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100 OPPORTUNITIES FOR FINLAND AND THE WORLD

Radical Technology Inquirer (RTI) for anticipation/ evaluation of technological breakthroughs

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From the original Finnish book written by Risto Linturi,
Osmo Kuusi and Toni Ahlqvist (2013)"Suomen 100 uutta mahdollisuutta".

Translated, updated and edited by Osmo Kuusi and Anna-Leena Vasamo

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Content

Preface of the English edition

Dear Readers,

This book is the English edition of the Finnish report "Suomen 100 uutta mahdollisuutta" made by Risto Linturi, Osmo Kuusi and Toni Ahlqvist. The original report was published in 2013. The English edition is written especially for readers and potential users of the Radical Technology Inquirer outside Finland though also Finnish readers can benefit especially from the updated descriptions of the radical technological solutions. The English edition is edited, translated and updated by Dr. Osmo Kuusi and doctoral student Anna-Leena Vasamo.

In the translated preface of the Finnish edition, I introduced the Radical Technology Inquirer to the Finnish readers. I hope that the English edition will help to realize those great prospects that I presented in the Finnish preface concerning the value of the tool. The themes of the five chapters are similar in both language editions. However, the English edition uses less space for the Finnish pilot study and is specific for Finland's economic or political conclusions. Instead, this edition is more focused on methodological features of the Inquirer and how EU countries looking for technological strengths and various kinds of other actors e.g. companies can benefit from the tool.

The greatest differences in the contents of the English edition and the Finnish edition are in the Chapter 3 and in the concluding Chapter 5. The Chapter 3 just introduces basic evaluation principles of national skills and national access to the markets of Radical Technological Solutions. The Finland specific evaluations are not described. The concluding Chapter 5 does not discuss megatrends that were identified in order to check the Global Value Producing Networks (GVPNs). In practice, the megatrends were not used in the selection of the GVPNs.

In the preface of the Finnish edition, I pinpointed the Finland specific action proposals of the report. In the Chapter 5 of the English edition, Finland specific proposals are replaced by possible benefits that the international community can get from the Inquirer. I think that the whole EU, EU countries, European companies and other European actors could

benefit much from the Inquirer. The Committee for Future has already informed technology assessment units of the parliaments of EU countries (the EPTA-network) about the Inquirer. A suitable way to update internationally the Inquirer and promote its use on national level is a project financed by EU. For example, a project financed in the Horizon 2020 program might be a good choice for Europe.

I like to end this preface of the English edition as I ended the preface of the Finnish edition.

”The journey is just beginning!”

Ville Vähämäki
Member of the Parliament of Finland (the Finns Party Parliamentary Group),
Chair of the Radical Technologies section of the Committee for the Future

Preface of the Finnish report

Dear Readers,

You are holding a study of the radical technologies of the future commissioned by the Parliament of Finland's Committee for the Future. In this preface, I am going to give grounds to why this study is exceptional by European, and perhaps even global, standards. I will also justify why this report is worth reading and how it should be read and interpreted.

This study is meant for everyone interested in the future, whether the reader is an enlightened citizen, a researcher, an entrepreneur, or an investor looking for new investment opportunities. In this preface, my purpose is not to discuss the results of our research in a very profound manner, but to give a clear overview of what we have done. In order for me to be able to justify the value of our research, and especially to be able to compare it with other similar studies, I am going to have to use a slightly deeper analysis in the following paragraphs.

In Finland, no preceding model exists for national level evaluation of emerging radical technologies on a similar scale. In our study, we will discuss one hundred new technologies in the context of altogether twenty different value-producing networks. By value-producing networks, we mean such clusters of demand and areas of change that have been created by global megatrends and the needs of citizens. In addition, a four-level model has been created for scoring different radical technologies in order to be able to organize them into different types of listings. Indeed, this organizing of the technologies in order of priority is the most important value added by our research.

Almost anyone can make different kinds of listings of the most important technologies, but hardly anyone is able to explain why one technology is more important than the other or which criteria has been used to form the listing. Another important added value of our method is that we can also arrange the technologies from the perspectives of different value-producing networks. In practice, the one and the same technology can be used for many different purposes, and the same technology can have an impact in several value-producing networks. In addition, we can arrange the technologies in a way that allows us to see which technology sectors are in need of more sales promotion, where we need more research and product development, or which technology sectors require more support via domestic pilots. This has been evaluated by examining the radical technologies from the perspective of Finland's export clusters. We give our policy recommendations that support the growth of the economy and exports in Chapter 5.3. The impatient reader might want to skip directly to that chapter. [1]

[1] In the Chapter 5 of the English edition, the Finland specific conclusions of 5.3. are replaced by the discussion about the potential benefits that the international community might get from the Inquirer.

With our method, different promising radical technologies can be arranged into a priority order based on their anticipated promises. While comparing other similar technology listings, which have been made in abundance around the world, one can note that the criteria that have been used to create those listings cannot necessarily withstand closer scientific scrutiny. Some of the listings may have been made purely for the sake of entertainment. Other listings, in turn, may stress the interests of their authors. As the most important notion regarding the listings made by other instances, I will note that almost without exception, these listings mix together technologies, which are in different stages of development, making their comparison impossible. Our four-level model, in turn, separates technologies, which are in different stages of development, and the added information drawn from this is a key factor in evaluating what political actions are required to advance the different technologies. Some technologies are barely on the desks of researchers, others are already tested and piloted, while some technologies are about to be commercialized as new products. Therefore, an important added value of our research is that we have created a model with which different technologies can be listed in an order of priority. Going forward, our model can be developed and improved in order to get even better and more accurate results in the future.

Next, a few words about the birth of the four-level model of radical technologies: the main research question of our study was how we could find the radical innovations and technologies of the future. I also set a staggering challenge to find and create a tool with which technologies could be organized automatically. I was especially interested in being able to search for emerging technologies in such a listing, as long as the list is updated at regular intervals. Finland's leading researchers in the field of technology foresight, namely Mr. Osmo Kuusi, Mr. Risto Linturi, and Mr. Toni Ahlqvist, were selected as the team of experts. When the contribution of the Committee for the Future's Permanent Expert, Mr. Olli Hietanen, was included, it was clear that our team was highly qualified by international standards as well.

The four-level model has been developed little by little and in many different phases. The first step was to create the model, which at the time was a three-level model, were taken already in 2012 while making the intermittent report by Mr. Osmo Kuusi called "Radical technological solutions of the future". The framework for the radical technology model took shape on the whiteboard over several discussions. It wasn't until this project, however, that the actual modeling exercise begun. The preliminary study and the consequent project combined the thinking of different people, research institutes, and the Committee for the Future in a creative way. The model developed piece by piece. The three-level model became a four-level model, and who knows if additional levels will appear in the future. The main features of the four-level model are described in the summary of the report.

Chapter 1 describes twenty value-producing networks, which are considered as the most important for Finland's future. A value-producing network describes an area of societal and technological change, which is based on worldwide needs. We estimate that by 2030, people and organizations will fulfill most of their needs through these twenty value-producing networks. The question of which value-producing network will grow largest is not essential in terms of Finland's exports, because the size of each value-producing network is sufficiently large for even a small market share to be significant for Finland. By getting acquainted with the value-producing networks selected for the study, the reader

will get a very good view of the technology development of the future. For each value-producing network, we'll go through the current situation and its expenses, the new operating model with its savings, the maturity of technological development, challenges of the transition period, legal and structural barriers, and the potential threats of the new technology.

Chapter 2 describes the one hundred selected technological areas or solutions which might develop into world-changing products or services. These most promising radical technological solutions have to be available by 2020, at the latest. This would indicate that the impact of these technologies could be vast by the year 2030. A key observation of our study is that when technologies are compared with each other, it is important also to evaluate the maturity of these technologies. For each technology, we give a short introduction referring to open internet sources, present the recent vanguard products or inventions, application areas, levels of market development and scientific interest, as well as the connections to the value-producing networks and export networks. The one hundred technologies have been divided into eleven groups, which are: control of metabolism of human beings and other organisms, social innovations, human-machine interface technologies, algorithms and systemic solutions based on the information technology, measuring and imaging, movement and transportation, robots, mimicking of nature and cyborgs, essential enabling materials and industrial raw materials, energy technology, and messaging technologies and protocols. Hence, the enlightened reader may study the radical technologies of the future per group, according to his or her own interests. For the reader interested in a specific technology or theme, it might be worth noting, however, that many of the technologies presented in Chapter 2 could belong under several different groups, even though they have been listed in only one group for this report's presentational reasons.

The third level of our four-level model, which focuses on the customer knowledge in different export areas, is described in Chapter 3. This level reduces the view with which we could evaluate the entire field of radical technologies in such a way that we examine the potential of the technologies for the Finnish export sector especially from the point of view of customer knowledge. Indeed, the key notion of our model is that, when considering radical technologies, one must press how easy it is for Finnish actors to access the clientbase of the new technologies. In this chapter, we describe the most significant existing networks, through which we can commercialize technologies that produce value to the previously described areas more efficiently than potential competing countries. In addition, we describe the areas of our export industries, in which our leading position can suffer if our competitors adopt important, value-producing technologies faster than we do.

Chapter 4 describes the possibilities that scientific basic research opens for technological breakthroughs. In the past, the breakthroughs of basic scientific research have shown as technical breakthroughs with quite a long delay. Our four-level model describes the non-linear impact of basic research both on the level of the radical technologies as well as on the level of global value-producing networks. Considering the level of radical technologies, the advancement of science is a very essential factor that causes changes. In most cases, it takes years or even decades from the time of a scientific breakthrough before the first applications come on the market. A key observation made in this study is that attempts should be made to shorten this delay by increasing the communication between researchers and the appliers of technology. In Chapter 4, the "hottest" fields of science

globally are also presented. By examining the changes in these heat maps annually; one can observe how the centers of gravity in basic research are changing over time. Because basic research impacts radical technologies with a delay, the changes in basic research have to be examined going back even ten years into history.

The conclusions and results of the report and the correspondent policy recommendations are presented in Chapter 5[2]. In this preface, I have already gone through some of the conclusions and the chapter is very short, so the impatient reader can easily read the whole chapter. The chapter includes our most important notions, which have risen during the making of the research. The essential foresight policy recommendations will be made later by the Committee for the Future, when responding to the Government Report on the Future published in autumn 2013.[3]

In my view, the most important targets for future development are the development of the model that was created as a result of the report, as well as the updating of the calculation matrix. Due to the rapid development of radical technologies, I can note that although our research is absolutely right at this point in time, it will most certainly be wrong in a half a year or one year. Therefore, this type of research requires continuous updating. One option could be to open a website, on which all this material with its hyperlinks would be uploaded. Through the website a citizen could also suggest new radical technologies and give estimations on why this particular technology is important.

I want to express my gratitude to the members of the working group, namely Mr. Risto Linturi, Mr. Osmo Kuusi, and Mr. Toni Ahlqvist. Instructing this work has been a pleasure and it has been great to see how excited and dedicated you have been to this cause. The value of this work will increase in the future, and you have written such a report that will be read years from now. I thank Mrs. Päivi Lipponen, Chair of the Committee for the Future, for her encouragement and for creating a great atmosphere within the entire Committee for the Future. At the same time, I thank the entire Committee for the Future, as well as Dr. Paula Tiihonen, Committee Councellor of the Committee for the Future, and Mr. Olli Hietanen, Permanent Expert of the Committee for the Future.

"The journey is just beginning!"

Ville Vähämäki,
Member of the Parliament of Finland (the Finns Party Parliamentary Group),
Chair of the Radical Technologies section of the Committee for the Future

[2] In the English edition, the Finland specific conclusions are replaced by the discussion about the potential benefits that the international community might get from the Inquirer.
[3] In its response statement in autumn 2014, the Committee for the Future made its recommendations.

Introduction and Main Features of the Inquirer

Since 1990s, the Committee for the Future of the Finnish Parliament ("Eduskunta") has anticipated and evaluated the social impacts of new technologies. These technology assessment activities have benefited much from the international cooperation and especially on common activities of the EPTA (European Parliamentary Technology Assessment network) The new anticipation/evaluation method or the new tool can be seen on the one hand as a continuation of the earlier activities of the Committee and on the other hand as a new approach.

Based on the idea of MP Ville Vähämäki and the preliminary study made by Osmo Kuusi, the Committee for the Future started the development effort of the tool in spring 2013. The tool was developed by three researchers with long and broad expertise in technology foresight and assessment: Risto Linturi (Sovelto Ltd.), Osmo Kuusi (What Futures Ltd.) and Toni Ahlqvist (VTT, Technical Research Centre of Finland).

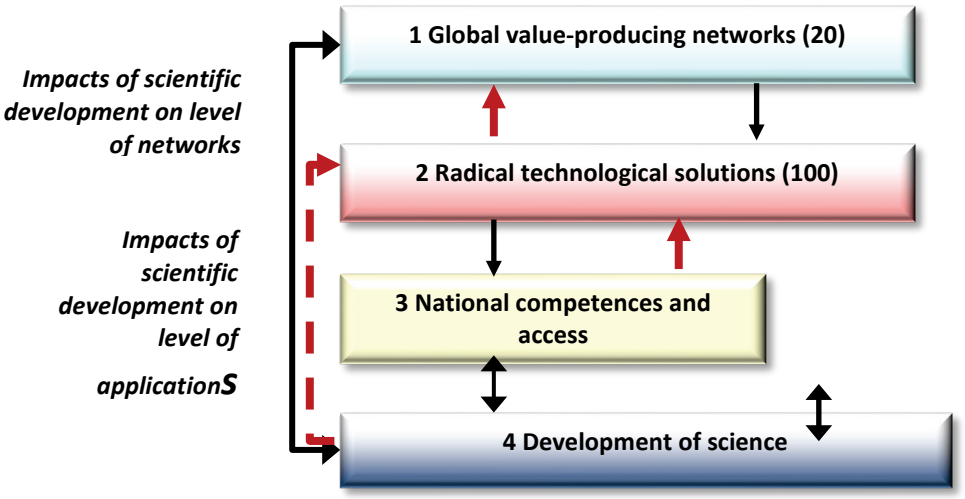
The Radical Technology Inquirer is based on systematic study of open data sources of the Internet, evaluations of experts and crowdsourcing. The first list of 100 promising technological solutions was found based on facilitated Facebook discussion. About 600 persons have registered to the discussion pages. About 100 activists have suggested promising Internet sources of technological breakthroughs. Like extensive technology Delphi studies of NISTEP in Japan (http://www.nistep.go.jp/en/)
or the first cycle of BMBF Foresight 2007-2009 in Germany
(http://www.isi.fraunhofer.de/isi-wAssets/docs/v/de/publikationen/07_Dritter_Bericht_Teil-II_englisch.pdf), the Inquirer provides an expert based whole picture of future possible promising technological developments. Besides the "technology push" approach of those studies, the Inquirer includes also "demand pull" side. It is given by "Global Value-producing Networks"(GVPNs). A basic feature of the tool is the flexible use of information that makes the updating of the Inquirer easier. The expert information and expert judgments are complemented with rich information of Internet sources. On the other hand, the Inquirer is more systematic in the selection and evaluation of promising technological options than e.g. the Top Ten lists of the MIT Technology Review
(http://www.technologyreview.com/).

The main elements of the method/tool are illustrated in the picture 1. Its key elements are global value-producing networks (20) and promising radical technological solutions or breakthroughs (100). The idea is to evaluate any emerging technological breakthrough based on the anticipated values of 25 indicators: anticipated impacts on the 20 global value-producing networks (possible impact values 20,10,5,3,1) ; the anticipated maturity of the breakthrough 2020-2030 (values 1-4); the scientific promise of breakthrough technologies (0-2); breakthrough focused global market R&D activity (0-1) ; (Finnish) national competence in the breakthrough (0-1); and national access to relevant application areas of the breakthrough (0-3). Red arrows in the picture 1 illustrate these ways to evaluate radical technological solutions. Potentially important connections that the model does not take into account explicitly are illustrated with black arrows.

Based on 25 indicators, a list of 100 most promising technological breakthroughs was built. The most promising 25 get ****, the next 25 ***, the next 25 ** and the rest ones *. A bit simplifying, the star status is based on the sum of the impacts on the 20 global value-producing networks that is multiplied with the sum of the values of the other indicators. The pilot evaluations and the implied level list of solutions were made by the authors of the pilot project and the scientific adviser of the Committee for the Future Olli Hietanen. The impacts on the 20 global value-producing networks were ad hoc judgments of four evaluators. The evaluations of the scientific promises of the technological breakthroughs are based on the Science Maps of the Japanese NISTEP institute (www.nistep.go.jp/HP_E/researchworks/...sciencemap/index.html). The evaluations of global market R&D activity are based e.g. on the recent patenting. The exel-table of the appendix illustrates the evaluation method showing how 100 radical technological solutions are evaluated to the four stars groups.

The key idea of the Inquirer is that the list of 100 most promising technological solutions is continuously challenged based on most recent developments. The challenge can happen from the generic perspective or for example from the point of view of technology portfolio of some company. There will be a comparative stable generic "basic list" and from various perspectives made special lists. In the generic evaluation of the pilot study, the perspective is global in anticipated impacts on the 20 global value-producing networks, in the maturity of the breakthrough 2020-2030, in the scientific promise and in R&D activity. The competence and access indicators are actor dependent even in the generic evaluation. Because the first application of the method was built for the use of the Finnish national technology and science policy, evaluations are made based on Finnish national competences and Finnish national access.

Figure 1. Four levels of the generic evaluations of the pilot study



1 Global Value-producing Networks (GVPNs)

The global value-producing networks (GVPNs) are perhaps the most innovative element of the Inquirer. They combine emerging technological possibilities and customers' needs or their potential demands in 20 clusters. In the Finnish pilot study, their key features are defined as follows:

1. A global value-producing network describes an area of technological and societal change based on global demands. The global value-producing networks have been chosen from a Western perspective, which is familiar to Finns. In the pilot study, the economic or social impacts of the networks have been described using the impact figures on the Finnish economy. The figures anticipate possible savings or welfare impacts in the Finnish home market as well as the potential in the Finnish export markets. Besides Finland, the figures also indicate the relative importance of the value chains in similar developed countries.
2. Because of the big global market, the exact size of the global market is not relevant from the point of view of an economy the size of Finland. The export potential of a network for Finland might be great even if the global market related to the network is not especially large on global scale. The total size of each selected global value-producing network is so large that a niche in the value-producing network can be highly significant for a small country like Finland.
3. Though the twenty global value-producing networks are selected especially from the Finnish perspective the authors of the pilot study anticipated that by 2030, people and organisations worldwide will satisfy most of their demands or welfare producing activities through them.

Some global value-producing networks resemble industries. However, organisations and individuals participate in many global value-producing networks simultaneously, and the idea that an organization or its activity belongs just to one global value-producing network does not apply here. The global value-producing networks aim to comprehensively cover all aspects of life and society, but the areas of biggest volatility i.e. probable big change have been highlighted in the descriptions.

In this English edition like in the Finnish edition, any GVPN has got a description of 1-3 pages. At first, the current state of the value-producing network is described from the perspective of a country like Finland and its people. Next is anticipated what will be the promising new operating model that the new technological development will open. The possible savings and added value created by the new operating model are discussed as well as challenges of the transfer period. The introduction of GVPN also discusses the threats of the emerging global value-producing network and how to prepare for them. The English names of 20 networks are the following:

1. Automation of passenger vehicle traffic
2. Automation of commodity transport
3. Manufacturing close to customers

4. Virtualisation of retail trade and services
5. Local or functional food
6. Distance presence and remote control of tools
7. Individualisation of learning and guidance
8. Self-care based and personalized healthcare
9. New capabilities for those who have lost their functional health
10. Equipment that increases awareness of the environment
11. Functional materials and new material technologies
12. Functional added value of intelligent goods
13. Sustainable energy technologies
14. Raw materials from untapped areas of the Earth and space
15. Participatory forms of entertainment, culture and influence
16. National defence and antiterrorism
17. Functionalization of spaces and structures
18. Operation models for self-organising communities
19. Virtualisation of identities and social structures
20. Democracy, freedom and social cohesion

In the English translations of the 20 global value-producing networks, we use the four-level indexing system of the Figure 1.

1.1. Automation of passenger vehicle traffic

Current situation and its expenses: Passenger car traffic makes up the majority of passenger vehicle kilometres and expenses. There are nearly three million passenger cars in Finland and the annual average of passenger vehicle kilometres is 17,000 kms. Passenger cars account for a significant, quickly depreciating part of national wealth, which is very inefficient use. Calculation using the current total kilometres driven, the expense per vehicle kilometre is 0,45€ and the total expense of the equipment is 20 billion euro per year, as per the tax authorities. The average number of passengers per car on the road is 1.2. If the average speed is 50 km/h approximately 700 million hours are spent driving, part of which is for work time and part of which is for leisure time. In new urban areas, the cost of a parking spot is calculated as 40–80,000 euros and one car may require several parking spots. According to research, the annual cost of collisions is estimated to be approximately two billion euros.

New operating model with its savings: Communal, driverless robotic cars are preferred in passenger vehicle traffic. As a service integrated with public transportation, about a million robot cars would be enough to guarantee that everyone who needs a car would get

one to their door in less than three minutes even during the rush hours. The utilization rate of the equipment would improve and using the figures of the tax authorities, about one third of the costs would be cut. According to estimations, robotic cars don't cause collisions in the same way as humans do, and nowadays only 10% of all accidents are caused by technology. The main costs to society that results from the retention of cars are cut and the urban structures are improved. Transportation subsidies paid by municipalities are dramatically decreased. The time spent driving is freed up for more efficient or entertaining uses. The resulting savings would be approximately 10–20 billion euros annually in Finland, and furthermore, the operating model has a significant effect on increasing regional and other kind of equality as well as individual freedom.

How the technological maturity is developing: Experts and manufacturing companies themselves estimate that driverless traffic will be technologically ready for mass production by 2020. Among others, Audi, BMW, Continental, GM, Google, Mercedes, Nissan, Toyota and Volvo are developing and testing the technology. Many of the features of the robotic car are already available in new car models. Fully automated test cars have driven about one million kilometres in normal traffic without collisions.

Challenges of the transfer period: Robotic cars have been designed to move among normal traffic, so there are no technical problems in the transfer period. However, getting used to riding in a robotic car will take time. Zoning, urban planning and road planning as well as education and public transportation investments should account for the changes in order to avoid expensive investment mistakes. For example, new parking buildings and garages are zoned continuously, even though the buildings are going to be finished only after the new technology is estimated to be in use.

Legislative/structural barriers: At the moment, the Finnish law restricts the use of a driverless passenger car on streets and motorways. In the USA, many states have already revised their legislation to allow experiments, but for now a person with a driver's licence is required to sit in front of the controls. In order for communal cars to be available to everyone inexpensively, the division between car rentals, taxi traffic and public transportation should be revised, unless the driverless car is regarded as a normal rental car, which would not require a taxi permit. The liability issues related to driverless cars should be solved in such a way that directs the incentive to the stakeholder that has the best possibility to avoid the problems.

Threats of the new technology: If the technology matures and becomes available to car dealerships without collective preparation by the society, traffic and the costs and detriments related to it will increase. If new technologies are not regulated, chances of vandalism and risks of terrorism will increase.

1.2. Automation of commodity transport

Current situation and its expenses: According to the Confederation of Finnish Industries (EK), the costs of logistics in Finland are approximately 30 billion euro per year. The share of logistics in total production costs is double compared to the rest of Europe. The logistics cost is a burden both for the Finnish exports and the home market.

In addition, citizens spend a significant share of their time picking up goods from stores. This adds to overall vehicle kilometres travelled and increases the need for parking spaces.

New operating model with its savings: The loading, unloading and distribution of goods can be handled with robotics, in case the goods are transported in automatically movable and loadable boxes. The standardization of small containers eases automation. When the loading and unloading are automated, intermodal transportation becomes easier and the most efficient method of transfer can be used on each leg of the transit.

More direct routes can be used to deliver e-commerce goods to most people's home or to a robotic distribution centre at a walking distance. The possibility to remote control the selection and loading of goods will save much time that consumers and businesses now spend picking up goods.

The time saved by citizens can easily rise to one million hours per year. The urban city structure will become renewed and more efficient. Savings in working hours can realistically be several tens of thousands of man-years, and the savings from equipment and traffic optimisation as well as faster inventory turnover and improved quality can rise to more than a billion euro. The reforms would bring several billions of extra value annually.

How the technological maturity is developing: Robotic containers are manufactured in Finland by KoneCranes, among others. The lifting and transfer of containers can be automated by current technology as can be the loading and unloading of shipments that include standard sized boxes and boxes that fit inside them. Robotic transportation already functions reliably enough in closed areas and experiments on public roads have begun in several countries. Many companies already have automated warehouses and assembly lines, in which packing and loading are automated.

Challenges of the transfer period: Intermodal transportation is poorly developed in Finland. A large part of goods arrive in Finland in trucks on ro-ro ships, and their unloading and redistribution happen in distribution centres that are not connected to railways. Retail uses non-stackable euro pallets in transfer of goods. There are several actors in the logistics chain, and the reform will not start easily through the market mechanism alone.

One of the most promising paths for the reform could be a combination of an online store and an automated brick and mortar distribution centre, or distribution near homes organised by shopping centres. Posti, the Finnish postal and logistics service company, is already in process of automating the pick-up points of goods, but the readiness to robotic distribution hasn't been taken into account. A need for the relocation of workforce is related to the transfer period as the number of professional drivers decreases.

Legislative/structural barriers: Robotic distribution centres are an infrastructural system that requires actions from zoning officials. The creation of a unified system requires either a large operator or standardization. For the time being, robotic traffic is not allowed on public roads according to the law. Liability issues related to new policies must be solved.

Threats of the new technology: If logistics becomes handled by robots in a large scale, it must be ensured that there are no system-wide vulnerabilities, and that no single chain of events can hurt the central operating mechanisms of the society. Only local risks are acceptable.

1.3. Manufacturing close to the customer and the revolution of industrial structures

Current situation and its expenses: Manufacturing, transportation and trading services of goods comprise nearly half of Finland's GDP. The costs include the development, manufacturing, warehousing, importing, distribution, marketing of goods as well as related administration and training, among other factors. Currently, manufacturing is mostly based on economies of scale, where the development costs are combined with investments in manufacturing machinery and large production batches. Spatial concentration and continuous specialization of industrial manufacturing have increased the costs of logistics and, simultaneously, increased search costs. In addition, the share of transaction costs has increased, even though the mechanisms of transactions and logistics have become more efficient.

New operating model with its savings: Robotisation brings flexibility to production lines. A robot can produce even individualized products efficiently and serial production can be distributed. In 3D printing, a model can be downloaded off the Internet and, taken to the extreme, a functional product can be printed at home. However, printing of products will most likely increase faster at shopping centres, hardware stores and express production services, health care centres, special stores and repair services, rather than at homes.

Industrial serial production of goods will be replaced part by part with a model of distributed production, where the product is produced closer to the user and in an individualized manner. Savings will come from reduced transaction and capital costs as well as from the removal of the costs of rigid production structures. New added value is created through individuality, positive local employment effects, energy and material efficiency as well as larger product ranges and improved accuracy in matching customer needs.

Rapid production is estimated to have substantial near-future impacts on the structures of medical science, manufacturing, building and food industry, retail and logistics. The size of the industry is estimated to grow to over one thousand billion euro, of which Finland's share would be several billions. Impacts on the structures of Finnish industries and retail can grow significantly beyond this, even surpassing the current commercial and human impacts of the Internet by 2030.

Individualized production, which does not rely on economies of scale, is also related to energy production. In individualized production, it is possible to optimize energy use according to the availability and cost of energy as well as to use self-produced energy.

How the technological maturity is developing: With 3D printing, goods can be printed close to the consumer. There are also other technologies that make manufacturing close to the consumer possible. Production of casted moulds is already well mastered, as well as that of small plastic objects, jewellery, prosthesis and medical instruments, and several tools. There are still both quality and competitiveness challenges related to the printing of larger plastic objects, demanding surfaces and materials such as metals. Printing of ceramic objects and even large structures is advancing rapidly at the moment, as well as printing of electronics and biological and biocompatible materials for use in medical science. With the help of nano pulp and other new materials, 3D printing can become a significant manufacturing method relatively quickly. This is influenced by the flexibility of the technology as well as the low capital cost of the equipment.

Challenges of the transfer period: Rapid manufacturing is a tool of manufacturing close to the customer that first and foremost grows the home market as well as improves the balance of trade through decreased imports. The actors, who would benefit the most from rapid manufacturing, are relatively dispersed and traditional, and they are not used to product development. Typical problems that accompany structural changes can be expected as rapid manufacturing transforms the structures of retail and industries. However, these problems will only worsen if tension is built due to slow progress. Rapid manufacturing is not yet largely understood in Finland and the whole industrial paradigm change has been discussed too little. Issues related to the old industrial paradigm are still seen as being of most importance.

Legislative/structural barriers: There are no actual legal barriers to rapid manufacturing and individualized manufacturing but product liabilities should be redefined in relation to changes in operating models as rapid manufacturing diffuses further. Rapid manufacturing eases piracy, taking it back to the early decades of the patent system and the current legislation seems functional to handle that. As the United States government believes strongly that rapid manufacturing will return jobs from China to USA, it is not likely that the United States would impose stricter laws to the use of 3D printers.

Threats of the new technology: The biggest threats to Finland are related to the diffusion of the prosumer concept in our customer base and home market without our industry and retail sector reacting to it. Other threats can be inept users using rapid manufacturing machinery to produce products and parts that will cause accidents. As the manufacturing becomes easier, printing of purposefully harmful objects will also be a threat, including the production of dangerous substances and biomaterials.

1.4. Virtualisation of retail trade and services

Current situation and its expenses: Each year Finns spend over three hundred million hours travelling to services and retail stores. The location of retail stores and services has a big impact on the urban environment and transportation system. Location impacts the value of the urban environment and it's being directed by land use planning and zoning.

Retail stores and services account for about 10 per cent of GDP in Finland. The goods are transported to the stores from wholesale firms' logistics centres, where goods arriving from the manufacturers are sorted into cargo loads that are delivered to retail and specialty stores.

