdated as well as the increasing of diversity of disciplines. Additionally, students do not receive immediate or personal feedback if the class is full of students. These problems have been tackled by means of flipped learning, computer-assisted exercises and competence-based qualifications.

General description of the development: Flipped learning refers to a model in which the basics of a topic are explained with the help of videos or animations. Students can learn these basics at their own pace. With the teacher present, students complete exercises that may be computer-simulated problem-solving tasks or other tasks to which a computer is able to provide immediate feedback. The teacher can use all his/her time on problem situations, discussing things with the class and providing personal encouragement.

Flipped learning enables the use of the best explainers globally. Students can choose the explainer that best suits their learning style. Even things that the students' own teacher is not knowledgeable in can be explained correctly and concisely. This saves time in teaching preparations and gives students the opportunity to listen to the same explanation several times and by different persons, if they wish. In exercises, immediate feedback and monitoring of the students' progress by a machine improves learning outcomes and increases students' motivation to learn.

Changing degrees and qualifications so that students demonstrate their knowledge and skill to a third party rather than the teaching organisation will provide opportunities for alternative learning methods. This will also eliminate the need for students to apply for and be admitted to an educational institution. This institution-centric structure is outdated, as comprehensive and high-quality online teaching is available for almost all vocational and academic topics and school subjects, provided globally, even free of charge, by the best-known educational institutions in the world.

Degrees can be automated so that a computer can test students' knowledge with the help of simulations, a massive question database and artificial intelligence. This allows external parties to verify subject-specific understanding at any time and for any subject. This method is already being widely used in areas of special expertise in which the client wishes to ensure a maintenance organisation's adequate expertise, for example.

Resources and motive for development: Online teaching is obviously first and foremost being developed based on altruistic or marketing motives. The aim is to make teaching as widely available as possible. Because uploading lectures to networks is comparatively simple, it is being done on a wide scale. The clients of marketing and support organisations have a particularly large motive for developing competence-based qualifications that are independent of teaching.

Impact on value-producing networks, ART 87																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	0	0	1	0	0	0	3	3	5	3	10	0	0	3	20	1	1	5	5	10	***350

Progress since the previous report: The corresponding ART in the previous report was "2.12 Schools in the cloud," which ranked in the highest group. Online learning has started to grow as a well-funded business. Duolingo offers free-of-charge language courses in 23 languages. Teaching videos by Khan Academy have been translated into over 65 languages, and the US government studied the efficiency of Khan Academy's learning material in teaching in field tests during the 2015–2016 academic year. The material provided by Khan Academy already fully covers most school subjects.

A significant proportion of higher education teaching is freely available at the global level. Many providers of MOOC courses fund these operations by charging a fee for degrees. Particularly in the ICT sector, technical degrees prepared by clients have become a widespread and systematic activity organised through third parties. These degrees and microdegrees or other certificates of competence are required as a prerequisite for agreements and employment.

Interesting sources published after the 2013 report (087)	
Short description of the link	**link**
Duolingo – free-of-charge language teaching in 23 languages	https://en.wikipedia.org/wiki/Duolingo
MOOC trends	https://www.class-central.com/report/5-mooc-trends-of-2015/

Interesting sources published after the 2013 report (087)	
Verification of academic certificates through a blockchain	https://medium.com/mit-media-lab/what-we-learned-from-designing-an-academic-certificates-system-on-the-blockchain-34ba5874f196
A platform for gamifying learning	http://www.seppo.io/
Enhancing learning efficiency with precise neurostimulation	http://www.hrl.com/news/2016/0210/

2.9.88 Robotised physical remote work, AI as superior (088) ***

Target area of the ART: It has been normal for work to be carried out at the location that it is intended to affect. If a place needed sowing, repairs or construction, workers went there to perform the required work. This assignment was normally provided by a human, either a supervisor or a client. By using information technology, we can now skip the journey altogether. We can simply move bits or send only the tool, which we then control remotely. Work is increasingly often commissioned and led by a data system based on orders placed or other observations. A human foreman is not needed.

General description of the development: Avatars, i.e. telepresence robots, have been developed to allow people to perform dangerous or remotely located tasks with remote control. At first, these tasks comprised tasks involving the army, rescue departments, mines, the seabed, space and other dangerous conditions.

Telepresence is now becoming so simple that it is worth using simply to avoid travelling. In practice, the simplest avatars are only remote-controlled videophones on wheeled stands. Unlike a traditional videophone, callers can control this avatar and e.g. move about the corridors of a site they are visiting, controlling their own location and the direction they are looking at. More advanced avatars are also able to use tools and manipulate substances or items.

Platform economy, the Internet of Things, simulation and artificial intelligence contribute to this development. Machines tell people what they should do next. Machines taking on the role of supervisor is related to avatars. They both promote the independence of work from location and distances, relying on the same principles. In other words, the distance to a supervisor and the target of work may both grow. Employees receive their assignments through a platform and perform their work for the platform. The stimuli for assignments come from elsewhere, gathered by IoT, and the impacts of work are visible elsewhere, conveyed by robots. The location of the worker is not important.

Resources and motive for development: The motive of start-ups funded by venture capitalists is to create new business to utilise rapidly advancing technology. Some industrial companies focusing on robotics are developing remote control because of customer demand and competition. Academic research plays a significant role in the remote controlling of robots. The product development of the arms industry has a clear and significant motive.

Impact on value-producing networks, ART 88																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	5	10	3	5	0	0	5	0	10	3	5	0	3	3	3	10	5	3	0	10	***249

Progress since the previous report: This ART is new. Numerous companies have begun selling avatars since the publication of the previous report. At the research level, remote-controlled robots have advanced so that users can now use them to perform physical work naturally through haptic interfaces and virtual glasses. An interesting example of natural remote control at the whole-body level is Toyota's new pilot robot.

Some remote-controlled robots have progressed to practical applications, such as Hiab's crane that is operated with VR glasses. Apple's HealthKit is a platform that conveys health information measured by the patient at home to a physician. Uber and many other platform economy companies forward orders placed by their customers to their employees, coordinated by a data system. A study by MIT shows that employees like having an AI as a supervisor.

Interesting sources published after the 2013 report (088)	
Short description of the link	**link**
Collaboration between humans and robots, a robot supervisor	http://qz.com/255093/human-workers-will-take-orders-from-robots-and-they-will-like-it/
MacKinsey: 120 AI-based business ideas, a matrix	https://medium.com/@thoszymkowiak/120-machine-learning-business-ideas-from-the-new-mckinsey-report-b81b239f336
Main categories of tech-augmented human workers	http://theconversation.com/introducing-operator-4-0-a-tech-augmented-human-worker-74117?utm_source=facebook&utm_medium=facebookbutton
Uber and autonomous transport	https://www.fastcompany.com/3050250/what-makes-uber-run
AI in near-future health care applications, a review	https://venturebeat.com/2017/07/23/what-ai-enhanced-healthcare-could-look-like-in-5-years/
A review of the current status of telepresence robots – usability achieved	https://www.engadget.com/2017/08/11/the-best-telepresence-robot/
Risks of AI – an open letter signed by a large number of people	http://futureoflife.org/misc/open_letter
Apple HealthKit – a remote health care platform	http://www.patentlyapple.com/patently-apple/2014/09/stanford-duke-prepare-major-trials-with-apples-healthkit.html
An assessment of the economic impacts of AI & robotics	http://europe.newsweek.com/robot-economy-artificial-intelligence-jobs-happy-ending-526467
AI is taking jobs from lawyers	https://www.kauppalehti.fi/uutiset/tekoaly-vie-juristeilta-tyota---haaste-on--miten-kay-seuraavalle-juristien-sukupolvelle/igcqTD4x
The S Group tests machine vision in monitoring shelves	https://yle.fi/uutiset/3-10074281

Interesting sources published after the 2013 report (088)	
Loading logs onto a truck with VR glasses	http://www.hiab.com/en/global/HiVision/
Toyota's humanoid robot moves more naturally	https://spectrum.ieee.org/automaton/robotics/humanoids/toyota-gets-back-into-humanoid-robots-with-new-thr3

2.9.89 Encrypted and anonymous telecommunication (089) ***

Target area of the ART: Many people want to be anonymous on the Internet. Possible reasons for this include a threat targeted at the person in question due to political oppression, for example, or the person's own wish to act criminally without the risk of being caught. The need for encryption may also be related to government-level spy operations, trade secrets and normal protection of privacy. Systems based on encryption include online banks, cryptocurrency and all data network services requiring reliable authentication.

General description of the development: The development of the best-known anonymous system, the Tor network (The Onion Router), has been funded by the United States Department of Defense. A considerable number of the users of the Tor network are drug and arms dealers, human traffickers, money launderers and other criminals. Services of this part of the Internet, also called the dark web, include hacking tools, denial-of-service attacks, assassinations and information leaks.

The structure of the Tor network is based on voluntary nodes that numbered 7,000 at the time this report was written. These can make it very difficult to monitor how a browser is used. Cracking a single node does not eliminate the protection due to its onion-like encryption. Some Internet services prevent activity if the request comes from a well-known part of the Tor network.

More common than anonymising a user is to encrypt the content of a message either fully or with regard to passwords that allow access to confidential data. Telecommunication between the sender and the recipient is encrypted with a protocol in which the encryption algorithm is public information or at least known to both parties. In addition to this algorithm, the parties need an encryption key that the sender can use to encrypt the data into a form that is readable only by the recipient with either the encryption key used or its secret counterpart.

A common encryption method today is for the sender to encrypt a message using the recipient's public key, which the sender is aware of. The encrypted message can only be opened with the recipient's secret key. According to investigations, these public-key encryption methods, which are also used in blockchains that are considered to be secure by design, will be hackable with quantum computers in the near future, at least in their currently used primary form.

Resources and motive for development: The community developing the Tor network is wide and at least partly comprises sincere advocates of privacy. Wide-scale and clear use of the network for criminal activity has led to academically and governmentally motivated attempts to crack the encryption of the Tor network. Research into encryption algorithms and their decryption is an activity based on academic, governmental and criminal motives.

Impact on value-producing networks, ART 89																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	3	3	0	0	0	0	3	20	5	0	1	0	0	0	3	0	5	3	0	3	***294

Progress since the previous report: This is a new ART that was established due to the increasingly extensive criminal use of the anonymous part of the Internet as well as the continuously growing role of encryption. New encryption methods have been developed. Google has begun to investigate how telecommunication can be protected from quantum computers. Several governments participated in shutting down the operation of AlphaBay, a dark web marketplace for drugs.

Interesting sources published after the 2013 report (089)	
Short description of the link	**link**
The security of encryption methods cannot be proven	https://www.theregister.co.uk/2017/12/15/crypto_mathematical_backdoors/
Darknet/anonymous Internet	http://apps.washingtonpost.com/g/page/world/nsa-research-report-on-the-tor-encryption-program/501/
High-rate quantum key distribution for communication with qudits	http://advances.sciencemag.org/content/3/11/e1701491.full
Websites steal users' CPU power to mine cryptocurrencies	https://www.engadget.com/2017/12/15/as-online-ads-fail-sites-mine-cryptocurrency/
Encryption with a camera	http://www.uusisuomi.fi/tiede-ja-ymparisto/72056-tieteellinen-lapimurto-nokia-n9n-kameralla-maailmankaikkeuden-ika-ei-riita
Google is looking into encryption to fend off quantum hackers	https://www.wired.com/2016/07/google-tests-new-crypto-chrome-fend-off-quantum-attacks/
AlphaBay, a dark web marketplace for drugs, was shut down	https://www.theverge.com/2017/7/14/15975140/alphabay-dark-web-drug-marketplace-police-shutdown-silk-road
Fast encryption (MS)	http://www.theregister.co.uk/2016/02/09/researchers_break_homomorphic_encryption/
Several links related to AI security/threats	http://www.express.co.uk/news/science/668886/AI-major-threat-microsoft-artificial-intelligence

2.9.90 Platforms for local sharing & collaboration (090) **

Target area of the ART: People are cooperative and social by nature, even though attention is often drawn to selfish motives and areas of dispute. We also have many common goals that benefit us all if we undertake to work for them together.

Data systems and platform economy applications in particular make transactions inexpensive and effortless. It is increasingly easy for us to participate in even minor communal work. Data systems also reduce the cost of complexity and individuality. They enable goods and services to be produced nearby, provided that search costs, trust requirements and other transaction costs can be solved with platform technology.

This ART includes social and technological innovations and platform economy technologies that promote local manufacturing, projects based on communal work, recycling or other forms of sharing economy that are for the most part non-commercial in nature.

General description of the development: In terms of their effects, Linux and Wikipedia are among the broadest achievements that are for the most part based on communal work. Of these two, Wikipedia is more clearly organised according to the platform economy model. Combining observations and information or producing an extensive software in collaboration with others is excellently suited for implementation in data networks.

Rather than monetary gain, many platforms appeal to other motives for activity. When the compensation for work is an increase in reputation, this is referred to as a reputation economy. On the other hand, it is also possible that our own contribution only feels sensible because it allows to make the matters important to us a part of the larger entity or an economy of scale. Participation may also be a condition for gaining access to a service.

Platforms can fund their activity with donated funds, as is the case with Wikipedia, or profit from advertising, as many others do. On the other hand, a platform may take part of the profit from transactions or sell some output of a consolidated work to fund the activity. A platform can also be organised so that the participants each produce a part of it without shared costs being incurred. For example, this is the operating principle behind the Bitcoin system.

Radical ideas about an economy with autonomous devices as main actors have been conceived. Platform cooperatives are being tested. We write about a sharing economy, imagining a world in which the marginal cost is getting close to zero. We marvel at organisations transitioning from hierarchies to peer-to-peer networks. The consumerisation of health care equipment, organisation of peer groups, the Open Artificial Pancreas System and the Uber of the Seas concept indicate that this trend is unlikely to leave many sectors untouched.

Resources and motive for development: Crowdsourcing and peer groups are very important in development activities in this area. The innovations in this area are created by individual programmers and small groups before expanding into large-scale activity as the number of participants increases. Development work is very extensive at the grassroots level, and only a small part of it rises up to conquer the world. Academic research and the product and service development of large organisations play a lesser role than crowdfunded and start-up funded companies and loosely organised interest groups.

Impact on value-producing networks, ART 90																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	0	5	5	5	0	3	3	3	0	0	5	0	0	3	3	0	0	3	3	0	**164

Progress since the previous report: The closest corresponding section in the previous report was "2.13 Freely organizing remote work and organizations that form on the Internet," which ranked in the highest group. eBay and Shapeways, which were mentioned in the report, have continued to grow since then. Jeremy Rifkin's Zero Marginal Cost Society has been published, containing important contemplation of the background of the development. Recent development is represented by the service Be My Eyes, in which volunteers act as the eyes of visually impaired people through a mobile phone application.

An idea of platform cooperatives has been developed to replace commercial operators like Uber with user-created structures similar to cooperatives. The public authorities have made their data repositories available for shared use. Package lockers are being installed in residential buildings to develop local manufacturing and distribution. Distributing a basic income is being considered as a tool for local production.

According to one estimate, 3D printing could reduce global trade by 40%. WikiHouse is offering building design as open source projects. Opendesk connects furniture design to local makers. Similar platforms are available for finding medical services and several other types of professionals. Combinations of a global platform and local implementation are expanding rapidly.

Letgo platform for recycling opened in 2015, combines local and global activity into glocal activity. Letgo's value has increased to $1 billion, and the platform conveyed 9 million messages per day in autumn 2017. Swap.com, which is in partial Finnish ownership, is a thrift store for used apparel. In 2017, its turnover was roughly €20 million, and the most recent capital investment was roughly the same amount.

Interesting sources published after the 2013 report (090)	
Short description of the link	**link**
Zero Marginal Cost Society	https://www.youtube.com/watch?v=5-iDUcETjvo
Platform co-ops	http://www.shareable.net/blog/how-platform-coops-can-beat-death-stars-like-uber-to-create-a-real-sharing-economy
The Be My Eyes application	https://vimeo.com/113872517
Letgo for local recycling, valued at over $1 billion	http://nordic.businessinsider.com/letgo-app-buy-sell-used-items-online-2017-9?r=US&IR=T
Helsinki: A 3D city as open data	http://www.hri.fi/fi/ajankohtaista/uuden-sukupolven-kaupunkitietomallit-helsinkiin/
Ecological residential neighbourhoods	https://www.fastcompany.com/3060167/this-new-neighborhood-will-grow-its-own-food-power-itself-and-handle-its-own-waste
Crowdsourced translation/learning	http://www.theguardian.com/education/2012/feb/14/web-translation-fails-learners
Basic income should be distributed as modern tools	https://www.tulevaisuustalo.fi/artikkelit/perustulo-ja-uusi-universalismi/
Robotisation & AI could reduce inequality	https://www.forbes.com/sites/timworstall/2017/06/25/getting-capitalism-wrong-ai-will-reduce-economic-inequality-not-increase-it/
3D printing could reduce global trade by 40%	https://www.gtreview.com/news/global/3d-printing-could-wipe-out-40-of-world-trade-by-2040/

Interesting sources published after the 2013 report (090)	
A review of the open source code market	http://techcrunch.com/2015/12/15/the-golden-age-of-open-source-has-arrived/
Package lockers for residential buildings	http://www.iltasanomat.fi/taloussanomat/art-2000005005045.html
Writers Café – peer collaboration	http://www.kboards.com/index.php?board=60.0
Flipboard curating	https://about.flipboard.com/magmaker/flipboardchat-summary-how-to-curate-news-magazines/
Opendesk – global furniture design	https://www.opendesk.cc/
A P2P energy trading platform	http://www.technologyreview.com/news/544471/renewable-energy-trading-launched-in-germany/
WikiHouse – an open source building design project	http://www.wikihouse.cc/
The Open Artificial Pancreas System	http://openaps.org/

2.9.91 Commercial platforms for sharing economy (091) ****

Target area of the ART: Employment services and the trade of work-based products and services are looking for new forms in the era of the platform economy. In addition to the seeking and finding of employees or services, this ART also discusses the exchange forums of a platform economy. Exchange forums refer to services in which we can make our achievements available to other people and from which potential customers can order them. The focus is on primary and secondary paid employment and profit-seeking platforms. Non-profit platforms and platforms based on communal work or recycling are discussed in ART 90.