The total volume of online shopping is nearing the turnover of retail trade and was already 10 billion euro in 2011. However, in 2011 Finns bought only two billion euro worth of goods from online shops.

A significant portion of all services is immaterial over-the-counter services. Following the service reform of the banking industry, a large part of the over-the-counter services of the private sector have been automated. On the contrary, automation of the public sector's services has proceeded slowly. In addition, the public sector spends a significant amount of resources on transporting citizens to services using taxi transport. According to the Finnish Transport Agency, the subvention of taxi transport is almost as large as the subvention of that of the entire bus transportation.

Majority of the automated services are ones in which the client fills in a self-service form or with which information is gathered. Consultative services and services which include measurements or selection have not been virtualised, although phone services have been widely automated.

New operating model with its savings: Opportunities for the use of online stores and virtualised services are increased in the new operating model. In the trade of goods, the search and selection phases are altered to resemble a normal shopping experience through virtual reality. For example, one can use a virtual mirror to look at clothes and the goods can be picked up from virtual shelves in a normal manner. The virtual store can be located in the home or at the corner shop, which is equipped with, for example, a larger display and measurement devices.

Instead of the post office, goods ordered from online stores are delivered to a robotic distribution automat at a walking distance. The Finnish logistics firm Posti has already opened 294 package delivery automats and aims to increase the amount to 1500 by the year 2016.

Services are nearing the use experience of over-the-counter services, where a customer service assistant can look at a common form and discuss the problem interactively. If the service requires measuring or fitting, the user will be delivered the technology with which the required information can be gathered and delivered to the service provider.

Savings are accrued from the decreased travel time, reduction of the size of parking spaces, service spaces, and physical store spaces, increased assortment, and geographical

distribution. Services can be offered where workforce is easily attainable and one doesn't have to travel to consume the services. In totality, a much larger entity than the current online trade is being discussed. The savings effect and impact on people's everyday life is also much more significant compared to the automation of the banking industry.

How the technological maturity is developing: The virtualisation of over-the-counter services is completely feasible technically. The operational reliability and costs are at a good level. Both the virtualisation of retail store spaces and the delivery of goods conveniently to a walking distance are technically feasible, but require experimentation and investments. The gathering of information, which requires measurement from the client, is in large parts technically viable and inexpensive, but is not yet common.

Challenges of the transfer period: Many people don't want to answer to a videophone when an unknown person calls. This is probably because of habits. IT systems developers strive to remove the person out of the service process through automation, and perhaps that is why services which require consultation have not been attempted to be transferred onto the computer. Slow and clumsy logistics has restrained the trade of goods online, as the customer has had to stand in a queue at a post office at a distant location to pick them up.

Legislative/structural barriers: In many instances the legislation requires a signature or physical presence and already the electronic identification is cumbersome to many people. Due to old habits, many people who require help are rather transported from their homes to the service desk and back instead of the service assistant visiting the customer's home for help. Changes are opposed emotionally by appealing to social contacts, even though the trips to services and stores are meaningful social experiences to only few people.

Threats of the new technology: For some people, isolation is a threat when opportunities to it are increased. However, it has been reckoned that corner shops and goods delivery automats would improve the cohesion of the neighbourhood.

1.5. Local or functional food

Current situation and its expenses: The economic value of the foods industry is about 10 billion euro in Finland. In the United States, about 10 per cent of GDP is spent on food, which is double compared to Finland.

For now, the portion of local and functional food in people's diets is small and local food is not always healthier or more ethical than food that is produced in large units. However in the future, people will probably set stricter standards for their food in terms of healthiness, freshness, and variety as well as the ethical and ecological aspects of manufacturing. Local manufacturing is one means that opens new possibilities to meet these standards. Obesity is increasly a worldwide problem. With improved technologies, people can measure the direct physiological impacts of their nutrition on health and more specifically on metabolic problems. This will increase their awareness of the importance

of nutrition. As self-care healthcare becomes more common in the world (see 1.8) more attention will be paid to the healthiness of nutrition everywhere.

Even though the challenge of functional food is realized globally, obesity and other challenges related to nutrition are still very pertinent. According to national statistics, in Finland 20% of men and 19% of women are so overweight that it is harmful to health. The criterion is a body mass index of 30 or more. According to a national study, over one third of all greenhouse gas impacts of the Finnish consumer results from food. In the study, the environmental footprint of the food intake of the consumer is determined by basic ingredient choices. In addition, households are throwing out about 500 million euro worth of edible food. This equals the annual CO2 emissions of roughly 100,000 cars.

Even now, it is possible to follow the healthiness and ecological aspects of the food purchased in supermarkets quite closely through product labels and barcodes. IT systems also help connect the information to the customer. On the other hand, basic ingredients are increasingly being purchased through multiple middlemen. That makes events that decrease consumers' trust possible, such as the EU horsemeat scandal. Together with the desire for freshness, events like these advance the local production of food.

Healthy nutrition plays a central role in the prevention of almost all common diseases and especially in the avoidance of the so-called metabolic syndrome. The avoiding of illnesses and quality of life detriments related to obesity alone would save billions of euros in Finland. If efficiently produced, local food will be more common it can reduce the transportation costs of food significantly. It can also reduce food related spoilage. Along with these nationally central impacts, functional food offers a very promising opportunity to the Finnish exports.

New operating model with its savings and how the technological maturity is developing: The use of personal genetic information and new knowledge concerning cell metabolism open new opportunities to improve the healthiness of nutrition. Based on improved measurements of healthy ingredients we can promote healthy food choices. Furthermore, more accurate knowledge of the growing conditions and nutrient content of plants create possibilities for accurate tailoring of large-scale production. Although new, genetically engineered plant varieties, new lighting technologies, carbon dioxide fertilising, as well as robotics and other automation, productivity will increase especially in local production.

Conditions for local production of food on balconies, rooftops or home gardens will improve. Local food's benefits from ecological and ethical points of view also support this. Sustainability of production can be tracked with more accurate labels of origin. During this decade, personal measurement devices for tracking one's own bodily functions and metabolism are likely to be common. They will promote awareness of the importance of nutrition on individual level. The impact of cholesterol measurements on the demand of functional food is likely to be less dominant because other more important indicators of healthy food and because of individualized health related information.

Based on both scientific knowledge and subjective perceptions, Finland has the opportunity to improve much its balance of foreign trade especially by producing functional food.

Challenges of the transfer period and threats of the new technology: The central problems of the transfer period are deeply rooted prejudices and fears toward new kinds of nutrition and new production methods of food. In order to handle fears related to genetic modification it is important that with new techniques, such as zinc-finger nucleases, genetically modified crops can be compared in scientifically solid way with crops that have been produced by traditional crossover. This may be pivotal in changing attitudes and approval procedures for those GM crops that would otherwise be developed at significantly higher costs using traditional crossover. On the other hand, due to the strong prejudices even small adversities can ignite the fears again.

1.6. Distance presence and remote control of tools

Current situation and its expenses: We spend most of our time travelling. Commute and other work related travel make up one third of all our travels. In Finland, about 1,5 million man-hours per working day are spent on work related travel, which equals almost half a billion man-hours per year. The main reasons for these travels are the need to encounter other people, use machinery and equipment, or perform measurements, control and maintenance operations. Because travelling is time consuming, we leave many things undone that would be worth doing if it weren't for the distances.

One might think that the only cost of commuting is the cost that results from the means of transportation, but this is not correct because commuting happens during leisure time. Proximity of the workplace influences the choice of the employer and the living distance affects the cost of housing. In addition, work-life balance is becoming even more important to people and they do not want to spend it in commute.

New operating model with its savings: More and more often we can operate machines remotely and control them with the help of distance presence. We can follow other people's actions, guide them and learn from their actions without being in the same space with them physically. With the help of technology, we can also achieve an experience almost identical to physical presence without travelling, and we can perform the desired inspections and measurements without being in the same space with the measuring devices.

With the help of these distance presence operating models we can reduce travel times, increase work outputs, choose a place to live more freely, spend our leisure time wisely, and develop a better connection to even those partners and tasks that are located far away from us. The benefits can be billions of euros per year even in a country like Finland.

How the technological maturity is developing: Machines and equipment are becoming remote controllable at an accelerating pace. Remote controllable robots that grab tools like a human are in the experimentation phase. Remote controllable devices that fly, walk and move on wheels; robots that participate in meetings and training, through which the participants are transmitted most of the feeling of participation; remote controllable snowploughs, lifting equipment, excavators, and research equipment are already usable. There are an endless number of similar examples. The technology is already mature, but there is little use experience and the awareness of possibilities is poor.

Challenges of the transfer period: The structural change will require rearrangements and they will lead to significant lack of needed expertise. During the transfer period these demands are difficult to manage, and many times we are taken outside of our comfort zones and everything that would be possible is not even comprehended. Many beneficial changes are such that they fall outside of everyone's job description and the tasks are too miniscule for the top management of the organisation. Savings in commuting time are deemed unimportant by many people, because the savings impacts the operations only indirectly and a typical organisation does not feel responsibility for the commutes of its employees.

Legislative/structural barriers: Current legislation does not allow robots to move on public lanes. The legislation also restricts flying measurement devices. Remote work is not allowed to be controlled in the same way as work performed at the physical workplace and work agreements often prevent arduous work. Due to taxation, a home office becomes twice or three times more expensive than an office at the employer's premises. In addition, work commutes are subsidized both in taxation and in public transportation, even though they usually take place during the rush hour, which is the most expensive time from the point of view of the organiser of the transportation.

Threats of the new technology: The most significant threat of the remote controllable devices is terrorism and vandalism. This must be taken into account when the systems are designed.

1.7. Individualisation of learning and guidance

Current situation and its expenses: Close to 200,000 people work in different training and guiding positions in Finland. About one third of an individual's lifetime preceding retirement is spent in full-time education and a significant portion of one's career is spent learning as well as in guiding, teaching, and consultation tasks. Teaching is typically organised in a physically centralized manner in special buildings causing half a billion trips per year in Finland.

The teaching that is tied to physical structures creates inefficiencies especially in teaching new things. The quality and content of teaching is constrained to the capabilities of local teachers. Degrees become the main motive for participating in teaching, and degrees do not measure the best know-how but rather the internalization of the out-dated teaching content of the teachers.

In the current mode of teaching, the teacher has very little individual time for each student. In addition, the students often don't have the possibility to choose a learning method that suits his or her style of learning nor the appropriate contexts for learning the things that fit his or her inclinations and objects of interest. Furthermore, different subjects are difficult in different ways depending on the student and the current mode of teaching supports individual advancement just through books.

The demands for know-how varies and changes rapidly. A sluggish system in the transfer of know-how leads to an increasing deficit of know-how despite the investments directed at teaching. This is mirrored throughout the whole economy.

New operating model with its savings: Many possibilities of information technology are combined in the new operating model. The lectures of the best experts are attended independently online, the exercises are performed on the computer or with the help of remote controllable robots and simulators, and the instructor supervises the performance and directs it, if required. Gaming is applied to teaching. Discussions and peer learning take place in shared projects online or by meeting in person. Virtual glasses and remote controlled robots are used in on-the-job learning. The robots give examples of the work to be performed, and with their help the instructor can supervise and guide the learner without being physically present. Know-how is proven and evaluated independently from the teaching, and in rapidly changing areas the proof of know-how is temporary.

How the technological maturity is developing: Khan Academy, Google Glass and many simulations as well as teaching programs and hobby-like networks of communal learning already demonstrate the practicality of the new methodologies. As the technology matures, space and time have lesser importance in the transfer of know-how.

Challenges of the transfer period: The current educational institutions are ponderous for several reasons. Degree systems and finance are tied to the way teaching is organised. Political decision-making, interests of trade unions, and habitual values and reverences all slow down necessary changes.

Legislative/structural barriers: Legislation sets significant restrictions on the contents of teaching and the way teaching is organised. In Finland, teaching is significantly supported through public funding, but the contents and methodologies that are funded are mostly out-dated. There is quite little private education and it cannot function as the driver for development. The models for the transfer of knowledge are defined by public education, which reduces open area that is not restricted by the regulation.

Threats of the new technology: People easily lose their sense of belonging to the same culture as people's worldviews become even more varied. They might lose their shared identity even though they are close to each other physically.

1.8. Self-care based and personalized healthcare

Current situation and its expenses: Healthcare operations can be divided into activities for prevention of diseases and other health impediments, diagnosing diseases, and treatment of diseases and other health impediments. The possibilities of self-care healthcare are especially related to the diagnosing and preventing activities, even though the self-care offers possibilities for new kinds of treatment practices as well. On the other hand, future personalized medicine will provide patient specific treatments using the improved possibilities to take into account the genetic and other types of differences between patients.

The Internet already offers very good information to discover the possibilities for treatment based on symptoms. It is especially useful for patients who suffer from difficult chronic illnesses such as the MS disease who can actively form peer communities and utilize the information offered by the Internet.

The self-care healthcare may have a significant role in improving psychological health. New ways to take care and take responsibility not only of one's own psychological wellbeing, but also that of relatives, colleagues and those who suffer from loneliness, are examples among others. The new practices can increase wellbeing in general but also cut costs for the public sector. Cost savings are created, for example, through the reduction of the number of people who are not able to work because of mental problems. These kinds of impacts are discussed in more detail in relation to the global value production network 1.9.

According to the statistics of Finland's National Institute for Health and Wellbeing, the total healthcare expenses were about 17 billion euro or about 9 percent of GDP in 2011 in Finland. Self-care healthcare may specifically impact the costs that are related to special health care's outpatient care, short-term ward treatment, psychiatric care, basic health care's outpatient care, and different laboratory and imaging examinations. At the moment, the cost of these services is about 5 billion euros in Finland. Secondary impacts cover all other activities within the realm of healthcare. Active relatives and support persons may also have a substantial impact on the care of those with lowered psychological abilities, among others (see 1.9).

In addition to the direct savings effects on healthcare, self-care healthcare can be anticipated to have many other kinds of impacts. Activation in terms of self-care seems to promote the prevention of health impediments. Treatment results will improve when illnesses are detected at an early stage. Citizens might change their habits towards healthier ways. Fewer sick days are taken and the citizens' general quality of life improves.

New operating model with its savings as the technological operation models advance: The organisation and delivery of treatment will most likely be based on the interaction of the patient and the treatment professionals, even though the technical possibilities for self-care would much improve. However, the encounters between treatment professionals and patient may be radically different than they are currently.

In which way the self-care and the personal healthcare will combine in the future? The encounter between the doctor and patient might happen in 2020's as follows. After the patient has described his or her symptoms in the electronic appointment booking service, he or she is given advice as to where reliable information can be searched from, and following the advice, the patient searches the Internet for information about his or her symptom or illness. At home or easily attainable as a service, the patient has measuring devices that equal or surpass the current laboratory examinations in quality. The patient meets the doctor and the doctor makes an initial diagnosis based on the discussion. The doctor can flexibly use the Internet for peer support from other professionals and for searching different databases. The databases that are opened for the patient as well include treatment recommendations based on the symptoms and classified evidence of the efficacy of treatments. The diagnosis is routinely linked to the patient's personal genetic information, which is downloaded from the national genetic information bank.

The patient can look at photos and videos of corresponding situations and even get the contact information of the closest peer sufferer at their consent. In either case he or she will always be directed to some discussion forum that matches his or her diagnosis.

Next, the diagnosis is tested with self- made tests that the doctor and the patient agree upon. These tests kits or biochips are available, easy to use and inexpensive and recognise the health problem from saliva. However, professionals will still make tests that are not easy to accomplish and require high reliability. After the tests, the doctor or other treatment assistant is met again either in person or online. If the treatment goes according to expectations, a new meeting is not necessary, but all stages are saved to an electronic medical report. Medical reports functions as the basis of new treatments. In addition to the patient himself, they will be interpreted by the patient's own doctor and/or the person in charge of the patient.

As processes similar to the above develop, new technological advancement open substantial possibilities for cost savings especially in the staff expenses and the utilization of premises. Interest in health that self-care activates will most likely lead to increasing worry about health. The positive outcome is the advancement of the early detection of illnesses and prevention of health impediments, but it is also likely to lead to unnecessary contacts to healthcare in terms of improving health. This may reduce the cost effectiveness and cost savings that are otherwise attainable through self-care.

Challenges of the transfer period and legislative/structural barriers: Key problems of the transition period are the reliability and risk of incorrect diagnoses based on self-care and easy tests. The liability issues related to incorrect decisions significantly slow down the diffusion of even those self-care solutions that have lower risks. On the other hand, the risk of slow progress is that self-care patients actively turn to foreign, uncontrolled online services.

Threats of the new technology: Increase of so-called medicalization and wrong choices based on superficial information are permanent risks that are difficult to handle. Use of medicine for other purposes than treatment of actual diseases and symptoms might increase. They might be used as a remedy for, for example, inhibiting sorrow reactions, slowing down alopecia, reducing overweight or reinvigorate erection.

1.9. New capabilities for those who have lost their functional health

Current situation and its expenses: Functional e.g. mobile capabilities can be lost due to an inborn disability, illness, accident, or aging. The most seriously disabled people are those who are not able to cope independently at home even with support but need continuously assisted living services. In Finland, elderly people who are in poor shape make up the largest group of those who have lost their functional capabilities. According to national statistics at the end of 2011, 25% of all people over 75 years old had at least lowered functional capabilities. They did not cope or coped poorly without continuous help from others. Two thirds of them were dependent on continuous care. Majority of those suffered from late stage dementia. Besides oldpeople, the lost capabilities group consisted of developmentally disabled and mentally ill people as well as those with spinal

cord disability, among others. A large group with less seriously lowered functional capacities was those whose vision or hearing disability substantially lowered their functional capability.

The lowered functional capabilities of the above-mentioned groups have to do with the preconditions of coping in everyday life without continuous support from other people. Those on disability pension make up a large group of people with lowered functional capabilities. The majority of them cope in everyday life without support from other people and the lowered functional capability has to do with coping in working life. In Finland in 2009, two main reasons for retiring due to disability were musculoskeletal disorders (34%) and mental health problems (30%).

Mental health problems have continuously increased as a reason for retiring due to disability. The notion of psychological functional capability is related to a person's life management, satisfaction, mental health and psychological wellbeing. Work performance and the general experience of life's meaningfulness are closely related. The general experience of life's meaninglessness is an important factor that impacts functional capability and general wellbeing also for those who have left the workforce at retirement age or who have been left outside of it at an early age. Especially in these groups the experiences of meaninglessness are accompanied with experiences of loneliness.

Inability to work causes a lot of costs. It was evaluated in 2012 in Finland that the cost of disability pensions due to early retirement caused by mental illness alone is almost 10 billion euros per year or about 5 % of GNP because of the lost contributions to the workforce.

In 2030, brain injuries and illnesses will represent a central part of public expenses related to lowered functional capability to cope in everyday life, unless treatment practices change radically. Alzheimer's disease is becoming increasingly relevant in the lives of Finns. The average life expectancy is 81 years for a person born in Finland in 2010. In 1950, the same was only 65 years, and in 1980, 75 years. About one in every 14th person over 65 years old and one in every 6th person over 80 years old suffers from dementia. Hence, it has been estimated that without breakthroughs in prevention and treatment, in 2030, there will be about 130,000 persons with memory disorders as opposed to the approximately 85,000 of those suffering today.

In 2007, the cost of dementia treatment in Finland was estimated to be about 24,000 euro per patient. 60–80% of the direct costs consist of long-term institutional care. In addition, at least about one third of the total number of persons with memory disorders consists of those who suffer from mild memory disorders with noticeable memory problems. In 2030 without breakthroughs in the care, the annual costs might be about 2% of GNP without indirect costs. This includes the suffering caused to the patient himself and their close ones e.g. relatives compared to the retention of memory health.

We can estimate that already now about two thirds of costs accrued to the public sector from permanently lowered functional capability are related to brain diseases. Considering the impacts of lowered functional capability to quality of life, and that the problem can be expected to become more difficult, we are undoubtedly talking about one of the most challenging problems of the future.

New operating model with its savings and the development of technological maturity: The big question is what kind of effects technological solutions will have in solving the deeper questions related to the meaningfulness of human life. All solutions that improve employees' motivation and interaction at the workplace will have impacts on wellbeing at the workplace as well as on the amount of disability pensions that are caused by mental health problems.

Many new technologies help those with permanently lowered functional capability to cope in a cost effective way, even though they cannot affect the causes of lowered capability: robotic legs, medication dispensers, artificial eyes, housekeeping robots, distance assistants, even more intelligently functioning control bracelets, and other equipment that compensate for losses in functional capability.

In case of other disorders besides memory disorders, new assistive devices may even make other people's help completely unnecessary and persons with devices may feel on par with functionally healthy people. However, the outlook is not very promising for those suffering from memory disorders, if the underlying causes or advancement of the disorder cannot be impacted. The most promising and cost effective option is clearly the prevention of these disorders (see 1.8). At the moment, the only treatment to Alzheimer's disease are medicines that reduce the speed of the advancement of the disease and temporarily improve functional capability, and there are no new treatment methods in sight – at least ones with no risks. This is a reasonable conclusion even though a new, very promising compound has been found in animal testing.
(http://www.express.co.uk/news/uk/426932/Missing-Link-found-in-cure-for-Alzheimer-s)
It can be anticipated, however, that treatment practices will develop in such a way that, similar to cancer treatments, cure attempts with a high risk of death will become accepted in dementia treatment. This is related to the development of attitudes and practices regarding euthanasia.

Challenges of the transfer period: As the financial situation of the state and municipalities is increasingly troublesome, it is more and more difficult to justify actions that will increase the deficit of public finance, even though the effects on aged people's wellbeing would be significant. On the other hand, assistive devices and new treatments of memory disorders could become important export products for Finland, and the aged population are an increasingly large group of voters.

Legislative/structural barriers: Changes in legislation are required to allow treatments with very high risks of death to those suffering from difficult dementia.

Threats of the new technology: Generous governmental support for the diffusion of new technology may lead to a significant growth in the number of people who, at high costs, cope better independently but demand a notable financial contribution from other citizens. Allowing treatments with high risks of death to those with memory disorders might lead to an uncontrollable increase in euthanasia.

1.10. Equipment that increase awareness of the environment

Current situation and its expenses: Almost all human decision making is based on observations of the operational environment. We measure, illustrate, compare, frame, and make decisions based on the information gathered. We are interested in physical and chemical properties, shapes and actions, as well as socioeconomic behavior. The more accurate and timely information we receive of the objects of our interests, the more likely it is that our decisions are correct and our operational models lead to efficient results. Information gathering is a key part of all industries. In most industries, the lack of measured or gathered information is also the biggest obstacle of operational development.

The navigator is a good example of a device that measures our location and calculates the route to the destination while giving us directions on where we should turn and when. An outdoor thermometer tells us how we should dress and the echo sounding system used by fishermen tells them where they should fish and whether the water depth is enough for the boat to pass. Sensors attached to public transportation vehicles deliver information about their location, which we can see at the station as waiting time or as a change in schedule. A camera helps us tell others about our observations. A notable amount of measurement devices for observing the environment and far larger databases of information are related to professional tasks, but in people's everyday life there are still very little information and measurement devices that describe the environment. We have to trust approximate observations or common perceptions.

New operating model with its savings: The Internet already contains a vast amount of information about the environment and the amount of information is multiplying at a fast rate. We are informed of crimes, restaurants, available dating partners, and landscapes of our environment. The so-called big data that is gathered into Internet databases gives us ever more accurate information about the state of our operational environment and opportunities. New sensors help gather this knowledge more accurately and more properties of our environment. With only minor added devices, the camera of a smartphone can detect heat leaks, material compositions, and other details. In the near future everyday life will be enhanced by devices with which chemical and biological properties can be easily recognized and even recognize the different varieties of mushroom in the forest. The diffusion of advanced measurement devices into everyday life will further add to the information that is already online and will add to its comparability. Our ability to observe and receive information about our operational environment is about to grow exponentially with the help of robotics, virtual glasses such as Google Glass, and other devices that gather and process information. Google Glass can tell us our conversational partner's emotional state and analyse their pulse, variation of the moisture of their skin, and other information that is already on the Internet. The increasing amount of information and its refinement with the help of cloud services will lead to significant savings in research and learning costs, decision making of organizations, and individual level activities.

Development of technological maturity: Big data type solutions are diffusing at a fast rate. As robotics diffuses, information gathering becomes more common. Smartphone accessories that perform chemical tests are in the prototyping phase and inexpensive biological sensors are being developed in laboratories. For example, it has been demonstrated in a laboratory setting that people can be seen through walls with simple

and very inexpensive methods. The speed of development is indicating that by the beginning of 2020 our everyday ability to make sense of our environment will be multiplied compared to our abilities of today. In professional tasks it is likely that in the near future, for example, a police officer will be able to detect people who have used drugs even from a distance.

Challenges of the transition period: Protection of privacy will be challenged when it becomes easier and easier for people to acquire information about their environment and people moving in their proximity.

Legislative/structural barriers: Increasing information does not involve many legislative barriers, because the principles of open data have already been applied in administration. However, protection of privacy will put pressure towards legislation, because many new technologies reveal things about people that they have gotten used to keeping private.

Threats of the new technology: Increasingly detailed information about people's locations will enable more accurate actions by criminals.

1.11. Functional materials and new material technologies

Current situation and its expenses: All of our goods and nutrition are based on diverse raw materials and it is used in either end products or in intermediate phases. Finnish industries are especially raw material intensive. The raw materials and their production methods impact the costs, features, processes, energy intensiveness, knowledge requirements, industrial waste, and competitiveness of the end products.

In order for Finland to succeed in the future, the industries of our country should invest especially in the development of materials' features and utilization of materials that others have developed according to the so-called functionality principle. The Functional Materials Programme of Tekes, the Finnish Funding Agency for Innovation, describes the functionality approach as a deep understanding of materials and their features, tailoring of materials for application in special use cases, as well as paying attention to manufacturability and the lifecycle of the materials. Another, economically oriented way to define these materials is the radically higher added value per kilogram compared to non-functional materials.

About half of Finland's exports of goods (c. 26 billion euro) between the spring of 2012 and spring of 2013 consisted of goods categorized as refined raw material. Part of them represents only minor added value compared to unrefined basic raw material from the nature (see 1.14) and part of them is functional material with a distinctly higher degree of processing: board and paper, pulp, timber, wood panel, chipboard, plywood, oil products, plastic, plastic boards and films, colors and lacquers, copper, nickel, gold, zinc, silver, aluminum, metal sheet products, pipes, yarns, furs, minerals. Other Finnish production such as machine manufacturing is largely based on the use of raw materials. In a wider sense, for example drug manufacturing, which is important to Finland, can be assimilated with functional materials.

New operating model with its savings and development of technological maturity: New types of surfaces, lightweight structures, and building materials that are suitable for rapid manufacturing as well as materials with superior strength qualities are expected breakthroughs in the field of material technology. New materials may lead to considerable labor and material cost savings in the construction industry as well as savings in the machine-building industry through machines that contain much less metal. In addition, new materials may lead to numerous improvements that radically reduce labor, energy costs, and materials costs as well as bring new features to products in almost all industries.

New ways to produce materials will also be learned. Nanotechnology, biotechnology, and chemistry will converge and functional materials may be produced by, for example, manipulating bacteria.

Utilization of rare earth elements is a special challenge for Finland. Yrjö Myllylä (2011) sees opportunities in rare earth elements, especially in the platinum group metals, that are required by information technology and other high-tech industries. The relatively strongest platinum metal deposit in Finland runs through the Ranua, Posio, Taivalkoski and Kuusamo areas to Russia. Investing in these rare earth elements is key, if the logistics streams from Russia want to be diverted towards the Gulf of Bothnia and Finland instead of the Arctic Ocean.

Challenges of the transition period: New materials are often not applicable to current processes and their utilization may require vast systemic changes. Therefore, the use of even very important new materials may progress slowly at first and then grow exponentially as structures change. Traditional industries are poorly prepared for these kinds of phenomenon and new opportunities may progress too slowly in Finland, if there are not enough advocates. There is a lot of knowledge related to old materials and processes that becomes outdated as materials are modernized. This manifests as a need for re-education of workforce and may also manifest as structural unemployment as the transition progresses. That is why change has its opponents. A reform-oriented mindset plays a key role.

Legislative/structural barriers: Many regulations and processes are tied to current materials and their properties. A new material may be better than the previous one in a structure that is designed in a slightly different way, but norms and practices may notably slow down the change.

Threats of the new technology: New materials and processes may involve dangers that are not recognized by the users of the materials. On the other hand, new materials may quickly replace export goods that are important to Finland.

1.12. Functional added value of intelligent goods

Current situation and its expenses: The majority of structures and goods are not able to communicate with their environment. Goods also don't communicate widely with each other, and they don't form a vast Internet of Things yet. Packages don't know their

addresses in a computer-readable format or monitor their method of transport or their circumstances.

A significant part of assembly and maintenance tasks consists of the search for parts. Goods rarely know how to look for their own user manuals. Flower pots don't assist the user with timely watering and sails don't give instructions for sailing. Our environment is full of goods that we don't know how to use and that don't help us to learn. In addition, the continuously shortening life of goods is highlighted in the consumption culture. The so-called "optimal lifecycle" after which a product is either broken down or too old-fashioned to be used is a key factor in the product design of many companies.

All of the above causes costs in maintenance operations, building and assembly tasks as well as in the use of products. In Finland, maintenance operations employ over 100,000 persons. The intelligence of goods also impacts the ways of working of hundreds of thousands employees and consumers in logistics, retail, building, and manufacturing industries.

New operating model with its savings: Both assembly and maintenance operations would become simpler, if components knew where they were ordered to and what they were meant for, machines could order the spare parts they need, roof structures would tell when there is too much strain, and structures would signal when there is too much moisture. Wall structures could also monitor their own condition – for example, wall structures that detect mold have been developed at VTT, the Technical Research Centre of Finland. The vicinity of savings may be notable, but also part of the benefits requires investments in infrastructure. If product manufacturing is directed towards lifecycle thinking through legislation and incentives, it will result not only in cost savings but also in material savings.

Development of technological maturity: The technology is relatively mature, and automated factories and solutions in agriculture, such as robotized cowsheds, can already be controlled remotely. Distant reading and distant programming are diffusing to the world of products. Printed intelligence is a growing field of technology. It already enables the adding of different kinds of intelligence, such as sensors, indicators, Internet links, and holograms to products at a reasonable cost.

Applications of printed intelligence are often also eco-efficient and environment friendly. For example, batteries produced with printed technology are already fully biodegradable.

Challenges of the transition period: Problems of the transition period can be an uncontrolled increase of information masses, in which the information moving in multiple directions cannot be vastly utilized. In addition, the increased complexity of structures can cause unforeseen system level problems. If the use of products begins to require information technological skills, it can become a problem especially for the elderly population.

Legislative/structural barriers: Structural barriers can affect the multiple producers of products and lack of standards. In addition, legislation should solve possible challenges related to information growth and citizen monitoring.

Threats of the new technology: The threats of increased intelligence are most likely related to the functioning of an especially complex, networked technological system. These can be, for example, viruses and spying programs that are spread through products, machines, and infrastructures, which are intended for disturbing the functioning of the Internet of Things or for gathering information of the actions of singular people, groups, communities, and societies within the Internet of Things.

1.13. Sustainable energy technologies

Current situation and its expenses: Due to its industry structure and climate, Finland uses a lot of energy. In 2012, the total energy consumption was 1.267 petajoules, i.e. about 380 terawatt-hours, out of which electricity was 85.2 TWh. Finland's energy imports are notable, about 70 percent, and the main import partner is Russia. In 2012, diverse energy products were imported into Finland to the value of 13,4 billion euro and 6,3 billion euro worth of energy products were exported from Finland. The consumption of renewable energy had risen to 30 percent in 2012, while the consumption of oil was 24%, coal 10%, natural gas 8%, imported electricity (net imports) 5%, hydro and wind power 4%, wood fuels 23%, peat 5%, and others 3%.

Quoting the Finnish Government's briefing to the Parliament (National energy and climate strategy), certainty of the availability of energy and its inexpensive price are key prerequisites for the growth of today's global economy. However, the projections of development in this regard are uncertain and include risks.

According to the briefing, it can be anticipated that the growing wealth of China and India will keep the demand for fossil fuels at a high level, although the development of the prices will most likely fluctuate strongly. The deployment of shale gas resources and the use of LNG (liquefied natural gas) becoming more common in global trade will moderate the price development of gas and the competitiveness of gas can be anticipated to stay relatively good. In addition, coal will most likely be available at an inexpensive price compared to other energy sources, but the environmental requirements and costs will considerably diminish the attractiveness of coal as a fuel.

Without significant political reforms global energy consumption will increase so much that it will become impossible to limit the global increase in temperature to 2 degrees Celsius. According to the International Energy Agency (IEA), all possible measures related to energy production and consumption must be deployed in order to reach the target of 2 degrees. Energy consumption must be made more efficient and the majority of energy must be produced without coal.

Energy production with renewable energy sources should be tied to civil engineering and energy systems. Transportation should rid itself of oil as soon as possible.

New operating model with its savings: There is no reason to explain the high significance of new energy technologies. The development of technology seems to support the targets presented by the Finnish Government at least in terms of direct solar energy and battery development.

Development of technological maturity: The prerequisite for new energy technologies is the cost of energy produced with them and the required investments. The cost of solar energy has declined over the long term in a very promising manner, and the decline can be expected to continue due to the increasing production scale and the many inventions in sight. The battery technology is also continuously developing, and the most recent news indicates that the price of high-performance batteries is already nearing the investment costs of dispatchable power plants. The continuation of this development would lead to big changes.

Two patent based indicators can be used to anticipate the worldwide success of renewable energy sources based on technological development. One indicator are the patents that have been approved in the United States between June 11th, 2010 and June 11th, 2012 (www.uspto.gov) and have the type of energy in question mentioned in the abstract. The other indicator used for this purpose in the research of Kuusi (2013) describes the portion of the patents that have been approved between June 11th, 2010 and June 11th, 2012 out of all those patents that have been approved after the year 1976 that mention a key term related to the energy type in their abstract.

Based on new patents, a few more technological breakthroughs can be expected in solar energy than in wind power. 'Solar power' was mentioned in the abstract of 5,601 approved patents in the aforementioned time period and the portion of new patents of this kind was 17%. There were about as many new patents related to wind power, but the difference was that the portion of new patents out of all was only 13%. The relative decline of the world market price of solar energy compared to that of wind power also points towards a similar development as the indicators show. Solar energy that is directly applied to the structures of buildings, other built environment, and vehicles seems like an especially promising opportunity.

The development of patenting supports the view that local production of energy is becoming stronger. Interest towards nuclear power seems to be diminishing – in the aforementioned time period, there were 3,929 new nuclear power related patents and the portion of them out of all was 11%. Also lithium batteries, which are essential to the development of electric vehicles, are developing quite fast measured with new patents. There were 437 abstracts that included the words 'lithium battery' and the portion of new patents out of all those that had been approved since 1976 was 17%. With regard to climate change mitigation, it is promising that patent applicants are increasingly referring to climate change in their patent documents ('climate change' 1,115, portion of new patents 19%) and that carbon dioxide capture is one of the fastest growing sectors of patenting ('carbon dioxide capture' 2,104, portion of new patents 24%).

Challenges of the transition period: The supply of power will face significant seasonal and weather related variability as the share of solar energy and wind power grows. This must be compensated either by power storage or load following power plants. Shortsighted regulation and possible compensations related to load following power plants and guaranteeing of sufficient energy may notably slow down the transition to new power sources. If the price development of solar energy and energy storage technologies continues on the same path, major energy investment decisions that are currently underway may turn out to be unprofitable. The investment payback calculations don't

typically account for the decline of energy prices, which seems likely in light of solar energy trends.

Legislative/structural barriers: Connecting renewable energy to the electricity grid as small-scale production is still problematic. There are notable barriers to the creation of energy self-sufficient or mainly energy self-sufficient regions. An intelligent electricity grid is not ready and the consumer is still not participating in balancing rapid changes in the demand of electricity. There are neither signals nor incentives for it.

Threats of the new technology: If energy companies don't introduce dynamic pricing on consumer markets that directs consumer behavior, the large-scale purchasing of household solar panels will lead to market disturbance, overlapping investments, and possible financial trouble for the energy companies. If the capabilities for storing energy don't develop fast enough as the share of solar and wind power grows, it leads to possibly expensive and short-lived solutions to guarantee emergency supply.

1.14. Raw materials from untapped areas of the Earth and space

Current situation and its expenses: The fast economic growth in Asia has increased the demand for ores and it has made it economical to utilize ores that have been previously discovered but deemed as uneconomic. At the same time, the rise of prices has raised interest in previously unexamined sources of raw materials not only on the Earth but also beyond. The unutilized or underutilized regions in raw material sourcing on the Earth are found especially in deep ocean bottoms and arctic areas.

Until now, the deep ocean bottoms have been significantly utilized only for oil and gas. According to Steve Scott, Professor Emeritus of Ore Genesis Geology at the University of Toronto, copper, zinc, lead, and gold can be found around submarine volcanic arcs in the deep ocean in similar sulfide deposits as on dry land. The deposits are formed in the shape of mounds, which can have a very high metal content. Even small amounts can be utilized profitably. Compared to mines on land, there is no need for a well. The drilling of a mining well costs 4,500–7,500 USD per meter and the building of a mining tunnel costs 1,200–2,300 USD per meter. In addition, there is no acid formation or surrounding rock to be extracted from the ore. There are little environmental problems. Nautilus Minerals Inc. is a pioneer in utilizing ocean floor minerals and has been the first to begin the extraction of minerals from seafloor massive sulfide (SMS) deposits in the regional waters of Papua New Guinea. The targets of the exploration are copper, gold, and silver.

In Finland, the invigorated mining activity has mainly been related to the utilization of previously discovered ores. Chrome, nickel, copper, zinc, cobalt, silver, and gold are the main metals quarried and refined in Finnish metal mines. Finland's share of the total production of gold and nickel within the EU region is significant. Europe's largest known nickel deposit is located in Talvivaara, Sotkamo. However, more than 90% of the nickel concentrate refined in Finland is still imported mainly from Russia. Chrome can be extracted from only a few places on the Earth, but Finland's chrome resources are notable.

Iron, which is used as raw material for steel, is not currently quarried in Finland, although there is potential for mining production of iron in Eastern Lapland. Therefore, all iron concentrates that are refined in Finland are imported from abroad, mainly from Sweden and Russia. Steel is the most important product that is produced out of iron. The total recycling rate of steel is 90% in Finland.

Bauxite, the raw material for aluminum, is not quarried in Finland, but we are a significant recycler of aluminum raw material. Recycling requires 5% of the amount of energy that is required in producing aluminum from virgin bauxite ore. When an aluminum can is produced from recycled aluminum, as much energy is saved as is consumed in using the computer for one day (Stena Recycling).

There are no uranium mines in Finland, but there are such large deposits of uranium in the ground in Finland that exploration for uranium has revived after the prices have risen. According to a report by the OECD's nuclear power program and the IAEA, the economically utilizable uranium resources of the world are estimated to suffice for the needs of the current nuclear power plants for the next 85 years.

New operating model with its savings: The development of robotics will have an impact on the utilization of new regions and natural resources. Robots that operate in oceans in a depth of 4–5 kilometers are already well-established technology. Diverse measurement devices are continuously developing and help explore promising deposits in places that are difficult for humans to approach.

There is increasing interest towards asteroids that circle the Earth at a close distance. Optical methods are used to acquire information of their composition and the most promising asteroids are planned to be charted still in this decade, so that robots could be sent to them to look for water that would be used especially in space as well as rare platinum group metals that would be meant to be brought to Earth. These are found in the Earth's crust only in places, where asteroids have hit earlier, but in some asteroids their concentration has been very high.

Finland's bedrock is considered as a very potential location for finding so-called high tech metals. They are necessary for new technological devices such as cell phones, flat screens, catalysts, and solar panels (GTK). These metals include niobium, tantalum, indium, gallium, germanium, scandium and rare earth metals, among others.

Challenges of the transition period: There are specifically fast signals of change related to material technology at the moment, and nothing can guarantee that the metals that are valuable now would be as important and valuable in the future. Therefore, there are higher risks involved with large-scale mining now than before. On the other hand, the fast growth of the Asian countries creates continuously growing price pressure towards limited resources.

Legislative/structural barriers: Controversial or undefined status of ownership of new areas clearly complicates development.

Threats of the new technology: There are many well-known risks involved in mining. The risks of utilizing the arctic area, ocean bottom, and space are partly unknown. A significant industrial position in space offers a clear military position as well.

1.15. Participatory forms of entertainment, culture and influence

Current situation and its expenses: The Finnish Ministry of Education and Culture reports on its website: "Culture is a significant entity in the economy. Its share of GDP is bigger than that of the primary sector's industries. Culture's share of foreign trade and consumption is notable as well. In 2005, Finland exported culture products and services worth over 700 million euro. In the same year, households spent 5,5 billion euro in total on culture. This information can be found in the report about Culture Satellite Accounts produced by Statistics Finland and the Ministry of Education and Culture. The report is the first to investigate the weight of culture in the frame of national accounts.

In 2005, culture's share of Finland's GDP was 3,2% and it employed 4,2% of the workforce. Culture's share of GDP was larger than, for example, that of the primary sector, traditional industries or tourism.

People use a large part of their leisure time engaged in different commercially produced or hobby-like events, games, entertainment, and social media of the information networks. Events and hobbies can also be politically oriented and diverse impacting on the surrounding society is a significant part of acting in information networks and events.

The so-called Internet generations (those born in the 1990's) and younger ones have grown up in a period of interactive and visually rich technological entertainment. There are extensively developed computer programs, video games, and means of self-expression in use.

New operating model with its savings: People are spending an increasing amount of time engaged in online games, simulated worlds, and worlds where computer games and the physical world connect. The same is happening with Napster and other non-channel based means of listening to music as well as common discussions and sharing of music and entertainment online. Technical assistive devices of sports are becoming a part of social media, and commonly created phenomenon such as flash mobs are descriptive of the power of social media in interactions in the physical world, the same way as in people's common activity in areas of unrest and riots. Virtual travels are collected online, cultures are interacting in online games. The information network helps with coping in foreign places and cultures. More and more people communicate with others in a foreign language almost daily with the help of automatic, free of charge translators. Hobbies and culture leads to the birth and strengthening of professional contacts as well as learning skills that are important in work.

Development of technological maturity: Technology is already used widely however, the speed of development remains fast – for example, games are becoming even more realistic and more massive in terms of the user populations (cf. for example, iPhone games with multiple users). Gaming experiences are already of even "better quality" than visual

perceptions in the real world. Devices that recognize the motions and gestures of the user are already transferring the user's character into the virtual world and the feel of presence and experience of interaction are becoming stronger. It is only a matter of time when movies become interactive in a similar way as games and if they could partly be based on real-time "crowdsourcing". On the other hand, this has been experimented with, and it has been noted that the quality of the stories typically becomes weaker and mediocre.

Challenges of the transition period: The transition period is already underway and as a problem one could mention especially the capacity of individuals and society in adopting new use experiences and continuously renewing technology.

Legislative/structural barriers: Legislative barriers are primarily related to protection of privacy. For this reason, it is essential that legislation focuses on solutions, meaning that is takes care that the information within the system is not used for the wrong purposes. The most crucial structural barriers may be related to the citizens' experiences of how the information is used in the system and which issues citizens can really influence.

Threats of the new technology: A threat is technologization taken too far, i.e. that people won't be able to really function in the world without (information) technology. A threat is citizens losing touch with both each other as well as with the problems of the real world. The potential for political manipulation also grows, if people numb themselves with entertainment based on technology by living in parallel realities while distancing themselves from physical communities and societal experiences. On the other hand, social media has been shown to strengthen and widen social connections.

1.16. National defense and antiterrorism

Current situation and its expenses: The purpose of national defense is to ensure peace in such a way that citizens and organizations can operate within the nation freely, bound by the law, and the opportunity to independently pass laws that benefit the citizens abides without pressure from outsiders. The Finnish defense budget is about 3 billion euro, in addition to about a year's time of military service and refresher courses out of the study and work career of almost every Finnish man.

During a traditional war the enemy has been disturbed or forced by destroying its defense capabilities, production facilities, logistical connections, and civilians' livelihoods and in extreme cases by occupying regions of foreign nations. More often disturbance is achieved by economical means by enforcing the internal disturbances of a nation, blocking trade relations and destroying or disturbing information technological action and stealing economically valuable information.

New operating model with its savings: A larger part of illegal activity funded by foreign nations has shifted to terrorist attacks carried out by local cells of distributed networks, phishing of information through information networks, disturbance over the information networks, and use of remotely controlled devices as weapons. The damage caused to the enemy is maximized without causing large economical or man losses to self. Blocking these activities is most effective in international cooperation by means of signal listening

of the information networks, recognizing abnormal behavior and tracking abnormal purchasing behavior.

Development of technological maturity: Autonomous and remotely controlled drones, robot insects, high-performance capacitors, laser cannons, DNA-writers, accurate aerial imaging of UAVs, artificial noses, pattern recognition, and chemical recognition and cyber war make old means of national defense insufficient.

Challenges of the transition period: In terms of national defense, the most effective means of responding to new threats are difficult to implement without comprehensive intelligence from outside the national borders and without the ability to interfere with information systems outside national borders.

Legislative/structural barriers: New threats require thorough pondering of the nature and means of national defense.

Threats of the new technology: There are diverse new robotized biological and chemical weapons of mass destruction in sight, which are capable of precision strikes. The incompatibility of the new weapons of mass destruction and the old national defense equipment is apparent. The vulnerability of a society based on information networks and automation is growing and is obvious.

1.17. Functionalization of spaces and structures

Current situation and its expenses: The built environment forms a significant part of our national wealth. The construction industry is sensitive to economic fluctuations, but its part of GDP is typically close to one tenth.

The urban environment comprises of buildings; transportation, energy, water and waste management, as well as information networks and the structures, equipment and built natural elements that are related to them.

The targets of the functionalization of spaces and structures are improvements in the profitability of building and maintenance activities as well as in the economic efficiency of the spaces and the effectiveness of their use. Today, functionality is added via information technology. The incompatibility of different parts of information technology is one of the biggest blocks of this development. The added value of information technology is mainly created through measurement, sensor, and network technologies, and programs. In addition, the safety point of view is important both in terms of information security as well as physical security through the monitoring of the condition of the infrastructure and inhibition of crime.

New operating model with its savings: The five big lines of development in the future of the urban environment are: 1) The amount and usability of digital information in the built environment grows. 2) The development of the performance of information models, calculation methods, and information technology will enable better planning and virtual testing. 3) The digital and physical worlds will be interrelated throughout the entire

lifecycle. 4) Service-based program integration, systems that self-direct according to the situation, social media, and location technologies will enable services in the built environment that are automatically tailored to the needs of the users. 5) The information modeling of the existing built environment is a significant challenge, which requires developing of the methods and technologies.

Information modeling in particular, will create opportunities for great savings because renovations can be implemented in a holistic manner. The structures can be made lighter with new materials, functionality can be added by, for example, turning the outer walls into solar panels, rooftops into gardens, roads into solar panels, windows and interior walls into displays, lamps into base stations among others. Structures can be made self-healing, so that they intrinsically detect their maintenance needs and use conditions.

Development of technological maturity: At the moment, the state of the art solutions in the information and communication technology of the built environment are mainly individual services. Small, progressive actors, such as the Finnish Lonix, have delivered vastly integrated solutions from information modeling to maintenance in over a hundred locations in ten countries, but the share of the entire building base is still very small. Advanced demand is limited, and for the most part, the producers and consumers of the built environment information technology have pigeonholed themselves into narrow specializations. Service providers offer specialized niche-services for limited needs. Today, there are four state of the art service bundles: 1) planning, contracting, use, and maintenance services, 2) distance services, 3) safety services, and 4) new health services. Traditional processes don't match the needs of information modeling thinking yet.

Challenges of the transition period: A special challenge will be the adaptation of the construction industry to new technological opportunities. The industry is conservative. Reforms must be implemented via public standardization, which is often a complicated and lengthy process. The explanation to this is that location and layout become the main selection criteria for the builder customer as the customer typically doesn't have the knowledge to estimate lifecycle costs, which leads to the building costs often becoming the sole aspect directing the builder's actions.

Limited advanced demand is also a problem. According to a roadmap by VTT (the Technical Research Centre of Finland) that charted the ICT solutions of the built environment in 2008, the designers of single-family houses don't always know how to offer advanced solutions because there is not sufficiently accurate information available in the market (Paiho et al. 2008). On the other hand, there is not always even the kind of products available that would match advanced demand. Large actors are dominating the markets and safeguarding already achieved benefits is a priority.

Education is also required both in the construction industry as well as in societal industries that are more widely related to infrastructures, such as in legislation and planning. Other challenges of the transition period will be a lack of technological standards and possibly many overlapping solutions.

Legislative/structural barriers: Legislative and structural barriers are especially related to the fact that the consequences of the actions of a multidimensional networked system are difficult to perceive. Therefore, it is difficult to implement binding legislation. Another

possible barrier is the citizens' negative experiences or fears about how the information collected by the system are used.

Threats of the new technology: New kinds of problems can emerge in a society that is becoming even more complex and more networked through an increasing amount of technological solutions. These can be, for example, technological problems that pile up through the Internet of Things, such as spy programs, viruses, and increased monitoring. Even more wicked threats can be the incompatibilities and malfunctions of multidimensionally networked technological solutions that can be difficult to locate and allocate responsibility. Therefore, the technologies should have such internally controlled interfaces that would make it possible to separate a certain solution from the system.

1.18. Operation models for self-organising communities

Current situation and its expenses: The current society is organized mainly through the hierarchical structures of the state, municipalities, companies, and the third sector. In each organization, there is typically a clear ownership and administration structure, common resources, and defined, often times regulatively limited responsibilities and tasks. Organised activities covers the entire economy and there is only limited self-organising in the operation models. At its widest, self-organising is represented in the birth of new companies and in the actors of the third sector, but once they are born, they also start abiding to traditional structures. Under the pressure of municipalities of many sizes and capabilities, the state has regulated the activities of the municipalities in a very detailed manner and there has been little room left for local democracy. As the meaning of distance diminishes and remote collaboration increases, it must be noted when increasing the size of the municipalities that organization models based on geography will not yield the benefits of local democracy the same way as earlier, but they might in fact be a barrier to collaboration.

New operating model with its savings: Self-organising and gamified means of organization have been proven functional in the areas of science, society, healthcare, and product development, among others. The Linux project is one of the most impressive examples of the new way to organize collaboration following the open-source product development model. Linux is not the only significant open-source product development project – networked open source projects have grown into a large phenomenon in many areas of information technology in industrial applications, robotics, entertainment, and office automation.

At its best, self-regulation produces specialization and exchange at lower transaction costs than markets and hierarchies. Through self-organization, open development enables more diverse approaches than hierarchy as can be concluded directly from the theories of transaction costs. In addition, self-regulation produces value through producing as well as consuming which means that through action, also the use value increases. Alvin Toffler demonstrated this prosumer value in his book The Third Wave (1980) and it has been analyzed by, among others, Ilkka Tuomi in his book Networks of Innovation (2003).

Self-organizing, communal operation models can lead to common structures that do not depend on geography. The municipal structure could be partly replaced by industry specific, geographically independent virtual municipalities. Another example are global communities, such as fan communities that are formed around a certain theme, such as heavy metal music or a certain soccer team. A third example could be partly randomly organized demonstrations that are based on a sort of "snow ball effect" that spreads in social media. Recent examples are the Arab Spring of 2012 and the events of the spring of 2013 in Brazil. Working groups of the information networks are informal and temporary networks in which citizens can meet each other and, for example, develop ideas and products. These working groups could partly replace, or at least complement, traditional organization structures. One such working group, into which over three hundred members have independently joined, has participated in commenting on this report on Facebook and the commentators have suggested many of the ideas for this report.

Development of technological maturity: There are already plenty of technologies to support self-organised action model. Contract structures related to open source approach are an important part of the action model, as are the shared development equipment that are common in open source software projects and the open electronics that are related to open source hardware development projects, that anyone can freely use in their own projects. Also the use of open data and so-called "big data" are typically based on the self-organised action model. Technologies to utilize the combined computational capacity of thousands, even millions of home computers have continuously been refined and cloud services ease the starting of projects based on the self-organized action model.

Social media solutions, starting from the already diffused Facebook, LinkedIn, and Twitter, can function as essential channels of self-organization. Crowdfunding and crowdsourcing, both of which may be used for various purposes from companies' prototypes to complex political questions, can be interesting modes of self-organization. Crowdsourcing is also a mode of operation that is continuously on a rise in companies' product development. Companies, such as Dell, Procter & Gamble, and Lego, have been applying this type of approach to their product development for a long time. Interesting modes of the self-organization are local currencies, time banks, and Internet currencies that have been introduced both on a physical local level as well as in virtual worlds. Prediction markets, in which users can bet on different ideas and applications, are also interesting applications for the self-organization. For example, Abramowicz (2007), has noted that they could even be used to predict political consensus.

Challenges of the transition period: The challenges of the transition period are related to difficulties in integrating the systems of different organizations and the operation models of individuals as all current organizations attempt to keep their position also in self-organised operations. One comparison for the transition period is the Finnish digital healthcare system and a related "health card": a light and efficient system that supports self-organization has already been created in Estonia. This is difficult to realize in Finland because the field of actors is so diverse and established. In addition, there are significant new challenges related to self-organization and new tools of exchange, which surpass national money as well as cross-border commercial collaboration models.

Legislative/structural barriers: Legislative barriers are primarily related to the freedom of the individual in economical activity, protection of privacy, and the extent of monitoring

in a nation state, for example. In addition, it is challenging to build legislation for virtual realities when conceptual structures are based on the physical world. In principle, citizens should have the same rights in physical and virtual realities, but it can still be pondered whether, for example, stealing a virtual avatar or robbing a time bank is equal to the robbery of money or material in the physical world. The forming of communal rules related to virtual worlds and enforcing these rules especially in international activities is a structural barrier in this development.

Threats of the new technology: Key threats to self-organizing and communal operation models are deeply rooted traditions, which may hamper openness on the grassroots level. Citizens who are used to long-term macro level developments may also think that there is nothing that can be done. Government level may also impact self-organization to some extent. In a similar manner to today's social media culture, the diffusion of self-organizing operation models requires a certain "transparency tolerance" and the acceptance of a spectrum of opinions. However, this should not lead to the acceptance of "online bullying" or other anti-social forms of communication.

1.19. Virtualisation of identities and social structures

Current situation and its expenses: A person plays multiple roles during their life and even has different roles on a daily basis. In a search for a job or in a profession we attempt to be suitable for the job, in a hobby community we behave according to the group identity of that community and within the family we adapt yet another role. Life is fulfilling and living different roles. In major cities, these roles rarely mix and a person can live a very fragmented life. It is even possible that a person fears that people from his or her different life circles would meet each other. Facebook has changed this by making the life circles of different people visible to each other, but at the same time the information network has enabled for a person a completely different kind of online life in secret from even the closest people in the physical world.

In the future, citizens' identities will be increasingly virtual. In addition to this, citizens may have multiple different electronic identities, as which they can have conversations in different channels. In the future, virtual identities may also have more and more signs of citizenship. For example, Ondrejka (2007: 46–48) has spoken about three kinds of citizenship. The first one, geographical citizenship, refers to traditional territorial understanding of citizenship. The second, honorary citizenship can be offered to especially distinguished citizens. As the third one that Ondrejka mentions, virtual citizenship refers to citizenship in virtual communities in particular.

Virtualisation is already impacting the forms of political activity. Political activities can be based on new kinds of background philosophies, examples of which have been so-called "pirate parties" and information society parties. Adapting from Hintikka (2008), it can be noted that political activism that utilizes virtuality can be divided into hactivism, where the Internet and virtual worlds are used to reinforce impact and for activity that is focused solely on virtual worlds. The new, emergent political activity has been called "open politics".

A key term in virtualization, as well as in self-organising, is empowerment. It is based on virtual "mass movements", the power potential of masses and distributed networks. Empowerment opens channels for global interaction around themes that can be very local. For this reason, a positive future for virtualisation can be the empowerment of citizens and the voice of citizens being increasingly heard. On the flipside, there is a possibility of vast monitoring and global level spying, of which we've already gotten examples during the "spying leaks" in the United States and the UK in the summer of 2013.

New operating model with its savings: Social media has created a situation where an employer or a collaboration partner searches for and sees a person's background and acquaintanceships. Because it's difficult to speak one thing to one person and another to someone else or to falsely acquire lists of acquaintanceships, the truthfulness and credibility of one's role created in social media is strengthened. Social media prevents the fragmentation of roles and forces one to stand behind their words, which makes it an integrative world in that sense. Open people are more at peace with themselves and the youth has embraced that vastly as their own approach. The one who is left outside is somewhat suspicious and abnormal. Cognitive dissonance is emphasized – one has to act as he speaks or speak as he acts – in all communities, because social media communities are strongly overlapping. This eases collaboration by increasing trust and reducing abuse. People's real skills, situations, and needs also become visible more easily and networked, self-organising specialization and exchange become more efficient. The world becomes more transparent and that has significant implications. People are more willing than before to collaborate in networks that are visible to themselves, and the more open an individual is, the more his or her influence over his or her local community grows. At the same time, the vulnerability of an individual can increase.

Development of technological maturity: A significant amount of technology already exists. The listing of virtual technologies can be started from Facebook, LinkedIn, and Twitter, which act as the messengers of virtual interaction. In addition, different virtual worlds, such as Second Life, and online games of thousands of users, such as World of Warcraft or the Finnish mobile game Clash of the Clans, are already in vast use. Technology is widely used in the corporate world and in entertainment, but there are still relatively less applications in public administration.

Challenges of the transition period: The challenges of the transition period are especially related to the very differing degrees of transparency of power structures, the inability of people with role fragmented lives to adjust to a new transparency, the weak protection of virtual identities, and people's alienation from the real world as virtual roles bring them more satisfaction.

Legislative/structural barriers: Legislative barriers are primarily related to the protection of privacy and to how certain pieces of information can be used, and what the meaning of private digital space is. Identity thefts will become prominent means of abuse as the significance of virtual identities grows.

Threats of the new technology: Societal activity based on virtual identities has interesting consequences and risks that may not even be fully understood on a larger scale. One risk posed by virtualization and "networkation" is related to the potentially "eternal memory" of information systems and its application as a means of monitoring.

For example, Albrechtslund (2008) has spoken about so-called participatory surveillance, which is based on the norms that emerge in virtual interaction and their limits. Also Zimmer (2008) has noted that different protocols and algorithms that structure data can create a sort of power that is based on panoptic sorting, i.e. system gatekeepers hold a vast amount of information that can be used for diverse purposes. Citizen level participation that is based on virtual identities can also have other kinds of consequences. For example, Jarrett (2008) has said that virtual worlds can create "flexible" and "anti-political" model citizens out of their users. Therefore, the threat is that users become sort of "power blind" actors, who quietly and without themselves noticing continuously adapt to different needs of societal power.

1.20. Democracy, freedom and social cohesion

Current situation and its expenses: Democracy regulates the interaction of individuals and their organizations. Simply put, the target is to encourage collaboration, i.e. positive sum game, and to avoid destructive, i.e. negative sum game. Another target is that nobody's freedom or opportunities to participate is limited neither through regulation nor resource scarcity. It can be assumed that the proponents of democracy are unanimous about these targets. Opinions about details may vary.

The apparent purpose of democracy is that everyone's needs are taken into account. This is realized when the vote of each individual carries significance. Sufficient social cohesion is required in order for people to feel that the democratic mechanism is useful and necessary enough to participate in it.

Political and military machinery, police force, the judicial system, and the transfer payment system can be counted as the costs of democracy, in addition to part of the state's and municipalities' social and health sector and education sector costs and infrastructure costs.

New operating model with its savings: Specialization and exchange is historically the most important wealth creating positive sum game, and there is no end in sight for the development it started. Emile Durkheim demonstrated how mechanical solidarity, i.e. the requirement of equality, must give way for organic solidarity, i.e. co-operation ability related to differentiation as specialization increases. In historical review, this has been demonstrated as the continuous loosening of roles and increase in tolerance. In a pluralistic society, transparency increases cohesion and trust between actors, when it is transparency between citizens and transparency in the use of power.