General description of the development: In a platform economy, the role of a platform is often to market services to customers, choose someone to perform a job from among applicants, monitor feedback from customers and manage payment traffic from customers to the platform and from there to the performer of the work. The platform reduces transaction costs and provides a reliable third party between the customer and the service provider. The platform conveys both quality assessments and payment traffic and removes unreliable parties from the service.

The most common paid services in a platform economy are related to taxi services, with Uber, Didi and Lyft being the largest operators. Uber alone had over 1.5 million active drivers in its system in autumn 2017.

Renting apartments for short-term visits has become significant business. AirBnB’s turnover was estimated to be $3 billion in 2017. Most of the apartments are homes or second apartments that are rented out when the owners do not need them. Typical customers are travellers. The host’s job is to maintain the cleanliness of the apartment. Offering breakfast is being considered.

YouTube is a good example of a platform that allows users to display their own work. Vloggers and bloggers are new professions that earn some of the advertising income generated by their websites. For popular vloggers and bloggers, producing videos or writing columns and uploading them online may be their primary job. 3D models, photographs and problem solving also have their own platforms that convey paid work and paid output of this work. For example, in 2016 Shapeways delivered a million items designed by its members to its clients and remitted the price of the models in question to each designer.

Resources and motive for development: The most important development motive is to develop new business models and grow business operations. Start-ups funded by venture capitalists are the most important developers.

Impact on value-producing networks, ART 91																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	10	5	0	5	0	0	5	10	20	3	10	0	3	3	5	3	0	5	5	5	****582

Progress since the previous report: The closest corresponding section in the previous report was "2.13 Freely organizing remote work and organizations that form on the Internet," which ranked in the highest group. Uber and Lyft have increased their turnover roughly a hundredfold since the writing of the previous report. Uber's operating loss will exceed $2 billion. The Chinese Didi is becoming a global competitor.

AirBnB has rapidly grown into a worldwide accommodation giant and operates at a profit. The Uber of the Seas is under development. Google directs customers to online medical services. According to studies, the most active country in the world in online work is India. The nature of online work clearly differs by country. The nature of work above and below the algorithm has been studied extensively.

Interesting sources published after the 2013 report (091)	
Short description of the link	**link**
Uber's business model and other examples	http://www.nytimes.com/2015/01/29/technology/personaltech/uber-a-rising-business-model.html
Making media dynamic by buying, header bidding	http://marketingland.com/programmatic-header-bidding-will-disrupt-media-2017-202040
Connecting with an online physician by googling	http://gizmodo.com/google-tests-connecting-doctors-with-online-patients-1645412934
Programmatic (online) trading is eating the advertising market	http://www.telegraph.co.uk/connect/media-and-technology/things-we-learned-advertising-week-new-york/
A map of the distribution of online freelance work	http://ilabour.oii.ox.ac.uk/where-are-online-workers-located-the-international-division-of-digital-gig-work/
Workforce on demand (Deloitte)	http://dupress.com/periodical/trends/human-capital-trends-2015/?id=us%3A2el%3A3dc%3Adup1179%3Aeng%3Acons%3Ahct15
Work above and below the algorithm	http://www.druckerforum.org/blog/?p=1097

Interesting sources published after the 2013 report (091)	
The privatisation of health care services in Finland	http://yle.fi/uutiset/terveyspalvelut_yksityistyvat_nopeasti/7623506
Advertising is moving away from social media	https://www.linkedin.com/pulse/week-advertising-became-fatally-ill-nea-barman
From organisations to networks	http://interactioninstitute.org/blog/2013/07/31/why-networks-for-social-change/
Steem – social media blockchain money, paying for posting	https://forum.bittiraha.fi/t/steem-sosiaalinen-media-lohkoketjussa/3188
Uber of the Seas (and inland waters)	http://www.seatrade-maritime.com/news/middle-east-africa/uber-of-the-sea-is-near-but-is-the-industry-ready-for-the-sea-change.html

2.10 Globalising technology interfaces

Microsoft, Apple and Google, among others, have demonstrated the power which products that become industrial standards can have if they connect people and consolidate their digital output. When products include interfaces with which they are programmed and used, they initially lead to the creation of technical ecosystems that rely on them and later to extensive sociotechnical systems.

These sociotechnical systems may encourage practices that are contradictory to the way in which individual states wish to organise matters. However, it is difficult for an individual state to demand changes to global interfaces or completely exclude itself from these ecosystems due to problems.

Technical interfaces increasingly often organise the framework for social, political, economic and even military interaction. As they become common, the interfaces discussed in this section produce economies of scale, connectivity and increasing opportunities for financial exchange and social cohesion. Interfaces have clear stability, and typically the only way to change them without losing the userbase is by expanding its functionality.

IoT, robotisation, AI, virtual reality and biotechnology are each expanding the significance of technical interfaces as they expand and generating new, increasingly significant interfaces. It is important but challenging to anticipate these.

Globalising technology interfaces	
ART-ID	**The ARTs in the group**
92	Modular interfaces for robot ecosystems
93	M2M trade and other online commerce
94	Global wireless broadband
95	Cloud computing and storage services

Globalising technology interfaces	
96	AI performing local work on global basis
97	P2P trust solutions, blockchain
98	Digital art and digital experience platforms
99	MyData and GDPR
100	AR & VR platforms and content standards

2.10.92 Modular interfaces for robot ecosystems (092) **

Target area of the ART: The benefits of robots are demonstrated in many ways in other sections of this report. This ART focuses on the ways in which the development of robots can be expedited with interfaces and modularity. Robots have traditionally been developed in comprehensive projects. Parts made by the electromechanical or IT industry may have been used in their development. The actual robot and its system programs and even applications have been designed within the same overall project.

Specialisation according to the structures of mature industry requires established interfaces. A mature ecosystem makes it possible to assemble a robot using one operator's robot body, a second one's gripping devices, a third one's external senses and AI developed by a fourth operator. Due to the complexity of this field, it is unlikely that any one operator will be able to achieve the best results in every one of its areas.

General description of the development: The development of robotics is progressing towards interfaces between functional modules. The price of the control electronics of actuators is decreasing from dozens of Euros to less than ten. Robotic arms, sensors and software platforms are being sold and developed in separate projects. Shared interfaces are being sought. The strongest modularisation is being established between Arduino and Raspberry Pi. The clearest modularity is currently represented by the development of quadcopters and the extrusion technology of 3D printers.

Modular robotics has a clear connection to the development of IoT and AI, within which several parallel interfaces and platforms are being created. These can potentially create separate ecosystems in which modularity is realised, but combining modules intended for different ecosystems will likely be difficult.

Resources and motive for development: Robots are being researched extensively based on academic motives, commercial competition and goals of new business areas. Modular robotics is an area of academic research through swarm intelligence and homogeneous, cooperative robots in particular, but also through robot ecosystem interfaces. In the area of commercial robotics, interfaces and robot ecosystems are a new objective.

Impact on value-producing networks, ART 92																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
3	0	10	10	1	1	1	5	3	5	3	3	0	3	3	0	0	5	5	0	5	**189

Progress since the previous report: The corresponding section in the previous report was "2.53 Modular robotics," which ranked in the highest group. Clear progress has been made since then. Several Linux or Windows modules costing less than $10, as well as Arduino IoT control cards, have gone on sale. Inexpensive robotic arms have been launched on the market.

The development of autonomous transport has sped up the development of AI processors and modular sensors used in robotics. Mobile phones have become increasingly capable in their role as robots' senses, user interfaces, telecommunication units and CPUs. A new ROS interface has been developed for modular robotics. The RoboEarth cloud service has been developed to allow robots to learn from each other. ABB and Kawasaki have agreed upon shared interfaces. Universal Robots has published its application development interfaces.

Interesting sources published after the 2013 report (092)	
Short description of the link	**link**
A $9 computer with WiFi, Linux, etc.	http://postscapes.com/9-single-board-computer-chip
Raspberry Pi Zero $5	http://www.engadget.com/2015/11/28/raspberry-pi-eric-schmidt/
A low-price, 5 degree-of-freedom robotic arm KATIA, Carbon Robotics	http://techcrunch.com/2016/01/06/this-robotic-arm-can-do-everything-from-3d-printing-to-laser-cutting-to-cake-decorating/
A €134 robotic arm, uArm, open source	http://www.wired.com/design/2014/03/kickstarter-robot-arm-ufactory/
An information model for robots, OPC UA Robotics Companion Specification	https://opcfoundation.org/markets-collaboration/vdma-robotics/
Universal Robots is creating a software ecosystem	https://blog.universal-robots.com/pioneering-universal-robots-ecosystem
MS & FB's open source AI ecosystem gains more support from others	https://www.engadget.com/2017/10/11/microsoft-facebooks-ai-onxx-partners/
IoT sensors – Ruuvi	https://tag.ruuvi.com/
Raspberry Pi 2 $35	http://www.bbc.com/news/technology-31088908
Comparison of Arduino and Raspberry Pi	http://readwrite.com/2014/05/07/arduino-vs-raspberry-pi-projects-diy-platform
Interfaces for software robotics, MS Flow	http://www.zdnet.com/article/microsoft-leaks-flow-its-ifttt-like-tool-for-automating-actions-across-apps/
RoboEarth, a shared robot cloud service for robot learning	http://www.bbc.co.uk/news/technology-25727110
ABB & Kawasaki to develop robot interfaces together	https://global.kawasaki.com/C3171127-1.pdf
Robot Operating System ROS for modular robotics	https://spectrum.ieee.org/automaton/robotics/robotics-software/the-origin-story-of-ros-the-linux-of-robotics

2.10.93 M2M trade and other online commerce (093) ****

Target area of the ART: Various algorithms and suitably taught AI are able to recognise patterns, play games and look for things that interest us in data networks. Based on this data and capabilities, machines can trade on our behalf. Machines can also have their own programmed needs, such as ones related to shelf fullness or battery charge. Within the desired limits, an AI can be granted the right to make deals independently regarding the best products and services it finds.

This ART includes trade monitored or performed by machines as well as other e-commerce, excluding the platform economy, which is discussed in ARTs 90 and 91.

General description of the development: Computers have long been able to identify credit card misuse and other anomalies in trade in which people deviate from their usual habits in a suspicious way. AIs or similar algorithms have also profiled users and used these profiles as the basis for choosing news, social media messages, advertisements or offers.

Machine capability to react quickly has been found to be essential in the stock market, in which prices change very rapidly as a result of good or bad news. AIs are able to react to these changes much more quickly than humans, and the positive impact of this speed is often greater than the probability and negative effects of erroneous interpretations. Machines already play the dominant role in the stock market. Machines' role in other trade is also clearly increasing.

E-commerce has expanded rapidly from trading services to trading goods. The advancement of logistics, large variety, reliability of peer reviews and habit have accelerated growth. A typical online shop displays the products either in standard groups or according to profiling and other similar customer preferences. As a new operating model, the customer's own AI assistant looks for products online according to the customer's wishes and discusses them with him/her. The customer does not necessarily even see the online shop's website. The significance of B2B e-commerce is on the rise, and the degree of automation is high. Today, some wholesalers do not differ much from an AI-controlled cloud service.

Resources and motive for development: The development motive is based on competition between IT companies, e-commerce competition and customer demand. Academic research and start-ups have a clear but lesser role.

Impact on value-producing networks, ART 93																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	5	3	5	5	1	5	20	5	5	3	0	3	1	0	0	5	5	0	5	****405

Progress since the previous report: This is a new ART that was established due to the growth of e-commerce and because of machines increasingly often participating in making exchange decisions.

The EU's Payment Services Directive (PSD2) provides many operators with direct access to customers' account details. This is likely to accelerate the development of e-commerce and particularly the development of customers' own AI assistants. AI assistants have rapidly become more common, with notable operators including Google, Apple, Amazon and Microsoft. Google Assistant is able to shop at Walmart.

Lyft has developed an interface that allows customers to call and pay for a robot taxi. GM, Ford and several other companies have announced their support for it. The full autonomy of robot taxis has been conceptualised. A robot would find its customers, charge for rides, pay its own costs and act similarly to an entrepreneur.

Retaining the freshness of food for months at room temperature may materially change the e-commerce of food.

Interesting sources published after the 2013 report (093)	
Short description of the link	**link**
Food preserved with MATS is tasty, lasts a year at room temperature	http://fortune.com/2017/08/11/amazon-whole-foods-home-meals/
The EU's Payment Services Directive (PSD2) – broad impact on payment traffic	https://transferwise.com/gb/blog/what-is-psd2
Fast adoption of AI assistants challenges marketing	https://www.inc.com/bill-carmody/fast-adoption-of-ai-leaves-many-marketers-scrambli.html
Ford's self-driving cars to be available via Lyft's interface in 2021	https://www.theverge.com/2017/9/27/16373574/ford-lyft-self-driving-car-partnership-gm
Google Assistant & Walmart – voice shopping	https://blog.walmart.com/innovation/20170823/walmart-google-partner-to-make-shopping-even-easier-heres-how
Self-ownership of robot taxis – autonomous entrepreneurship	http://www.bbc.com/news/technology-30998361
Economy between autonomous devices – transaction costs now too high	http://www.impactlab.net/2014/09/19/micro-payments-between-connected-devices-could-enable-a-new-layer-of-the-economy/

2.10.94 Global wireless broadband (094) ****

Target area of the ART: Almost all our devices are global, mass-produced products. They increasingly often require a telecommunication connection to operate. In order for the various products to be convenient to use, we need both wireless and wired telecommunication standards. The mainstream global interfaces and their characteristics are normally taken into account in product design, and the use of more rare (i.e. country specific) communication methods may be problematic or impossible.

General description of the development: Researchers have started developing procedures shared by manufacturers for communication between cars. The development of 5G networks particularly takes into account the exponentially growing number of wireless sensors as a result of advancements in IoT, the growing need for capacity caused by audiovisual information, and the fact that many robots require low latency.

Overground robots may be controlled via satellites, and an Internet protocol operating in space has also been developed. The long delay in acknowledging the receipt of data, which disturbs devices, is an obstacle to the use of existing protocols at interplanetary distances and even from the surface of Earth to a geostationary orbit.

Several operators have advanced in their projects to create global Internet coverage with the help of low Earth orbit satellites, balloons in the upper atmosphere or solar-powered aircraft.

Resources and motive for development: The telecommunication sector is a highly competitive area. Suppliers of network equipment, launchers of satellites and major users of telecommunication are developing standards, equipment and services based on competitive motives and the pursuit of new business areas. Academic research promotes projects indirectly and in the long term.

Impact on value-producing networks, ART 94																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	5	5	0	0	0	0	10	3	5	5	3	0	1	5	5	5	5	5	5	5	****360

Progress since the previous report: The closest corresponding ART in the previous report was "2.100 Internet for robots," which ranked in the third group. Nokia has now published a white paper for a 5G network. Promises have been made regarding schedules for testing the 5G network. Alphabet is developing a Skybender connection that operates with millimetre waves. The aim is to create a directed, wireless 1 GB/s connection. A total speed of 1.59 GB/s has been achieved in a 5G network over a 20 MHz radio channel from one antenna to several terminal devices. LTE and 5G connections have been planned for car-to-car communication.

OneWeb has raised $1.7 billion in funding and intends to launch its satellite-based Internet services in 2019. Google, Facebook and several other parties are designing systems based on satellites, ultralight aircraft or balloons for providing an Internet connection to people living outside the existing connections and to devices that require a continuous global connection.