The shift from economies of scale towards efficient mass customization and individualized production as well as increasingly inexpensive production equipment and networked activity leads to improved balance of resources.

As was demonstrated by Castells, people's division into those who are in a space of flow and those who are in a space of places reduces cohesion locally. Increasing direct interaction globally diminishes the role of local democracy and opportunities to act.

Development of technological maturity: The development of information networks and travel has led to increased global interaction on the level of the individual. Simultaneously, nations have begun to spy each other's citizens after technology has enabled it. Remote controllable equipment and remote work reaching physical tasks narrows the opportunity of local actors to regulate events in their own area.

Robotics, information technology and other technological development enable the sourcing of various skills and starting the production of even complex goods and services without large capital or other centralized resources.

Challenges of the transition period: More and more common issues are globally shared. Democratic mechanisms are either regional or they have been organized very far away from the people whose interests they are promoting through collaboration bodies of local democracies. Democratic mechanisms have not adapted structurally to the release from the chains of time and place that information networks provide.

Legislative/structural barriers: Legislation is based on regional democracy and regulation of education as well as specialization and exchange by means of limiting options. It is impossible to create operating conditions for democratic structures that cross national borders by means of national legislation. International agreements or virtual states are required for that.

Threats of the new technology: Facilitation of interaction that crosses geographical borders is a significant threat to regionally organized democracy, and its ability to regulate interaction without distancing from democratic targets has been diminished.

2 Radical Technological Solutions

In order to be a radical technological solution that is suitable for the list of 100, the technological solution has to be important for many global value-producing networks (GVPN) or it has to be crucial for some GVPNs. This implies that the radical technological solution will be able to change current practices either by saving costs, easing people's everyday lives or by increasing comfort or by strengthening or weakening power structures. The solution should be available in the consumer or the user market by 2020, at the latest, and its impacts should be vast by the year 2030. To have been selected on the list, the minimum requirement is that the principles of the solution have already been proved in a scientific publication.

Symbolically, the radical technological solution is like a forest that now includes just small trees or saplings. The future value of the "radical technological solution forest" is evaluated based on heights its highest trees in 2030. In less metaphorical terms, the value of a solution is based on the best technologies or the best practices among multiple technical execution options of a function in 2030. Many execution options are included to the same radical technological solution if their development efforts have a shared functional target.

The description of each radical technological solution begins with an ingress that summarizes the recent state of the art of the solution and its future prospects in 2020 and 2030 if the solution delivers on its promise as anticipated. After this, today's various leading achievements related to the solution and most relevant background documents are presented as hyperlinks. These open Internet sources are the empirical basis on which anticipations concerning the state of art in 2020 and 2030 are based upon. After the hyperlinks, most promising execution options of the functional challenge of a solution are described using the information of the hyperlinks. The information of the hyperlinks is then used for the anticipation of the most probable application areas of the radical technological solution. Next, the general maturity level of a radical technological solution is evaluated. The radical technological solutions are categorized into four levels of maturity:

1. Scientific principles that make the technological breakthrough possible are proved and the functionality is demonstrated in a peer referred scientific paper
2. Prototype that is scientifically or commercially demonstrated. The functionality of the prototype fulfills requirements of the commercialization
3. Enough actors that have financial resources develop the technological breakthrough that is close to commercialization
4. Increasing amounts of products are delivered to customers, new application areas emerge and prices of the products decrease

If the solution is evaluated to be currently in the stage 4, its recent growth prospects are further evaluated based on the cited Internet sources with the indicator anticipated market volume in 2030 divided by 2014 market volume (at least 2)

- High growth rate 2–8, yearly 5–15%
- Breakthrough growth rate over 8, yearly over 15%

After the maturity level, the scientific interest of the solution and global active development work focused on it are shortly evaluated. In addition to the recent commercialization opportunities of a radical technological solution, the likelihood of its success in the long term is affected by the scientific interest toward the field. This interest supports development opportunities, and other vast and active development work. The most important background source of the evaluations is the Science Maps of the Japanese NISTEP institute (http://www.nistep.go.jp/en/).

Finally, the linkages to the global value-producing networks (GVPN) are evaluated. In the linkages to the global value-producing networks (GVPN), minor linkages are not bolded and especially significant linkages are highlighted with both bolded and underlined text. Unlike the Finnish report, the linkages to Finnish export channels are not discussed in this summary.

In order to help the users of the tool to see connections between radical technological solutions, the solutions are presented in the following groups. The grouping is done only for improved readability and it is no way used in the indexing of the solutions. The solutions included to this summary belong just to the seven first groups.

Control of metabolism of human beings and other organisms

Social innovations

Human-machine interface technologies

Algorithms and Systemic Solutions based on the Information technology

Measuring and imaging

Movement and transportation

Robots

Mimicking of nature and cyborgs

Essential enabling materials and industrial raw materials

Energy technology

Messaging technologies and protocols

Control of metabolism of human beings and other organisms

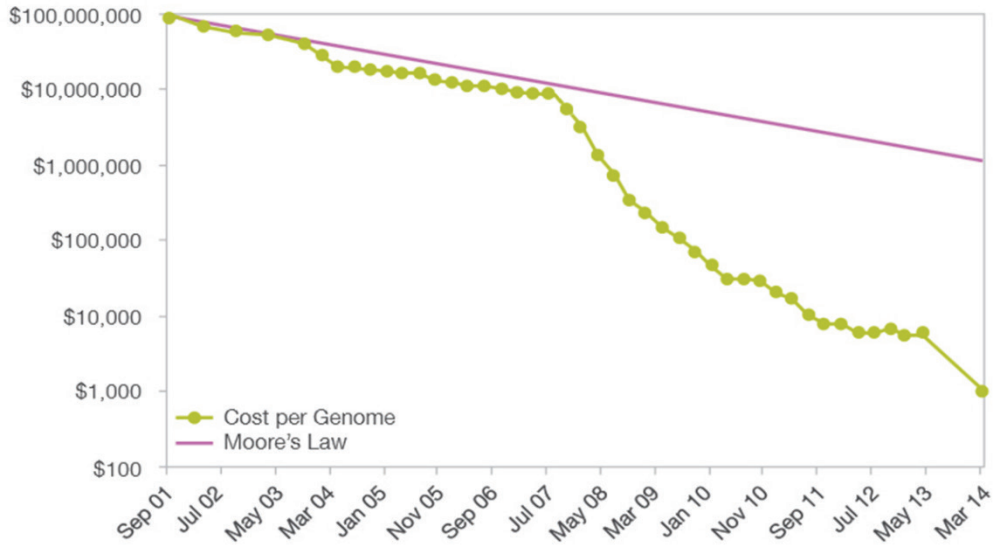
This group includes radical technological solutions that monitor or change the metabolic systems of human beings or other organisms. Medical applications based on the use of robotics are discussed elsewhere.

2.1. Routine and complete DNA sequencing ****

Ingress: Cheap whole-genome sequencing is already now available for all kinds of organisms. In countries like Finland, whole genomes of most people will probably be sequenced in 2030. Genetic variation influences almost all human diseases. DNA sequencing will guide physicians in choosing the best drug to treat a specific patient for a specific disease while risking the fewest side effects. In 2030, the personalized electronic health records will combine clinical and whole-genome sequencing data as well as data from an individual's environment including daily routines, exercise and diet regime. Patient specific models of organs, overall anatomy and physiology will be developed into 3D/4D models creating virtual replicas of a patient's body. People might easily compare their genetic information and make more or less valid conclusions using interpretation tools available on the Web. The possibilities for detection, genetic modification and controlling of whole-genome sequenced organisms are radically better in 2030 than now.

Background information and examples:
http://engineering.columbia.edu/researchers-report-novel-approach-single-molecule-electronic-dna-sequencing
http://www.illumina.com/systems/hiseq-x-sequencing-system.ilmn
http://www.nature.com/nature/journal/v487/n7406/full/nature11236.html

Recent vanguard product(s) or invention(s): DNA can be threaded through protein nanoscale pores under an applied electric current to produce electronic signals of four building blocks of DNA: A, C, G and T. The reported nanopore-based sequencing by synthesis (Nano-SBS) strategy can accurately distinguish four DNA bases by detecting 4 different sized tags. HiSeq X Ten of the U.S. company Illumina enables "extreme" volume $1000 genome sequencing for institutes performing population and disease studies. It means that the apparent stagnation of the development during 2011-2013 has now ended (see the picture, source: http://www.futuretimeline.net/blog/2014/01/16.htm).



The diagnosis and treatment of cystic fibrosis illustrates recent possibilities for inherited diseases. Instead of checking for the six mutations most commonly linked to this disease, the new HiSeq X Ten based tests are able to discern a total of 139 genetic variations that give rise to cystic fibrosis. They will also tell doctors whether a patient is among the 4% who has a mutation that's targeted by a specific, costly drug. Whole-genome sequencing has begun to reshape the way physicians diagnose and treat cancer as well.

Application areas in 2030: Cancer diagnosis and treatments, personal risks of many diseases and personal healthcare, study of inherited personal properties, addition of useful properties to various kinds of organisms, social activities, optimized insurances, criminal investigations.

Market development: 4, market growth
High growth rate 2014-2030 yearly 5-15%

Scientifically highly interesting

Impacts on the value chains: 1.4, 1.5, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.15, 1.16, 1.18, 1.19, 1.20

2.2. Biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms ****

Ingress: Biochips (also referred to as microarrays) and biosensors function as cheap miniature labs that can replace laboratory work with more streamlined research and high-speed diagnosis of DNA, proteins or other large molecules. They will be basic tools of the personal healthcare in 2030. They will open possibilities for radical restructuring of

the recent health care systems. They will provide effective tools also to all other sectors that handle living organisms e.g. to the food industry.

Background information and examples:
http://www.kurzweilai.net/detecting-single-samples-of-smallest-known-viruses
http://phys.org/news/2012-12-pocket-blood.html#jCp
http://www.engadget.com/2013/05/25/iphone-biosensor-cradle-brings-us-one-step-closer-to-having-tric/
http://www.scienceworldreport.com/articles/13249/20140303/complete-medical-check-up-chip.htm
http://www.scienceworldreport.com/articles/7910/20130702/nano-device-detects-bacteria-minutes-instead-weeks.htm
http://www.scienceworldreport.com/articles/8477/20130729/simple-saliva-samples-reveal-serious-illnesses-cancer-diabetes.htm

Recent vanguard product(s) or invention(s): A new device about the size of a business card could allow health care providers to test for insulin and other blood proteins, cholesterol, and even signs of viral or bacterial infection all at the same time—with one drop of blood. Researchers have created a super-sensor that can detect even single samples of the smallest known viruses. Based on a recent study, it may be possible to detect serious illnesses in their early stages with the help of a simple saliva test. It currently takes a long time to measure a bacterial infection's response to antibiotic treatment. Using laser and optical technology, a team of physicists has reduced this time to a couple of minutes. iPhone biosensor cradle brings us one step closer to having tricorders of science fiction.

Application areas in 2030: Biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms. Personal healthcare with simple tests without laboratory studies. Rapid diagnoses of ingredients of various kinds of biomaterials e.g. allergens in food.

Market development: 4, market growth
High growth rate 2014–2030 yearly 5–15%

Scientifically highly interesting

Impacts on the value chains: 1.4, 1.5, 1.7, 1.8, 1.9, 1.11, 1.13, 1.16, 1.17, 1.18, 1.19, 1.20

2.3. Small portable magnetic resonance imaging scanner *

Ingress: Magnetic resonance imaging is one of the most important imaging methods used in medicine. However, MRI scanning has one major disadvantage: The machines are huge, extremely expensive, and almost impossible to transport. The healthcare of developing countries will greatly benefit from small portable magnetic resonance imaging scanners. Also, other kinds of uses beside medicine are possible. They are already in use in the Antarctic, helping researchers to study the effects of environmental change by analyzing the structure of ice masses or drilled ice cores. Portable scanners can deliver important

data - directly and online - during production processes. Industrial manufacturers of sausages, cheese or candies, for instance, can use it to analyze the fat or water content of their food products.

Background information and examples:
http://www.news-medical.net/news/2008/07/08/39842.aspx
http://onlinelibrary.wiley.com/doi/10.1002/mrm.25147/abstract
http://www.arabianbusiness.com/female-saudi-scholar-develop-portable-mri-scanner-449570.html

Recent vanguard product(s) or invention(s): Researchers have succeeded in developing small, less expensive, and portable magnetic resonance spectrometers that can even be powered by batteries. Instead of the large superconducting magnets that have to be cooled with liquid helium and nitrogen, extra-strong permanent magnets are installed in their devices. There is no need for cooling anymore.

Application areas in 2030: Medical applications, food industry, geology, control of industrial processes. Portable systems will be available for siting in unconventional locations such as intensive care units, physician offices, surgical suites, ambulances, emergency rooms, sports facilities, or rural healthcare sites.

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.7, 1.8, 1.9, 1.10, 1.11, 1.14, 1.16, 1.17, 1.18

2.4. Drugs based on genetically modified organisms ***

Ingress: Future individualized healthcare will be based much on pharmacogenomics. Pharmacogenomics uses a person's genes to explain the difference between how one person responds to a drug compared to another. Instead of drug chemicals alien to human metabolism, the pharmacogenomics uses various therapeutic proteins. Genetically modified bacteria, plants or other organisms are able to produce these proteins e.g. antibodies, blood product substitutes, vaccines and hormones. Mathematical models of the bioinformatics help to see what kinds of impacts protein-protein or protein-DNA interactions related to a drug have on a patient. An example of the achievements of the pharmacogenomics is protein that activates immune systems to destroy many kinds of cancer cells.

Background information and examples:
http://www.ahdbonline.com/issues/2010/march-april-2010-vol-3-no-2/87-article-87
http://qjmed.oxfordjournals.org/content/97/11/705.2.full
http://www.cosmosmagazine.com/news/genetically-modified-plant-produces-insulin/
http://blog.planprescriber.com/2014/03/28/anti-cd47-cancer-drug/
http://neurosciencenews.com/regrow-limbs-peripheral-nerves-axonal-regeneration-dual-leucine-zipper-kinase-dlk/
http://www.scienceworldreport.com/articles/8265/20130719/mathematical-models-based-individual-dna-select-ideal-drugs.htm

https://www.doria.fi/handle/10024/97260
http://www.nejm.org/doi/full/10.1056/NEJMoa1300662
http://www.theguardian.com/science/2013/oct/13/craig-ventner-mars
http://www.washington.edu/news/2013/09/30/uw-engineers-invent-programming-language-to-build-synthetic-dna/
http://www.cbsnews.com/news/artificial-dna-breakthrough-could-lead-to-new-drugs-treatments/

Recent vanguard product(s) or invention(s): Successes are found especially in cancer therapies e.g. a protein that activates immune systems to destroy many kinds of cancer cells. A possible breakthrough technology that can rapidly start or halt the expression of any gene of interest simply by shining light on the cells

Application areas in 2030: Prevention and improved treatments of all kinds of diseases. Knowing one's genetic code and how it affects the risk for eventual illness will allow a person to make adequate lifestyle and environmental changes at an early age to avoid or lessen the severity of a disease. Similarly, advanced knowledge of specific disease susceptibility will allow the creation of a personalized health plan, careful monitoring with sophisticated assessments (eg, the use of specialty biomarkers), and will facilitate the introduction of protein based treatments at the most appropriate stage to maximize the therapeutic impact. Famous gene researcher Creig Venter believes that in future a Digital Biological Converter attached to a computer would receive DNA sequences over the Internet to synthesise proteins, viruses and even living cells. A step towards that is a new programming language for synthetic DNA.

Market development: 4, market growth
High growth rate 2014-2030 yearly 5-15%

Scientifically highly interesting

Impacts on the value chains: 1.4, 1.5, 1.7, 1.8, 1.9, 1.11, 1.16, 1.19, 1.20

2.5. Nanorobots (nanobots) in the health promotion *

Ingress: Nanorobots are devices ranging in size from 0.1–10 micrometers and constructed of nanoscale or molecular components. They are able to move and manipulate nanoscale objects. Monoclonal antibodies have already many kinds of applications in medicine. If we do not call monoclonal antibodies nanorobots, vanguard nanorobots are still in prototype phase. A big problem of commercialization is how to multiply protypes without multiplying methods of the pharmacogenomics or monoclonal antibodies. In 2030, it is possible that nanorobots are e.g. able to make surgery operations and transport medicines in the body. The use monoclonal antibodies will probably increase much in the treatments of autoimmune diseases (e.g. rheuma), cancer and in viral infections.

Background information and examples:
http://www.sciencedaily.com/releases/2013/03/130313160757.htm
http://phys.org/news/2013-08-dna-nanorobots-tag-cellular.html
http://www.scienceworldreport.com/articles/8194/20130716/artificial-organelles-transform-free-radicals-water-oxygen.htm
http://gizmodo.com/magnetic-microbots-perform-eye-surgery-without-a-single-598784256

Recent vanguard product(s) or invention(s): If we consider that monoclonal antibody is nanorobot there are already very many kinds of applications of nanobots. Monoclonal antibodies are established tools in biochemistry, molecular biology and medicine. A recent achievement is monoclonal antibody that can effectively reach inside a cancer cell. Another promise of this kind of nanorobot is a collection of DNA molecules some attached to antibodies that attach a fluorescent tag to the cancer cell surfaces. A clear nanobot (or actually microbot) uses a series of electromagnetic coils positioned outside the eye. The microbot can be guided and controlled with remarkable precision, allowing even delicate surgeries to be completed without having to open the eyeball

Application areas in 2030: Monoclonal antibodies are already extensively used in diagnostics and in the treatments of autoimmune diseases (e.g. rheuma), cancer and in viral infections. Other kinds of nano- or microbots might be used in 2030 beside these uses e.g. in plaque purification of blood veins or in eye surgery.

Market development: 2, prototypes that are scientifically demonstrated or 4, increasing amounts of monoclonal antibody products delivered to customers.

High growth rate 2014-2030 yearly 5-15%

Scientifically interesting, especially nanobots using monoclonal antibodies

Impacts on the value chains: 1.5, 1.8, 1.9, 1.11, 1.12, 1.16

2.6. Longer life time and slower aging processes **

Ingress: Aging is not inevitable. Human beings and mammals have a lifespan during which the renewal of the bodily functions become slower and degeneration proceeds. Fishes do not have similar aging mechanism. Scientists have found means to stop aging and postpone and possibly mitigate diseases tied to aging such as cardiovascular disease, neurodegenerative diseases, and diabetes. Genetically programmed genes that control aging, among them the SIRT2/SIRT1 genes, when altered, can change our health and lifespan. It is possible that drugs combating aging may be available already before 2020. A problem is that the drugs possibly promote cancer.

Background information and examples:
http://www.biosignaling.com/content/9/1/11
http://phys.org/news/2014-01-protein-sirt1.html
http://www.nature.com/news/molecules-in-the-brain-trigger-ageing-1.12891
http://news.harvard.edu/gazette/story/2013/05/making-old-hearts-younger/

http://www.scienceworldreport.com/articles/8894/20130819/girl-never-ages-hold-key-biological-immortality-video.htm
http://news.sciencemag.org/biology/2014/05/young-blood-renews-old-mice
http://www.humanlongevity.com/

Recent vanguard product(s) or invention(s): Many genes that have impacts on aging processes have been identified. The most promising is Sirt1 gene (Resveratrol-protein) that performs a wide variety of functions in biological systems. It seems to have positive impacts besides aging on obesity-associated metabolic diseases, cellular senescence, cardiac aging and stress and prion-mediated neurodegeneration. Its problem seems to be cancer promotion. Sirt1 protein inhibits gene p53-dependent apoptosis of damaged cells including cancer cells. This might be the risk of the 2014 launched "super-sirt" which functions despite the metabolic stress of obesity that inhibits Sirt1 activity. NF-κB — molecule seems to have similar functions than Sirt1 in the brains of mice. Animals lived longer than normal when they were injected with a substance that inhibited the activity of NF-κB in immune cells in the hypothalamus of mice.

Application areas in 2030: Drugs that have impacts on aging and postpone and possibly mitigate diseases tied to aging, such cardiovascular disease, neurodegenerative diseases, and diabetes.

Market development: 2, prototypes that are scientifically demonstrated

Scientifically highly interesting

Impacts on the value chains: 1.5, 1.7, 1.8, 1.9, 1.15, 1.17, 1.18, 1.19, 1.20

2.7. Continuously monitored personal health ****

Ingress: Fitness-related wearables have dominated the market of the personal health monitors. With 2030 devices, healthcare provider or a person might be able to monitor continuously what is going on inside the person during various situations and environments. There are already available various precision diagnostic technologies that show that this vision is reasonable. Based on advances in fields such as artificial intelligence, wireless sensing, imaging diagnostics, lab-on-a-chip and molecular biology, the Qualcomm Tricorder XPRIZE launched in 2010 a $10 million global competition that stimulates innovation in order to realize this vision.

Background information and examples:
http://www.qualcommtricorderxprize.org/files/qtxp.org/QTXP_Guidelines_20130701_v18.pdf
http://sys03-public.nbcnews.com/technology/tiny-medical-electronics-dissolve-harmlessly-inside-your-body-6146659
http://news.cnet.com/8301-11386_3-57448666-76/wireless-tooth-tattoo-can-detect-bad-bacteria/
http://www.newsmaxhealth.com/newswidget/wristband-sensor-monitor-blood/2013/07/01/id/512832

http://gizmodo.com/5882725/the-miraculous-nasa-breakthrough-that-could-save-millions-of-lives
http://www.engadget.com/2014/01/16/google-smart-contact-lens/
http://www.scienceworldreport.com/articles/12786/20140210/first-nanomotors-ever-controlled-inside-living-cells.htm

Recent vanguard product(s) or invention(s): Swiss scientists have developed a new wearable monitor — about the size of a wristwatch — that can track blood pressure as accurately as the standard pressure cuff used by doctors worldwide. A team of researchers has created a form of electronics that can be implanted in a patient's body then forgotten about — because the implants will dissolve within a week or two. A sensor was affixed to a cow's tooth and tailored to detect a sample of bacteria described as causing surgical infections and leading to stomach ulcers. NASA has developed biocapsule—made of carbon nanotubes— for astronauts. The capsules' porous natures allow medication to pass through their walls, but the nanostructures are strong enough to keep the cells in one place. Once all of the cells are expended, the Biocapsule stays in the body, is stable and is unnoticed.

Application areas in 2030: The following "Core list" of Qualcomm Tricorder XPRIZE describes some main targets of the continuous monitoring: Anemia; Urinary tract infection,lower; Diabetes,type 2; Atrial fibrillation; Stroke; Sleep apnea, obstructive; Tuberculosis; Chronic obstructive pulmonary disease (COPD); Pneumonia; Otitis("ear infection"); Leukocytosis; Hepatitis A; and the absence of those conditions

Market development: 4, market growth
High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.8. Brain implants that restore or develop brain functions **

Ingress: In 2011, a paralyzed woman picked up a bottle of coffee and took a drink. She did it using a robot arm controlled by a sensor in her brain. The sensor read her neural activity and told the arm what to do. Besides that achievement, many kinds of brain implants are already in use. Deep brain stimulation (DBS) is used to treat symptoms of Parkinson's disease. DBS uses a surgically implanted, battery-operated medical device. US Defense Advanced Research Projects Agency, or DARPA, launched 2014 a $70 million program to help military personnel with psychiatric disorders using electronic devices implanted in the brain. Recently, implants use to restore function lost to disease, but they could be used to enhance function, too. In 2030, they might promote for example quick learning, memory processing, language translation or night vision.

Background information and examples:
http://www.businessinsider.com/brain-implants-will-give-us-superpowers-2014-4
http://www.npr.org/blogs/health/2014/05/27/316129491/military-plans-to-test-brain-implants-to-fight-mental-disorders
http://www.wired.co.uk/news/archive/2014-06/25/paralysed-man-moves-hand
https://www.youtube.com/watch?v=ogBX18maUiM,http://www.technologyreview.com/news/429204/a-brain-implant-that-thinks/
http://edition.cnn.com/2012/04/14/health/battery-powered-brain
http://www.telegraph.co.uk/science/science-news/9875931/Scientists-create-sixth-sense-brain-implant-to-detect-infrared-light.html
http://www.bbc.co.uk/news/science-environment-23447600

Recent vanguard product(s) or invention(s): Many kinds of application in the treatments of diseases e.g. paralyzation, depression and Parkinson disease. Memories are changed and new cognitive functions developed. A team was able to make the mice wrongly associate a benign environment with a previous unpleasant experience from different surroundings. Researchers have used a neural implant to recapture a lost decision-making process in monkeys—demonstrating that a neural prosthetic can recover cognitive function in a primate brain. Scientists have created a "sixth sense" by creating a brain implant through which infrared light can be detected.

Application areas in 2030: Treatments of diseases e.g. paralyzation, depression and Parkinson disease. Improved senses, control of equipment and messages using implants in brain, promotion of learning.

Market development: 4, market growth in treatments of diseases, 2, prototypes that are scientifically demonstrated in other kinds of applications

High growth rate 2014-2030 yearly 5-15%

Scientifically interesting

Impacts on the value chains: 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.17, 1.18, 1.19

2.9. Drugs that prevent dementia ****

Ingress: Alzheimer's disease is the most common type of dementia, a general term used to describe various diseases and conditions that damage brain cells. Alzheimer's disease accounts for 50 to 80 percent of dementia cases. The main cause of the Alzheimer is known: β-amyloid plaque. Drugs that destroy β-amyloid (Aβ) (e.g. antibodies) have had minor impacts on people that already have symptoms of the Alzheimer disease because the plaques develop during a very long time. The disease may take hold 25 years before symptoms appear. The most promising strategy now is to use new brain scans and other methods to find and treat people before they have symptoms of mental decline. Breakthroughs in treating Alzheimer's disease might be that scientists have uncovered a rare gene mutation that keeps plaque from forming in the brain. A common gene variant

seems to protect a person because it promotes synaptic connections between neurons in all phases of life.

Background information and examples:
http://www.star-telegram.com/2012/07/11/4094128/alzheimers-researchers-make-major.html
http://www.ucsf.edu/news/2014/05/114196/better-cognition-seen-gene-variant
http://www.alz.org/research/science/alzheimers_treatment_horizon.asp
http://www.express.co.uk/news/uk/426932/Missing-Link-found-in-cure-for-Alzheimer-s
http://www.brandeis.edu/now/2014/april/alzheimers.html
http://www.ncbi.nlm.nih.gov/pubmed/24601543
http://www.scienceworldreport.com/articles/12872/20140213/brain-scans-may-predict-symptoms-of-alzheimers-years-before-they-appear.htm

Recent vanguard product(s) or invention(s): Scientists have uncovered a rare gene mutation that keeps plaque from forming in the brain. The researchers found that people who carry a single copy of the KL-VS variant of the KLOTHO gene perform better on a wide variety of cognitive tests. KL-VS allele did not seem to protect people from age-related cognitive decline. But overall the effect was to boost cognition, so that the middle-aged study participants began their decline from a higher point.

Application areas in 2030: Cognitive skills and independent living of people especially older than 75 years.

Market development: 4, market growth, 2 prototypes of more efficient than recent inefficient cures based on genetic information

High growth rate 2014-2030 yearly 5-15%

Scientifically highly interesting

Impacts on the value chains: 1.5, 1.7, 1.8, 1.9, 1.10, 1.18.1.19, 1.20

2.10. Repairing and regrowing of human organs, (stem) cell cultivation **

Ingress: In 2030 stem cells might replace cells lost in many devastating diseases for which there are currently no sustainable cures, for example in diabetes to replace the loss of insulin-producing beta cells; liver cells destructed by alcohol or regrowth of human corneal tissue to restore vision. The 2012 Nobel priced discovery that mature cells can be reprogrammed to become pluripotent opened better opportunities for these kinds of applications. Experts now consider, however, that making purpose-built tissues may be far in the future.

Background information and examples:
http://www.nobelprize.org/nobel_prizes/medicine/laureates/2012/yamanaka-facts.html
http://www.nature.com/news/stem-cells-cruise-to-clinic-1.12511
http://discovermagazine.com/2014/jan-feb/05-stem-cell-future

http://news.sciencemag.org/sciencenow/2013/07/scientists-grow-human-livers-in.html?ref=hp
http://www.nature.com/news/stem-cells-reprogrammed-using-chemicals-alone-1.13416
http://www.medicaldaily.com/stem-cells-fingernails-are-key-regrowing-amputated-finger-tips-246748

Recent vanguard product(s) or invention(s): Shinya Yamanaka and John Gurdon received the 2012 Nobel prize for the discovery that mature cells can be reprogrammed to become pluripotent. This discovery is solving the ethical and immunological problems related to the use of embryonic stem cells. Using this progress in 2013, researchers succeeded in generating mini-livers, or liver buds, from stem cells that were taken from human skin and reprogrammed to an embryonic state. In 2030 a person with liver failure would get tens of thousands liver buds that seem to function like a whole liver. Perhaps also recently created brain organoids, formations of cells that mimic some of the brain's regions, might function like liver buds. Because the buds and organoids are generated from the skin of each individual patient, recipients will have to rely on immune suppressing drugs to avoid rejection. Also own skin cell based whole organs do not have immunological problems. Researchers have identified a way to enhance regrowth of human corneal tissue to restore vision. Experts now consider, however that making purpose-built tissues may be far in the future, because figuring out the exact recipes to turn cells into functioning bone, heart or spinal cord will take time. However, detached fingertips are already regrown using a wound powder called MatriStem that activates fingernail stem cells. Researchers have also identified a way to enhance regrowth of human corneal tissue to restore vision.

Application areas in 2030: In 2030 stem cells might replace cells lost in many devastating diseases for which there are currently no sustainable cures, for example in diabetes to replace the loss of insulin-producing beta cells; liver cells destructed by viruses or alcohol or regrowth of human corneal tissue to restore vision. Probably the growing of whole organs is still in experimental stage.

Market development: 4, first applications of stem cells, 2, prototypes of whole organs available

Breakthrough growth rate 2014-2030 yearly over 15%

Scientifically highly interesting

Impacts on the value chains: 1.5, 1.7, 1.8, 1.9, 1.11

2.11. Synthetic cartilage in human joints *

Ingress: About 27 million people in the United States suffer from osteoarthritis. This can result in pain, swelling, and eventually even loss of motion in the joint. Knees and joints in the hand are particularly affected. There are already cures available for osteoarthritis. Experts from a wide variety of fields have collaborated to research and they have created an extremely tough and stretchy biocompatible material that may be used in the future to

replace damaged cartilage in human joints. This and similar materials seem to have also important uses in robotics.

Background information and examples:
http://www.ucsfhealth.org/treatments/cartilage_repair/
http://cleantechnica.com/2012/09/09/biocompatible-material-much-tougher-than-cartilage-developed-may-be-able-to-replace-damaged-cartilage-in-joints/
http://medcitynews.com/2013/07/synthetic-cartilage-implant-designed-to-restore-natural-joint-mechanics-in-osteoarthritis-patients/
http://www.iflscience.com/health-and-medicine/made-order-cartilage-could-combat-osteoarthritis

Recent vanguard product(s) or invention(s): An extremely tough and stretchy biocompatible material that may be used in the future to replace damaged cartilage in human joints. This newly created gel that combines different polymers is able to stretch to 21 times its original length, and is, more impressively, also extremely tough, biocompatible, and capable of self-healing. Another synthetic cartilage implant for patients with osteoarthritis, Cartiva SCI is made with a polyvinyl alcohol cryogel that mimics natural cartilage and provides flexible cushioning for natural joint movement.

Application areas in 2030: Medical applications, robotics

Market development: 4, market growth
High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.6, 1.8, 1.9, 1.11

Social Innovations

Here are radical technological solutions that connect technological solutions closely to social innovations. This category includes interface solutions that mainly do not concern the interface between human beings and machines but the interaction between human beings or the human sense making.

2.12. Schools in the cloud ****

Ingress: New information and communication technology (ICT) has challenged traditional practices of education. On the web, a huge amount of knowledge is readily available. The new ICT promotes self-directed, interest-based learning where problem-solving, innovation and creativity drive education. In emerging practices of education, learners themselves play a key role as creators of knowledge artifacts that are shared. Schools in the cloud use cross-institutional, cross-cultural educational opportunities and social

networking that in 2030 will probably be based much more on game-like practices and on simulations. The new pedagogical practices, for example Computer-supported collaborative learning (CSCL), are inclined to break down boundaries between teachers and students, higher education institutions, and disciplines. Techniques of distance presence e.g. virtual eyeglasses make possible personalized and face-to-face like guiding.

Background information and examples:
https://www.khanacademy.org/about
http://code.edx.org/
http://www.learninglight.com/guide/e-learning-companies-in-india
http://www.otavanopisto.fi/inenglish/otava-folk-high-school
http://usergeneratededucation.wordpress.com/2013/03/22/schools-are-doing-education-1-0-talking-about-doing-education-2-0-when-they-should-be-planning-education-3-0/
http://edutechwiki.unige.ch/en/Computer-supported_collaborative_learning
http://www.bbc.co.uk/news/technology-22891283
http://www.elearningguild.com/publications/index.cfm?id=29&from=home&utm_campaign=ebookolf105&utm_medium=email&utm_source=elrnindli

Recent vanguard product(s) or invention(s): Khan Academy has four thousand lectures on the web and millions of users daily. Its library of content covers mathematics, science topics such as biology, chemistry, and physics, and also the humanities with playlists on finance and history. In the Khan model, lectures are followed as homework and training happens in school using computers. Globally the edX platform now has 27 university partners, all offering online courses in a wide range of subjects. Especially students from developing countries benefit from those courses and e.g. in India there are many companies that provide eLearning services.

Finland has belonged to leading counties in the pedagogy of Computer-supported collaborative learning (CSCL) and Otava Folk High School has been a forerunner of the school in the cloud. It has organized distance high school courses since 1990s and monthly workshops with experts from a number of fields such as pedagogy, futures studies, media, multiculturalism and IT-technology. It has also been a forerunner of the Real-Time Delphi method. It is an effective web-based method for the use of expert knowledge.

Application areas in 2030: Education, learning, transfer of knowledge

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent R&D-paths

Impacts on the value chains: 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.13. Freely organizing remote work and organizations that form on the Internet ****

Ingress: Many different forms of collaboration and sales of work deliverables are created on the Internet. Earlier, remote work has been suitable only for tasks in which the deliverable is intangible, but with the help of remote controlled devices and remote presence techniques, remote work can have a physical dimension as well. Free organizing enables the emergence of trust and working without the organizer or payer knowing the worker or even his/her location. Only the result and peer reviews matter. Such a way of organizing the exchange of work and services, which is independent from the traditional ways of organization, easily bypasses state borders, authorities and traditional financing and decision-making mechanisms as well as liability issues. At the same time, however, they may offer very low transaction costs, a significant improvement to the equality of resources and attainability of services. The birth of the Linux operating system is one of the best-known examples of the benefits of these new ways of organization.

Background information and examples:
http://www.howstuffworks.com/how-to-tech/5-ways-to-make-money-on-internet.htm#page=0, http://dl.acm.org/citation.cfm?id=2212883

Recent vanguard product(s) or invention(s): eBay and other online auction websites, Shapeways, time banks.

Application areas in 2030: All measurable work deliverables, which can be performed, ordered or delivered over the Internet, or work deliverables which, prior to purchase, require a level of trust that can be created through peer reviews on the Internet.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Several independent paths of R&D

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.14. Human recognition systems ***

Ingress: Facebook is planning to incorporate most of its 1 billion-plus members' profile photos into its growing facial recognition database. The intention is to improve the performance of its "Tag Suggest" feature in pictures. The feature uses facial recognition technology to speed up the process of labeling or "tagging" friends and acquaintances who appear in photos posted on the network.

The technology currently automatically identifies faces in newly uploaded photos by comparing them only to previous snapshots in which users were tagged. Facebook users can choose to remove tags identifying them in photos posted by others on the site. When

3D pictures of faces are available the automatic recognition of faces is still easier. In 2030, a mobile phone like equipment might be common that is able to identify a person from taken photo. Genetic information also provides possibilities to construct possible pictures of faces. When genetic information from a human cell is combined with the facial recognition database, this kind of software will be able to suggest possible faces of the person to whom the cell belongs.

Background information and examples:
http://money.cnn.com/2014/04/04/technology/innovation/facebook-facial-recognition/
http://findbiometrics.com/human-recognition-systems-receives-second-award-in-two-week-span-with-aoa-best-innovator-award/
http://www.wired.co.uk/news/archive/2013-05/7/artist-dna-portraits
http://www.iflscience.com/health-and-medicine/forensic-scientists-build-crude-3d-mugshots-dna

Recent vanguard product(s) or invention(s): Operational in major airports such as London Gatwick Airport and London City Airport, MFlow Track incorporates multi-modal biometric eGates, including 'iris-at-a-distance' technology (a World-first) to automate the secure and fast flow of passengers through restricted areas within an airport, whilst MFlow Journey utilises passive facial recognition technology (another World-first) to track and measure people flow throughout an airport in order to provide real-time operational intelligence and queue time information.

Application areas in 2030: Social networks, safety industry, entertainment, trade and personal service industries

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.15. Emotion management in robots and automatic recognition of emotions ***

Ingress: Many research groups are developing computers that can read facial expressions and track basic states like confusion, liking or disliking. For example, wearable devices, such as electronic bracelets, can detect stress or excitement by measuring minimal changes in the sweat level. The applications of emotion management technologies are wide ranging. Medically, it could help people with autism spectrum disorders to read emotions; commercially, it could be used to evaluate ads by tracking viewers' emotional response. A 2030 target is to develop personal service robot, which follows its master and learns the master's activities and imitates her or his behavior. It could learn basic daily routines and help the master in everyday activities. In 2030 you could probably upload your own face and voice to make your digital assistant look and talk just like you.

Background information and examples:
http://www.ted.com/talks/david_hanson_robots_that_relate_to_you.html
http://www.bbc.co.uk/news/magazine-17733455
http://www.popsci.com/technology/article/2013-03/talking-head-could-let-you-send-texts-featuring-your-frustrated-face
http://edition.cnn.com/2014/06/06/tech/innovation/pepper-robot-emotions/
http://phys.org/news/2014-06-tokyo-museum-robot-human.html#jCp

Recent vanguard product(s) or invention(s): The new robot guides at a Tokyo museum look so eerily human and speak so smoothly they almost outdo people. Pepper is a robot designed to read, and respond to, its user's mood. Pepper gets feedback from its user via facial-recognition technology and a bank of cameras, audio recorders and sensors in its head. Instead of being programmed, Pepper learns how to behave over time. Feedback is uploaded to cloud storage where it can be used by other units to modify the way they behave. The robots will tailor their interactions with users based on what mood they perceive.

Application areas in 2030: Better computer interfaces, entertainment industry, service robots, helping devices for autistic persons, marketing

Market development: 3, close to commercialization

Many independent R&D-paths

Impacts on the value chains: 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.17, 1.18, 1.19

2.16. Capturing and content searching of personal life ***

Ingress: The electronic devices we carry with us will soon be able to store spaces, sounds, and images of our body and environment as a continuous stream. When life is captured in this manner and organized according to personal emotional states, locations, spoken words, and other people and objects related to the same event, we get a useful lifelong archive to be used for many purposes. Search systems and narratives are key in these applications, because of the large amount of data that is created. The ability to seach for specific events according to emotions, locations, characters, and subjects becomes important.

Background information and examples:
http://memoto.com/
http://singularityhub.com/2013/02/10/recording-your-life-allowing- others-to-view-it-as-virtual-reality-world-lifelogging/
http://www.ucorder.com/IRDC260r- pocket-camcorder.html

Recent vanguard product(s) or invention(s): An inexpensive camera that is attached to a lanyard around the neck costs around 50 euros and is able to store a five-hour long video or densely snapped still pictures for a significantly longer period of time. Content search for keywords in sound recordings is in continuous use in safety technology.

Application areas in 2030: Replacemet of notebooks, search for lost objects, virtual tourism, social media, learning of different stages of a work procedure, recalling of events, people, subjects, and places, police and other official activity, research.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.1, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.18, 1.19, 1.20

2.17. Automatic speech recognition and translation ***

Ingress: Voice recognition software has steadily improved over the years. Hands-free computing belongs now to the biggest advantages of talk-to-text programs and works already now rather well though mumblers have still difficulties of being understood. The largest benefits are to those with limited mobility or a disability that restricts keyboard and mouse use. A recent breakthrough by the Skype and Microsoft Translator teams in neural network-based speech recognition has reduced errors in speech recognition by more than 30 per cent. Text-to-text translation programs produce already rather comprehensible results between main languages of the world. In 2030, it is possible that chatting in the web is possible using native languages, at least between main language speakers.

Background information and examples:
http://www.youtube.com/watch?v=Nu-nlQqFCKg
http://voice-recognition-software-review.toptenreviews.com/
http://www.dailymail.co.uk/sciencetech/article-2641653/Dont-bother-learning-foreign-language-Skype-soon-let-translate-spoken-foreign-words-real-time.html
http://www.nuance.com/for-business/by-solution/customer-service-solutions/solutions-services/inbound-solutions/loquendo-small-business-bundle/automated-speech-recognition/index.htm
http://imtranslator.net/translation/english/to-urdu/translation/

Recent vanguard product(s) or invention(s): Microsoft has unveiled its new speech recognition software for Skype. Called Skype Translator, the software decodes speech on the fly. For example, a German could chat with an English speaker in real-time. The software will be released as a beta for Windows Phones in late 2014.

Application areas in 2030: Social media, tourism, international meetings, entertainment, distant work, education, multicultural communities

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Scientifically interesting

Impacts on the value chains: 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.18. Crowdfunding and micro finance **

Ingress: Crowdfunding involves the collection of finance from backers—the "crowd"—to fund an initiative and this usually occurs on an Internet platform. The initiative might be commercial (e.g. to create and sell a new product) or financing campaign for a startup company. It could also be a nonprofit (e.g. to raise funds for a school or social service organization), political (to support a candidate or political party) or charitable (e.g. emergency funds for an ill person or to fund a critical operation) initiative. There are two primary types of commercial crowdfunding: reward-based crowdfunding where entrepreneurs pre-sell a product or service to launch a business concept without incurring debt or sacrificing equity/shares. The other is an equity-based crowdfunding where the backer receives unlisted shares of a company, usually in its early stages, in exchange for the money pledged. The company's success is determined by how successfully it can demonstrate its viability.

Background information and examples:
http://en.wikipedia.org/wiki/Crowdfunding
http://www.crowdfunding.com/
http://www.kickstarter.com/
http://www.gofundme.com/success/
https://www.invesdor.com/fi

Recent vanguard product(s) or invention(s): The most popular crowdfunding platforms are the American Gofundme and Kickstarter. The Gofundme collects grants for single persons or projects. The Kickstarter, like the Finnish Invesdor, collect funds for investments. According to 2014 home pages of Kickstarter, since its launch in 2009, 6.6 million people have pledged $1 billion, funding over 65,000 creative projects. In 2014, project creation was open to creators in the United States, the United Kingdom, Canada, Australia, New Zealand, and the Netherlands. But some projects makers seem to be also from other countries e.g. Poland and Taiwan. Examples of funding successes related to games: "Now is your chance to help GMT bring Twilight Struggle out for PC, Mac, Linux, iOS, and Android!" $391,047, $50,000 goal, "Handcrafted Polyhedral and Six Sided Dice made from 6 Different Metal Alloys and nearly 100 Species of Exotic Woods" $291,920, $9000 goal.

Application areas in 2030: Funding of development projects, marketing.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent paths of R&D

Impacts on the value chains: 1.3, 1.4, 1.12, 1.13, 1.14, 1.15, 1.18, 1.20

2.19. Open data and big data ****

Ingress: Open data implies that data should be freely available to everyone's usage and republish as they wish, without restrictions from copyright, patents or other mechanisms of control. Big data is looking for effective ways to handle information when world's technological per-capita capacity to store information has roughly doubled every 40 months since the 1980s. Big data uses statistical and system analysis methods e.g. genetic algorithms, machine learning, natural language processing, signal processing, simulation, time series analysis and visualization in order to infer relationships, dependencies and perform predictions of outcomes and behaviors. It has been realized that Open data is a key for trustful and sustainable Big Data. Besides volume (amount of data), Open data seems to be not only sustainable but also effective way to manage two other aspects of Big data: velocity (speed of data in and out), and variety (range of data types and sources). The key link in the value chain for open data is the consumer (or the citizen). On balance, consumer-driven sectors of the economy will benefit most from open government data that has direct relevance to the choices individuals make as part of their day-to-day lives.

Background information and examples:
http://en.wikipedia.org/wiki/Big_data
http://blog.ted.com/2013/02/09/ted-weekends-big-data-gets-personal-2/
http://blogs.smithsonianmag.com/science/2013/04/google-search-terms-can-predict-the-stock-market/
http://newsroom.cisco.com/feature-content?articleId=1167305
http://www.technologyreview.com/featuredstory/513696/deep-learning/
http://www.businessinsider.com/ibms-watson-may-soon-be-the-best-doctor-in-the-world-2014-4

Recent vanguard product(s) or invention(s): Google databases are the most important recent sources of Open data. Open source scientific articles and books are an important open source of information. People deliver more and more Open data information concerning themselves to Internet and Google. Google databases are also very important sources of business information though some members of Open data community consider that this information does not meet the strictest requirements of open data.

Application areas in 2030: Geographic information, medicine, economics, language translation, business strategy, futures research, culture studies etc.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent paths of R&D

Impacts on the value chains: 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

2.20. Gamification ****

Ingress: Gamification is the use of game thinking and game mechanics in non-game contexts to engage users in solving problems. In strategic games, players see changes in environment and learn from each other based on results of their actions. Strategic games motivate players to cooperate with others. Common targets of the own team are visible and players are able to see continuously how any team member contributes to targets. Behaving independently, team members realize what they should do and they learn quickly from others how to do. In organizations and in whole society, the gamification might improve much independent learning and realizing of social issues/problems and how to manage them. Gamification improves cooperation skills and the demolition of unnecessary hierarchies. In 2030, young people that are familiar with web games will have key positions in the working life. It is reasonable to expect that gamification is then much more common practice than now.

Background information and examples:
http://www.gamification.org/
http://en.wikipedia.org/wiki/Gamification
http://www.ted.com/talks/jane_mcgonigal_gaming_can_make_a_better_world.html
http://eprints.ru.ac.za/366/1/Rowntree%26FoxVietnam.pdf
https://www.superbetter.com/
http://www.ted.com/talks/jane_mcgonigal_the_game_that_can_give_you_10_extra_years_of_life.html

Recent vanguard product(s) or invention(s): Khan Academy has used much gamification in learning activities. Amazon has gamified evaluations of readers, and Kickstarter has gamified microfunding.

Application areas in 2030: Learning, marketing, planning, crowdsourcing, independent health care, body exercise, logistics, social issues, management, coordination

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent paths of R&D

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.12, 1.13, 1.15, 1.17, 1.18, 1.19, 1.20

Human – machine interface technologies

This group includes radical technological solutions the functionality of which depends mostly on interaction between human beings and machines. Recently human-computer interaction and in the future the human-intelligent machine interaction can be viewed as two powerful information processors (human and computer/machine) attempting to communicate with each other via a constrained interface. Besides computer -to-user interface and user-to-computer interaction, interfaces might replace senses of person with sensor equipment e.g. cameras.

2.21. Interfaces reacting on movements ***

Ingress: Using new interfaces on computers are able to perceive your eye movements, your location, your gestures and positions and their own environments. An armband lets you use the electrical activity in your muscles to wirelessly control your computer, phone, and other favorite digital technologies. With the wave of your hand, it will transform how you interact with your digital world. Equipment is able to add you to a picture that lives based on your eye movements and to show to you the picture in that way that you can see around a corner. The construction of 3D virtual things and their handling will be easier. Moving in the virtual world will be easier as well as computer playing.

Background information and examples:
https://www.thalmic.com/myo/
http://www.ijstr.org/final-print/feb2014/Eye-Movement-Based-Electronic-Wheel-Chair-For-Physically-Challenged-Persons.pdf https://www.leapmotion.com/
http://www.theverge.com/2013/3/6/4071162/kinect-fusion-3d-object-scanning-coming-in-future-kinect-for-windows
http://blog.ted.com/2008/04/11/wii_remote_hack/

Recent vanguard product(s) or invention(s): Kinect and Lep motion represent most advanced products in the market. Kinect fusion is able to do 3D model of a human being from which you can identify the human being and his and her gestures.

Application areas in 2030: 3D-interfaces, gaming, 3D modelling, robotics

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19

2.22. Glasses of augmented reality ****

Ingress: The Google Glass, glasses of augmented reality, will be probably common in 2030. The 2014 "explorer" version of the Google Glass is lighter than a pair of sunglasses. It can take pictures and videos and share them with other persons. According to Google, it provides the equivalent picture to that of a 25-inch HD display when viewed from eight feet away. It shows routes on the map with spoken directions, sends messages about meetings and provides information concerning various things e.g. the weather. It is also a gaming platform. The explorer version has also a mod which allows home appliances to be controlled using Google Glass hardware. Many new features will be probably available in 2030. There is already software available that augments in the camera picture with some interesting features of the environment e.g. making holograms or amplifying invisible motion. Graphene smart contact lenses might in 2030 give thermal infrared and UV vision. Augmenting applications of audio signals are already available in the market. Sensors of the glasses might even be able to inform the user about chemical environment of the glasses. Perhaps it might be able to transmit smell messages.

Background information and examples:
http://www.knowyourmobile.com/google/google-glass/21388/google-glass-release-date-specs-features-now-available-uk-price-ps1000
http://news.cnet.com/8301-1023_3-57578072-93/google-releases-full-google-glass-explainer-video/
http://www.pcmag.com/slideshow/story/308711/16-cool-things-you-can-do-with-google-glass/16,
http://bits.blogs.nytimes.com/2013/02/27/scientists-uncover-invisible-motion-in-video/
augmented vision
http://www.newscenter.philips.com/main/standard/news/press/2013/20131028-philips-and-realview-imaging-conclude-worlds-first-study-to-evaluate-live-3d-holographic-imaging-in-interventional-cardiology.wpd#.U7uaC7Gs9K1
http://www.augmentedaudio.com/
http://phys.org/news/2014-04-patent-google-sharpens-contact-lens.html
http://www.extremetech.com/extreme/178593-graphene-smart-contact-lenses-could-give-you-thermal-infrared-and-uv-vision
http://themindunleashed.org/2014/06/first-scent-message-transmitted-aross-the-atlantic-via-the-internet.html

Recent vanguard product(s) or invention(s): The recent most advanced glass of augmented reality is the Google Glass. The 2014 "explorer" version of the Google Glass is lighter than the average pair of sunglasses. Google claims it provides the equivalent picture to that of a 25-inch HD display when viewed from eight feet away. The built-in camera is a 5-megapixel unit with 720p video capture, while audio is handled via a bone conduction transducer. It sends the audio vibrations directly through the small bones in ear, which are heard as sound. Its onboard storage is 16GB. The device is fully synced with Google's cloud storage. The launch price of the Glass in 2014 was about 1500$.

Application areas in 2030: Education and advising, tourism, geographic information, social media, gaming, general way of life interface – continuous contact with the augmented reality

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Many independent paths of R&D

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19

2.23. Interfaces based on feeling of touch****

Ingress: Some haptic interfaces use feeling of touch. Already now game controllers vibrate and hinder movements. In emerging technologies, tactile contents are carefully created and synchronized with visual and auditory cues to create effective and immersive experiences and increase the interest of users while playing video games, watching movies, etc. The technology is integrated into theater seats, gaming chairs and vests, rides, gloves, shoes, hand-held devices and controllers, clothes, to create another dimension of sensory feedback. For example, while playing an intense driving simulation game, users feel road conditions, gravel, traction, acceleration, brake, explosions, collisions, etc. Touch screens come alive with textures and edges that e.g. blind persons can feel. In 2030, haptic technologies might enable a smart phone's touchscreen technology and vibration capabilities to simulate the physical sensation of touching something.

Background information and examples:
http://www.dailymail.co.uk/sciencetech/article-2249504/IBM-reveals-vision-future-technology.html
http://senseg.fi/
http://www.core77.com/blog/materials/from_the_holy_cow_department_disney_uses_bursts_of_air_to_create_virtual_haptic_feedback_25361.asp
http://www.disneyresearch.com/project/surround-haptics-immersive-tactile-experiences/
http://www.fastcolabs.com/3019621/ultrahaptics-may-be-the-next-revolution-in-touchscreen-phones
https://www.youtube.com/watch?v=2QkbVr4J7CM&feature=youtube_gdata_player

Recent vanguard product(s) or invention(s): The company Senseg makes touch screens come alive with textures and edges that users can feel. In haptic technology Aireal, gamers can feel virtual objects, experience the sensation of touching various textures, or get kinetic feedback. All without any need to wear gloves, vests or suits. Puffs of air can be controlled in terms of varying strength and speed. An innovation, called UltraHaptics, uses an array of ultrasonic transducers to generate a complex set of sound waves. When enough ultrasound waves are focused on a point above, say, a tablet's surface they can generate a definite sensation in a human fingertip thanks to the high sensitivity of the nervous system.

Application areas in 2030: Touch screens, body status sensors, vehicles, games, distance guiding of robots

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.9, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16,1.17, 1.18,1.19, 1.20

2.24. Large haptic screens***

Ingress: Many technologies make it possible to increase the sizes of screens. With large screens, it is possible to present people in their natural sizes and the screen fills the whole sight of a person. Recently, large touch screens allow drawing directly on the screen using a special pen or fingers. Using multiple pen colours or highlight and bold features, one can stress the importance of certain content by either highlighting or underlining it for easier understanding and note taking. These kinds of screen are very suitable for interactive working, including interactive distance work. In 2030, whole screen might be based on flexible screens. Carbon nanotubes or graphene are suitable material for these kinds of screens.

Background information and examples:
http://www.touchboards.com/samsung/Samsung650TS.html
http://www.samsung.com/ie/consumer/pc-peripherals/professional-lfd-displays/touchscreen/LH65TCPMBC/EN
http://www.multitaction.com/
https://www.youtube.com/watch?v=2QkbVr4J7CM&feature=youtube_gdata_player
http://multitouch.com/product_plus.html
http://cen.acs.org/articles/92/web/2014/01/Carbon-Nanotube-Transistors-Help-Displays.html?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+cen_nano+(Chemical+And+Engineering+News+NanoFocus)

Recent vanguard product(s) or invention(s): The Samsung 650TS Touch Screen LCD Display features a screen size of 65 inches and a high brightness level of 510 nits delivering high-quality images even in well-light rooms. The 650TS offers advanced touch sensitivity up to the edges of the screen. The touch screen features accurate optical sensor technology resulting in improved touch reliability and responsive even when interacting in the edges and corners. The 650TS also allows users to connect and access content over a computer or network. Content accessible includes a number of possible popular formats like Power Point Presentations, Photos and Videos.

Application areas in 2030: All kinds of interaction, especially distance interaction will benefit from haptic screens. Large touch screens are especially suitable for educational and discussion purposes promoting participation, better visual presentation and more efficient meetings.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.11, 1.15, 1.16, 1.17, 1.18, 1.19

2.25. Digital mirror **

Ingress: Digital Mirror connects 3D-camera or some other 3D measuring instrument to a large screen. The Digital Mirror takes picture of something in front of it, typically a person and shows her or his mirror picture or in some way manipulated picture on the screen. Recently, most popular Digital Mirrors are used in retail stores and in marketing events. A person can 'try on' more than 50 fashion items such as dress, jacket, sunglasses, necklace or other seasonal hottest fashion items in less than a minute. Besides camera and computer, a key element of the recent Digital Mirror is Body Sensor that identifies full body movements of user. A recent Digital Mirror is able to "show" what is happening inside the body of a person in front of the Mirror. In 2030 the Digital Mirror with its measurements will probably promote customized production and personalized health care.

Background information and examples:
http://www.youtube.com/watch?v=35pRdcjTaTY
http://www.youtube.com/watch?v=oLBPhh01yiY
http://www.magicmirror.me/Features
http://abcnews.go.com/blogs/health/2014/04/16/weird-digital-mirror-shocks-with-internal-organ-reveals/

Recent vanguard product(s) or invention(s): Magic Mirror is an interactive mirror for the retail stores, events or marketing agency to engage and immerse the non-engaged users into their personalized brand experience. By combining Microsoft Kinect's motion-capture camera with medical imaging tests, French researchers have created a "digital mirror" that appears to peel back the skin of users and expose their organs.

Application areas in 2030: Fashion stories and other commerse of personal products, personal guiding, personal health care

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.4, 1.6, 1.7, 1.8, 1.15, 1.17, 1.19

2.26. Thoughts monitored from brain and action based on them **

Ingress: There are different ways to monitor brain activity that represents a person's thoughts and feelings. The easiest way is to monitor EEG brain waves. Already now there is an available cheap high-resolution multi-channel portable EEG scanner with developed software that is able to scan what a person is thinking. Using this kind of tool, it is possible to give orders to computer just thinking about the order. This is very promising possibility for augmented reality glasses e.g. for the Google Glass. Another approach is to use

magnetism. Magnetic resonance imaging (MRI) has required big machines but there is currently available a portable MRI tool and further options are opening with new magnetic materials e.g. the graphene. Activated areas in the brain related to a specific thought differ much from person to person. It is, however, possible to find typical figures of activated areas related to the thought if the impact of the person specific brain folding is eliminated. Besides monitoring, magnetic waves and electric implants will in 2030 provide also possibilities to have impacts on the behavior of persons or other organisms. Two rats have been able to cooperate in a common task using the "telepathy" of implants in their brains.

Background information and examples:
http://www.ted.com/talks/tan_le_a_headset_that_reads_your_brainwaves.html
http://www.emotiv.com/
http://techcrunch.com/2014/07/09/forget-ok-glass-mindrdr-is-a-new-google-glass-app-that-you-control-with-your-thoughts/
http://rt.com/news/read-brain-scan-letters-919/,
http://www.foxnews.com/science/2014/03/28/know-what-youre-thinking-scientists-find-way-to-read-minds/,
http://cacm.acm.org/magazines/2014/3/172519-reading-brains/fulltext,
http://www.nbcnews.com/science/mind-meld-scientist-uses-his-brain-control-another-guys-finger-8C11015078,
http://www.wired.com/2013/05/brain-stimulation-math/,
http://www.nbcnews.com/science/science-news/two-rats-thousands-miles-apart-cooperate-telepathically-brain-implant-f1C8608274
http://blog.hospitalclinic.org/en/2014/07/lidibaps-participa-en-el-projecte-emblematic-graphene-flagship/

Recent vanguard product(s) or invention(s): The Emotiv EPOC software uses sensors to tune into electrical signals produced by the brain to detect user thoughts, feelings, and expressions. It is based on a high-resolution multi-channel portable EEG scanner. A cheap version of EPOC (about 300$) of the Emotiv company functions as an interface for specific games, the more expensive version uses exlicitly the EEG information. The Neurosky biosensor picks up on brainwaves that correlate to your ability to focus. The app then translates these brainwaves into a meter reading that gets superimposed on the camera view in Google Glass. Two rats — one in North Carolina, the other in Brazil — worked together on a task by communicating telepathically, thanks to implants in their brain. Electrical signals from a "leader" rat's brain were collected, encoded and then zapped into the "follower" rat's cortex in the form of an electrical signal. The follower rat then pressed one of two levers based on a light visible only to the leader rat.

Application areas in 2030: Thoughts that control tools and persons, following of thoughts and feelings of others, new interfaces, entertainment, marketing, gaming, artistic activities, criminal activities, police work

Market development: 3, close to commercialization

Impacts on the value chains: 1.2, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.27. Flexible and transparent screens using cheap materials

Ingress: Indium is now the most important material of touch screens. Though its price has remained rather stable during last ten years there is an urgent need for a substitute material before 2030. In 2014, Samsung informed about an important patent concerning graphene based touch screen. It also announced a major breakthrough in touch screen production with a method to synthesize large areas of graphene on a semiconductor. The method seems to improve much the method employed by 2010 physics Nobel prize winners Andrei Geim and Kostya Novoselvov. Actually, besides graphene there is also now the opportunity to replace indium using carbon nanotube. Independently researchers in China and Finland have solved the basic difficulty in the carbon nanotube based semiconductors: the chirality. In comparison with indium, graphene or carbon nanotube based touch screens have two interesting further properties: they are flexible and transparent. Wide, flexible and transparent screens will provide many options for robotics, espionage, games and other entertainment, artistic activities, distance presence and virtual life.