Interesting sources published after the 2013 report (094)	
Short description of the link	**link**
FCC: Thousands of satellites seeking to use radio frequencies	http://spacenews.com/fcc-gets-five-new-applications-for-non-geostationary-satellite-constellations/
Google's Skybender 5G, utilisation of millimetre waves, Centaur, Titan	http://indianexpress.com/article/technology/tech-news-technology/google-project-skybender-5g-internet-planes/
Alphabet promises a 1 GB wireless connection	http://www.wsj.com/articles/alphabet-looks-to-wirelessly-connect-homes-to-internet-1465417866

Interesting sources published after the 2013 report (094)	
Nokia's 5G white papers	https://networks.nokia.com/solutions/white-papers/5G-technical-white-papers
OneWeb has raised $1.7 billion in funding for its satellites	https://techcrunch.com/2017/11/07/oneweb-is-a-step-closer-to-bringing-its-global-satellite-based-internet-services-to-earth/
Interplanetary Internet, discussion of the latency problem	https://tools.ietf.org/html/rfc4838
A wireless, optical FSOC network for 12 million Indians	http://www.mwee.com/news/google-replaces-fibre-connectivity-free-space-optics
1 Gb/s exceeded over a 20 MHz channel in a 5G network	http://www.eurekalert.org/pub_releases/2016-03/uob-bal032316.php
Communication between cars, LTE, role of 5G	http://spectrum.ieee.org/cars-that-think/transportation/infrastructure/cars-talk-to-cars-on-the-autobahn
5G networks, a slideshow	https://www.facebook.com/ZTECorp/photos/pcb.755127304567731/755126827901112/?type=3
5G, status of IoT in 2016	http://www.techweekeurope.co.uk/networks/voip/mobile-telecoms-predictions-2016-182776

2.10.95 Cloud computing and storage services (095) ****

Target area of the ART: Computers, smartphones and other devices connected to the Internet have a limited memory capacity and processing speed. A fast telecommunication connection allows a device to rely on shared computing and memory capacity available online. Existing applications often operate so that the results are computed in online servers and only displayed in the user's terminal device.

The term used for this is cloud services, which refers to computing and memory capacity as well as various applications available in a cloud. Computing capacity is transferred from the data centres of many user organisations to service providers' cloud in order to save maintenance costs, even out loads and minimise risks and needs for capital that are related to equipment procurement.

General description of the development: Cloud services have quickly become mainstream. Both memory capacity and computing capacity can be rented easily and as needed. This requires the applications to comply with the interfaces of virtual servers and work stations. Cloud services are also increasingly created at the application level. An increasing number of machines and devices include functionalities that are implemented with cloud services.

According to the most dramatic expert forecast, the annual cost of storage space used in cloud services will decrease by 97%, i.e. to one thirtieth, between 2015 and 2020. This estimate is based on the spread of new cost-effective memory technology.

The newest trend in cloud computing is special processors that are required for efficient artificial intelligence or quantum computing. The computing capacity of these special processors is provided as a cloud service, with customers paying according to the computing capacity and amount of time used.

The use of computing services involves complex data security issues. Computing or data storage is implemented in the machines of another party. The machines may be located within another country and be subject to its legislation. Cloud services also involve latency caused by telecommunication. In order to reduce latency, service providers have sought to decentralise their cloud services to be closer to the users.

Cloud services are very efficient and fast with regard to computational tasks and tasks involving data searches because they are usually located along a fast connection and in an efficient computing centre. They obtain the data required by an application from the Internet more quickly than a terminal device and also compute them faster. Shared data is not stored separately in each terminal device.

Resources and motive for development: This sector is very competitive. Development is commercially motivated within the electronics industry and among service providers. Service providers also develop electronics, competing with the actual electronics industry. Academic research mostly plays an indirect role by promoting component technology in the long term.

Impact on value-producing networks, ART 95																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
7	3	5	5	5	1	0	0	10	3	3	3	0	0	3	0	3	3	5	0	5	****399

Progress since the previous report: The corresponding section in the previous report was "2.28 Cloud computing," which ranked in the highest group. The area of big data has now been divided into ARTs related to artificial intelligence because the area grew to be too broad.

The scope of cloud services is now roughly $300 billion, and it is estimated to continue to grow rapidly. In addition to their spread, their qualitative development has also been significant. NAND Flash is likely to supersede disk memory. The production cost of cloud services' memory capacity is estimated to decrease by half every year. Amazon offers the GPU power of Petaflops for AI applications at a rate of $200/h. IBM has provided a quantum computer for test use as a cloud service.

Interesting sources published after the 2013 report (095)	
Short description of the link	**link**
NAND Flash – reduced memory prices promote cloud services	http://www.zdnet.com/article/enterprise-storage-trends-and-predictions/
Cloud computing to grow radically faster than other ICT	https://www.forbes.com/sites/louiscolumbus/2017/04/29/roundup-of-cloud-computing-forecasts-2017/
IBM's 5 qubit quantum computer available for testing online	http://www.wired.com/2016/05/ibm-letting-anyone-play-quantum-computer/

Interesting sources published after the 2013 report (095)	
Amazon: Petaflops GPU $200/h, $80/h with a 3-year agreement	https://aws.amazon.com/about-aws/whats-new/2017/10/introducing-amazon-ec2-p3-instances/
Development trends in cloud computing	http://intelligence.org/2014/05/12/exponential-and-non-exponential/
Due to IoT, computing is moving to the edge of clouds	https://www.economist.com/news/business/21735022-rise-internet-things-one-reason-why-computing-emerging-centralised
Cloud-linked computer Solu	https://www.kickstarter.com/projects/676993694/solu-a-new-breed-of-computing

2.10.96 AI performing local work on global basis (096) ****

Target area of the ART: It is debatable whether machines perform work or whether they are simply tools that improve the efficiency of their users. This debate easily excludes some essential element of the transition caused by artificial intelligence, remote influencing and cloud services. Changes are taking place in the relationships between humans and machines as well as distances and power structures.

This ART examines the work performed by AI primarily independently and on a global scale. Particular attention is given to tasks that have until now been carried out under the supervision of local people, even when computers have been utilised. The tasks referred to here are partially included in a platform economy, which is discussed elsewhere in this report, as well as machine interpretation, for example. However, the focus of this ART is not the substance of work but economic geography.

General description of the development: Artificial intelligence is now evolving rapidly from a gamer into a taxi driver, anticipator of maintenance needs, stockbroker and sports reporter. Some applications are very experimental, but the applications considered to be AI can already perform many tasks that were previously performed by humans.

In some tasks, an AI can be taught with synthetically produced material. Other tasks require a great amount of data that may need to be continuously updated as well as an abundance of feedback from users. This type of extensive need for data produces economies of scale. If the development efforts are extensive and easily adapted to special national characteristics, only few global operators will remain on the market after the early stage of development. If their cost-effectiveness is materially better than having a human perform the same task, local human labour is replaced by services provided by a global AI.

The first impacts of local work becoming global are seen within the media, e-commerce and the platform economy, with advertising and ordering of goods and services gradually moving to international platforms, even if some of the work is performed in the target countries. Local travel agencies are also clearly among those that suffer from this. The PSD2 is anticipated to lead to similar impacts in the banking sector.

Resources and motive for development: The development motive is considerable among platform business developers, financial sector operators, IT companies that develop smart assistants and start-ups funded by venture capitalists. Crowdfunding is a potential and widely used channel, particularly in measurement and analysis tasks.

Impact on value-producing networks, ART 96																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	10	10	5	5	0	3	3	10	20	5	5	10	3	5	20	5	5	10	5	20	****636

Progress since the previous report: This is a new ART that was established to monitor this new trend that may have a significant impact. According to a report by McKinsey, global technology giants invested $20–30 billion in the development and adoption of AI to improve their services. Netflix estimates that the adoption of AI has improved its annual turnover by $1 billion.

PwC estimates that AI will boost the world economy by almost $16 trillion by 2030. Roughly half of this growth is anticipated to arise from increased productivity, with the other half arising from AI-based consumer products and services, particularly within health care, the financial sector and the automotive industry. Accenture anticipates that bank services will become AI-based within three years.

Interesting sources published after the 2013 report (096)	
Short description of the link	**link**
PwC: AI will boost the world economy by $16 trillion by 2030	https://qz.com/1015698/pwc-ai-could-increase-global-gdp-by-15-7-trillion-by-2030-with-much-of-the-gains-in-china/
Technology giants invest $20–30 billion in AI services	https://www.forbes.com/sites/louiscolumbus/2017/07/09/mckinseys-state-of-machine-learning-and-ai-2017/
Accenture: bank services to become AI-based within 3 years	http://www.cnbc.com/2017/03/28/ai-to-become-main-way-banks-interact-with-customers.html
The UK examines the impact of AI on jobs	http://www.zdnet.com/article/uk-looks-at-impact-of-ai-and-robotics-on-jobs-and-society/
A review of the legal and public impacts of AI	https://ainowinstitute.org/
Study of the impacts of the digital economy	https://www.weforum.org/agenda/2016/10/why-politicians-shouldnt-forget-about-the-digital-economy
AI affects the work of travel agencies	https://www.theguardian.com/sustainable-business/2017/feb/17/holidays-travel-automated-lastminute-expedia-skyscanner

2.10.97 P2P trust solutions, blockchain (097) ***

Target area of the ART: Agreements between people and organisations can be disputed or falsified. The most important agreements are usually verified by a trusted third party, typically by an authority. The most important task of many organisations is to manage what rights or obligations each party has with regard to something.

The authenticity of documents and signatures is the most important thing that must be verified in agreements and transactions related to such agreements. If it can be easily and irrefutably verified between the contractual parties, there is no need to use the often slow and rigid services of centralised and, for the most part, national organisations. This ART examines solutions based on blockchain technology and other decentralisation for verifying the privacy and authenticity of documents and transactions related to them.

General description of the development: Blockchain technology is based on an encrypted log that is distributed to the parties. New transactions are added as blocks that include a summary of the previous transactions. A block can branch out, but the previous blocks cannot be falsified without breaking the chain's encryption from the very start.

A blockchain is well-suited for the decentralised and reliable maintenance of various registers and transactions. The computing capacity required by blockchains is increasing according to the number of both transactions and parties involved. The inefficiency of the first blockchain implementations has been criticised.

The reputation of blockchains has increased together with Bitcoin, but many parties are using blockchain technology to develop systems that differ greatly from each other and deviate from the original application. For example, a digital city project in China is using blockchain technology to distribute access rights and carry out access control. There are also plans to use blockchains in stock trading and other trading in securities as well as in verifying the log data of telephone conversations.

IBM supports a project by the Linux Foundation to develop an open source code platform for blockchains. There are several platform projects and general-purpose blockchain implementations already on the market. This area is expanding rapidly. It has a great impact on rationalising administration and bypassing the power and supervision structures of traditional organisations.

Resources and motive for development: Companies in the financial sector and IT companies are the most motivated to develop this area. Public actors follow this area actively. Academic research is limited for the time being.

Impact on value-producing networks, ART 97																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
6	0	5	5	3	1	3	3	10	5	3	0	0	0	1	3	0	5	3	0	5	***330

Progress since the previous report: This is a new ART that was established due to more extensive application of the technology behind the cryptocurrency Bitcoin. This system, known as a blockchain, is suited for decentralised verification of the authenticity of documents and reliable verification of transaction chains.

A great number of potential applications have been proposed, but there are only a handful of completed, practical, wide-scale applications on the market. Ethereum has become a cryptocurrency alongside Bitcoin and also a notable public blockchain platform for other applications. Roughly 240 Ethereum applications were in operation at the end of 2017.

These are largely small-scale games and other experimental social applications. Ethereum allows special requirements to be set for transactions.

Through two different alliances, the financial sector has developed the blockchain platforms Hyperledger and Corda, with the latter made available with an open-source licence. Sovereign has developed a blockchain application for voting. Tunisia is testing a blockchain-based currency. IBM is participating in a blockchain-based logistics project in Finland. Central banks are considering a blockchain currency.

Interesting sources published after the 2013 report (097)	
Short description of the link	**link**
Corda blockchain developed by banks to be open-source	http://www.reuters.com/article/us-banks-blockchain-r3-exclusive-idUSKCN12K17E
Trust-based online platform Ethereum (blockchain)	https://www.ethereum.org/
The energy consumption of Bitcoin mining is growing rapidly	https://digiconomist.net/bitcoin-energy-consumption
A blockchain project by banks (Hyperledger)	http://www.coindesk.com/hyperledger-technical-steering-committee/
242 operational applications for Ethereum, hundreds under development	https://www.stateofthedapps.com/
A blockchain-based voting system	https://www.newscientist.com/article/mg23531424-500-bitcoin-tech-to-put-political-power-in-the-hands-of-voters/
Comparison of Ethereum, Hyperledger and Corda	https://medium.com/@philippsandner/comparison-of-ethereum-hyperledger-fabric-and-corda-21c1bb9442f6
Blockchain applications, several links	http://www.ibtimes.co.uk/factom-signs-smart-city-deal-roll-out-blockchain-verification-across-china-1542059
Blockchain trust structures, several links	https://techcrunch.com/2016/02/03/lets-be-honest-about-the-problems-with-blockchain-and-finance/
Blockchain in a logistics solution (Kouvola Innovation, IBM)	http://www.kinno.fi/article/teknologiajatti-ibm-ja-kouvola-innovation-yhteistyohon-kehitteilla-teollisen-internetin
Support for electronic voting grows	https://www.itnews.com.au/news/nsw-electoral-commission-given-54m-to-rebuild-ivote-465738
Blockchain in verifying logistics agreements	https://www.bloomberg.com/news/articles/2016-10-23/cotton-bales-7-000-mile-trip-heralds-blockchain-future-in-trade?bcomANews=true
IBM: blockchain to boost marketing	https://digiday.com/marketing/programmatic-dumb-system-doesnt-learn-ibm-cmo-michelle-peluso-using-ai-blockchain-clean-media/
Tunisia's post office trials blockchain-based currency	https://www.coindesk.com/tunisias-post-office-trials-crypto-powered-payments-app/
A blockchain-based currency for central banks?	https://www.technologyreview.com/s/600980/a-bitcoin-style-currency-for-central-banks/
A blockchain-based Ethereum application for the grocery trade	https://tokenmarket.net/blockchain/ethereum/assets/ins-ecosystem/

2.10.98 Digital art and digital experience platforms (098) ***

Target area of the ART: Digitalisation, together with AI, robots and virtual realities, is creating new tools for producing art and other experiences. Radical technologies enable completely new forms of art and entertainment. They also allow earlier works to be copied easily and experienced virtually. This development produces new, global, technological interfaces between distribution activity, applications, recordings and terminal devices.

General description of the development: 3D printing has consolidated its position. Several global and local services are available, including Shapeways. Artists can make 3D models of objects they design available on this platform, from which customers can order a 3D print of said objects. This can also be done by those who copy art works. Designers no longer have to conform to the conditions or restrictions of industrial manufacturers, as service providers agree to print everything. 3D printers also make it possible to manufacture very complex and functional objects inexpensively. Kinetic art is one of the beneficiaries.

Games and game-like worlds have become three-dimensional. Blender and numerous other 3D modelling programs enable the creation of increasingly realistic and impressive 3D animations and the types of worlds which people can enter virtually and start conversing with animated characters. Digital technology also enables increasingly diverse and realistic soundscapes.

Robotics is advancing towards dancing and otherwise moving machines. Robots can move aesthetically in the sky, draw impressive patterns in sand or extrude and arrange food on display artistically. Robotics makes it possible to transfer aesthetically impressive phenomena into the physical world interactively, without the artist's physical presence. The artist can see and hear his/her audience and react to its emotions. AI can seek to mimic this.

By 3D printing material, we can convey smells and flavours digitally. 3D printing of genetic material also allows biological properties and biotechnical material to be distributed digitally.

For the time being, development is scattered. Past experiences with the establishment of printing technology, musical instruments, radio, television and IT indicate that content production is directing manufacturers towards standards. Interactive digital art works and other experiences have been based on the movements of the user's body and hands as well as speech. In the future, they can also be based directly on brain activity. The development potential is very broad.

Resources and motive for development: Trying out new methods is motivated by artists' desire to experiment and renew themselves. Academic motivation is clear in some forms of expression. The motivation of the game industry and providers of 3D printing services is clear. Crowdfunding is a natural channel for many kinds of projects.

Impact on value-producing networks, ART 98																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
4	3	0	3	3	0	0	5	5	5	3	5	0	0	3	3	10	3	0	5	3	***236

Progress since the previous report: This ART is new. After breakthroughs related to deep learning, CAN-type AI has been increasingly used to create artistically impressive works. Google's AI is able to produce beautiful photos using ordinary Street View images. 3D printers are being used to create an abundance of kinetic art. Self-illuminating quadcopters have been used as replacements for fireworks. Disney has introduced a wide display surface created by a rotating LED strip. A human EEG has been converted into a live stream online.

Interesting sources published after the 2013 report (098)	
Short description of the link	**link**
AI creates art (Creative Adversarial Networks, CAN)	https://arxiv.org/pdf/1706.07068.pdf
Google AI makes Street View images aesthetically beautiful	http://www.diyphotography.net/google-ai-now-takes-professional-photos-based-street-view-images/
A robot plant hires artists to produce its offspring with BC contracts	https://singularityhub.com/2016/12/21/this-bitcoin-eating-plant-robot-hires-artists-to-make-its-babies/
The future of music	http://www.hs.fi/kulttuuri/a1390984545889
Brainternet – an EEG into a real-time "online publication"	http://www.wits.ac.za/news/latest-news/research-news/2017/2017-09/can-you-read-my-mind
Quadcopters replace fireworks	https://www.facebook.com/thisisinsider/videos/1506168603023866/?fref=nf
A show of 1,218 drones – quadcopter art	https://www.wired.com/story/olympics-opening-ceremony-drone-show/
Disney: A wide display surface created by a rotating LED strip	https://www.facebook.com/techinsider/videos/877767765754914/
The significance of design – tree-shaped wind turbines in cities	https://www.facebook.com/NowThisNews/videos/752323541524439/?fref=nf
3D printed kinaesthetic art	http://www.uusisuomi.fi/kulttuuri/76636-3d-tulostuksella-luotiin-huimaava-naky-avaa-isoksi-ja-nauti
VR experience/entertainment centre VOID	http://thevoid.com/
3D printed fabric & sensors in therapeutic use	https://www.facebook.com/MicMedia/videos/1277499499026746/

2.10.99 MyData & GDPR (099) ***

Target area of the ART: Many pieces of information are valuable. Information about an individual's character, spending habits and situation in life is helpful in directing marketing and other messages effectively. Information can also make people susceptible to exploitation and dangers. In Europe, there is a wide-spread notion that individuals have the right to decide upon the information pertaining to them.

This notion is referred to as MyData, and it is more of a trend than a clear operating model. Many pieces of information concern bilateral contractual transactions, and it is not explicitly established whether e.g. the method used to perform maintenance on site falls more to the maintenance worker or the customer.

General description of the development: MyData is a trend and open development project to create shared interfaces for citizens to be able to own and manage the data pertaining to them that is collected by various organisations in their person registers.

The development of MyData may have significant value to the national economy in many ways, such as by removing locks on e-commerce, questioning the dominance of operators such as Facebook and facilitating the portability of data. It can also facilitate everyday life and increase a feeling of fairness or control.

The General Data Protection Regulation (GDPR) is a regulation in EU law on data protection and privacy. It provides for the storing and disclosure of personal data in many respects, in the spirit of MyData. The GDPR has come into effect, and organisations are required to implement it in their data systems within the EU area. Violations may result in a very large turnover-based sanction.

Resources and motive for development: Within the EU, development is controlled or enforced by the states, and companies are quickly developing their IT systems to comply with the requirements of the GDPR. Other development of MyData can progress based on this work.

Impact on value-producing networks, ART 99																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	1	3	3	5	0	0	3	10	3	5	0	1	0	5	0	3	5	3	0	5	***275

Progress since the previous report: This ART is new. The MyData community has grown into a sizeable movement, with the theme being made part of the Government Programme in Finland. The GDPR was prepared and put into effect after the previous report. Its impact is expected to be substantial, manifesting both as changes to current data systems and as new business opportunities because of the requirements for the portability of data.

Interesting sources published after the 2013 report (099)	
Short description of the link	**link**
The GDPR could ramp up cyber extortion demands	http://www.computerweekly.com/news/450430554/GDPR-could-ramp-up-cyber-extortion-demands-warns-researcher
If formulated poorly, the GDPR could impede AI development	https://www.wired.com/story/dont-make-ai-artificially-stupid-in-the-name-of-transparency/
Ecosystem of traffic data	http://www2.liikennevirasto.fi/julkaisut/pdf8/lts_2014-42_liikennetiedon_visiot_web.pdf
Value of MyData to the national economy	http://www.libertyglobal.com/PDF/public-policy/The-Value-of-Our-Digital-Identity.pdf
MyData in the Government Programme	http://fi.okfn.org/2015/05/29/mydata-mukana-strategisessa-hallitusohjelmassa/

Interesting sources published after the 2013 report (099)	
Introduction to the concept of MyData	http://www.hs.fi/paakirjoitukset/a1402548692688?jako=95b0ef985b6f760000529c9bb30bf7da

2.10.100 AR & VR platforms and content standards (100) ***

Target area of the ART: According to forecasts, augmented and virtual reality are growing into a large-scale business. Above all, we are talking about content business within the framework of experiences, teaching and other methods of interaction. They also involve an entirely new way of using data systems, electronics devices connected to the Internet and observing the environment.

The development of devices for this new environment is at a rapidly progressing breakthrough stage. For the time being, software has been developed separate for each device, but interfaces can be expected to become standardised. The market favours devices with the largest amount of content available, and this leads to a self-perpetuating cycle. This ART examines the development of AR/VR platforms from the perspective of standardisation.

General description of the development: The technical development of VR and AR glasses is described in ARTs 19 and 20 in this report. The most notable suppliers of VR glasses are now Oculus, which is owned by Facebook, and HTC, each of which have their own, device-specific development environment.

Several notable manufacturers have recently introduced devices on the market that are Windows 10 compatible and based on joint specifications by Microsoft and Intel. Google has introduced its own Daydream environment for phones that use Android. The Unity environment is a game engine that was originally designed for 3D games. It can be used as part of applications made for most VR worlds.

In addition to AR glasses, AR applications are also being used in normal mobile devices. Mobile devices show elements of augmented reality behind them, as though the user is looking through a screen. The first popular AR application was SkyMap, which showed the names of constellations and planets when pointed at the night sky. The next sensational application was the game Pokémon GO. The number of AR applications is increasing rapidly. Apple’s development environment is ARKit, while Google has published a development environment called ARCore.

The development of Microsoft’s HoloLens and other mixed reality glasses based on Microsoft and Intel’s shared platform is taking place in the same Windows 10 environment as the development of similar VR glasses. Magic Leap, the sensational newcomer in AR glasses that raised a billion in funding, has also announced features of the development version of its product and has stated that the product will be on sale in 2018.

For the time being, the AR/VR world is device-oriented. The applications comprise games, expert applications and other narrow software. Based on similar previous transitions, we can deduce that the use of devices by experts may become differentiated by device, with one group of experts becoming long-term users of a device that is left in a narrow market segment.

General entertainment and experiential applications, but particularly shared worlds of experiences and communication applications, will lead to polarisation. The platform with the widest variety of content will obtain the largest clientele and an increasing amount of content through development strengthening itself. It is therefore unlikely for a large number of incompatible platforms to remain on the market for a long period of time. On the other hand, we can say that the platform-level standardisation of VR/AR content will have significant effects, with the most essential of them being the acceleration of the development of content and peripheral devices.

Resources and motive for development: Platform development is a highly competitive field. IT companies have major motives for its development and the funding for the field continues to be considerable. Funding from venture capitalists is also considerable.

Impact on value-producing networks, ART 100																					
Maturity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
5	3	3	3	3	0	0	3	3	5	0	5	0	0	10	0	5	1	3	0	0	***235

Progress since the previous report: This is a new ART that was added because the consolidation of AR/VR platforms will have an extensive impact on the use of information technology. The development environments Apple's ARKit, Google's ARCore and MS's Mixed Reality Windows 10 have all been recently released. Unity is 10 years old and already has a wide variety of applications available for it. Unity has been adapted to all essential AR and VR environments.

Interesting sources published after the 2013 report (100)	
Short description of the link	**link**
MS's Mixed Reality software platform, AR & VR	http://uk.pcmag.com/feature/88781/microsofts-mixed-reality-plans-go-far-beyond-hololens
Copyright issues with photographs used in AR	http://www.gamesindustry.biz/articles/2016-10-20-pok-mon-go-is-just-the-beginning-of-an-absurd-copyright-struggle-in-ar
Google's Daydream and ARCore progress in AR development	https://www.engadget.com/2017/10/05/google-ar-ambitions/
The IEEE starts the standardisation of VR/AR	https://www.theverge.com/2017/5/10/15605472/ieee-standards-association-ar-vr-working-group

2.101 Miscellaneous challengers (101)

Some of the observations compiled do not fit the ARTs described above, and none of them are, for the time being, significant enough to warrant having their own place on the list. However, these challengers have been listed here both due to general interest and in view of possible future versions of this report. These phenomena have the potential to grow or become linked to other important future observations in a significant way.

Interesting sources published after the 2013 report (101)	
Short description of the link	**link**
An efficient osmotic power plant where seawater and freshwater combine	https://phys.org/news/2017-05-harnessing-energy-freshwater-saltwater.html
Secret recording of videos becomes easier	https://www.hs.fi/elama/art-2000002892344.html
FB shows off its radical interface research	http://mashable.com/2017/04/19/facebook-brain-interface/
The mesentery – a new organ found in humans	http://www.sciencealert.com/it-s-official-a-brand-new-human-organ-has-been-classified
Two monkeys cloned (from a non-embryonic cell), humans cloneable?	https://www.nbcnews.com/news/world/chinese-scientists-clone-monkeys-break-barrier-human-cloning-n840736
Audio codec, HD phone calls	http://spectrum.ieee.org/telecom/standards/full-hd-voice-will-soon-give-your-phone-an-audio-upgrade
A hubless wheel	https://www.youtube.com/watch?v=cPsY2NfPJtw
Solidifying soybean oil without creating trans fats	https://www.eurekalert.org/pub_releases/2016-12/pu-ppc120116.php
Printing on nanoparticle coating with UV light, reversed with heat	https://sciencealert.com/scientists-invent-a-new-way-of-printing-on-paper-with-light
A hypersonic plane	http://nextbigfuture.com/2015/11/skreemr-hypersonic-passenger-plane.html
Chemical improvement of short-term memory with methylene blue	http://www.eurekalert.org/pub_releases/2016-06/rson-mbs062116.php
Superionic ice – a new state of water confirmed	https://www.sciencealert.com/scientists-find-a-strange-new-form-of-superionic-water-ice
SR-72, flight speed of Mach 6, 4,500 MPh – a conjecture	http://nordic.businessinsider.com/lockheed-martin-sr-72-fastest-plane-ever-71-blackbird-military-defense-tech-fastest-spy-plane-mach-2017-10
Noise-cancelling technology under development	https://www.facebook.com/humansofthefuture/videos/679308942226788/
An iron-based superconductor, 55 K	https://www.nature.com/articles/s41535-017-0076-x
TED: Technology to give the benefits of city life anywhere	https://www.ted.com/talks/julio_gil_future_tech_will_give_you_the_benefits_of_city_life_anywhere
Electrochemical treatment instead of antibiotics	http://www.eurekalert.org/pub_releases/2015-11/wsu-rda110915.php

3 Conclusions and results

The world is constantly changing. Some of the changes spread effortlessly into various societies by means of the market economy. Other changes cause pressure, leading to threats and opportunities based on the capability of each state to change their structures and draw the attention of organisations and citizens to new opportunities that are already noticeable. Uncontrollable partial optimisation prevents many changes and endangers developments that are beneficial for the whole.

The list below describes ten important general megatrends. Most of the things examined in this report touch upon one or more of these megatrends, with some of them strengthening them, some adapting to them and others reversing the direction of the megatrends. The period examined in this report, from 2018 to 2037, is relatively short, and significant changes to these megatrends cannot be anticipated with a high probability.

Megatrend level of common changes

1. Globalisation progresses: telecommunication, virtual presence, logistics, opening of borders, movement of capital and intellectual capital, relocation of jobs.

2. The development of the population and its resources in Finland and the EU: The population is ageing while family size is growing smaller, the elderly are increasingly active. Health and skills are improving less in Finland and the EU than elsewhere.

3. The development of the population and its resources elsewhere in the world: the population is continuing to grow, but the differences between countries are great. Metropolisation is continuing. The level of the population's health and education (skill) are improving.

4. Changes in the world's centres of power: The influence of Asia, BRIC countries and N11 countries is increasing. Regional and global administrative unification.

5. The imbalance issues in economic growth and foreign trade continue in Finland and the EU countries. Economic growth is strong in Asia and the BRIC countries.

6. Increasing inequality in the world: inequality in standard of living, problems in food security, tribalism, terrorism, extremist movements and disruptive behaviour are growing

7. Climate change is progressing, biodiversity is decreasing and environmental quality is weakening in the poorest areas of the world.

8. Limited resources are growing scarce and their price is increasing.

9. Development of people's values, experience of the world: multiculturalism, new experiences, culmination of the conflict between religious collectivism and individuality, increasing environmental awareness, strong fear of technology.

10. Unification of scientific and technical knowledge: unification of natural sciences particularly at the level of nanoscale phenomena, unification of technologies and human sciences through AI connected to services.

If the operating models in several value-producing networks change rapidly towards challenger regimes, we may be talking about Kondratiev waves facing a crisis that may involve considerable and rapid changes in megatrends that are difficult to anticipate.

3.1 Summary of the results of the RTI model described in this report

The most important output of this report is its method for evaluating the importance of technological solutions. The method is systematic and capable of clearly and justifiably placing various anticipated technologies in order of importance according to their potential effectiveness on society. This simultaneously creates a structure in which it is easier to discuss the importance and potential effects of things in a more structured manner, taking various value-related perspectives into account.

All the ARTs listed in this work can be considered to be potentially important and effective. They have been placed in this order based on their probability and the extent of their impact. Technologies that touch several value-producing networks have the most extensive effects on society and the largest need for structural changes. The Internet is a good example of a phenomenon that traverses value-producing networks and has changed sectoral structures, dismantled silos and led to significant legislative needs.

The primary purpose of this report is to anticipate social challenges and phenomena caused by technology. The list of the technologies' effectiveness (Table 2) below reflects this goal. The total potential value for each ART is calculated by adding up the value-production network-specific evaluations of the effectiveness of the ART, and multiplying the sum with the probability indicated by the maturity level of the ART. The broadest general attention should be focused on the ARTs that received four or three stars, whereas those that received one or two stars can be examined within the scope of their own sectors or their key value-producing networks, which are indicated in their scores.

Table 2. Summary of the results of the radical technology foresight 2018–2037. Note! Those interested in comparison find a summary of the results of the foresight report prepared in 2013 in Attachment 6.

ART-ID	**Anticipated radical technology (ART)**	**Maturity**	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	**Total potential value**	**Value level**
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
12	Neural networks and deep learning	5	10	10	5	10	3	3	5	10	5	20	20	10	5	20	10	10	5	5	5	20	955	****
28	Autonomous cars and trucks	5	20	20	0	3	5	0	10	10	5	10	5	0	10	5	0	5	20	3	3	0	670	****
6	Environment scanning & positioning	7	20	20	3	3	0	0	3	0	5	10	3	0	3	10	3	5	5	0	0	0	651	****
96	AI performing local work on global basis	4	10	10	5	5	0	3	3	10	20	5	5	10	3	5	20	5	5	10	5	20	636	****
2	DNA reading and writing (full genome)	7	1	3	0	20	0	10	0	3	3	0	0	10	5	20	0	0	10	0	5	0	630	****
70	Rapid development of photovoltaics	7	5	5	10	5	20	5	10	1	3	3	3	0	0	3	0	0	5	3	3	0	588	****
91	Commercial platforms for sharing economy	6	10	5	0	5	0	0	5	10	20	3	10	0	3	3	5	3	0	5	5	5	582	****
11	Speech recognition/synthesis and interpreting	6	3	3	0	3	0	0	3	10	5	5	10	3	10	5	5	5	5	10	5	3	558	****
16	Real time 3D-modelling of environment	6	20	20	10	5	0	0	5	0	1	5	0	0	3	5	0	5	5	0	3	3	540	****
5	Material scanner - hyperspectral camera	5	5	10	5	10	0	5	5	5	5	5	3	10	3	10	1	0	10	5	1	5	515	****
73	Transportable batteries and supercondensators	7	20	10	0	0	5	0	5	0	3	5	0	0	5	5	0	10	3	0	0	0	497	****

ART-ID	**Anticipated radical technology (ART)**	**Maturity**	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	**Total potential value**	**Value level**
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
38	3D-printing of things	7	1	5	20	0	0	3	3	3	3	5	5	0	1	0	5	3	3	3	3	1	469	****
20	VR-glasses, MR-glasses and virtual reality	6	3	3	5	0	0	0	5	3	5	3	10	1	3	3	5	10	1	3	10	5	468	****
26	Radical growth in computing power	4	10	10	5	5	0	5	5	10	5	10	5	5	0	5	0	10	5	5	0	10	440	****
30	Quadcopters and other flying drones	7	1	20	3	3	0	1	5	1	3	5	3	0	0	5	0	1	10	0	0	0	427	****
3	Personal health diagnostics systems	5	5	3	0	10	0	0	5	1	3	3	0	20	10	5	3	3	5	3	5	0	420	****
15	Verbot/chatbot, talking/corresponding robots	5	5	5	0	3	0	0	3	5	10	10	5	3	0	5	5	10	5	3	3	3	415	****
93	M2M trade and other online commerce	5	5	5	3	5	5	1	5	20	5	5	3	0	3	1	0	0	5	5	0	5	405	****
95	Cloud computing and storage services	7	3	5	5	5	1	0	0	10	3	3	3	0	0	3	0	3	3	5	0	5	399	****
41	Ubiquitous environment and Internet of Things	4	3	10	10	5	0	3	10	10	5	5	3	3	0	10	0	5	5	5	3	3	392	****
67	LED-farming, robotic farming	6	0	5		20	5	3	5	3	3	3	3	3	0	0	0	3	3	0	5	0	384	****
14	Facial and emotion recognition and projection	4	3	1	0	3	0	0	3	5	10	10	3	3	3	5	10	10	5	5	10	5	376	****