Background information and examples:
http://www.graphenetracker.com/samsung-patents-graphene-based-touch-screen/
http://www.smg-indium.com/Docs/IndiumPriceCharts.pdf
http://www.graphenetracker.com/samsung-patents-graphene-based-touch-screen/
http://www.nanowerk.com/nanotechnology-news/newsid=35808.php#ixzz38rYyuMd6
http://www.bbc.co.uk/news/technology-13886438,
http://www.youtube.com/watch?v=3sAc4nqAbOs
https://machineslikeus.com/news/researchers-reach-ultimate-carbon-nanotube-goal
http://www.rsc.org/chemistryworld/2014/06/tungsten-alloy-catalyst-produces-pure-chiral-carbon-nanotubes
http://pubs.acs.org/doi/abs/10.1021/nn3026172?journalCode=ancac3;
http://phys.org/news/2014-03-carbon-nanotubes-real-world-applications.html

Recent vanguard product(s) or invention(s): Samsung has filed an application for what could potentially be a key patent on touch screens. (US patent application number 20140055407, February 27, 2014) The key sensing components in the device are made from graphene or carbon nanotubes. Professor Yan Li's research team from Peking University and professor Kauppinen's research team from Aalto University have independently developed novel strategies to produce carbon nanotubes with specific chirality by applying different catalysts. This opens the possibility for carbon nanotubes based flexible and transparent touch screens.

Application areas 2030: robotics, espionage, games and other entertainment, artistic activities, distance presence and virtual life.

Market development: 3, close to commercialization

Scientifically interesting

Impacts on the value chains: 1.1, 1.6, 1.7, 1.10, 1.11, 1.12, 1.14, 1.15, 1.17

Algoritms and Systemic Solutions based on the Information technology

To this category belong radical technological solutions that are mainly based on algorithms or ways to use information technology that have radical impacts on information system architectures and applications.

2.28. Cloud computing ****

Ingress: The main providers of information technology have invested in massive datacenters that hire processor resources and memory capacity. This kind of datacenter hardware and software is called a Cloud. Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. When a Cloud is made available in a pay-as-you-go manner to the general public, it is called Public Cloud. The customer of the Public Cloud can use its big memory capacity and efficient processing avoiding investment costs in hardware. With cloud computing, multiple users can access a single server to retrieve and update their data without purchasing licenses for different applications. Cloud computing allows enterprises to adjust their IT resources to meet fluctuating and unpredictable business demand. In 2030, organizations and single persons will probably have more often search problems or pattern recognition tasks where fast and efficient processing and big memories are needed.

Background information and examples:
http://stackoverflow.com/questions/9723040/what-is-the-difference-between-cloud-grid-and-cluster; https://cloud.google.com/products/compute-engine
http://en.wikipedia.org/wiki/Cloud_computing

Recent vanguard product(s) or invention(s): Cloud services of IBM, Microsoft and Google

Application areas in 2030: Big memory capacity and efficient processing either freely or in a pay-as-you-go manner avoiding investment costs in hardware. Firms might also provide customized cloud services to various customers (the Private Cloud not made available to the general public).

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent paths of R&D

Impacts on the value chains: 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, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.29. Grid computing ***

Ingress: In 2014, there are about 3 billion Internet users in the world. They mainly use their personal computers. There are billions of various kinds of computers or smart mobile phones that are connected to the Web. The processing capacity of these machines is very much underused. Through the Web, users of the data processing machines can share the processing capacities with others for grid computing. A grid is a collection of computers or other Web connected machines that are owned by multiple parties in multiple locations and that are connected together. The grid computing is decentralized model of computing unlike the Cloud computing which is based on centralized model. Grid computing can occur over many administrative domains. Besides owner accepted grids, viruses are used for stealing of processing capacity. Some criminal grids have used the capacities of many millions of computers. There are various reasons why this will be a big risk for the safety of the Web in 2030.

Background information and examples:
http://www.internetlivestats.com/
http://stackoverflow.com/questions/9723040/what-is-the-difference-between-cloud-grid-and-cluster; http://en.wikipedia.org/wiki/Grid_computing
http://en.wikipedia.org/wiki/BOINC,
http://www.csc.fi/english
http://catless.ncl.ac.uk/Risks/28.10.html#subj3
http://en.wikipedia.org/wiki/Botnet

Recent vanguard product(s) or invention(s): Berkeley Open Infrastructure for Network Computing (BOINC) is an open source middleware system for volunteer and grid computing. The intent of BOINC is to make it possible for researchers to tap into the enormous processing power of personal computers around the world. It was originally developed to support the SETI@home project. It is now a platform for distributed applications in various areas of science e.g. mathematics, medicine, molecular biology, climatology, environmental science, and astrophysics. As a high performance distributed computing platform, BOINC has about 320,121 active participants and 512,197 active computers (hosts) worldwide processing on average 6.6 petaFLOPS as of July 23, 2014. BOINC is funded by the National Science Foundation (NSF) of the United States.

Application areas in 2030: Possibilities for efficient computing freely or with payments without supercomputer investments

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent paths of R&D

Impacts on the value chains: 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.12, 1.15, 1.16, 1.18, 1.19, 1.20

2.30. Pattern recognition and pattern search services ***

Ingress: The recognition of visual patterns grows as the algorithms improve, the amount of data increases, and the operational capacity grows. The biometrical recognition of people, recognition of license plates, landscapes, objects, and recognition based on the shape of molecules are all advancing. Inexpensive pocket cameras recognizes people's faces and smile. Image archives recognize familiar people. 3D cameras and 3D images of patterns will make recognition easier, because a 2D image is different depending on the viewing angle and some of the information has been lost, which makes comparability difficult. The more images and 3D models of patterns are stored into the cloud services of the information network as open data, the easier it will be to recognize objects, materials, and people that come across in the environment. As robotization and devices of augmented reality diffuse, this ability will become even more important both in special fields and in everyday life.

Background information and examples:
http://en.wikipedia.org/wiki/Pattern_recognition
http://www.google.com/insidesearch/features/images/searchbyimage.html
http://www.users.cs.york.ac.uk/~nep/research/3Dface/tomh/

Recent vanguard product(s) or invention(s): As an everyday application, Google's Picasa's ability to identify a person from his/her face is interesting, although the 3D recognition that is still in the development stage is significantly more accurate. Microsoft Kinect Fusion software is the vanguard of the field on the mass market.

Application areas in 2030: Games, security technology, military technology, robotics, service and maintenance, social media, recognition of objects, people, animals, plants, structures, materials and images in general.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.31. Effortless 3D imaging of parts ***

Ingress: Several inexpensive machines are being developed, which enable the production of 3D models of objects and humans. Traditionally, these machines have been based on laser scanning in the engineering world, and ultrasounds, X-rays, or magnetic resonance imaging in medicine. Both the machines and the software related to them have been very expensive and their use has required special knowhow. 3D imaging of the outer surface of objects is transitioning to the mass market as a result of the diffusion of 3D printing, 3D gaming, and 3D films. The solutions are becoming very affordable and 3D objects of the surrounding environment's forms have begun to appear online at an increasing speed. In the near future, it is likely that with the help of a smart phone and a cloud service, one can

produce a satisfactory 3D model of any object by using devices that look like microwave ovens and cost a few hundred euros, the 3D models will resemble the original with a 0,1 mm accuracy. After a transition to terahertz waves, the machines will be able to measure forms that are left out of sight and they will reach an accuracy that will be sufficient for almost all uses.

Background information and examples:
http://arstechnica.com/business/2013/04/new-443-3d-scanner-on-sale-looks-awesome-shoots-lasers/
http://www.matterform.net/
http://live.wsj.com/video/the-3d-scanner-that-puts-you-in-a-video-game/21674841-C6A5-49AF-BAD2-B7395558B9AA.html#!21674841- C6A5-49AF-BAD2-B7395558B9AA

Recent vanguard product(s) or invention(s): Museums are producing 3D models of their artifacts so that copies of them can be 3D printed. The machines are very large and very accurate. An example of an inexpensive, easy-to-use machine that is aimed for the mass markets is the Matterform, which costs less than 500 euros. Movie and game studios are modeling their actors and their facial expressions very accurately and are already routinely using the models in both games and movies. The most recent promise is being able to insert a lookalike character of the player into games.

Application areas in 2030: Service and maintenance, games, reproduction of products, object recognition, producing parts that fit the form of a body or an object, measuring.

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Several independent paths of R&D

Impacts on the value chains: 1.2, 1.3, 1.4, 1.6, 1.7, 1.9, 1.11, 1.12, 1.15, 1.16, 1.18, 1.20

2.32. Real-time 3D modeling of the environment ****

Ingress: Cartographers have made a 3D model of our environment. In laboratory conditions, drones are already able to model the interior spaces. New 3D cameras and laser scanners, improving algorithms, and increasing processing power make it possible to produce a 3D model of the environment in real-time. This ability is key when robots move autonomically in their environment, in order for them to recognize their location in the environment, other objects that move in the environment, and changes compared to the previous model. The machine's ability to move in the natural environment and recognize its objects opens a very large amount of application possibilities.

Background information and examples:
http://www.youtube.com/watch?v=bRgEdqDiOuQ
http://www.cds.caltech.edu/~yhhuang/lectures/icra2012_ws.pdf
http://www.araa.asn.au/acra/acra2010/papers/pap151s1-file1.pdf

Recent vanguard product(s) or invention(s): On the level of mass products, Kinect Fusion is connected to robotics and real-time 3D mapping. Google's driverless car draws up a dynamic model of its environment in real-time.

Application areas in 2030: Robotics in general, traffic, industry, retail, entertainment, education, security.

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.9, 1.10, 1.12, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.33. Self-organizing virtual world from the 3D data of the Internet *

Ingress: Cameras or photographers increasingly add location information to the photographs they upload on the Internet. Via pattern recognition, photographs taken in the same location can be combined and even very detailed 3D models can be created automatically from the photographs that are stored online. Fixed and changing structures can be distinguished from a sufficiently large amount of images. As the amount of photographs and processing capacity increase and algorithms improve, an even more accurate 3D model of the world is created online.

Background information and examples:
http://www.ted.com/talks/stephen_lawler_tours_microsoft_virtual_earth.html
http://archive.org/details/BlaiseAguerayArcas_2007

Recent vanguard product(s) or invention(s): Microsoft's Virtual Earth project has the most advanced algorithm and Google is making the fastest advancements in the imaging of the whole on the global level in a unified form.

Application areas in 2030: The construction of a detailed 3D model of the world. Tourism, social media, virtual tourism, intelligence, services, traffic, robotics.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.10, 1.12, 1.15, 1.16, 1.18, 1.19, 1.20

2.34. Predictive analytics based on self-organizing data **

Ingress: Predictive analytics encompasses a variety of statistical techniques from modeling, machine learning, and data mining that analyze current and historical facts to make predictions about future. There are many kinds of methods available in this field: traditional statistical prediction methods e.g. the regression analysis, simulation models and data mining of interesting weak signals of change. Concerning the emerging fields of predictive analysis towards 2030, the analysis of Big Data of the Internet seems to be especially interesting development path. A special challenge of technological development is to identify wild cards or important early seeds of change from massive data bases. For this purpose, methods of self-organizing data are especially interesting. To those belong various types of artificial neural networks e.g. self-organizing maps. Methods of the self-organizing data require new user attitude because they often answer to questions that are not presented.

Background information and examples:
http://www.predictiveanalyticstoday.com/what-is-predictive-analytics/
http://en.wikipedia.org/wiki/Artificial_neural_network
http://en.wikipedia.org/wiki/Unsupervised_learning,
http://en.wikipedia.org/wiki/Self-organizing_map
http://en.wikipedia.org/wiki/Adaptive_resonance_theory

Recent vanguard product(s) or invention(s): SAS analytics, IBM predictive analytics, SAP predictive analytics, RapidMiner, Angoss predictive analysis and STATISTICA have effective and customer benign statistical tools for predictive analytics. An important data source of self-organizing data is the Google Cloud Storage. Besides various clustering methods of data, methods of artificial neural networks e.g. Self-organizing maps (WEBSOM, PicSOM) might provide tools for the identification of weak anticipative signals of change.

Application areas in 2030: As already now, predictive analytics will be probably used in actuarial science, marketing, financial services, insurance, telecommunications, retail, travel, healthcare, pharmaceuticals and other fields. In financial services credit scoring models are especially important. These models rank-order individuals by their likelihood of making future credit payments on time.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent paths of R&D

Impacts on the value chains: 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.15, 1.16, 1.18

2.35. Universal memory based on new materials and solutions **

Ingress: In 2014, Hewlett-Packard asked interested partners to participate in developing a universal memory called the Machine. According to HP, the Machine will not be a server, workstation, PC, device or phone but an amalgamation of all these things. It's designed to be able to cope with the masses of data produced from the Internet of Things, which is the concept of a future network designed to connect a variety of objects and gadgets. HP is developing the Machine in an open process. There are various technological possibilities to realize that option before 2030. One promising possibility is the Racetrack Memory. IBM has informed that it is working on developing Racetrack Memory before 2018. Racetrack is a proposed new shockproof system that is said to be 100,000 times faster than current hard drives, while also being 300 times more energy-efficient. Like a videocassette, Racetrack Memory would store data magnetically. It uses the spin of electrons rather than an electronic charge. There are various possibilities to use the spin. A studied possibility is to store on a tiny unmoving nickel-iron nanowire. Another studied possibility is graphene that has microscopic holes called vacancies in its "chicken wire". A different possibility to use graphene or carbon nanotubes is "spasers". They are like nano-scale lasers sending optical signals called surface plasmons. Other ways to use lasers have also been studied. A different way to construct universal memory is the nonvolatile random access memory where nanoelectromechanical switches function as logic devices.

Background information and examples:
http://www.iflscience.com/technology/new-type-computer-capable-calculating-640tbs-data-one-billionth-second-could
http://www.gizmag.com/racetrack-memory-faster-than-hard-drives/16952/
http://phys.org/news/2013-06-magnetic-clouds-graphene.html
http://www.extremetech.com/extreme/180728-graphene-spaser-brings-optical-computing-to-the-nano-scale
http://inhabitat.com/revolutionary-superman-memory-crystals-can-store-data-virtually-forever/
http://www.orc.soton.ac.uk/fileadmin/downloads/5D_Data_Storage_by_Ultrafast_Laser_Nanostructuring_in_Glass.pdf
http://www.nantero.com/

Recent vanguard product(s) or invention(s): IBM has informed that it is working on developing Racetrack Memory before 2018. Manchester scientists have shown a graphene-based way towards the Racetrack Memory. They have shown that electrons condense around graphene holes into small electronic clouds, and each of them behaves like a microscopic magnet carrying one unit of magnetism or spin. Researchers at the University of Southampton have demonstrated high-density five dimensional data storage in crystal with ultrafast laser writing. Nantero's NRAM nanoelectromechanical switches can function as logic devices, enabling development of fast, radiation-tolerant logic devices that are scalable to 65nm and below.

Application areas in 2030: All kinds of equipment that process information. A special opportunity concerns the saving of energy. Computers and other electronics are currently estimated to consume approximately six percent of the world's electricity, with that number forecast to increase to 15 percent by 2025.

Market development: 2, prototypes available

Many independent research paths

Impacts on the value chains: 1.3, 1.4, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.15, 1.16, 1.18, 1.19

2.36. Simulation and mapping of brain ***

Ingress: The Allen Human Brain Atlas was published in the journal Nature on September 2012. It is comprehensive atlas of the adult human brain that reveals the activity of genes across the entire organ. The map was created from genetic analyses of about 900 specific parts of two brains. From more than 100 million measurements on brain pieces, with some only a few cubic millimetres, the scientists found that 84% of all genes are turned on in some part of the organ. Two billion dollar projects continue the effort of the Allen Human Brain Atlas: EU Human Brain Project (HBP) and US Government BRAIN. It might, however, happen that in 2030 applications of artificial intelligence will be even more important than the results of the brain mapping projets. Google is developing Deep-learning software that attempts to mimic the activity in layers of neurons in the neocortex. The software learns, in a very real sense, to recognize patterns in digital representations of sounds, images, and other data. IBM has developed new information system architecture following the model of brain, too.

Background information and examples:
http://www.guardian.co.uk/science/2012/sep/19/scientists-create-atlas-of-human-brain?newsfeed=true
http://en.wikipedia.org/wiki/Human_Brain_Project
http://www.nih.gov/science/brain/
http://www.technologyreview.com/featuredstory/513696/deep-learning/
https://www.youtube.com/watch?feature=player_embedded&v=gQ3HEVelBFY#at=275
http://www.scienceworldreport.com/articles/8326/20130723/new-microchips-mimic-brains-information-processing-real-time.htm
http://www.cnet.com/news/brain-inspired-circuit-board-9000-times-faster-than-an-average-pc/
http://www.wired.com/2013/12/qualcomm-zeroth/

Recent vanguard product(s) or invention(s): Allen Institute has developed the Human Brain Atlas. EU Human Brain Project (HBP) is a 10-year scientific research project, established in 2013, which aims to simulate the complete human brain on supercomputers e.g. in order to simulate drug treatments. EU is investing in the project about one billion euros. Nearly as large will be BRAIN initiative of the US Government. Its theme seems to be much broader than the theme of the EU project. Besides experts in the field like neuroscientists, medical scientists and biologists important partners are aimed to be corporate experts in microelectronics, optics, wireless communication and mining of 'big data' EU Human Brain project and BRAIN project of USA. Many new software products of artificial intelligence are available e.g. Deep-learning software developed by prof. G.E. Hinton in Toronto University.

Application areas in 2030: Machine learning, shape recognition, more effient computers, human health

Market development: 2, prototypes available

Many scientifically interesting research paths

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.15, 1.16, 1.18, 1.19

2.37. Quantum computers *

Ingress: In quantum computing, a qubit or quantum bit is a unit of quantum information—the quantum analogue of the classical bit. A qubit is a two-state quantum-mechanical system, such as the polarization of a single photon. Photons can have two polarization states, and interaction with the atom can change the photon from one state to another. By that same token, interaction with the photon can change an atom's energy level from a "ground" state to an "excited" state. The two states are vertical polarization and horizontal polarization. In a classical system, a bit would have to be in one state or the other, but quantum mechanics allows the qubit to be in a superposition of both states at the same time. Continuing counting from two different starting points helps computer to avoid local maxims in optimizing tasks. Other computers are not able to follow the logic of the quantum computer, which makes the quantum computer suitable for ciphering. The pioneer in the field has been 512-qubit D-Wave Two quantum computer. In some optimization problems, the D-Wave handily beat the test PC—finding solutions up to 3,600 times faster. But unless the problem is specially tailored to fit the quantum computer, it has to be translated. The D-Wave performed on par with the classical computer when working on problems in need of translation.

Background information and examples:
http://en.wikipedia.org/wiki/Qubit
http://www.scienceworldreport.com/articles/13946/20140410/new-atom-photon-switch-herald-breakthrough-quantum-computers.htm
http://singularityhub.com/2013/06/05/google-buys-quantum-computer-for-artificial-intelligence-lab-at-nasa/
http://www.scienceworldreport.com/articles/7901/20130702/d-wave-processor-actually-employ-quantum-mechanics-annealing.htm

Recent vanguard product(s) or invention(s): D-Wave Systems, Inc. is a quantum computing company, based in Burnaby, British Columbia, Canada. On May 11, 2011, D-Wave System announced D-Wave One, described as"the world's first commercially available quantum computer. In May 2013, it was announced that a collaboration between NASA, Google and the Universities Space Research Association (USRA) launched a Quantum Artificial Intelligence Lab based on the D-Wave Two 512-qubit quantum computer that would be used for research into machine learning, among other fields of study.

Application areas in 2030: Ciphering, optimization, horizontal counting

Market development: 3, close to commercialization

Scientifically interesting

Impacts on the value chains: 1.3, 1.4, 1.6, 1.10, 1.11, 1.12, 1.13, 1.15, 1.16

Measurement and picturing

This category includes radical technological solutions where the main function is to measure or to identify shapes, locations, ingredients or other properties of things.

2.38. Cheap Lidar ***

Ingress: Lidar is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Lidar has been used extensively for atmospheric research and meteorology. As the price of the Lidar systems had gone down, Lidar has become an essential part of autonomous navigation of automobiles and unmanned ground vehicles (UGVs). In the future, they will also be essential elements of air vehicles e.g. of quadcopters. Many Lidar systems have been tested in various robotic platforms and UGVs which demonstrated mostly obstacle avoidance capabilities. In 2030, it will probably be essential in addition to obstacle avoidance capabilities in many mobile robotic systems, as robots are increasingly required to operate in harsh environments and interact safely and effectively with humans, other vehicles and their environment.

Background information and examples:
http://en.wikipedia.org/wiki/Lidar
http://www.lidarnews.com/PDF/LiDARMagazine_SudharsananMoss-LowCostLiDARImager_Vol3No2.pdf
http://blog.lidarnews.com/lidar-unit-for-250-in-2014
http://web.stanford.edu/class/me302/PreviousTerms/2013-02-04_ME302.pdf,
http://www.dragoninnovation.com/projects/32-lidar-lite-by-pulsedlight

Recent vanguard product(s) or invention(s): Many cheap concepts of Lidar systems are close to the market stage. German supplier Ibeo will supply lidar systems for an undisclosed automaker in 2014. It is informed that the price of a single Lidar will be 250$.

Application areas in 2030: robotics, 3D modelling, shape recognition, movement and location recognition, safety sector, geographic mapping, maintenance, trade, traffic, construction sector

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Impacts on the value chains: 1.1, 1.2, 1.3, 1.6, 1.7, 1.9, 1.10, 1.12, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19

2.39. Lenseless camera and image construction based on data analysis ***

Ingress: Described as a "lenseless camera" the screen developed in MIT extends liquid-crystal display devices while enabling the screen to both capture images and display them. Lenseless cameras use to be based on single pixel "whole picture" sensors. Single pixel sensors take multiple low-resolution images of a subject, each corresponding to a single light in an LED array below the sample. Each of these snapshots is correlated because they record the same scene in a different way. The picture is reassembled using data analysis of those snapshots. These kinds of lenseless cameras are possible using metamaterial mated with some electronics and processing software. This is also the method that is used in cameras with many lenses. Pelican's 16-lens camera means that the camera is capable of capturing 16 different points of view simultaneously. Single pixel sensors are especially useful in longer-wavelength regimes such as the terahertz (THz) gap, the region of the electromagnetic spectrum falling between microwave and IR frequencies where conventional electronics and semiconductor devices no longer function. The areas, which need effective lenses, like astronomy or microscopy might belong to first users of lensless cameras or cameras with many lenses. In 2030, a main application area might be autonomous navigation of automobiles and unmanned ground vehicles (UGVs).

Background information and examples:
http://www.bbc.co.uk/news/technology-21057270
http://www.informationweek.com/hardware/handheld/mit-unveils-lensless-camera/222002840
http://spie.org/x92169.xml
http://www.technologyreview.com/view/516351/lensless-camera-takes-multiple-view-pictures/
http://www.phonearena.com/news/Pelican-Imagings-16-lens-camera-could-arrive-in-Q1-Q2-2015-digital-imaging-has-run-out-of-gas_id51524
http://petapixel.com/2013/07/29/hack-transforms-common-microscopes-into-gigapixel-superscopes/
http://www.iflscience.com/technology/camera-develops-pictures-algorithms-not-lens

Recent vanguard product(s) or invention(s): Described as a "lenseless camera" the screen developed in MIT extends LCD devices while enabling the screen to both capture images and display them. Lenseless camera built at Bell Labs uses no lenses and only a single pixel. This lenseless design is simple and easy to construct and suffers none of the aberrations usually associated with lenses. With many pixels, it's possible to create many different images of the scene. Pelican's 16-lens camera having 16 separate lenses means that the camera is capable of capturing 16 different points of view simultaneously. With

16 different lenses, you can be certain that everything in your pictures will always be in focus.

Application areas in 2030: Interfaces of electronics, robotics, cameras, 3D picturing

Market development: 3, close to commercialization

Great scientific interest, especially the optics and sensors are a focus area of research

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.8, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16, 1.17, 1.19

2.40. "Material Radar"****

Ingress: We call equipment Material Radar if it is able to identify material ingredients of an object –also of human being - safely in an environment where people are present. There are at least two promising roadmaps towards 2030 in Material Radars: molecule detection laser scanners and sensors that can track movement through a wall. An advanced recent first type of Material Radar is a mobile, rack-mountable system. It fires a laser to provide molecular-level feedback at distances of up to 50 meters instantly (in just picoseconds). This Material Radar can identify molecules of explosives, chemicals (e.g. pharmacological substances) and bioweapons. According to a company that has invented this Material Radar, it is able to penetrate clothing and many other organic materials and offers spectroscopic information. In 2030 – and probably already much earlier - Material Radars will be installed in airports and border crossings all around the world. The Material Radar is ten million times faster—and one million times more sensitive—than any currently available system. It can be used systematically on everyone passing through airport security. Perhaps the U.S. government or Russian government already collects molecular data on travelers without their consent, or even knowledge that it's possible. A second type of Material Radar is a wireless system that can track movement through a wall. It can now detect gestures as subtle as the rise and fall of a person's chest. Both types of Material Radars have very many kinds of potential applications.

Background information and examples:
http://davidbrin.blogspot.fi/2012/07/accelerating-dangers-opportunities-from.html
http://www.geniaphotonics.com/
http://www.scienceworldreport.com/articles/8881/20130816/new-method-molecular-imaging-demonstrated-first-time.htm
http://people.csail.mit.edu/fadel/wivi/,http://www.sciencecodex.com/bombdetecting_lasers_could_improve_security_checkpoints-118953
http://rt.com/news/russia-laser-bomb-detector-947/
http://newsoffice.mit.edu/2014/could-wireless-replace-wearables
http://edition.cnn.com/2014/05/02/tech/innovation/molecular-sensor-fits-in-your-hand/
http://www.scienceworldreport.com/articles/13249/20140303/complete-medical-check-up-chip.htm

Recent vanguard product(s) or invention(s): Genia Photonics has 30 patents on molecule detection laser scanner type of Material Radar, claiming incredible biomedical and industrial applications—from identifying individual cancer cells in a real-time scan of a patient, to detecting trace amounts of harmful chemicals in sensitive manufacturing processes. Also, BioPhotonic Solutions has developed a laser that can detect micro traces of explosive chemicals on clothing and luggage. Russians also seem to have a similar technology: announced in April 2012, their "laser sensor can pick up on a single molecule in a million from up to 50 meters away." In MIT, CSAIL team has developed a wireless system that can track movement through a wall. They can now detect gestures as subtle as the rise and fall of a person's chest. From that, they can determine a person's heart rate with 99 percent accuracy. The research could be used for health-tracking apps, baby monitors, and for the military and law enforcement.

Application areas in 2030: Safety sector, quality control in industry, medicine, personal services, robotics e.g. unmanned ground vehicles, mining, agriculture, various daily activities of people.

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Impacts on the value chains: 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, 1.20

2.41. Cheap gas sensors ***

Ingress: At present, gas sensors either have poor selectivity, so that quite complicated and frequent calibrations are required, or they are very expensive. Since monitoring needs for environmental, security, and medical purposes are growing fast, the demand for sensors that are low cost, low power consuming, highly sensitive, and selective detection is increasing as well. Great efforts have been devoted to exploit semiconductor based sensors, ranging from one-dimensional wires e.g. carbon nanotubes to two-dimensional arrays or films e.g. graphene. Besides nanocarbons, the LED technology has been used e.g. in the production of low power consuming and fast response carbon dioxide sensors. In 2030, price level of the sensors will probably be so low that one can use gas sensors in all stages of production process and to monitor environment in any place where one is able to connect sensors to the information networks (homes, built infrastructure, natural environment).

Background information and examples:
http://www.youtube.com/watch?v=24rbe8ntzNg&feature=related
http://www.gassensing.co.uk/news-production-facility/
http://ledmicrosensor.com/advant.htm
http://www.gasera.fi/products/custom-projects/development-projects/
http://www.nanowerk.com/spotlight/spotid=30826.php#ixzz39WsqrhcH
http://pubs.rsc.org/en/Content/ArticleLanding/2014/NR/c4nr00332b

Recent vanguard product(s) or invention(s): Gas Sensing Solutions Ltd (GSS) is a pioneer in the development and production of gas sensors. GSS specialises in ultra-low power consumption, non-dispersive infra-red (NDIR) carbon dioxide sensors. European consortium MINIGAS, led by VTT Technical Research Centre of Finland, is developing a miniature gas sensor to detect greenhouse gases. The MINIGAS sensor is aimed to be 5 cubic cm (cm3) in size and at least twice as sensitive as other sensors of its size. A team of Chinese researchers has now developed low-cost gas sensors by trapping single-walled carbon nanotubes (SWCNTs) in paper and demonstrated their effectiveness by testing it on ammonia.

Application areas in 2030: Industrial processes, protection of nature, agriculture, food security, safety sector, smart houses, monitoring of everyday living, robotics

Market development: 3, close to commercialization

Scientific interest great, sensors are foci of active research

Impacts on the value chains: 1.2, 1.3, 1.4, 1.5, 1.6, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, 1.16, 1.17

2.42. Very sensitive camera sensors based on nanocarbons **

Ingress: Advances in the production methods of nanocarbons (cf. 2.27) have improved the possibilities to use them also in cameras. Using nanocarbons, it is possible to produce very sensitive camera sensors. Using three color filters - for red, green, and blue wavelengths - would allow the graphene sensor to build up a normal full-color pixel. It could also be more efficient in low-light than recent camera sensors in mobile phones, as a single layer of graphene absorbs just 2.3-percent of passing light. Meanwhile, the graphene-based system could be more sensitive to light than traditional camera sensors, reflecting light back out through the layers and so getting a second opportunity to register it. This could mean roughly twice the light detection efficiency.