ART-ID	Anticipated radical technology (ART)	Maturity	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	Total potential value	Value level
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
19	Smart glasses, AR-glasses and augmented reality	5	0	5	5	10	0	0	10	3	5	0	5	0	3	3	5	10	5	3	3	0	375	****
13	Pattern recognition and other AI platforms	5	3	5	5	5	0	0	5	10	5	10	5	0	0	3	3	3	3	5	0	3	365	****
94	Global wireless broadband	5	5	5	0	0	0	0	10	3	5	5	3	0	1	5	5	5	5	5	5	5	360	****
87	Flipped learning and proficiency demonstrations	5	0	0	1	0	0	0	3	3	5	3	10	0	0	3	20	1	1	5	5	10	350	***
27	Walking robot and walking assists	5	5	5	1	0	0	1	10	0	10	5	3	0	10	0	1	5	5	0	5	0	330	***
97	P2P trust solutions, blockchain	6	0	5	5	3	1	3	3	10	5	3	0	0	0	1	3	0	5	3	0	5	330	***
22	Fast and dense memory materials	7	3	3	0	0	0	0	3	3	3	3	0	0	0	10	0	5	3	0	5	3	308	***
66	Biotechnical meat and meat imitations	5	0	5	0	20	0	0	5	0	3	3	0	5	0	0	0	5	3	0	10	0	295	***
89	Encrypted and anonymous telecommunication	6	3	3	0	0	0	0	3	20	5	0	1	0	0	0	3	0	5	3	0	3	294	***
23	Memristors and neural processors	3	3	10	0	0	0	0	0	5	5	10	10	3	3	10	5	5	3	5	10	10	291	***

ART-ID	Anticipated radical technology (ART)	Maturity	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	Total potential value	Value level
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
7	IR, THz and GHz transmitters and receivers	5	5	10	0	3	5	3	5	0	0	3	0	0	0	5	0	10	5	0	3	0	285	***
42	New robotized services	4	3	0	3	3	1	1	10	5	10	5	5	0	3	3	0	10	3	0	0	5	280	***
99	Mydata and GDPR	5	1	3	3	5	0	0	3	10	3	5	0	1	0	5	0	3	5	3	0	5	275	***
4	Lab on a chip	4	5	5	3	5	0	10	5	3	3	3	0	5	0	10	0	0	3	3	0	3	264	***
1	Reading and editing thoughts from the brain	3	3	0	1	3	0	0	5	1	5	3	3	5	5	10	5	20	3	5	5	3	255	***
88	Robotized physical remote work, AI as superior	3	5	10	3	5	0	0	5	0	10	3	5	0	3	3	3	10	5	3	0	10	249	***
84	Gamification of collaboration and society	4	3	1	0	3	3	1	1	3	0	0	5	5	1	3	10	3	0	10	5	5	248	***
98	Digital art and digital experience platforms	4	3	0	3	3	0	0	5	5	5	3	5	0	0	3	3	10	3	0	5	3	236	***
100	AR & VR platforms and content standards	5	3	3	3	3	0	0	3	3	5	0	5	0	0	10	0	5	1	3	0	0	235	***
8	LiFI networks and other led technology	6	0	0	1	10	0	0	10	0	0	0	0	3	0	0	0	5	5	0	5	0	234	***
50	New separation techniques & circular economy	5	0	5	5	5	3	5	3	5	0	3	0	3	0	1	0	0	0	0	3	3	220	***

ART-ID	**Anticipated radical technology (ART)**	**Maturity**	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	**Total potential value**	**Value level**
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
24	Quantum computers and quantum communication	3	3	3	0	0	0	0	3	10	10	0	0	0	0	10	0	0	20	5	3	5	216	***
56	Cyborgs uniting biology and mechatronics	3	0	0	0	3	5	5	0	0	1	3	3	10	20	5	1	5	5	0	0	5	213	***
37	Sensitive robotic fingers and arms	4	0	5	5	5	0	0	3	0	3	10	5	0	1	0	0	5	3	3	3	0	204	***
57	Radical longevity	3	0	0	0	3	0	0	3	1	0	3	5	20	5	0	5	5	3	0	10	5	204	***
83	New power sources for vehicles	6	10	10	0	0	5	3	3	0	0	0	0	3	0	0	0	0	0	0	0	0	204	***
86	Crowd funding and microfinancing	6	1	1	3	0	1	0	0	3	0	0	3	0	1	0	3	0	0	5	3	10	204	***
35	Easier access to space	6	0	0	1	0	0	5	1	5	5	3	3	0	0	3	0	1	1	1	3	1	198	***
60	Genetic editing techniques, CRISPR/Cas9	5	0	0	0	5	0	3	0	0	5	0	0	10	5	0	0	3	5	0	3	0	195	**
92	Modular interfaces for robot ecosystems	3	0	10	10	1	1	1	5	3	5	3	3	0	3	3	0	0	5	5	0	5	189	**
29	Light person & cargo transport vehicles	4	10	5	1	3	0	0	5	3	0	3	3	0	5	0	0	3	5	0	0	0	184	**
34	Hyperloop and other tunnel technology	4	10	5	0	0	0	0	10	3	0	0	3	0	0	0	0	1	3	3	3	5	184	**
59	GMO producing substances and organs	4	0	0	3	10	3	5	1	3	0	0	0	5	3	0	0	3	5	0	0	0	164	**

ART-ID	Anticipated radical technology (ART)	Maturity	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	Total potential value	Value level
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
62	Microbiome, metabolism and genetics of cells	4	0	0	0	5	0	0	0	3	0	0	0	20	10	3	0	0	0	0	0	0	164	**
90	Platforms for local sharing & collaboration	4	0	5	5	5	0	3	3	3	0	0	5	0	0	3	3	0	0	3	3	0	164	**
25	New nanomaterials in electronics	3	0	3	3	0	3	3	3	0	0	3	0	10	10	10	0	3	3	0	0	0	162	**
10	Small particle accelerators, femto and nanolasers	4	5	5	3	1	0	0	0	0	3	5	0	5	0	5	0	3	5	0	0	0	160	**
17	Easy 3D-imaging of things	5	1	5	5	0	0	0	3	3	0	3	3	0	1	3	0	3	1	1	0	0	160	**
46	Light and strong or insulating materials	4	5	5	5	3	1	3	10	0	0	0	0	0	3	1	0	3	1	0	0	0	160	**
53	Artificial muscle and artificial skin	3	0	5	3	3	3	5	3	0	5	10	0	0	5	1	0	5	0	0	5	0	159	**
18	Deep learning material for expert AI	3	0	0	0	5	0	3	3	3	0	10	5	3	0	5	0	5	3	0	0	5	150	**
32	Light continuously (24/7) flying aircaft	4	3	3	0	0	0	3	3	3	3	3	1	0	0	10	0	0	5	0	0	0	148	**
72	Grid level energy storage	5	0	0	3	0	20	0	0	5	0	0	0	0	0	0	0	0	1	0	0	0	145	**
21	Motion based and haptic user interface	4	0	5	3	0	0	0	3	0	5	0	5	3	3	0	3	5	1	0	0	0	144	**

ART-ID	Anticipated radical technology (ART)	Maturity	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	Total potential value	Value level
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
61	Simulating living cells, artificial cell	3	0	0	1	5	1	10	0	0	0	1	0	5	0	5	5	1	3	3	3	5	144	**
55	Smart materials and their simulation techniques	4	0	0	5	0	3	5	0	0	0	0	0	0	0	5	10	3	3	1	0	0	140	**
63	Repair of organs, cultivating cells	5	0	0	3	5	0	5	0	0	0	3	1	5	3	0	0	3	0	0	0	0	140	**
75	Cheap small fuel cell and micro-turbine CHP	5	3	3	0	0	10	0	5	3	0	0	0	0	0	0	0	0	3	0	0	0	135	**
51	Antibacterial and repellent surfaces	4	5	3	5	3	3	3	3	3	0	3	0	1	0	0	0	0	0	1	0	0	132	**
58	Nanoparticles and microbots in mammal body	4	0	0	0	5	0	3	0	0	1	0	0	10	3	3	0	0	3	0	0	5	132	**
65	Curing and preventing dementia	3	1	0	0	0	0	0	0	0	0	0	0	20	0	1	3	3	3	3	10	0	132	**
85	Cryptocurrencies/exchan-ge media bypassing banks	6	0	1	0	0	1	0	1	5	3	0	1	0	0	0	0	0	3	3	1	3	132	**
33	Radical waterborn traffic	5	3	5	0	0	3	1	1	1	1	3	1	0	0	1	0	3	3	0	0	0	130	**
54	Fresh water production	3	0	0	1	10	1	5	1	1	0	0	5	5	0	0	0	3	3	0	3	5	129	*
48	Nanomaterials as fibers, fabrics and reinforcement	3	3	1	5	0	0	20	5	0	0	0	0	0	0	0	0	3	5	0	0	0	126	*

ART-ID	**Anticipated radical technology (ART)**	**Maturity**	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	**Total potential value**	**Value level**
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
74	Artificial leaf and synthetic fuels	3	3	3	0	0	10	0	10	5	0	0	3	0	0	0	0	0	5	0	3	0	126	*
81	Power lasers, ray guns, railguns	5	0	1	5	0	5	3	3	0	0	3	0	0	0	0	0	0	5	0	0	0	125	*
49	Production of nanomaterials	5	3	3	5	0	5	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	120	*
39	3D-printing of buildings and constructs	4	3	1	0	0	3	1	10	1	0	3	1	0	0	0	0	5	0	0	1	0	116	*
40	Self organizing and swarm intelligence	3	0	5	5	5	0	3	5	5	0	5	1	0	0	0	0	1	0	0	0	3	114	*
52	Structural materials replacing concrete	4	0	0	0	0	0	10	10	0	0	3	0	0	0	0	0	0	3	0	0	0	104	*
69	Cryogenics of biomaterials	4	0	3	0	3	0	0	0	3	0	3	0	3	3	5	0	0	0	0	3	0	104	*
9	Plasmonics and photonics	3	0	0	0	0	10	5	5	0	0	0	0	5	0	3	0	5	0	0	0	0	99	*
64	3D-printing of organs and biomaterials	3	0	0	3	5	0	3	0	0	3	5	3	5	0	3	0	3	0	0	0	0	99	*
77	Off-grid and micro-grid - solutions	4	3	0	0	3	5	0	3	1	1	0	1	0	0	0	0	0	1	0	3	3	96	*
44	Robotic tailor	3	0	0	10	0	0	0	0	5	3	5	0	0	0	0	0	5	0	0	3	0	93	*
82	Cordless electricity transfer	3	3	5	3	0	3	0	5	0	0	3	0	3	3	3	0	0	0	0	0	0	93	*

ART-ID	**Anticipated radical technology (ART)**	**Maturity**	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	**Total potential value**	**Value level**
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
71	Capturing/storing solar heat, heat to electricity	4	0	0	3	0	3	3	5	3	0	0	1	0	0	0	0	0	1	0	3	0	88	*
80	Recovery/harvesting of kinetic energy	4	3	3	0	0	5	3	3	0	0	0	5	0	0	0	0	0	0	0		0	88	*
78	Carbon capture and co2-usage as raw material	3	3	3	3	3	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	*
79	Small fusion and fission plants	3	0	0	3	3	10	3	5	0	0	0	0	0	0	0	0	0	3	0	0	0	81	*
31	Personal VTOL and other light aircraft	4	5	0	0	0	0	0	3	0	0	3	1	3	0	0	0	1	3	1	0	0	80	*
68	Plant and animal fibers, nanocellulose	4	0	0	3	0	0	10	3	0	0	0	0	0	0	0	0	3	0	0	0	0	76	*
45	Frictionless surfaces and levitation	4	5	3	3	1	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	72	*
36	Robotic insects & other biomimetics	3	0	0	0	3	0	0	1	0	3	3	0	0	0	5	0	3	5	0	0	0	69	*
47	3D-printing of metamaterials and compounds	3	0	0	3	0	5	5	0	3	1	5	0	0	0	0	0	1	0	0	0	0	69	*
76	Cheap efficient storage of hydrogen	3	5	5	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	*

ART-ID	Anticipated radical technology (ART)	**Maturity**	Passanger transport	Logistics	Manufacturing of goods	Sustenance	Energy supply	Production materials	Built environment	Exchange	Remote impact	Automation of work	Work and income	Healthcare	Redressing disabilities	Aquiring information	Proficiency & it's proof	Producing experiences	Safety and security	Collaboration and trust	Existential meaning	Power structures	**Total potential value**	**Value level**
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
43	New methods for manipulating materials/substances	3	0	1	5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	*
			32	40	26	32	20	23	37	31	28	31	24	27	19	32	17	32	32	17	21	23		

The most important results of the method are recorded in their entirety in the actual chapters. For each value-producing network, we have identified its current structure and potential paradigm-level transformation. The description of values, enablers and benefits was done systematically. The unusual breakdown of functions into value-producing networks opens up a fresh perspective into the way a society produces its key added values and provides a tool for anticipating systemic and structural transitions in the value-producing networks themselves. The fundamentality of the chosen added values provides a good basis for evaluating the social effects of potential technological advancement and operating methods related to objectives.

The value-producing networks are described through objectives, values and functions, but this description is very pluralistic and almost value-free with regard to the whole. Individual values, even opportunistic ones, and collective values are at the same level in the description. This was done to retain the anticipatory nature of the method. This can be seen in the low score received by the recovery of carbon dioxide, for example. Natural motives do not promote it particularly widely, and it needs to be supported by actions taken by legislators. Hence, the scores were assigned based on potential effectiveness, and they cannot be directly interpreted to indicate the commercial success or desirability of a technology, for example. With this evaluation method, a nuclear bomb would have received a very high score in the 1950s, and it has had a significant effect on the changing of the world.

As an evaluation by the authors based on this work, the following table illustrates how a transformation enabled by potential technological advancement in the value-producing networks can have a great number of both positive and negative effects. Positive effects are typically realised if a state or region seeks to promote the changes. A single state cannot prevent negative effects by obstructing development. These effects can be mitigated by taking control of the development and channelling it in a positive direction, which simultaneously helps minimise the adverse effects.

Transformation potential of value-producing networks	Resource efficiency	Labour productivity	Balance of trade and services	Income differences& unemployment	Wellbeing and health	Cohesion & meaningfulness	Sustainable development	Equality between regions	Efficient government	Freedom & democracy
Passenger transport	+++/--	+++	+++/--	+/--	+++/-	++/-	+++/--	+++	++/-	+++/--
Logistics	+++/--	+++	++/--	++/--	+/-	++/-	++/--	+++	++/-	+/--
Manufacturing of goods	++/-	+/-	+++/---	+++/--	+/-	+++/-	++/-	+++	++/---	+++/-
Sustenance	+++/--	+/--	++/-	++/-	+++/---	+++/--	+++/--	++/--	+/---	++/--
Energy supply	+++/--	+/-	+++/--	++/-	+/-	++/--	+++	+++	++/--	++/-
Materials	+++/--	+/-	+++/-	++/--	+/--	++/-	+++/-	+/-	+/--	++/--
Built environment	++/-	+++	++/--	+/--	+/-	+/--	++/--	++/-	++/-	+/-
Exchange	+++/--	++/---	++/--	+++/---	+/-	++/--	++/--	++/---	+/--	++/--
Remote impact	+/--	+++/--	++/---	+/---	++/-	++/---	+/-	++/-	++/--	++/---
Automation of work	+++/--	+++/--	++/---	++/---	++/-	+/--	+/--	+++/-	++/-	++/--
Work and income	++/--	+++/--	++/--	+++/--	++/--	+++/--	++/-	++/--	+/---	++/--
Health care	++/-	+++/---	+/--	+/-	+++/---	++/-	+/-	++/-	+++/---	+++/--
Redressing disabilities	+++/-	+++/--	++/--	++/-	+++/-	++/-	+/-	++/-	++/-	++
Acquiring information	++/-	++/-	+/--	+++/---	++/-	++/--	++/-	++	+++/---	++/--
Proficiency and its proof	++/-	+++/-	+/-	++/-	+	++/--	++	+++	++/-	+++
Producing experiences	+++/-	+++	++/--	++/---	++/-	++/--	++/-	++/--	+++/--	+/--
Safety and security	++/--	+/--	+/-	+/--	+/-	+/--	+/--	++/-	+/---	+/--
Collaboration and trust	+++/-	+++/--	++/---	+++/---	+/-	+++/--	++/-	+/--	+++/---	+++/---
Existential meaning	++/-	++/--	+/-	+/--	++/-	+++/---	++/-	++/--	+/--	++/--
Power structures	++/-	++/-	+/---	+/--	+++/---	+++/---	+++/---	++/--	+++/---	++/---

Collective will is not directly evident in this type of foresight model. Goal-oriented conclusions have been compiled separately under each value-producing network. They list the necessary or beneficial government actions related to the transformation of the socio-technical regime with which the benefits of technological advancement can be harnessed by society and any adverse effects can be avoided, wherever possible. We collected more than a hundred of these proposals that pertain to all administrative sectors and levels of activity. The proposals should be discussed one by one in connection with future outlooks in each administrative sector.

The radical technological solutions compiled in this work are described more extensively than in the previous report. Similarly to the previous report, we have determined the relative importance of each solution using a star rating system. The evaluation takes the potential opened by the solution in each value-producing network into account. These ideas for application were listed and evaluated in connection with each value-producing network. The values are subjective, but easier to verify than in the previous report. The rating scale is the same as in the previous report and it is described in more detail in connection with the value-producing networks in Chapter 1.

The maturity of each solution is described in connection with each ART. We sought to choose the maturity levels so that they correlate with the probability of the technology successfully entering the market. The maturity evaluation takes the same things into account as the previous report, but the evaluation instructions have been simplified and the scoring principle has been clarified. The rules for scoring are described in Chapter 2.

The product of the maturation probability and potential effectiveness of an ART provides the final score, based on which the ARTs were placed in order. The 25 most important solutions received four stars, while the following one fourth received three stars, the third fourth two stars and the final fourth one star. Although individual evaluations include subjectivity, the evaluations were reviewed by several experts, and the method is not particularly sensitive to variation in individual evaluations caused by personal opinions.

A material change to the calculation method compared to the previous report is that national effectiveness is not calculated separately in this report. There are two reasons for this. Existing export channels and national expertise are not particularly good predictors of which radical technologies will promote export in 2037 and in what ways. It is more a matter of will, successes and the forerunner status of the domestic market. Another important reason is that the value-producing networks represent national focus areas as is.

It is apparent that some of the value-producing networks described here do not seem to be as important in many countries, while they would like to increase the significance of other networks. This report seeks to describe the effectiveness of technology in Finland and other countries similar to Finland in their structures in which the value-producing networks described here are all significant. If a country's national economy deviates greatly from Finland, it can assign divergent weights to various value-producing networks in order to rectify the potential effectiveness. This same method can also be applied if the method is being used as a foresight tool in regional or urban development or in business' operating environment.

Many of the technological solutions evaluated to be among the most important are obviously important. What is then essential is the broadness of the examination. For example, AI has been evaluated from roughly three hundred perspectives. However, the scoring does provoke thoughts in some respects, such as the fact that mass-produced nuclear power plants are at the bottom of the list even though fusion energy is already within sight and material scanners make it to the top of the list. This is explained by the fact that material scanners impact a considerable number of value-producing networks. In the manner demonstrated by the Internet, this may make vertical systems horizontal and change many structures of society. Mass-produced nuclear power plants do not have a similar radical impact on various value-producing networks, even though they would greatly benefit society. It is worth keeping in mind that the lower end of the list also includes many things that have the potential to become very important and have a major economic or human significance even if they do not have a radical impact on social structures.

Compared to the list of one hundred technologies in the previous report, the new list shares many similarities, but improved grouping, technological advancement and a more carefully prepared evaluation framework have in some cases led to significant changes in ranking, both up and down the list. One important observation that must be emphasised is that, on average, the listed technologies that are significantly changing society are clearly more mature and the transformations described in the report are one step closer compared to 2013. We are now closer and, to a small extent, already in the middle of the radical transition anticipated by the report in several industries and administrative sectors.

3.2. Political recommendations

This report comprises twenty value-producing networks and one hundred ARTs that affect these networks. Each of these value-producing networks is a description of a notable paradigm challenge within its own subject area. In other words, the report divides society into twenty structural operating methods, each of which is subject to major and continuously increasing pressure created by technological advancement.

Political recommendations that favourably advance change and new professions that require improved expertise have been compiled at the end of the description of each value-producing network. The descriptions themselves provide the background of the benefits, enablers, obstacles, retardants and threats of the change.

The rate of change and the scope of the upcoming impacts of technology are not well known among rapporteurs and decision-makers. A significant part of the change is not seen because Finland has changed in the 2000s from a fast to a slow learner, and not many of the new technologies developed around the world have been adopted widely in Finland. Change is talked about in overly general terms, and resources have not been allocated to the anticipation of the cross-sectoral impacts of radical technologies and social innovations.

Experts follow development in their own field, relying primarily on the logic of the old operating model, the boundary conditions that they are used to and old rules of thumb. The future is not being taken into account in investments as a changing situation; instead, investors take great risks, believing in continuity, even if the probability of a radical change is higher than the probability of continuity. The impacts of several of the changes presented in this report will exceed the impacts of the change caused by the Internet to date, but significantly less attention is being paid to them now than was paid to the Internet during its early stages of development in the 1990s.

Due to the factors described above, considerable expansion of the cross-sectoral preparations for the impacts of radical technologies should be considered. The impact of the changes extends widely across value-producing networks and administrative sectors to things such as work, equality, sustainability and productivity, as indicated by the table presented earlier in this chapter. Sector-specific administrative development that starts from inside the paradigm and seeks to ensure the continuity of the existing structures is not enough to guarantee smooth adaptation in such a rapid and extensive transition.

The standard of living and well-being in Finland are based on the application of high technology both in the domestic market and in foreign trade. Since the 19th century, Finns have been quick to adopt technology, and Finland has created good conditions for technological advancement and the adoption of technology. However, the ability of Finnish society to adopt technology has materially slowed down in the 21st century. This ability must be restored in order for society to be able to adapt to an increasingly fast global change on its own terms.

- Finland must be able to improve productivity significantly in most of the value-producing networks presented in this report. This must primarily be done by first adopting the best practices enabled by global technological advancement on the domestic market.

- Finland must increase its investments in R&D in most value-producing networks, particularly in relation to the radical technological solutions evaluated to be important in this report, as they are drivers of growth.

- Finland must focus on new technologies that promote the domestic market, regardless of the current strength of the expertise or export industry that they are linked to. When heading for new regions, fast adoption of technologies in the domestic market is key to succeeding in export.

In Finland, public administration is the most important customer group in many sectors. New radical technologies typically enter the market through small growth companies. Demanding and progressive customers who are market leaders are significantly more essential to growth companies than R&D subsidies.

Competition law and procurement procedures must be developed further so that public administration becomes a progressive customer. Procedures must also be developed so that meritorious performance by a supplier produces added value to the supplier. We must determine which actions for promoting this fit within EU directives.

Technological advancement has enabled and made sensible many operating models that were not taken into account in the drafting of existing laws. Many currently used methods of organisation and divisions of responsibility are also outdated in comparison to structures enabled by new technology. It is natural for established companies to favour regulation that supports their operating model and prevents practices that are strange to them and open up the competition for new operators. Old, large companies are poor drivers of change, particularly when their old operating methods are protected.

- The important technologies indicated in this report should be examined against existing legislation, and any obstacles to best new practices unlocked by radical technological solutions should be removed. This was done during the telecommunications revolution in the 1990s, when established companies were forced to compete with new operating models. This type of elimination of legislative obstacles and opening the path for new operating models should be done more quickly in Finland than other countries in order for Finland to adopt a new way of thinking and launch trials more quickly than customer countries. Several key needs for change are pointed out in connection with each value-producing network. Some of them are related to relaxing regulation while others are related to safeguarding new operating models.

Finland paid a great deal of attention to the development of technology in the 1990s. The administration and politicians have plenty of means to control Finnish debate and the development of expertise. In the 21st century, attention has primarily focused on the division of power and division of benefits as well as world politics. Finns have developed the view that technological advancement has slowed down, while the opposite has happened at the global level.

In the absence of stimuli and a feeling that technology is important, the only investments in technological advancement have been made through academic research, some export sectors and R&D subsidies for companies. The opportunities opened up by technology and new technologies in particular have not affected the key structures of society, and awareness of the technologies presented in this report is significantly low compared to the technological awareness that prevailed in the 1990s, for example.

- Public administration should harness the means of the attention economy and transfer of skills that are at its disposal in order to increase technological awareness in the areas identified as being important in this report. We can learn from the methods and intensity with which public administration contributed to fostering debate about an information society in the 1990s and accelerating the adoption of the Internet and mobile technology.

- Teaching about technology and future prospects should be increased at all educational levels, and the impact of technology on society and structural changes should be included in teaching.

- Finland is home to many organisations that are experts in the development of technology. In order for Finland to be well-prepared to seize opportunities provided by new radical technologies, we should constantly and systematically keep up with development and create shared open platforms for this purpose. We believe that the tool we have developed here is an excellent tool for these efforts.

The broad changes that are proven to be possible in this report and that extend to the foundations of the functioning of society raise the idea of the beginning of a new Kondratiev cycle and the old one encountering a crisis, which is normal for Kondratiev cycles. This report shows that the challenger regimes are maturing quickly and comparatively simultaneously, proceeding towards a potential, extensive transformation of the existing structures. Previous crises related to the beginning of a new cycle were linked to major wars, economic collapse and reorganisation of power structures at the global level. These characteristics and impacts should be investigated more broadly due to the seriousness of the matter, as observations suggest that such a crisis could potentially take place during the 2020s.

3.3 Further development needs of this report and the proposed method

In writing this report, its authors must admit their own limitations. Even at best, a report that examines all the different value-producing mechanisms of society and all technological areas and scientific disciplines at the concrete level can only be indicative in nature. The authors received a great amount of assistance through crowdsourcing. A large number of experts from different fields commented and provided suggestions for improving this report. The crowdsourcing was carried out via the broad and close-knit community https://www.facebook.com/groups/TuVRadikaalit/, in which all the discussions (in Finnish) on each topic can be found.

The authors are satisfied with the functionality of the Radical Technology Inquirer, the method created in this project. The current model was developed based on the instructions provided in the previous report and follow-up report and experiences gained in the process. The model still needs to be developed further:

- Linking the effectiveness evaluations provided by the value-producing networks more clearly to values and the transformation requires further development and better insight into potential dynamics and generation of added value. This can be done as an addition to the structure and knowledge established here.

- The radical technological solutions have now been described with the help of crowdsourcing and knowledge acquired by the authors. The descriptions can be specified and expanded on with the help of experts in each subject matter. The technologies are also advancing continuously, with new technologies being introduced, which is why it would be sensible to develop a continuous and open procedure for keeping the technological solutions up to date.

- The information on Finland's own expertise and challenges is incomplete in the report and requires further work. This kind of information is not available in a compiled form.

- The content of this report, including the links and calculation formula, should be implemented so that it is easy to maintain and browse as an online database. This would be a very small-scale project that would increase the timeliness and usability of the information, particularly among Finnish developers of technology strategies, customers who use technology, researchers, product developers and the media.

3.4 Acknowledgements

The authors would like to thank the Committee for the Future for the opportunity to write this work. We would especially like to thank Ville Vähämäki, Chairman of the steering group of the Radical Technologies project, both for presenting us with this ambitious challenge and for providing us with many useful stimuli and advice in the development of the method. Committee Counsellor Olli Hietanen also encouraged us and helped us make progress in this project with his plentiful constructive criticism.

Of those who commented, we would particularly like to thank Mikko Dufva, Tero Kauppinen, Leena Merisaari and Anni Linturi for their extensive and detailed comments on the draft report and Anni Linturi also for producing the images used in the report. Thanks are also due to the organisers and participants of the workshops who commented on the draft versions of the value-producing networks. They are mentioned by name in connection with the value-producing networks. For the key content and work without which this report would not be possible, thanks are due to the people who participated in the crowdsourcing of the technology sources on online forums. The names of the more than two hundred people who provided sources for this report are mentioned in connection with the ARTs.

Attachments

Attachment 1: Formulas of the tables in the Statement by the Committee for the Future

Terms. The calculations for the Tables in the Statement by the Committee for the Future are based on the following terminology that is here related to the 2018 results presented in Table 2 in section 3.1. of this report.

- *ART*. The project used crowdsourced observations of radical technology development news. These were divided into 100 “anticipated radical technologies” (ARTs). In Table 2, each ART is featured as a row.

- *Maturity* level of each ART can be found from the Maturity column in Table 2. It assesses the present maturity of the ART. The values vary between 1 (meaning that a theoretical model of a radical technology is presented by a reliable research institution) and 7 (several competing products exist on the market).

- *Value-producing network* characterizes activities that are organized to serve a recognizable global need, such as personal mobility, logistics, sustenance, built environment, exchange, existential meaning and so forth. There are 20 value-producing networks. In Table 2, value-producing networks are featured as columns.

- *Anticipated effectiveness.* The matrix structure of Table 2 is formed to record the anticipated impact of technologies in 2037. In the table, ART rows are cross-tabulated with the columns of value-producing networks (global needs). Each ART’s anticipated effectiveness in 2037 for each value-producing network has been scored and the result recorded to the respective cell. The possible anticipated effectiveness values are 0, 1, 3, 5, 10, 20. Scores 10 and 20 are given only for those ARTs that would have a transformative effect upon the value-producing network. Score 20 means that the ART is critical element in the radical transformation of that specific value-producing network.

- *Anticipated total effectiveness of an ART* is formed by summing the expected effectiveness scores along the respective row in Table 2. While the individual scores are visible in the rows of Table 2, there is no separate column for their sum.

- In Table 2 the column "*Total potential*" is calculated as follows:
  *anticipated total effectiveness of an ART * maturity of the ART*

- *Total potential* in Table 2 = *effectiveness index* in the 20 summary pages of the statement by the Committee for the Future

- Table 2 shows the ARTs in the order of anticipated effectiveness in 2037. The ART with the highest *total potential* is featured first. The results show that the top ART of "Neural networks and deep learning" is expected to influence all value-producing networks with minimum impact of 3. The *anticipated total effectiveness* of neural networks and deep learning is *191*. When that sum is multiplied with the present maturity of that ART (maturity level 5), we arrive at *total potential* 955.

Comparing the results of 2013 and 2018. Tables II and IV in the Statement by the Committee for the Future are based on comparing the quantitative results of the foresight projects in 2013 and 2018.

- The quantitative results of 2018 foresight are in the Table 2 in section 3.1.
- The respective quantitative results of 2013 foresight are in Attachment 6.

The Committee for the Future has compared the results of 2013 and 2018 to draw conclusions on the development that has occurred between the two projects. The reader should remember that this assessment does not compare simply the changes in the maturity values of the ARTs, which would reflect real-life progress of technologies during the past 5 years. It would be very crude foresight to study this and project similar maturation rate to the future. Instead, the comparison also takes into account the changes in the anticipated impacts of the ARTs. Thus, it becomes possible to include qualitative insight concerning the maturation and consequences of technologies in the future. Naturally, such assessment is also prone to bias in the sense that present-day hype regarding some technologies may influence it. However, the methodology between the two foresight projects (2013 and 2018) has followed the same principles. Therefore, a change in anticipated impacts between the two reports should tell us interestingly about things that are possibly or even probably happening in the future.

Formulas. The underlying the technology rankings in the statement by the Committee for the Future are grounded on above-outlined principles, results and terms. Below are presented the calculation formulas (I – VIII) used in the TOP lists of the Committee's statement. The formulas are made by MP Ville Vähämäki, the Chairman of the steering group of the Radical technologies project.

TABLE 2 in the statement by the Committee for the Future: Value-producing networks ranked by rate of development (formulas I, II)

I The anticipated effectiveness index of a value-producing network (x) (the total potential of the ARTs in a value-production network):

$$\sum_{1}^{100}(maturity\ (n) * ART's\ anticpated\ effectiveness\ in\ a\ value - producing\ network\ (x))$$

II Rate of development [dB] of a value-producing network (x) (growth of the total potential of the ARTs in a value-producing network)

*10 * LOG (new [2018] effectiveness index of a value-producing network (x)/*
original [2013] effectiveness index of a value-producing network (x))

TABLE 3 in the statement by the Committee for the Future: TOP 24 ARTs ranked by order of anticipated generic impact (formula III)

III Genericity score of an ART:

$$Calculate(In\ how\ many\ value - producing\ networks\ an\ ART's\ anticipated\ effectiveness\ is\ above\ 0) * \sum_{1}^{20}(anticipated\ total\ effectiveness\ in\ a\ value - producing\ network\ (n))$$

TABLE 4 in the statement by the Committee for the Future: TOP 24 ARTs ranked by development rate (formulas IV ja V)

IV The *effectiveness index* of an ART (= ART's *total potential* in Table 2):

$$maturity\ (ART) * \sum_{1}^{20} (\ anticipated\ effectiveness\ in\ a\ value - producing\ network\ (n))$$

V The rate of development [dB] of an ART (= growth of the total potential of an ART):

*10 * LOG (effectiveness index (ART) new [2018] / effectiveness index (ART) original [2013]))*

THE FIRST TABLE IN THE VALUE-PRODUCING NETWORK SUMMARY PAGES Effectiveness index of the ARTs in a challenger regime (Formula VI)

VI The effectiveness index of an ART in a value-producing network (x) (the potential of an ART in a specific value-producing network):

$$maturity\ (ART) * ART's\ anticpated\ effectiveness\ in\ a\ value - producing\ network\ (x)$$

THE SECOND TABLE IN THE VALUE-PRODUCING NETWORK SUMMARY PAGES Development rate of the ARTs in a challenger regime (Formulas VII and VIII)

VII The effectiveness index of an ART (= ART's *total potential* in Table 2):

$$maturity\ (ART) * \sum_{1}^{20} (anticpated\ effectiveness\ in\ a\ value - producing\ network\ (n))$$

VIII The development rate [dB] of an ART (growth of ART's total potential):

*10 * LOG* (effectiveness index *(ART) new [2018] / effectiveness index (ART) original [2013]))*

Attachment 2: Scoring example: How was the ART related to indoor farming scored?