Background information and examples:
http://www.slashgear.com/nokia-graphene-camera-tech-tips-true-pureview-without-the-bulk-04245872/
http://nanotechweb.org/cws/article/tech/49579
http://www.extremetech.com/tag/graphene

Recent vanguard product(s) or invention(s): Using nanocarbons, mobile phone producers develop very sensitive camera sensors. Research institutes develop much more sensitive graphene based sensors.

Application areas in 2030: Dark vision, optical sensors, cameras, robotics, traffic, games, entertainment

Market development: 3, close to commercialization

Scientifically interesting, sensors are foci of active research

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16

2.43. Printed cheap biosensors ****

Ingress: Printing technologies are used for low cost biosensors capable of diagnosing human health related issues. Printed biosensors can also sense the environment or the quality of perishable goods e.g. food products that indicate their own freshness. Antibody based assays are recently routinely used to detect specific medical conditions but the use of these tests is limited because they need to be carried out in laboratories by highly skilled technicians. A printed array of antibodies speeds up the testing process while reducing the expertise and complexity of equipment needed – introducing the possibility of hand held electronic scanners and far quicker diagnosis. Biostamp is a mesh of circuits and sensors that can record electrophysiological data like skin temperature and hydration state of the wearer. Biostamp's super thin stretchy electronics is connected directly on human skin. It is shower- and swim-proof during the two weeks it lasts before being naturally exfoliated with the skin. Paper is an order of magnitude cheaper than other materials, and printing processes are considerably faster than many of today's manufacturing methods. Scientists at MIT have developed carbon nanotube mechanical pencil, which with just a stroke of the point transfers a nanotube sensor onto a sheet of paper.

Background information and examples:
http://www.engadget.com/2013/03/11/biometric-sensor-printed-directly-on-skin/
http://www.vtt.fi/service/diagnostics_indicators_bioactive_paper.jsp?lang=en
http://www.swansea.ac.uk/research/impact/features/print-technology/
http://inhabitat.com/mits-carbon-nanotube-pencil-draws-delicate-sensors-onto-paper/

Recent vanguard product(s) or invention(s): Welsh scientists are using the latest printing technologies to develop a low cost biosensor capable of diagnosing a range of health conditions. In Finland, VTT's innovation center on printed intelligence is developing easy-to-use and cost-effective biosensors using paper as matrix material. Biostamp developed in University of Illinois is a mesh of circuits and sensors that can record electrophysiological data like skin temperature and hydration state of the wearer. Scientists at MIT have developed carbon nanotube mechanical pencil, which with just a stroke of the point transfers a nanotube sensor onto a sheet of paper.

Application areas in 2030: Medicine, sport, games, food industry, households, retail trade, industry, social media, construction, agriculture

Market development: 3, close to commercialization

Scientifically interesting

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.14, 1.16, 1.17, 1.18, 1.20

2.44. Graphene based terahertz devices ***

Ingress: Terahertz radiation occupies a middle ground between microwaves and infrared light waves. THz radiation has several distinct advantages over other forms of spectroscopy for example many materials are transparent to THz, THz radiation is safe for biological tissues because it is non-ionizing (unlike for example X-rays), and images formed with terahertz radiation can have relatively good resolution (less than 1 mm). However, technology for generating and manipulating it is in its infancy because its frequency of electromagnetic radiation has been too high to be measurable. Graphene research is opening options of needed measurements and manipulations and for simple and efficient design of graphene based functional THz devices. In 2030, many kinds of graphene based terahertz devices will probably be available.

Background information and examples:
http://en.wikipedia.org/wiki/Terahertz_radiation
http://en.wikipedia.org/wiki/Terahertz_time-domain_spectroscopy
http://www.prweb.com/releases/terahertz/032014/prweb11686016.htm
http://terahertztechnology.blogspot.fi/2013/04/abstract-graphene-metamaterials-based.html
http://terahertztechnology.blogspot.fi/p/terahertz-basics.html
http://pubs.acs.org/doi/abs/10.1021/nn406627u
http://www.opticsinfobase.org/abstract.cfm?URI=CLEO_SI-2014-SF1F.8

Recent vanguard product(s) or invention(s): Early commercial products of THz spectroscopy are in the market since 2007 but options to use graphene are still in the pilot stage.

Application areas in 2030: Non-destructive analysis of materials such as plastics and ceramics, quality control of pharmaceutical products, security inspections of sealed packages and containers, food and agricultural product quality monitoring, biopsy of tissues such as skin, communication

Market development: 3, close to commercialization

Scientifically interesting, optics is a key area of global research

Impacts on the value chains: 1.2, 1.3, 1.4, 1.5, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, 1.16

Moving and Transportation

This category includes radical technological solutions the main function of which is to move or to transport.

2.45. Self-driving car ****

Ingress: The development of self-driving cars started already long time ago. Automation has increased in cars and already now, some cars in the consumer market manage simple situations and tasks autonomously. In closed areas like in mining areas, in harbors and in storages many trucks function without drivers. Many states of the USA have given pilot licenses to self-driving cars on public roads. Also for example, the Netherlands is reviewing traffic laws to make large-scale testing of this technology possible on public roads. It seems that the development is now proceeding rapidly and car producers have promised that during the years2018-2020, self-driving cars will be in sale for consumers.

Background information and examples:
http://en.wikipedia.org/wiki/Google_driverless_car
http://www.wired.com/2014/06/cruise-self-driving-car-startup/
http://www.thesun.co.uk/sol/homepage/motors/4930389/mercedes-s-class-unveiled-best-car-in-the-world.html
http://www.sciencedaily.com/releases/2013/08/130816094643.htm
http://www.businessweek.com/news/2014-05-04/nokia-joins-musk-to-google-in-investing-in-intelligent-vehicles
http://www.ess.fi/uutiset/kotimaa/article1820116.ece?ref=ece_frontpage-section-teaser-groupSection-default
http://www.reuters.com/article/2014/06/16/netherlands-tech-autos-idUSL5N0OX3S420140616
http://www.theverge.com/2014/5/28/5758734/uber-will-eventually-replace-all-its-drivers-with-self-driving-cars
http://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-are-we-ready.pdf
http://gcn.com/Articles/2014/06/17/Army-autonomous-truck-convoy.aspx
'http://www.dailymail.co.uk/news/article-2652056/New-laws-drawn-allow-driverless-cars-Britains-roads-race-develop-transport-future.html
http://recode.net/2014/05/13/googles-self-driving-car-a-smooth-test-ride-but-a-long-road-ahead/
http://www.forbes.com/sites/chunkamui/2014/04/17/mit-and-stanford-researchers-show-robotaxis-could-replace-private-cars-and-public-transit/
http://www.scienceworldreport.com/articles/12324/20140121/driverless-taxis-in-european-cities-from-2014.htm
http://spectrum.ieee.org/automaton/robotics/military-robots/army-considers-replacing-thousands-of-

Recent vanguard product(s) or invention(s): The Google Self-Driving Car is a project by Google that involves developing technology for autonomous cars. The U.S. state of Nevada passed a law on June 29, 2011, permitting the operation of autonomous cars in

Nevada, The first license for an autonomous car was given in May 2012 to a Toyota Prius modified with Google's experimental driverless technology. Google's robotic cars have about $150,000 worth of equipment including a $70,000 lidar system. In April 2014, the Google team announced that their vehicles have logged 1,1 million autonomous kilometers. On May 28, 2014, Google presented a new prototype of their driverless car that had neither steering wheel nor pedals. Cruise Automotive startup run by a bunch of MIT graduates plans to make almost any car on the road autonomous. For a mere $10,000, the firm promises to install its RP1 highway autopilot system on any car, as long as it is the make of Audi A4 or S4 2012 or newer. Nokia Oyj plans to spend $100 million backing companies that develop intelligent-car technologies.

Application areas in 2030: Easier driving, traffic safety, driverless taxi, driverless good transport, monitoring tasks, military applications. In 2030, "robotaxis" will probably provide door-to-door service while enabling significant reductions in transportation cost, enhancing mobility for millions saddled with limited access to private and public transportation, relieving congestion, and reducing the need for parking. Robotaxis would enable much higher utilization by sharing otherwise unused cars.

Market development: 3, close to commercialization

Many independent R&D-paths

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.9, 1.10, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17, 1.18,1.19, 1.20

2.46. 1 or 2 wheeled vehicles for personal or good traffic ***

Ingress: Based on the improved ICT, electric motors and batteries, one or two wheeled self-balancing, battery-powered electric vehicles are developing and becoming practical. The rider controls forward and backward movement by leaning the one or two-wheeled vehicle relative to the combined center of mass of the rider and vehicle. The vehicle detects the change in the balance point, and adjusts the speed at which it is balancing the rider accordingly. In 2030, these vehicles will probably transport also goods without drivers. In comparison with bicycles, they are much more suitable for carrying than public transportation vehicles. They are especially suitable for urban environments and might replace the use of cars and equality in transportation.

Background information and examples:
http://en.wikipedia.org/wiki/Segway_PT
http://www.youtube.com/watch?v=6Tbl-z_1loc&feature=player_embedded#!
https://www.youtube.com/watch?feature=player_embedded&v=XgPArPAeYds
http://www.engadget.com/2014/06/21/solowheel-spirit-cruise-xtreme-orbit-hovertrax/
http://techcrunch.com/2014/02/10/urb-e-the-fold-up-electric-scooter-goes-live-on-indiegogo/

Recent vanguard product(s) or invention(s): The pioneer of the field is the Segway, which is a two-wheeled, self-balancing, battery-powered electric vehicle. The Urb-E folds

up to the size of a rollerboard suitcase. In one-wheeled vehicles, Solowheel and Honda are in the lead. Their weight of lightest one-wheeled is much more than 10 kg. The special Chinese edition of Solowheel costs in 2014 only 1,199 USD, but it won't be available outside China. The most advanced one-wheeled vehicle can reach a top speed of 16km/h and can go as far as 25km after a full two-hour charge.

Application areas in 2030: Light personal traffic, short distance good transport.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.8, 1.9, 1.12, 1.13, 1.15, 1.16, 1.17, 1.20

2.47. Quadcopters ***

Ingress: Drones, quadcopters or quadrocopters belong to the most promising applications of remotely piloted aircraft systems (RPAS). According to recent EU report, just as the internet technology in the early nineties gave way to many different applications, RPAS technologies should lead in the coming years to the development of a wide variety of different services in seeking, organization, assembling and transportation of things beside military uses. This will happen when drones or quadcopters will use other technologies, such as precision positioning such as Galileo. The US Federal Aviation Administration (FAA) has estimated that there will be 30,000 drones in US airspace by 2020. After a careful process, FAA selected in 2014 six unmanned aircraft systems (UAS) research and test site operators across the country. Especially in the EU but also in other countries, lacking or too restrictive regulatory frames for RPAS might mean some delay for RPAS future use. However, China and India will probably already in the near future be using commercially extensively quadcopters. Drone delivery has special appeal to the authorities of those countries, who are increasingly struggling to control both traffic and pollution in major cities. On top of that, e-commerce is growing much faster than the delivery infrastructure in rural and mountainous parts of China and India. In first commercial applications, quadcopters transport e.g. post or pizzas.

Background information and examples:
http://www.youtube.com/watch?v=4ErEBkj_3PY
http://aeroquad.com/content.php?s=c10c872fe2ddbcfcdca425203e80ba1b
http://www.youtube.com/watch?v=pp89tTDxXuI
http://www.youtube.com/watch?v=W18Z3UnnS_0
http://www.youtube.com/watch?v=xvN9Ri1GmuY
http://qz.com/120654/china-could-become-the-first-country-to-legalize-parcel-delivery-by-drone/
http://www.cnet.com/news/next-gen-drones-follow-wherever-you-go/
https://www.youtube.com/watch?v=E2stferhRgU
http://tech.firstpost.com/news-analysis/top-this-mumbais-francescos-pizzeria-uses-unmanned-drones-to-deliver-pizza-224184.html

http://ec.europa.eu/transport/modes/air/doc/com%282014%29207_en.pdf
http://gpsworld.com/faa-selects-six-sites-for-uav-research/

Recent vanguard product(s) or invention(s): In early commercial uses in China and India, drones can hit a maximum altitude of 100 meters and deliver parcels within two meters of its target. E.g. four-rotor drone took off with the pizza order from its outlet in central Mumbai's Lower Parel area and delivered it to a high-rise building in adjacent area. There are quadcopters that can fly ten hours with one charge of the battery. The typical maximum load in commercial applications is now about 3kg but even 10kg or more that the weight of the quadcopter is possible. A recent important vanguard development seems to be open source hardware and software projects dedicated to the construction of remote controlled four-rotor helicopters first of all the AeroQuad. You can make a quadcopter using just 50 €.

Application areas in 2030: Entertainment, industry, trade, safety sector, construction, measuring and logistics, maintenance

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Many independent paths of R&D

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.9, 1.10, 1.12, 1.13, 1.15, 1.16, 1.17, 1.18, 1.20

2.48. On-demand personal aviation services *

Ingress: Light and small on-demand airplanes are promising possibility because of light and strong carbon materials as well as developments in the battery technology and in the information technology. A personal air vehicle or PAV is an emergent aviation market that would provide on-demand aviation services. These airplanes should have vertical take-off and landing though they otherwise behave like airplanes. These vehicles would behave like taxis in various kinds of environment. The term PAV was first used by NASA in 2003 when it established the Personal Air Vehicle Sector Project. Controversial, this kind of prototype is the Skycar developed by Paul Moller. Moller has tried to develop skycars that are not more complicated than motorcycles or cars. The Skycar M400 is purported to ultimately transport four people; single-seat up to six-seat variations are also planned. It is described as a car since it is aimed at being a popular means of transport for anyone who can drive, incorporating automated flight controls, with the driver only inputting direction and speed required.

Background information and examples:
http://en.wikipedia.org/wiki/Personal_air_vehicle
http://www.flixxy.com/jet-pack-flying-machine.htm?a=1
http://moller.com/dev/ ; http://en.wikipedia.org/wiki/Moller_M400_Skycar

Recent vanguard product(s) or invention(s): The Skycar targets of Paul Moller seem to be difficult to achieve. The key element of the Skycar is the Wankel engine called the Rotapower engine. The Rotapower engine has never been produced as a product. In 2009, Moller claimed to have a backlog of 900,000 orders for the engine, but those claimed units were never manufactured. After fifty years and more than 100 million $ in expenditure the Skycar is often cited as a real world example of physical product vaporware. In April 2009, the National Post characterized the Moller M400 Skycar as a 'failure', and described the Moller company as "no longer believable enough to gain investors". Moller International continues now with reduced operations. But the development work continues anyway: the Rotapower engine 2013 prototype was able to produce 5 kW/kg of weight. Flynano is a single-seat carbon-fiber airplane designed for water operations and proposed as a "fun flyer" has taken its first test flights.

Application areas in 2030: Personal transportation, goods transportation, military use, border control, health care, entertainment.

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.10, 1.12, 1.13, 1.15, 1.16

2.49. Vactrains *

Ingress: A vactrain (or vacuum tube train) is a proposed design for very-high-speed rail transportation. It is a maglev (magnetic levitation) line using evacuated (air-less) or partly evacuated tubes or tunnels. The lack of air resistance could permit vactrains to travel at very high speeds 5–6 times the speed of sound (c) and in space applications even more than 10 c using relatively little power. Vactrains might use gravity to assist their acceleration. If these trains achieve the predicted speeds, the trip between Beijing and New York would take less than 2 hours, surpassing aircraft as the world's fastest mode of public transportation. However, without major advances in tunnelling and other technology, vactrains would be prohibitively expensive. Closest to the realization seems to be the vactrain between Shanghai and Peking. In USA a promising target is the vactrain between San Francisco and Los Angeles, which is one of the most traveled corridors in the American West. An especially interesting idea is to use vactrain for space launch.

Background information and examples:
http://en.wikipedia.org/wiki/Vactrain
http://www.answers.com/topic/vactrain#ixzz3FifGZdgj
http://www.bloomberg.com/news/2013-08-13/musk-shows-hyperloop-transport-design-for-people-to-cars.html
http://www.et3.com/
http://www.spacex.com/sites/spacex/files/hyperloop_alpha-20130812.pdf

Recent vanguard product(s) or invention(s): Various alternatives and routes of the vactrain are in the stage of concept plan. Researchers at Southwest Jiaotong University in China are developing a vactrain to reach speeds of 1,000 km/h. They anticipate that the technology could be put into operation by 2020 between Shanghai and Peking. A

challenging idea has developed by Dr. James Powell, former co-inventor of superconducting maglev in the 1960s. Since 2001 he has led investigation of a concept for using a maglev vactrain for cheaper space launch. The StarTram vehicles might reach up to 31,500 km/h within an acceleration tunnel. The needed escape velocity from the earth ground is 40,320 km/h. The long tunnel is needed to limit g-forces and drilling through the ice sheet in Antarctica is a suggested choice for lower anticipated expense than in rock.

Application areas in 2030: Rapid transportation, space launch

Market development: 2, laboratory prototype

Impacts on the value chains: 1.1, 1.2, 1.13, 1.14

2.50. Magnetic or superconductor based levitation *

Ingress: Magnetic levitation has been demonstrated for a variety of objects, from trains to frogs. In ElectroMagnetic Suspension (EMS) the electromagnet is above the object being levitated; the electromagnet is turned off whenever the object gets too close, and turned back on when it falls further away. Magnetic levitation trains are based on this kind of levitation: The train wraps around the track, and is pulled upwards from below. The servo controls keep it safely at a constant distance from the track. A phenomenon known as quantum locking allows a superconductor disk to float over a magnetic rail completely frictionlessly and with zero energy loss. If the magnetic field has suitable form the superconductor disk floats in the magnetic field keeping its position stable even if it is currying really large load. The weakness of superconductors is the very low temperature required by the recent superconductors. Another possibility to produce similar levitation is based on so called Casimir Effect which as far had functioned just on nano size systems. Also graphite or graphene can levitate in the stable way in the magnetic field but they are able to carry a load just of their weight. So far no one has developed a practical maglev-based actuator that converts some external source of energy into motion. Now in a new study, researchers for the first time have used a laser to control the motion of a magnetically levitating graphite disk. By changing the disk's temperature, the laser can change the disk's levitation height and move it in a controlled direction.

Background information and examples:
http://en.wikipedia.org/wiki/Magnetic_levitation
http://phys.org/news/2012-12-magnetically-levitating-graphite-laser.html#ajTabs
http://www.ted.com/talks/boaz_almog_levitates_a_superconductor.html
http://en.wikipedia.org/wiki/Casimir_effect

Recent vanguard product(s) or invention(s): Magnetic levitation trains are still the leading application in the field.

Application areas in 2030: Bearings of machines, Magnetic levitation trains, kinetic strong capacity batteries

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Scientific interest considerable, superconductors are actively researched

Impacts on the value chains: 1.1, 1.11, 1.13, 1.16, 1.17

2.51. CubeSat and other minisatellites **

Ingress: A CubeSat is a type of miniaturized satellite for space research that usually has a volume of exactly one liter (10 cm cube), has a mass of no more than 1.33 kilograms, and typically uses commercial off-the-shelf components for its electronics. Beginning in 1999, California Polytechnic State University at San Luis Obispo (Cal Poly) and Stanford University developed the CubeSat specifications to help universities worldwide to perform space science and exploration. For example, recently a team at NASA's Ames Research center worked on the future launch of cheap miniature satellites constructed with Android-powered Nexus One smartphones at the helm. The team plans to use the PhoneSats in future missions involving moon exploration, low-cost Earth observations, and testing of new technologies and components for space flight. Beside NASA, other commercial actors provide CuberSats space-launching places. Recently, the construction of an own satellite and its launching costs about 100 000$ but in the future the price might be radically lower. Then education institutes, companies and other organizations might think about the launching of satellites even without important reasons. The commercialization and development of space technology - e.g. new reaction engines and electric sails - promote the use of the space for many kinds of purposes.

Background information and examples:
http://fi.wikipedia.org/wiki/CubeSat
http://www.pcworld.com/article/261331/android_phones_will_power_nasas_new_fleet_of_mini_satellites.html
http://www.planetaryresources.com/2013/01/asteroid-mining-update-from-the-factory-floor/
http://www.theregister.co.uk/2012/11/29/esa_sabre_clearance/
http://www.scienceworldreport.com/articles/8241/20130718/true-spaceplane-enabling-radically-superior-engine-technology-receives-funding.htm
http://www.electric-sailing.fi/

Recent vanguard product(s) or invention(s): A team at NASA's Ames Research center in Moffett Field, California, is working on the future launch of cheap miniature satellites constructed with Android-powered Nexus One smartphones at the helm. An Antares rocket, a low-Earth-orbiting rocket that can carry up more than 1000 such miniature satelites and Nasa is providing such kind of opportunities without payment. An UK company Reaction Engines Ltd has developed new kind of rocket engine. This unique engine will use atmospheric air in the early part of the flight before switching to rocket mode for the final ascent to orbit. This is achieved by cooling down and compressing incoming air until it is nearly liquefied, like the oxygen used in conventional rockets. The British-built rocket/jet engine designed to enable Mach 6 flight. Another promising possibility for cheaper flights is electric sail. The electric sail is a new space propulsion

concept which uses the solar wind momentum for producing thrust .The electric sail developed in Finland is somewhat similar to the more well-known solar radiation pressure sail which is often called simply the solar sail. A full-scale electric sail consists of a number (50-100) of long (e.g., 20 km), thin (e.g., 25 microns) conducting tethers (wires).

Application areas in 2030: Space research, telecommunication, soil research, safety sector, entertainment, games, social media

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.4, 1.6, 1.10, 1.11, 1.13, 1.14, 1.15, 1.16, 1.18, 1.20

2.52. Light continuously flying equipments ***

Ingress: Strong and light materials as well as improved batteries and solar panels have made possible the continuous flying of motor airplanes without added fuel. The vehicles rise above the clouds and use solar panels in the day time and batteries in the night. These airplanes might replace telecommunication satellites and antennas and make aerial photography and control. Controlled e.g. by satellites, they can fly long distances. Even amateurs might make them using just some hundreds or thousands euros with future light materials and more effective batteries. In 2012, a 75kg carbon fibre vehicle with a pilot completed its first flight, taking a brief skip above a Finnish lake. According to the maker, recent technology gains mean that electric motors will now be the main power option of this cheap flying vehicle.

Background information and examples:
http://www.mnn.com/earth-matters/energy/stories/solar-powered-plane-can-fly-all-day-and-all-night
http://www.engadget.com/2012/06/16/flynano-proto-takes-to-the-air-electric-power/
http://www.youtube.com/watch?feature=player_detailpage&v=QGxNyaXfJsA#t=83s
http://www.telegraph.co.uk/technology/google/10766490/Google-buys-drone-manufacturer-Titan-Aerospace.html
http://www.techtimes.com/articles/5216/20140405/googles-loon-balloon-circles-globe-in-just-22-days-internet-for-all-remains-goal.htm

Recent vanguard product(s) or invention(s): Solar Impulse is a leading solution in the field. This solar-powered manned plane carries 12,000 solar cells on its wings and it has flight without using a single drop of fuel. The 3,600-mile intercontinental trip happened in 2012 from Switzerland to Monaco. The plane also flies at night. The vehicle's wings — which are also its solar panels — collect enough energy to fly during the day while also storing enough energy in batteries to continue the journey after the sun has gone down. Titan Aerospace develops with the Google solar-powered unmanned aircraft that can fly non-stop for years hundreds of meters above the ground, beaming wireless signals to the ground. The aim of these atmospheric satellites is to help bring internet access to millions

of people, and help solve other problems, including disaster relief and environmental damage like deforestation. Another possibility is to use balloons for those purposes.

Application areas in 2030: Military technology, border control, safety sector, terrorism, entertainment, gaming, logistics, telecommunication, geografical mapping, traffic control

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.10, 1.11, 1.13, 1.14, 1.15, 1.16, 1.18,1.19, 1.20

Robotics

This section specifies to those radical technological solutions that are connected to megatronics and function mainly autonomously or that are remote-controlled.

2.53. Modular robotics ****

Ingress: Traditionally, robots are constructed and programmed as integrated wholes. When the field of the robotics is expanding and maturing the modular approach is proceeding. Modularity will base much on programming platforms and interfaces, in which you can connect peripheral devices and sensors and their (sub) programs. When robots are constructed from ready modules with their own functional programs it is easier to provide robots with new functions because you have not to solve similar challenges many times. The modular robots can also be cheap providing nice possibilities for Arduino like open code development and robot competition activities. A new promising possibility is to use mobile phones as central units of modular robots benefitting from services in cloud. The peripherals of mobile phones like microphone, camera, inertia sensor and GPS are especially useful in many applications of robots. Future self-reconfiguring robots will be able to deliberately change their own shape by rearranging the connectivity of their parts - or independent small robots -, in order to adapt to new circumstances, perform new tasks, or recover from damage. For example, a robot made in the MIT of such components could assume a worm-like shape to move through a narrow pipe, and then reassemble into something with spider-like legs to cross uneven terrain.

Background information and examples:
http://techcrunch.com/2013/10/04/m-blocks/
http://arduino.cc/en/Main/Robot
http://www.letsmakerobots.com/taxonomy/term/84
http://www.robotchallenge.org/competition/
http://en.wikipedia.org/wiki/Self-reconfiguring_modular_robot

http://robosavvy.com/store/index.php/cPath/21_1203
http://www.ted.com/talks/keller_rinaudo_a_mini_robot_powered_by_your_phone.html?utm_campaign&utm_medium=on.ted.com-static&utm_content=awesm-publisher&utm_source=direct-on.ted.com&awesm=on.ted.com_Romo
http://www.wired.com/2014/03/kickstarter-robot-arm-ufactory/

Recent vanguard product(s) or invention(s): Arduino robots, in which every element of the platform – hardware, software and documentation – is freely available and is open-sourced. This means you can learn exactly how it's made and use its design as the starting point for your own robots. The Arduino Robot is the result of the collective effort from an international team looking at how science can be made fun to learn. The M-Blocks - developed at MIT - are reconfigurable, modular robots with no external moving parts. The cubes' ability to move results from harnessing the momentum of an internal flywheel (which can hit speeds of 20,000 revolutions p/m) — allowing them to climb over one another, make jumps, spin and roll around. And it can do all that without the need for wheels or legs. Magnets on the corners of the blocks are used for course correction and stability of these robots.

Application areas in 2030: Robotics, much easier ways to develop the robotics, special markets for various functionalities of parts and skills of robots.

Market development: 3, close to commercialization

Many independent R&D-paths

Impacts on the value chains: 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.9, 1.10, 1.12,1.13, 1.14, 1.15, 1.16, 1.17, 1.18, 1.20

2.54. A walking robot with hands ****

Ingress: Since the concept of robotics was coined, a robot that moves like a human has been the symbolic goal of the field of robotics. Mimicing the movements of a human has turned out to be more challenging than expected in terms of both the design of the joints as well as sensoring and programming of the movements. However, recent development has been rapid. New robots move quite reliably on two feet and the best ones are able to grab various hard and soft objects without breaking them. A robot that mimics a human is important, because the objects and equipment of our environment have been designed for the use of a human. Robots can be autonomous, but increasingly often robots are designed to be remote controlled, so that a human can perform tasks from a distance and interact with his/her environment in the most natural way possible.

Background information and examples:
https://www.youtube.com/watch?feature=player_embedded&v=R8UeT9r4cmg
http://www.desirethis.com/1419/kinova-mico-an-affordable-robotic-arm
https://www.youtube.com/watch?v=zkBnFPBV3f0

Recent vanguard product(s) or invention(s): The robots of Toyota and Honda represent the vanguard products of walking robots with hands. For example, Toyota's robot can play the violin. Aldebra Robotics offers the walking Nao robot to educational institutions for less than 10,000 euros. There are many different applications available for the robot.

Application areas in 2030: Services, remote presence, tasks in environments designed for humans, assisting of the elderly and disabled, education, entertainment, games, military technology.

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.13, 1.15, 1.16, 1.17, 1.19, 1.20

2.55. The cyber insect *

Ingress: A cyber insect refers to a device that usually flies and is the size of a dragonly or smaller. The demanding issues in the development of the cyber insects are miniaturization of electronics, creation of motors or artificial muscles that enable flying, and the power source. The challenge of flying with the help of wing strokes needs solving. With the help of a camera and sensors, cyber insects can observe their environment, move in it, and communicate via communication technology. When the manufacturing of the devices becomes automated, the cost will be very low. Cyber insects have been designed to be used in, for example, agriculture, military technology, as well as surveillance and rescue tasks.

Background information and examples:
http://en.wikipedia.org/wiki/Micro_air_vehicle
http://en.wikipedia.org/wiki/Nano_Air_Vehicle
http://www.thisiscolossal.com/2013/04/the-bionicopter-a-robotic-dragonfly-by-festo/
http://www.bbc.co.uk/news/science-environment- 22380287

Recent vanguard product(s) or invention(s): Harvard researchers have realized a device that is one inch in size, flies like an insect, and is accurately remote controlled. For now, electric conductors powers the device.

Application areas in 2030: Military technology, control and measurement tasks, rescue operations, agriculture, games, and social media.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.4, 1.5, 1.6, 1.10, 1.11, 1.15, 1.16

2.56. 3D printing of goods ****

Ingress: In 3D printing (additive manufacturing), parts or functional machines are built by adding material. The technological solution was first applied commercially in the 1980's. In addition to many other applications, parts of air and spacecraft and cars, hearing aids and other prosthesis, musical instruments, toys, copies of museum items, casts and molds, jewelry, and tools are already being routinely printed. For example, the aircraft manufacturer Boeing's flagship model, the Dreamliner, contains 30 different 3D printed parts and NASA is investigating 3D printing's capability to create lunar structures and bases directly on the moon, as flying bulky structures to the moon would be costly and inefficient. There are various techniques and, among others, plastics, ceramics, composites and metals can be used as material for the printed goods. The cost of the machines ranges from hundreds of euros to over one million euros. Since many key patents have expired, competition has accelerated the speed of development and printer sales have multiplied since 2010 and continues to grow very fast. The development has been especially fast in open source projects. There are still limitations to the technology, but the advantages compared to traditional methods is that complexity does not increase costs, there are less geometrical limitations and parts can be made more lightweight compared to traditional machining, there are no repeat mold costs, each unit can be unique, and, through inexpensive machines, manufacturing can be local and there will be no logistical costs. For many purposes, the output is good enough as it is, but in many cases surface finishing is required.