LED technologies were not yet presented as radical technologies in connection with food production in the 2013 foresight report[6]. In the 2016 follow-up report[7], the whole formed by urban vertical farming and LED farming was proposed as a new ART. This was based on a decrease in the cost of LED lighting and advancements in the production of different wavelengths, which allowed LED technology to be utilised in new areas, such as in creating optimal artificial lighting for plant growth inexpensively. Indoor farming based on LED lighting had already been commercialised in Japan and Finland, and there were indoor farming devices on the market.

This ART of indoor farming was therefore included as a new ART in the foresight report prepared in 2017–2018. At the same time, the robotisation of farming was added as part of this ART due to the fact that the participants of the crowdsourced monitoring of technology news, which served as the basis for this foresight project, were continuously making observations about food production becoming increasingly technical and robotised. In addition to enabling the gradual automation of outdoor farming, this trend also allows the scope of indoor farming to be expanded.

The Facebook group that scoured technology news also[8] screened technology news related to indoor farming. Of these, 22 are included in the project report and 37 are included in attachment 7 of the digital version of the project report. Before sharing their findings, the participants used Internet searches to verify that the phenomenon in question was real, as evidenced by several, mutually independent sources. The addition of a link often results in discussion, and other participants may find an even more informative link about the same subject or a link that introduces more recent advancements, which is ultimately left on the Facebook platform instead of the original link. As a result of this process, the Facebook group and project report include links such as a link provided by Risto Linturi to a story published in Helsingin Sanomat on 15 August 2015 about a lettuce farming factory in Vantaa; a link shared by Aleksi Rossi to a video published by the Huffington Post on YouTube on 8 January 2016 about a commercial indoor farming container; a piece of news found by Jussi Tunkkari, published in Maaseudun Tulevaisuus on 4 January 2017, about Natural Resources Institute Finland starting to test LED farming of potatoes in a mine in Pyhäjärvi in spring 2017; and a piece of news shared by Risto Linturi, published on the Nordic Business Insider website on 3 November 2017, about plans to open a vertical farm over a hectare in size near Seattle in spring 2018 to produce over 2 million kilos of herbs, vegetables and fruits per year without soil and pesticides, using LED lighting.

Based on all the observations linked to the Facebook group, Risto Linturi, who bore the main responsibility for implementing the project, evaluated the maturity level of LED-based, autonomous indoor farming to be 6 on a 7-point scale. At this level, which is the

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[6] TUVJ 2/2013 Tulevaisuuden radikaalit teknologiset ratkaisut

[7] TUVJ 1/2016 Teknologiamurros 2013-2016: Esiselvitys radikaalien teknologioiden kehityksestä 2013 katsauksen jälkeen

[8] https://www.facebook.com/groups/TuVRadikaalit/

second highest, the products in the ART are supplied to customers in increasing amounts and the economies of scale are expected to decrease prices considerably. R&D activity is at least partly based on internal financing, and the expansion of production has been clearly financed (the maturity criteria can be found at the beginning of chapter 2 of this project report). The observations related to indoor farming contained many examples of self-financed development work and expanding business areas and areas of application, which is why it is estimated that the rapid development of indoor farming now only involves low risks.

Linturi also assigned the effectiveness scores in the table below to the ART of indoor farming in relation to all the value-producing networks. The scoring was verified by Osmo Kuusi, the other author of this project report. Everyone interested in the subject also had the opportunity to comment on it in the Facebook group.

ART 67 LED farming, robotic farming		
VPN-ID	**(anticipated total effectiveness in a value-producing network (n))**	**Value**
Passenger transport		0
Logistics	The needs of food logistics are going to completely transform when cultivation shifts from cyclical and agriculture-dominated cultivation to continuous urban and factory cultivation.	5
Manufacturing of goods		0
Sustenance	The transformation of the food industry from cyclical agriculture to continuous and need-based, decentralised urban and factory cultivation.	20
Energy supply	LED farming will be a major consumer of energy and reducer of the need for load following plants.	5
Materials	Raw material efficiency improves in a closed cycle.	3
Built environment	The need for arable land and greenhouses will decrease and the use of indoor spaces in cultivation will increase. The need for moisture resistant indoor spaces will increase.	5
Exchange	Food trade will change radically as production decentralises and spreads to cities.	3
Remote impact	Farming can be controlled remotely, and the overall functionality of robot farming can be delivered globally.	3
Automation of work	LED farming facilitates the robotisation of food production.	3
Work and income	The increase in small-scale food production will expand the subsistence economy.	3
Health care	Increasing production that is based on individual needs and improving freshness by utilising local manufacturing will enhance the health effects of food.	3
Redressing disabilities		0
Acquiring information		0

ART 67 LED farming, robotic farming		
Proficiency and its proof		0
Producing experiences	A private garden and possible GMO production can provide experiences.	3
Safety and security	Individualised farming increases and reduces safety. The security of supply increases.	3
Collaboration and trust		0
Existential meaning	Nothing is as important as gardening – this idea will gain followers.	5
Power structures		0

The effectiveness scores estimated for ART 67 LED farming, robotic farming in each value-producing network in 2037.

Indoor farming naturally has the highest effectiveness score, 20 points, in the value-producing network of food production. According to the RTI criteria (chapter 1 of this report), this maximum score is assigned to an ART that is a necessary part of the most important transformative effect on the value-producing network's operating model. In other words, the transformation of food production is built specifically around the concept of robotised indoor farming.

According to the evaluation, indoor farming will not have a transformative effect on the goals of any other value-producing network, so it did not receive 10 points from any value-producing network. According to the RTI criteria, 5 points are assigned to an ART if *"the development of the ART delivers significant benefit with regard to the value related to the value-producing network's goal or is an important part of a whole that promotes the actual goal in a transformative way. In this context, a significant benefit would be an economic impact at the level of €100–1,000 million per year or, on an individual level, an impact of 50–500 million person-hours on everyday life per year"* in Finland. Indoor farming was evaluated to have this effect on the value-producing networks of cargo transport, the built environment, energy and experiences. For example, the objective of the value-producing network of the built environment is for people, animals, equipment and plants to have the facilities they need for mobility and activity with regard to location and conditions. The spread of indoor farming would have a significant impact on the use of facilities. Assuming that the transformation of transport into a robotised service will lead to a considerable decrease in the need for car parking, this would allow facilities such as underground parking garages to be converted into indoor farms, which will require a new type of robotics and control of temperature and humidity. Economic impacts have been anticipated by combining evaluations of the current volumes of the construction and maintenance industries to rough estimates of how much an average Finn might use time or money on indoor farms in the future and multiplying this figure with the estimated number of citizens.

It was similarly estimated that indoor farming could meet the three-point criterion in eight value-producing networks by 2037: *"3 points are assigned if the development of the ART delivers material benefit with regard to the value related to the value-producing network's goal or is part of a whole that materially promotes the actual goal."* The one-point criterion was not estimated to be topical for any value-producing network in 2037.

Robotised indoor farming earns its final score of 384 points when the effectiveness scores yielded by the various value-producing networks are added up (= 64 p) and multiplied by the ART's maturity value, which was 6 for indoor farming. In other words, the potential of indoor farming is multiplied by its uncertainty. With the calculated score, this example ART ranks among the top fourth of these one hundred ARTs with regard to its effectiveness. The representatives of the top fourth are indicated with **** in the report.

It must be noted that this scoring method is above all focused on the magnitude of the impact on social structures, which is why the scoring favours technologies that affect several different value-producing networks. For example, small nuclear power plants are estimated to affect a smaller number of value-producing networks: the value-producing network of energy by 10 points, the value-producing network of the built environment by 5 points and four other value-producing networks by 3 points for a total effectiveness score of 27 points. However, significant technological advancement has been observed in this industry since the 2013 foresight report. For example, several different reactor concepts are currently being tested around the world. For this reason, the maturity value of small nuclear power plants was determined to be 3. When the effectiveness score is multiplied with the maturity value, the total score becomes 81 points. The ART of small nuclear power plants ranks in the bottom fourth of the one hundred ARTs and is therefore indicated with *.

Attachment 3: Changes in which ARTs are followed in the evaluation

Similarly to the first foresight report prepared in 2013[9], we sought to organise the observations gathered about the advancement of radical technologies into one hundred ARTs. However, the ARTs are not fully the same as they were in 2013. This is due to more extensive monitoring over a longer period of time as well as the acceleration of technological advancement.

First of all, several ARTs that were previously monitored as separate ARTs have been removed from this report. For the most part, we did so by combining minor details that merge with other ARTs, dividing broad and important entities or changing the perspective based on new understanding. Secondly, this report includes technologies that had not been observed at the time of the previous report or that were previously progressing slowly. Now considerably more diverse changes have been observed. Thirdly, several ARTs have been expanded to make the scope of the problem area addressed by each ART clearer. For example, reading and writing of long DNA sequences have been combined into the same ART.

The need to renew the ARTs being monitored was discussed in detail in the report Teknologiamurros 2013–2016[10], and the changes made are for the most part in line with said report.

Plasmonics is an example of a new scientific phenomenon that is now being monitored. It refers to the manipulation of light (photons) with electricity. Applications of this field are for the time being difficult to anticipate, but they will at least be related to data transfer and new optical properties of materials. On the other hand, VR glasses, which have long been used for special purposes and have evolved slowly, have now been added as their own ART because a faster phase in their development and their breakthrough to becoming consumer products have clearly started.

One example of an ART merged with another is the ART "Synthetic cartilage in human joints" in the 2013 report, which has now been merged with the ART "Repair of organs, cell culture." "Spray-on textiles" is an example of an ART that was removed due to the slowing of development. In recent observations, it continued to be a technology patented by only one company, with no commercial applications yet available on the market.

An ART may also have been removed from the list due to its rapid growth. As a result, the ART becomes mainstream and is no longer considered to be radical. A good example of this is "Open data and big data," which was the number one ART in the previous report. Previously, access to data was an obstacle to many good solutions. Easier access to data was considered to open up major opportunities. The main attention in the forming of categories must be paid to the problem area that forms a bottleneck in the development of value production. Opening this bottleneck usually moves the problem to another node. Access to

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[9] TUVJ 6/2013 Suomen sata uutta mahdollisuutta: radikaalit teknologiset ratkaisut

[10] TUVJ 1/2016 Teknologiamurros 2013-2016: Esiselvitys radikaalien teknologioiden kehityksestä 2013 katsauksen jälkeen

data has rapidly improved so much that data transfer, processing and AI have become the new problem area or bottleneck. Significant development can be observed in these areas.

In other words, “Open data and big data” has, at least for the time being, been removed as a mature ART that has done its job, even though development is also continuing in this area. In its place, attention has been turned to the processing of data. ARTs related to AI have been added, as have ARTs related to the processing and transfer of big data as well as social regulation and global impacts, and specifications and descriptions have been clarified. We have also examined the ARTs related to the transformation of work in more detail and on a wider scale. Both of these changes were recommended in the report Teknologiamurros 2013–2016.

Attachment 4: Genericity table

Ranking	Anticipated radical technology (ART)	Genericity score
1	Neural networks and deep learning	3820
2	AI performing local work on global basis	3021
3	Autonomous cars and trucks	2010
4	Material scanner – hyperspectral camera	1854
5	Radical growth in computing power	1760
6	Ubiquitous environment and Internet of Things	1666
7	Facial and emotion recognition and projection	1598
8	Speech recognition/synthesis and interpreting	1581
9	Memristors and neural processors	1455
10	Commercial platforms for sharing economy	1455
11	Reading and editing thoughts from the brain	1445
12	Verbot/chatbot, talking/corresponding robots	1328
13	VR glasses, MR glasses and virtual reality	1326
14	M2M trade and other online commerce	1296
15	Rapid development of photovoltaics	1260
16	Personal health diagnostics systems	1260
17	Robotised physical remote work, AI as superior	1245
18	Environment 3D scanning & positioning	1209
19	Real-time 3D modelling of environment	1170
20	Pattern recognition and other AI platforms	1095
21	Global wireless broadband	1080
22	3D printing of things	1072
23	Smart glasses, AR glasses and augmented reality	1050
24	New robotised services	1050
25	Gamification of collaboration and society	992
26	DNA reading and writing (full genome)	990
27	Modular interfaces for robot ecosystems	945
28	Lab on a chip	924
29	Cyborgs uniting biology and mechatronics	923
30	Flipped learning and proficiency demonstrations	910
31	LED farming, robotic farming	896
32	Walking robot and walking assists	858
33	Digital art and digital experience platforms	826
34	Radical longevity	816
35	Cloud computing and storage services	798

36	Quadcopters and other flying drones	793
37	P2P trust solutions, blockchain	770
38	MyData and GDPR	770
39	Quantum computers and quantum communication	720
40	Transportable batteries and supercapacitors	710
41	Artificial muscle and artificial skin	636
42	IR, THz and GHz transmitters and receivers	627
43	Simulating living cells, artificial cell	624
44	Sensitive robotic fingers and arms	612
45	New nanomaterials in electronics	594
46	AR & VR platforms and content standards	564
47	Deep learning material for expert AI	550
48	Biotechnical meat and meat imitations	531
49	New separation techniques & circular economy	528
50	Fresh water production	516
51	Light passenger & cargo transport vehicles	506
52	Encrypted and anonymous telecommunication	490
53	Fast and dense memory materials	484
54	Hyperloop and other tunnel technology	460
55	Platforms for local sharing & collaboration	451
56	Light and strong or insulating materials	440
57	Easier access to space	429
58	GMO producing substances and organs	410
59	Small particle accelerators, femto and nanolasers	400
60	Easy 3D imaging of parts	384
61	Self-organising and swarm intelligence	380
62	Crowdfunding and microfinancing	374
63	Light continuously (24/7) flying aircraft	370
64	Antibacterial and repellent surfaces	363
65	Motion-based and haptic user interface	360
66	Curing and preventing dementia	352
67	Artificial leaf and synthetic fuels	336
68	Genetic editing techniques, CRISPR/Cas9	312
69	Radical waterborne traffic	312
70	3D printing of organs and biomaterials	297
71	Nanomaterials as fibres, fabrics and reinforcement	294
72	3D printing of buildings and constructs	290
73	Smart materials and their simulation techniques	280
74	Wireless electricity transfer	279
75	LiFi networks and other LED technology	273

76	Nanoparticles and microbots in mammal body	264
77	Off-grid and microgrid solutions	240
78	Repair of organs, cell culture	224
79	Cryptocurrencies/exchange media bypassing banks	220
80	Cryogenics of biomaterials	208
81	Microbiome, metabolism and genetics of cells	205
82	New power sources for vehicles	204
83	Plasmonics and photonics	198
84	Robotic tailor	186
85	Capturing/storing solar heat, heat to electricity	176
86	Power lasers, ray guns, railguns	175
87	Cheap small fuel cell and micro-turbine CHP	162
88	Carbon capture and CO2 usage as raw material	162
89	Small fusion and fission plants	162
90	3D printing of metamaterials and compounds	161
91	Robotic insects & other biomimetics	161
92	Personal VTOL and other light aircraft	160
93	Recovery/harvesting of kinetic energy	154
94	Production of nanomaterials	144
95	Grid-level energy storage	116
96	Frictionless surfaces and levitation	108
97	Structural materials replacing concrete	104
98	Plant and animal fibres, nanocellulose	76
99	Cheap efficient storage of hydrogen	60
100	New methods for manipulating materials/substances	27

Attachment 5: Developm. rate

Ranking	Anticipated radical technology (ART)	Developm. rate
1	P2P trust solutions, blockchain	13.8
2	MyData and GDPR	13.0
3	Biotechnical meat and meat imitations	12.1
4	AI performing local work on global basis	12.0
5	Small particle accelerators, femto and nanolasers	12.0
6	Neural networks and deep learning	11.4
7	LED farming, robotic farming	10.8
8	Verbot/chatbot, talking/corresponding robots	10.0
9	AR & VR platforms and content standards	10.0
10	New separation techniques & circular economy	10.0
11	Cheap small fuel cell and micro-turbine CHP	10.0
12	Radical waterborne traffic	10.0
13	Hyperloop and other tunnel technology	9.6
14	Microbiome, metabolism and genetics of cells	9.0
15	Quantum computers and quantum communication	8.2
16	New power sources for vehicles	7.8
17	Self-organising and swarm intelligence	7.8
18	New methods for manipulating materials/substances	7.8
19	Global wireless broadband	7.2
20	Genetic editing techniques, CRISPR/Cas9	7.0
21	Cheap efficient storage of hydrogen	6.6
22	3D printing of organs and biomaterials	6.5
23	Fast and dense memory materials	6.5
24	Speech recognition/synthesis and interpreting	6.4
25	VR glasses, MR glasses and virtual reality	6.0
26	New robotised services	6.0
27	Digital art and digital experience platforms	6.0
28	New nanomaterials in electronics	6.0
29	Smart materials and their simulation techniques	6.0
30	Cryogenics of biomaterials	6.0
31	Off-grid and microgrid solutions	6.0
32	Power lasers, ray guns, railguns	5.9
33	DNA reading and writing (full genome)	5.6
34	Quadcopters and other flying drones	5.4
35	Autonomous cars and trucks	5.4

36	Radical longevity	5.3
37	M2M trade and other online commerce	5.2
38	Production of nanomaterials	5.2
39	Environment 3D scanning & positioning	5.1
40	Crowdfunding and microfinancing	5.0
41	Repair of organs, cell culture	5.0
42	Real-time 3D modelling of environment	4.8
43	Robotised physical remote work, AI as superior	4.8
44	Carbon capture and CO2 usage as raw material	4.8
45	Memristors and neural processors	4.7
46	Transportable batteries and supercapacitors	4.5
47	Nanoparticles and microbots in mammal body	4.4
48	Robotic tailor	4.4
49	Ubiquitous environment and Internet of Things	4.3
50	Encrypted and anonymous telecommunication	4.3
51	Robotic insects & other biomimetics	4.2
52	Fresh water production	4.2
53	Cyborgs uniting biology and mechatronics	4.2
54	Rapid development of photovoltaics	4.2
55	IR, THz and GHz transmitters and receivers	4.1
56	Artificial muscle and artificial skin	4.0
57	Personal VTOL and other light aircraft	3.8
58	Material scanner – hyperspectral camera	3.7
59	Pattern recognition and other AI platforms	3.6
60	3D printing of things	3.5
61	Easier access to space	3.5
62	Reading and editing thoughts from the brain	3.4
63	Walking robot and walking assists	3.4
64	Artificial leaf and synthetic fuels	3.2
65	Facial and emotion recognition and projection	3.1
66	Commercial platforms for sharing economy	2.9
67	Small fusion and fission plants	2.9
68	Personal health diagnostics systems	2.6
69	Grid-level energy storage	2.5
70	Cloud computing and storage services	2.5
71	Nanomaterials as fibres, fabrics and reinforcement	2.4
72	Structural materials replacing concrete	2.4
73	Simulating living cells, artificial cell	2.3
74	3D printing of buildings and constructs	2.2
75	Light and strong or insulating materials	2.1

76	Frictionless surfaces and levitation	2.0
77	LiFi networks and other LED technology	1.9
78	Radical growth in computing power	1.7
79	Light passenger & cargo transport vehicles	1.7
80	3D printing of metamaterials and compounds	1.4
81	Flipped learning and proficiency demonstrations	1.3
82	Smart glasses, AR glasses and augmented reality	1.2
83	Light continuously (24/7) flying aircraft	0.9
84	Modular interfaces for robot ecosystems	0.6
85	Sensitive robotic fingers and arms	0.5
86	Wireless electricity transfer	0.0
87	Curing and preventing dementia	-0.1
88	Easy 3D imaging of parts	-0.1
89	Antibacterial and repellent surfaces	-0.1
90	Gamification of collaboration and society	-0.1
91	Recovery/harvesting of kinetic energy	-0.2
92	Lab on a chip	-0.4
93	GMO producing substances and organs	-0.8
94	Plasmonics and photonics	-1.5
95	Capturing/storing solar heat, heat to electricity	-1.5
96	Motion-based and haptic user interface	-1.6
97	Cryptocurrencies/exchange media bypassing banks	-1.6
98	Plant and animal fibres, nanocellulose	-2.3
99	Platforms for local sharing & collaboration	-2.6
100	Deep learning material for expert AI	-3.3

Attachment 6: The results of the original 2013 foresight.

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
								1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20	
****	2.19 Open data and big data	4		1	1	1	446	5	3	1	3	5	3	10	5	1	5	1	5	3	3	5	1	1	10	1	10	81
****	2.13 Freely organizing remote work and organizations that form on the Internet	4		1	1	1	413	5	5	3	5	5	5	5	3	3	1		1		1	5	3	5	10	5	5	75
****	2.22 Glasses of augmented reality	4		1	1	1	391	1	5	1	#		10	5	3	3	5	1	5		3	5	3	3	3	5		71
****	2.20 Gamification	4		1	1	2	384	1	1	3	5	1	1	3	3	3			1	1		20		3	5	3	10	64
****	2.72 Extremely dense processors that take quantum phenomena into account	4	2				370	5	5	1	3	1	5	10	3	5	1	5	5	3	1	10	1	1	3	5	1	74
****	2.12 Schools in the cloud	4		1		1	325			3	3	5	5	10	5	3	5		1		1	5	3	1	5	5	5	65

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
****	2.45 Self-driving car	3		1	1	2	325	20	10		3		1			3	3		1	5	5	1	3	3	1	1	5	65
****	2.02 Biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms	3	2	1	1	1	325				3	10		5	20	5	5	1		1			5	1	1	1	1	59
****	2.56 3D printing of goods	4		1	1	2	312			10	5		1	1	3	3		5	5	1	1	3	3		5	1	5	52
****	2.28 Cloud computing	4		1	1	1	308	3	3	3	3	1	1	10	3	1	5	1	1	1		5	3	1	3	3	5	56
****	2.43 Printed cheap biosensors	3	1		1	2	305	1	5	3	1	5	1	3	5	5	10	1	10		3		1	5	1		1	61
****	2.82 Rapidly cheapening solar energy	4		1	1	2	288	1	1	3		3						5		10	5			10	5		5	48
****	2.07 Continuously monitored personal health	4			1	2	275				3	10	1	3	10	3	1		1			1	1	1	5	5	5	50
****	2.01 Routine and complete DNA sequencing	4	2		1	1	258				1	3		5	10	5	5	1	1	3		1	3		1	3	1	43
****	2.40 "Material Radar"	3			1	1	256	3	5	3	1	3	1	1	5	1	10	10	1	5	10	1	3				1	64
****	2.09 Drugs that prevent dementia	3	2		1	2	248					1		10	10	20	1								1	1	1	45

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
****	2.53 Modular robotics	3		1	1	1	248		1	5	3	5	5	1		3	1		5	1	10	1	5	1	5		3	55
****	2.89 Rapidly charging light batteries and supercapacitors	4			1	2	242	3	3		1		5	1	1	1	5		5	5	1	5	3			5		44
****	2.74 Antibacterial and other dirt repellent materials and surfaces	4	1	1	1	3	238		1	1		3	1		5	5		10		3				5				34
****	2.32 Real-time 3D modeling of the environment	3			1	1	236	10	10	1	3		5	1		1	1		1		5	5	10	3	1	1	1	59
****	2.23 Interfaces based on feeling of touch	3			1	2	225	1	3	1	5		10	3		5	1	1	5		3	5	1	1	1	3	1	50
****	2.21 Interfaces reacting on movements	4				2	220	1	5	1	3		10	3	1	3	1	1	1		1	5	1	5	1	1		44
****	2.99 Electronic money, time banks	4				1	216		3	3	3	5	1	1	3	1	1		1			5	1		10	5	5	48
****	2.70 Robotic legs and the exoskeleton that reinforces movement	4		1		2	209		1	5	1			1	1	5		1	1		5	5	3		1	5	3	38
****	2.78 Cellulose nanofiber and – microfiber	4	1		1	3	208			3		1						10	5	5		1	1	5			1	32

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
***	2.54 A walking robot with hands	3				2	204	1	5	1	5		10	5	3	3	1		1	1		3	1	5		5	1	51
***	2.30 Pattern recognition and pattern search services	4			1	1	200	5	5	3	1		1	5	1	1	5				1	5	3	1	1	1	1	40
***	2.39 Lenseless camera and image construction based on data analysis	3	1		1	2	200	5	5	1	1		1		1		3	5	5		5	3	1	1		3		40
***	2.97 Wireless transmission 2.5 terabytes per second (vortex beam)	2			1	3	200	1	1		3		1	5		1	10		1			10	1	1	5	5	5	50
***	2.04 Drugs based on genetically modified organisms	3	2	1	1	1	193				1	3		5	10	10		1					3			1	1	35
***	2.14 Human recognition systems	3				2	188	1	3	1	3		5	3	3	1	5		1			3	10	3	1	1	3	47
***	2.31 Effortless 3D imaging of parts	4		1			185		3	10	5		1	1		1		3	1			5	1		5		5	41
***	2.52 Light continuously flying equipments	3			1	2	180	1	1		1		1				5	1		1	5	1	20		1	1	1	40
***	2.17 Automatic speech recognition and translation	3	1			1	172		1	3	3		3	10	3	3	3					5	1	1	1	1	5	43
***	2.38 Cheap Lidar	4				1	171	5	5	1			5	1		1	5		1		1	5	5	1	1	1		38
***	2.91 Solar heat and long-term storage of heat	4			1	2	171			5										10				10	3		3	31
***	2.68 Artificial cell and simulating life on cell level	2	2		1	1	168				1	10		1	3	5	5	5	1	5	5		1					42

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
***	2.71 Genetically modified organisms as producers of multi-use materials	3	2			2	160			1		10						10		5	5			1				32
***	2.47 Quadcopters	4		1		1	155	1	5	1	1		5	1		1	5		1	1		1	1	5	1		1	31
***	2.16 Capturing and content searching of personal life	4				1	153	1		1	3		1	5	3	3	1		1			5	3		1	5	1	34
***	2.80 Ultralight and strong materials	3			1	2	149		1	1			1			1	3	10	5	3	1	1	1	5				33
***	2.15 Emotion management in robots and automatic recognition of emotions	3	1			1	148		3	3	5	1	5	1	1	1		1	1			5	1		3	5	1	37
***	2.61 Sensitive robot fingers and hands capable of remote work	3		1		1	148				3		1	5	3	5	1		1			10	1	3	1	3		37
***	2.24 Large haptic screens	4			1		144			1	5		1	3	3	1		3				5	1	5	1	3		32
***	2.46 1 or 2 wheeled vehicles for personal or good traffic	4				1	140	3	5	1	1		1		1	3			1	5		1	1	5			3	31
***	2.41 Cheap gas sensors	3	1			1	136		1	1	1	1	1		1	3	3	1	3	5	5		5	3				34
***	2.90 Massive storage of energy in high capacity batteries	3		1	1	2	135			3									1	10	3		1	1	5		3	27
***	2.36 Simulation and mapping of brain	3	1		1		132	1	1		1		1	10	3	5	1	1	1			5	1		1	1		33
***	2.29 Grid computing	4			1	1	130			1	1		1	1	1	1			3			3	5		3	1	5	26

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
***	2.44 Graphene based terahertz devices	3	1			1	128		3	1	1	1			1	1	5	5	1	5	5		3					32
**	2.87 Piezoelectrical energy sources, harvesting of kinetic energy	2	1		1	2	120	3	3				1		1	1	3	1	5	5		1	1	3	1	1		30
**	2.26 Thoughts monitored from brain and action based on them	3					117		1		1		5	1	3	10	1		5			5	1	1	1	3	1	39
**	2.60 Robotic surgery and other cutting of biological objects	4			1	1	115			1	3	1	5		1	10		1				1						23
**	2.98 Multi-channel communication and software-based controlling of information networks	3			1	2	113	1	1		1		1	1	1	1	1		1		1	5	1		1	3	5	25
**	2.51 CubeSat and other minisatellites	4			1	1	110				1		1				5	3		1	5	1	3		1		1	22
**	2.06 Longer life time and slower aging processes	2	2			1	105					5		3	10	5						1		3	1	1	1	30
**	2.57 3D printing of buildings	2				2	105			5	5		1					10		1	1	1		5	1		5	35
**	2.93 Wireless electricity transmission (magnetism) for electric cars and other electrical devices	4				1	104	1	1				1				1		10	5	3			1				23
**	2.08 Brain implants that restore or develop brain functions	2	1			1	102				1		1	5	10	10	1		1			1	1	1	1	1		34

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
**	2.77 Nanocarbon as a reinforcement or as functional surface	3	1		1	2	100			1						1	1	5	5			1	1	5				20
**	2.27 Flexible and transparent screens using cheap materials	3	1		1	1	99	1					5	1			1	1	5	1	1	5		1				22
**	2.83 Efficient and light solar panels	2		1		1	99		1		1		1		1	1	3	3	5	5	5	1	3	1	1	1		33
**	2.85 The production of biofuels using enzymes, bacteria or algae	3			1	3	95	1	1	1								5		5	5		1					19
**	2.25 Digital mirror	3					93			3	#		1	1	1							5		5		5		31
**	2.35 Universal memory based on new materials and solutions	3		1		1	92			1	1			5	1	3	1	1	1	1		5	1		1	1		23
**	2.65 Artificial muscles	3			1	2	90		1	1	1		1		1	5	1	1	5		1	1		1				20
**	2.34 Predictive analytics based on self-organizing data	3				1	81	1	3	1	1	1	1	1		1	5		1		1	1	1	1	1	1	1	23
**	2.100 Internet for robots	3			1		81			1	1	1	3	3	1	1	3	1	1			3	3		1			23
**	2.42 Very sensitive camera sensors based on nanocarbons	3	1		1	2	80	1	1		1		1				5	1	3		1	1	1					16
**	2.75 Carbon nanotube yarn or thread	3	1		1	2	80											5	5	1	1		3	1				16
**	2.86 Flying wind power and other new ways to produce wind energy	3			1	1	80											1	5	5	5			3			1	20

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
**	2.58 3D and 4D printing of material	2			1	1	75			5	5	1			1	1		5	3	1		1	1				1	25
**	2.81 Spray-on textiles	3				1	74			5	1				1	1		5				3		3	1	1		21
**	2.18 Crowd funding and micro finance	4		1			72			1	1								1	1	1	1			5		5	16
**	2.10 Repairing and regrowing of human organs, (stem) cell cultivation	2	2			1	70					1		5	3	10		1										20
*	2.33 Self-organizing virtual world from the 3D data of the Internet	4				1	68											5		5				5				15
*	2.73 New building materials that replace reinforced concrete	2				1	68	1	1	1	1		1	5			5		1			3	3		3	1	1	27
*	2.03 Small portable magnetic resonance imaging scanner	3	1		1	1	63					1			1	5		1	3				3					14
*	2.05 Nanorobots (nanobots) in the health promotion	3				1	63			1				1	1	1	5	1			5		1	1	1			18
*	2.84 Artificial leaf and synthetic fuel from the sun light and carbon dioxide	3				2	60				1		1	1		1	3		5			1		1		1		15
*	2.96 LED "radio"	3					60			1		1						3	3	5	1	1	1	3			1	20
*	2.88 Serial production of small nuclear reactors, fission and fusion	3			1	1	56			1										5	5		3					14

		Maturity 1-4	Academic significance 0-2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0-3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
*	2.50 Magnetic or superconductor based levitation	4	1		1		55	1										1		5			3	1				11
*	2.48 On-demand personal aviation services	3			1	1	44	1	1		1		1				1		1	1		1	3					11
*	2.76 Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons	2	2		1	1	44					1			1			5		1	1			1			1	11
*	2.64 Biobots	2				1	40			1		1			5	5	1						3					16
*	2.63 Nanosurfaces that convert air moisture to water	3					39					1			1					1	1		1	3			5	13
*	2.37 Quantum computers	3	1				39			1	1		1				1	1	1	1		1	3					11
*	2.59 3D printing of organs	2			1	2	39			3	1	1				3		1				1				1		11
*	2.62 Robo-tailoring	2					34			5	3		1					1	1			1			1	3	1	17
*	2.55 The cyber insect	2				1	33				1	1	1				5	1				1	3					13
*	2.11 Synthetic cartilage in human joints	4					32		1				1					1		1	1		3					8
*	2.94 High-performance lasers, wireless power transfer, laser weapons	3			1	1	32						1		1	5		1										8

		Maturity 1-4	Academic significance 0 -2	Extent of independent R&D-paths 0-1	Finnish competence 0-1	Finnish access 0 -3	Score	Automation of passenger vehicle traffic	Automation of commodity transport	Manufacturing close to customers	Virtualisation of retail trade and services	Local or functional food	Distance presence and remote control of tools	Individualisation of learning and guidance	Self-care based and personalized healthcare.	New capabilities for those who have lost their functional	Equipment that increases awareness of the environment	Functional materials and new material technologies	Functional added value of intelligent goods	Sustainable energy technologies	Raw materials from untapped areas of the Earth and space	Participatory forms of entertainment, culture and	National defence and antiterrorism	Functionalization of spaces and structures	I Operation models for self-organising communities	Virtualisation of identities and social structures	Democracy, freedom and social cohesion	Total score 1.1.-1.20
*	2.66 Artificial, self-renewing skin	3					30			1	1			1	1		1	1	1			1	1			1		10
*	2.67 DNA memory	2	1			1	30		1				1			1	3	1	1			1		1				10
*	2.69 In-vitro meat and meat-like plant protein	2			1	1	27				1	5								1						1	1	9
*	2.92 Inexpensive storage of hydrogen in nanostructures	1	2				26	1	1	1			1					1	1	5	1				1			13
*	2.95 Nanoradio	1				1	24					1		1	1	1	3	1	5			1	1			1		16
*	2.49 High-performance lasers, wireless power transfer, laser weapons	2					20	3	1											5	1							10
*	2.79 Materials that levitate on nanolevel	1					3											1	1				1					3
	Total significance score	x						101	137	136	160	116	157	189	188	222	188	177	178	166	141	227	184	157	135	123	145	3227

Attachment 7: Sources of the ARTs and links to crowdsourced discussions

This section is only attached to the Finnish digital version of the report, as the crowdsourced discussions are in Finnish:

https://www.eduskunta.fi/FI/tietoaeduskunnasta/julkaisut/Documents/tuvj_1+2018.pdf

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