Background information and examples:
http://blog.ted.com/2013/02/07/7-talks-on-the-wonder-of-3d-printing/
http://www.youtube.com/watch?v=0gMCZFHv9v8
http://www.minifactory.fi/
http://triplehelixblog.com/2014/09/3d-printing-the-future-of-creation/

Recent vanguard product(s) or invention(s): EOS is the market leader in 3D metal printers. Currently, the most inexpensive 3D printers cost around 250 USD. The Finnish miniFactory is one of the most versatile machines in the 1,000 USD price range.

Application areas in 2030: Service and maintenance, art, small-scale industries, leisure activities, product development, research.

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Several independent paths of R&D

Impacts on the value chains: 1.3, 1.4, 1.6, 1.7, 1.8, 1.9, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.18, 1.19, 1.20

2.57. 3D printing of buildings **

Ingress: Researchers have developed concrete-like materials which are mixed with nanocellulose or other wood fibers, and will stiffen enough to be able to be extruded and casted in thin layers without a mold. This technique seems to be applicable to casting building elements and frames of whole buildings as 3D prints with the help of a robot. Complexity of the printed frames does not cause significant additional costs, which means that large furniture and the desired amount of curved walls and angles can be printed into the building. HVAC piping and possibly wiring can be inserted at the time of printing.

Background information and examples:
http://www.youtube.com/watch?v=JdbJP8Gxqog
http://www.theverge.com/2012/2/21/2811146/3d-printing-d-shape-monolite-enrico-dini
http://www.telegraph.co.uk/travel/ultratravel/the-next-big-thing/10110195/The-worlds-first-3D-printed-house.html
http://www.dezeen.com/2013/06/26/digital-grotesque-the-worlds- first-3d-printed-room/

Recent vanguard product(s) or invention(s): Contour Crafting has demonstrated a several meters tall printed wall. The computational speed of 3D printing a small, two-story house is 24 hours. The material is described to be much stronger and environment friendlier than conventional concrete. Enrico Dini has successfully researched a slightly different printing method.

Application areas in 2030: Building element manufacturing, ship frame printing, printing of buildings and other large, stonelike structures and objects.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.3, 1.4, 1.6, 1.11, 1.13, 1.14, 1.15, 1.17, 1.18, 1.20

2.58. 3D and 4D printing of material **

Ingress: Material extruding 3D printers have the principled skill to produce mixes of several different substances and even molecular level compounds part by part according to plan. For example, using 3D printers to produce metamaterial that makes objects invisible is under active research. Researchers have already managed to produce tissue-like material out of a mix of fats and water by injecting droplets of water inside lipids, or fat molecules, and creating a 'droplet network' from multiple droplets. The droplets can also be printed with protein pores to form pathways through the network that mimic nerves and are able to transmit electrical signals from one side of the network to the other. This way a muscle-like transformation has been achieved in places, where electricity has then been conducted. Researchers have also reported about the printing of medicine, and a DNA printer can also be regarded as a material producing 3D printer, although the result is string-like. A functioning battery has also been printed, and the researchers' goal is to print a robot, which would independently walk out of the machine after printing. Printing of so-called 'programmable materials' is considered 4D printing. In 4D printing, time is the fourth dimension and, after 3D printing, the printed materials

change shape or automatically reassemble in new ways that have been programmed into the material at the printing phase.

Background information and examples:
http://www.medgadget.com/2013/04/oxford-creates-new-type-of-3d-printed-replacement-tissue.html
http://www.3dprinter.net/print-me-invisible-with-metamaterial
http://web.mit.edu/3.042/team1_08f/project.html
http://www.ted.com/talks/lee_cronin_print_your_own_medicine.html
http://www.scientificamerican.com/article/what-is-4-d-printing-manufacturing/

Recent vanguard product(s) or invention(s): The majority of material printers are machines that have been specifically modified for research projects. However, the largest machines of Stratasys' Objet product line are able to inject 16 different light-sensitive polymers into the same object and to create material mixes at the time of printing. All printing materials used by Objet are light-sensitive polymer mixes.

Application areas in 2030: Research, product development, medicine, biology, electronics, robotics.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.3, 1.4, 1.5, 1.8, 1.9, 1.11, 1.12, 1.13, 1.15, 1.16, 1.20

2.59. 3D printing of organs *

Ingress: Using stem cells or otherwise cultivated cells to print tissue that mimics a functional organ's structure is called 3D printing of organs. The printing process has developed in such a way that cells remain viable during printing. As the stem cell technology has developed, cultivating cells from cells eligible for organ transplant also becomes easier. The 3D bioprinted biological systems not only resemble humans genetically, but they also respond to external stress as if they are living organs. This allows for more effective drug testing that shows side effects first hand. In addition to sparing animals from cruel testing, this technology could also mitigate the issue of developing drugs that work on animals, but not on humans. Bioengineering experts estimate that 3D printed human cells will replace animal testing by 2018. Another recent discovery of a use for 3D bioprinting is the printing of a model of a cancerous tumor that allows for a new way of conducting medical studies.

Background information and examples:
http://www.treehugger.com/clean-technology/new-technique-3d-printing-works-embryonic-stem-cells.html
http://www.bbc.co.uk/news/technology-18677627
http://www.ted.com/talks/anthony_atala_printing_a_human_kidney.html
http://www.nytimes.com/2013/04/15/science/rat-kidneys-made-in-lab-seen-as-step-to-human-transplants.html?_r=1&

http://inhabitat.com/3d-printed-human-cells-will-replace-animal-testing-in-five-years-says-bioengineer-expert/
http://www.sciencedaily.com/releases/2014/04/140410194613.htm

Recent vanguard product(s) or invention(s): Researchers have managed to print blood vessels, a functional kidney of a mouse and a functional liver, among others.

Application areas in 2030: Medicine, food industry, robotics.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.3, 1.4, 1.5, 1.9, 1.11, 1.15, 1.19

2.60. Robotic surgery and other cutting of biological objects **

Ingress: Many surgeons in Finland and abroad already perform surgeries using remote controllable robots. The surgeon sees a large, three dimensional image of the surgical site in front of him or her and uses a computer to control robotic arms that are performing the surgery. The method is far more accurate than normal surgery and, for example in urological and brain surgery, the success rates are higher. When robotic surgery is combined with magnetic imaging and later terahertz medical imaging, and the robot is allowed to, for example, independently remove harmful cancerous tumors while avoiding blood vessels and nerve fibers, the robot is able to coordinate its actions more accurately and faster than even an excellent surgeon. In the future, it can be anticipated that robots perform surgeries independently, under only technical supervision. For the time being, robots are expensive, but it stands to reason to assume that as patents expire and machines diffuse, prices will decrease following the common price development of robot technology. On a broader level, robots will remove bones from chickens and, for example, cutting of hair might become robotized.

Background information and examples:
http://www.bbc.co.uk/news/uk-england-18910623
http://www.thespec.com/news/local/article/757402--hamilton-robot-can-detect-and-treat-breast-cancer
http://www.wired.co.uk/news/archive/2013-06/11/robo-surgeons
http://www.scienceworldreport.com/articles/8268/20130719/intelligent-knife-detects-cancerous-tissue-cutting-tumor-during-surgery.htm

Recent vanguard product(s) or invention(s): The daVinci robot is used in about 800 different hospitals and it costs around one million euros. The surgical results are better than the average surgeon, but the capital cost is still significant.

Application areas in 2030: Medical diagnostics, surgery, invasive therapies, meat industry, beauty industry.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.3, 1.4, 1.5, 1.6, 1.8, 1.9, 1.11, 1.15

2.61. Sensitive robot fingers and hands capable of remote work ***

Ingress: As carbon nanotubes develops, materials are becoming so sensitive that they can indicate the properties of objects significantly better than the touch sensitivity of human fingers. Simultaneously, haptic materials have developed so that desired sensations can be generated very accurately to fingers and hands. With these combined, a human can handle and probe objects and materials via robotic hands. Sensitive robotic hands can also be made durable and strong, and when needed, they can be made large or small and be attached to a machine that walks, moves on the water or wheels or flies, and for example, be placed in a space that is dangerous for humans.

Background information and examples:
http://www.independent.co.uk/life-style/gadgets-and-tech/news/a-sensational-breakthrough-the-first-bionic-hand-that-can-feel-8498622.html
http://www.upi.com/Science_News/Technology/2012/06/19/Robot-finger-more-sensitive-than-humans/UPI-18561340131691/
http://www.wired.co.uk/news/archive/2013- 04/26/smart-skin
http://www.cbsnews.com/8301-205_162-57582601/watch-robot-hand- can-pick-up-50-pound-weight-use-tweezers/
http://www.scienceworldreport.com/articles/8293/20130722/paper-thin-electronic-skin-lights-up-response-touch-holds-promise.htm

Recent vanguard product(s) or invention(s): Development advances fast in many different research organizations. Prototypes are capable of significantly more demanding tasks.

Application areas in 2030: Prostheses, remote work, heavy and dangerous tasks, precision mechanics, robotics, entertainment, and social media.

Market development: 3, close to commercialization

Scientific interest: High

Impacts on the value chains: 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.11, 1.12, 1.15, 1.16, 1.18, 1.19, 1.20

2.62. Robo-tailoring *

Ingress: The development of robotics, precise 3D measuring of the body, and 3D modeling and design of accessories create a combination, which allows for automated measuring, cutting of fabric and sewing of custom-made clothing. At the same time, features that the clothing industry and even a good tailor would struggle to produce at any reasonable cost can be added to the clothes.

Background information and examples:
http://www.mnn.com/green-tech/research-innovations/stories/robot-sewing-machines-could-make-made-in-china-obsolete
http://phys.org/news/2012-06-darpa-issues-robot-imports.html

Recent vanguard product(s) or invention(s): For now, development happens in small companies, but the general development of robotics supports it. DARPA is activating and financing the development of this technology. The Finnish Nomo Jeans has developed the first part of the above-described process, but sewing is still done manually.

Application areas in 2030: Automated manufacturing of custom-made clothes, industrial clothing manufacturing without manual labor.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.3, 1.4, 1.6, 1.11, 1.12, 1.15, 1.18, 1.19, 1.20

Imitation of the nature and cyborgs

This group consists of radical technological solutions which are based on a key feature that has been either imitated from biology or that is used to augment humans' abilities without combining the technical solution with the human's biological machinery.

2.63. Nanosurfaces that convert air moisture to water *

Ingress: On the large scale, nanotechnology is first and foremost a technology of the surfaces. One of the most important things on Earth is water and in many areas there is water shortage especially in agricultural areas, but there is also a vast shortage of clean drinking water in developing countries. Many plants and animals are able to take the water they need from the air. Imitation of these mechanisms has led to surface materials, which enable gathering the moisture of air in liquid water. These materials can be essentially less expensive than the current desert water catchment systems, and they could be produced in small sizes and placed, for example, close to the roots of plants, so that long irrigation hoses would become redundant. There can easily be a gram of water

per cubic meter of desert air. If a thousand cubic meters of air go through a catchment system of one square meter, the daily production of even a small cathment system can be several liters of water.

Background information and examples:
http://www.bbc.co.uk/news/technology-20465982
http://www.treehugger.com/clean- technology/airdrop-design-pulls-water-air-to-irrigate-deserts.html

Recent vanguard product(s) or invention(s): Imitation of a Namib insect has enabled a more efficient way of utilizing air moisture in water production. The NBD-nano (short for Namib Beetle Design) is still in the product development phase.

Application areas in 2030: Sourcing of fresh and clean water in particularly dry areas.

Market development: 3, close to commercialization

Impacts on the value chains: 1.5, 1.8, 1.13, 1.14, 1.16,1.17, 1.20

2.64. Biobots *

Ingress: The development of biology and nanotechnology has enabled the development of goal-oriented, autonomously operating robots that move inside organisms or thatare based on the use of cells and organs inside the organisms. These devices can, for example, move with the help of biologically born cells or even the whole body directed by a computer or other installed logic, or they can use the brain of the biological organism to direct their actions, or they can be completely mechanical, but intended to operate independently inside a biological organism.

Background information and examples:
http://www.popularmechanics.com/how-to/blog/3d-printed-biobots-will-crawl-through-your-body-targeting-toxins-14735565
http://www.nbcnews.com/technology/mini-bio-bot-walks- when-its-rat-heart-cells-beat-1C7099426
http://www.gizmag.com/kinect-controlled- cockroaches/28108/

Recent vanguard product(s) or invention(s): A 3D printed biorobot advances to a desired direction via a rat's heart cells that contract and expand, following the chemical messages it receives. The movement of a cockroach is remote controlled through a circuit that is attached to the cockroach.

Application areas in 2030: Among others, monitoring and fixing of deficiencies of the body's internal functions, agriculture, military technology, rescue operations. Compared to living organisms, the biobots' inability to reproduce is a benefit in terms of security, but a constraint in terms of inexpensive manufacturing.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.3, 1.5, 1.8, 1.9, 1.10, 1.16

2.65. Artificial muscles **

Ingress: Biological organisms mainly use their muscles for autonomous movement. Muscles that contract as needed can be used for many purposes. Because structures that utilize electric motors or hydraulics are clumsy in small size, materials and structures that contract like muscles have therefore been researched especially in the area of robotics miniaturization. For example, if efficient and simple muscles can be produced, devices that fly like birds or insects become simpler to build.

Background information and examples:
http://phys.org/news/2012-11-wax-filled-nanotech-yarn-powerful-super-strong.html
http://phys.org/news/2013-07-artificial-muscle-humidity.html

Recent vanguard product(s) or invention(s): A "muscle" based on carbon nanotubes can be made to contract and expand strongly and very rapidly (2,5 mS) with heat or light impulses.

Application areas in 2030: Robotics, surgical instruments, miniature size chemical, optical, and other devices, prosthesis, entertainment.

Market development: 3, close to commercialization

Impacts on the value chains: 1.2, 1.3, 1.4, 1.6, 1.8, 1.9, 1.10, 1.11, 1.12, 1.14, 1.15, 1.17

2.66. Artificial, self-renewing skin *

Ingress: The skin's ability to renew itself and transmit sensations of touch would be useful in many devices. There have been attempts to incorporate these abilities into synthetic materials. The aim is to develop surfaces, which recognize touch and repair the damages that are created on the surface.

Background information and examples:
http://news.stanford.edu/news/2012/november/healing-plastic-skin-111112.html
http://www.wired.com/wiredscience/2012/11/synthetic-skin/

Recent vanguard product(s) or invention(s): The first synthetic material, which reacts to touch and is able to renew itself quickly and repeatedly at room temperature has been fabricated at Stanford University.

Application areas in 2030: Machinery, tools, prosthesis, robotics.

Market development: 2, laboratory prototype

Scientific interest: High

Impacts on the value chains: 1.2, 1.6, 1.9, 1.10, 1.11, 1,12, 1.15, 1.17

2.67. DNA memory *

Ingress: Today, artificial memory devices are used primarily in electronics. In addition to these cultural means, evolution has produced the nervous system and DNA as the key mechanisms of memory. These days, DNA code is being read and written routinely, and the solutions are becoming less expensive. As a memory device, DNA is extremely dense. About two thousand terabytes of data can be stored in one gram of DNA material, which equals about one million regular DVD discs. DNA can be stored as powder. As a memory device DNA is special in the sense that it can be incorporated into the genome of a living organism, where it spreads as cells divide. It can participate in protein production and direction of the cell's functions. DNA can also function as the memory used by intra-body devices.

Background information and examples:
http://physicsworld.com/cws/article/news/2013/jan/23/digital-files-stored-and-retrieved-using-dna-memory
http://www.extremetech.com/extreme/134672-harvard-cracks-dna- storage-crams-700-terabytes-of-data-into-a-single-gram

Recent vanguard product(s) or invention(s): Researchers of genetics write DNA sequence into a code of four bases almost routinely and several books have already been stored into the genome. In the UK, researchers of the European Bioinformatics Institute stored large text and audio files into DNA sequences and sent the file to their colleagues in Heidelberg, where the files were successfully read. Harvard researchers have managed to store 700 terabytes into one gram of DNA.

Application areas in 2030: Information will be able to be stored into very small space, information can be copied by copying DNA, and the conditions are good for storing information for a very long time period. Information can also be read inside the body, by biological mechanisms.

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.4, 1.7, 1.8, 1.10, 1.11, 1.12, 1.15, 1.16, 1.19

2.68. Artificial cell and simulating life on cell level ***

Ingress: Knowledge of cell biology has continuously increased. Cell metabolism and signaling is now known so well, and computers have become fast enough that researchers are pursuing modeling all the key mechanisms of cell activity starting from the cell's

genome. The model of a cell can be used for two purposes. If the model depicts the human or other animal's cell well enough, and the model simulates cell metabolism, the effects of genome errors, medicine, and nutrients on cell activity can be studied without the requirement of physical cells. This increases the speed and effortlessness of studies and decreases or removes the need for animal testing. The second important application for the technology is using the model in the design of artificial cells. When the cell can be designed to function in the desired way, the genome it is based on can be coded into real DNA and transferred to a real cell, the original DNA of which has been eliminated. Artificial cells can perform different tasks, such as combat pollution, produce raw materials for energy or other raw materials, and produce goods.

Background information and examples:
http://www.theverge.com/2012/7/20/3171866/stanford-computational-cell-model
http://www.newscientist.com/article/dn23266-craig-venter-close-to-creating-synthetic-life.html

Recent vanguard product(s) or invention(s): Researchers of Stanford University have created a computational model of Mycoplasma genitalium bacteria. The Craig Venter Institute has simulated for the first time the genes that are necessary for a whole living cell organism.

Application areas in 2030: medicine, pharmaceutical industry, energy technology, food production.

Market development: 2, laboratory prototype

Scientific interest very high

Impacts on the value chains: 1.4, 1.5, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, 1.16

2.69. In-vitro meat and meat-like plant protein *

Ingress: Currently, the production of feedstock required by meat production takes up an increasingly significant amount of arable land. Both genetically manipulated plants or balanced mixes of existing plants and growing animal based muscle cells in cell cultivations have been planned as options to replace beef cattle as a source of protein for people's requirements. Theoretically, cell cultivation is a notably efficient way of producing protein as compared to livestock, if we only learn to control the process and the result is satisfactory in terms of texture, taste, and nutrition. Cultivated protein also solves issues related to animal protection, in addition to issues related to adequacy of food and nutritional values.

Background information and examples:
http://en.wikipedia.org/wiki/In_vitro_meat
http://www.guardian.co.uk/science/2013/jan/05/the-future-of-food
http://spectrum.ieee.org/energy/environment/the-better-meat-substitute

http://www.dailymail.co.uk/sciencetech/article-2416808/Artificial-egg-PLANTS-backed-Bill-Gates-set-revolutionize-cooking-goes-sale-Whole-Foods.html

Recent vanguard product(s) or invention(s): In the beginning of 2013 Dr. Mark Post together with his research group produced the first hamburger steak made of artificial meat, which did not differ in terms of appearance or properties from a hamburger steak made of beef. The eating of the steak was demonstrated publicly for the first time in a seminar about the future of food in Turku, Finland on June 7th, 2013.

Application areas in 2030: Replacing meat as utilizing nutrients is more efficiently than the meat of a real animal. Also, in-vitro meat and meat-like plant protein are much better than conventional meat with regard to environmental impacts. Advances animal rights issues.

Market development: 2, laboratory prototype

Impacts on the value chains: 1.4, 1.5, 1.13, 1.19, 1.20

2.70. Robotic legs and the exoskeleton that reinforces movement ****

Ingress: Many heavy tasks require machines that are difficult to use. Researchers have developed wearable, motorized equipment, which enable a person to lift heavy loads and walk while carrying them. These assistive devices, especially robotic legs, have been developed also for the elderly and people who otherwise have low strength in their legs. Robotic legs sense the intention of moving from the tension of the muscles and reinforce it. This experience is aimed to be as close to natural movement as possible. Robotic legs have also been developed for people suffering from paraplegia. These movements are directed through hand movements. As an assistant to a healthy person, the exoskeleton can save a person from injuries and fatigue in heavy work, and for a person with low strength in their legs it enables movement without a walker and moving in stairways while functioning as an effective rehabilitation device at the same time. For paraplegics, robotic legs change their lives by enabling independent movement at the same level of freedom as other people without requiring help.

Background information and examples:
http://corporate.honda.com/innovation/walk-assist/
https://www.youtube.com/watch?feature=player_embedded&v=OBmrPDBO2ic
http://www.youtube.com/watch?v=OW2pBLQLHj0
http://www.extremetech.com/extreme/164638-how-to-make-a-brain-perceive-an-exoskeleton-as-its-new-body
http://www.designboom.com/technology/ekso-bionic-suit- wearable-robot-allows-paraplegics-to-walk/

Recent vanguard product(s) or invention(s): The HAL (Hybrid Assistive Limb) by Cyberdyne Inc. gives a person with weak leg or hand muscles ten times more strength. Commercialization is expected within the next two years and the estimated price is circa 20,000 USD.

Application areas in 2030: Advancing movement of persons with a frail physical condition, moving heavy objects, military technology, rehabilitation, entertainment, and camping.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Several independent paths of R&D

Impacts on the value chains: 1.2, 1.3, 1.4, 1.7, 1.8, 1.9, 1.11, 1.12, 1.14, 1.15, 1.16, 1.18, 1.19, 1.20

Key enabling materials and industrial raw materials

This group consists of radical technological solutions whose key purpose is manufacturing of multi-use materials or new mechanical, chemical or electrical property of the material. The production of energy materials is discussed separately.

2.71. Genetically modified organisms as producers of multi-use materials ***

Ingress: Despite the scarcity of food and energy, the society handles a massive amount of biomaterials as waste. For example in grain cultivation, two or three times as much pulp is produced as a side product. Annually, 180 billion tons of pulp grows on Earth – more than 20 tons per each inhabitant of the Earth. Researchers are developing bacteria that are able to convert pulp into starch, alcohol, or other necessary and easy-to-use nutrient, fuel, or raw material of goods. On a smaller scale, such bacteria is being developed whose modified genes can be activated so that the bacteria can grow functioning batteries or even drugs, very strong fibers, and complex material structures, which are not able to be produced efficiently with traditional processes.

Background information and examples:
http://news.sciencemag.org/sciencenow/2013/04/could-wood-feed-the-world.html
http://blogs.discovermagazine.com/notrocketscience/2012/01/03/genetically-engineered-silkworms-with-spider-genes-spin-super-strong-silk/#.UWkvShzF98E
http://www.youtube.com/watch?v=4Y8pGBfNNDs&feature=player_embedded
http://www.greencarcongress.com/2011/05/asu-20110503.html

Recent vanguard product(s) or invention(s): Converting pulp into starch with enzymes. Manufacturing of an especially strong silk by utilizing genetic modification. Manufacturing of batteries and solar panels through genetic modification of bacteria.

Application areas in 2030: Production of energy raw materials, production of food, stronger materials and complex fine surface structures.

Market development: 3, close to commercialization

Scientific interest very high

Impacts on the value chains: 1.3, 1.5, 1.11, 1.13, 1.14, 1.17

2.72. Extremely dense processors that take quantum phenomena into account ****

Ingress: Intel's Gordon Moore estimated in 1965 that the number of transistors in inexpensively produced integrated circuits would double about every two years. This has since proven to be accurate and there are now several billions of transistors in the densest integrated circuits. The number of transistors has a direct impact on the size of memory circuits and an essential significance for processing power as well. The continuation of Moore's Law has required ongoing innovation. Many experts have suspected that development would come to a halt in the 2010's due to quantum level phenomenon, as the size of transistors will have shrunk close to their area of impact. Several new inventions demonstrate that the barriers are solvable and development can advance as per Moore's law for at least a decade. This means about one hundred times the transistor density compared to current circuits. The means are new carbon-based materials, three-dimensional transistors, deference to quantum phenomenon, spintronics, and logic based on light. Increasing density is required in very many new applications.

Background information and examples:
http://newsroom.intel.com/community/intel_newsroom/blog/2011/05/04/intel-reinvents-transistors-using-new-3-d-structure
http://www.theglobeandmail.com/technology/tech- news/quantum-chip-breakthrough-to-unleash-ultra-fast-computing/article4516380/
http://www.techweekeurope.co.uk/news/ibm-carbon-nanotube-chip-97557
http://www.techweekeurope.co.uk/news/ibms-9nm-carbon-nanotube-transistor-outperforms-silicon-56872

Recent vanguard product(s) or invention(s): Intel's new 22nm bandwidth 3D transistor, and silicone based chips by Nokia and many other companies that are based on the utilization of light and quantum mechanics pave way to increased processing power in special applications. IBM has managed to use carbon nanotubes to create a 9nm transistor that doesn't have the heat problem typical to dense transistors.

Application areas in 2030: The continuation of Moore's law as development of computational processors, radically faster computation in a small space with impacts on, for example, information encryption and opportunities in simulation and optimization, pattern recognition in large databases as well as applications of virtual reality in the areas of games, entertainment, robotics, and communication. Indirectly impacts almost all future development.

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Scientific interest high

Impacts on the value chains: 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

2.73. New building materials that replace reinforced concrete *

Ingress: Steel and concrete play a major role in the built urban environment. Both cause a large amount of carbon emissions and bind energy. In addition, both only last for a limited time and cause significant maintenance costs. Concrete replacements have been in development and many alternative solutions have been brought to the market and the reports of product development laboratories have given promises for new breakthroughs. In particular, adding wood fibers, volcano ash, plastics, and nanocellulose to concrete has been researched.

Background information and examples:
http://www.youtube.com/watch?v=eBj-7z5LUAE
http://www.greenconcreteonline.com/
http://www.grancrete.net/
http://www.businessweek.com/articles/2013-06-14/ancient- roman-concrete-is-about-to-revolutionize-modern-architecture
http://phys.org/news146851488.html
http://www.atp.nist.gov/eao/sp950-3/strongwell.pdf

Recent vanguard product(s) or invention(s): The concrete of the Ancient Romans was significantly more durable than the present day's concrete and its ingredients have now been explained. Grancrete and other replacements to concrete and castable ceramic materials that are in the commercialization phase offer significant benefits compared to the current building materials.

Application areas in 2030: Building.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.11, 1.13, 1.17

2.74. Antibacterial and other dirt repellent materials and surfaces ****

Ingress: Bacteria, viruses, and mold cause significant damage to people and the environment. Microbes is often spread from surfaces by touch. Nanotechnology has

enabled the production of such surface materials and surface treatments, which can make even textile surfaces microbe repellent or destructive. Many of these processes are based on the use of nanostructured silver or titanium oxide. Depending on the method, surface treatment protects from microbes, mold, or contamination in general, this treatment will benefit medical instruments, dispensing devices, containers, treated surfaces, structures, textiles, and the equipment in the food and chemical industries as well as agriculture.

Background information and examples:
http://www.nanovations.com.au/Press%20Release/Paint%20technology%20from%20Nanovations.pdf
http://www.nanonext.net/nanonext/shoppingcart/products/Nano-Textile-Coating-AntiMicrobial--with-TiO2-.html
http://www.bluenanoinc.com/applications/antimicrobial.html
http://www.youtube.com/watch?v=IfUaKXasdD4

Recent vanguard product(s) or invention(s): The antibacterial properties of silver have been known for a long time, but as nanostructures the properties become significantly intensified. Fraunhofer and Bioni have developed an emission-free compound suitable for paint surfaces, which includes nanostructured silver, which repels mold and bacteria.

Application areas in 2030: Building, health care, food industry.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Scientific interest: high, for example water repellent surfaces are being actively studied

Several independent paths of R&D

Impacts on the value chains: 1.2, 1.3, 1.5, 1.6, 1.8, 1.9, 1.11, 1.13, 1.17

2.75. Carbon nanotube yarn or thread **

Ingress: Fibers and yarns are used as, for example, ropes, fabrics, conductors, and binders. Manufacturing of nanocarbon is becoming more efficient and nanotubes are electrical conductors. The tensile strength of nanotubes is about 20 times higher than that of steel. Yarns made of carbon nanotubes conduct electricity and, even though they are made of separate, intermittent parts, the spun yearn is significantly strong, and fabric woven from it is stronger than, for example, Kevlar.

Background information and examples:
http://www.youtube.com/watch?feature=player_embedded&v=4XDJC64tDR0
http://www.theregister.co.uk/2013/01/14/carbon_nanotube_threads_spun/
http://www.youtube.com/watch?feature=player_embedded&v=4XDJC64tDR0

Recent vanguard product(s) or invention(s): Researchers of Rice University have developed a process, which enables industrial scale production of carbon nanotube yarn. The spun yarn is thin as hair, flexible, has a tenfold tensile strength compared to steel, and is equivalent to copper in electrical conductivity.

Application areas in 2030: Textile industry, military technology, robotics, machines and equipment, building industry.

Market development: 3, close to commercialization

Scientific interest high, nano fibers are being actively studied

Impacts on the value chains: 1.11, 1.12, 1.13, 1.14, 1.16, 1.17

2.76. Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons *

Ingress: The current methods for producing fresh water consume a lot of energy or expensive disposable filters. Nanocarbons have been observed to be easily permeable to water and to filter undesirable materials, such as salt, in a way that the process does not require high pressure or disposing of valuable materials. Filters are used also in separation techniques of biotechnology, when usable ingredients are separated from biomass.

Background information and examples:
http://www.sciencedaily.com/releases/2011/03/110314140632.htm
http://cleantechnica.com/2012/07/06/mit-researchers-use-graphene-for-energy-efficient-desalination/
http://cen.acs.org/articles/91/web/2013/02/Carbon-Nanotube-Coated-Filters- Foil.html
http://www.popsci.com/technology/article/2013-03/smooth-refreshing-seawater
http://gizmodo.com/5990876/lockheeds-new-carbon-filter-takes-all-the-effort-out-of-desalinization
http://news.discovery.com/tech/tiny-channels-take-salt-from-seawater- 130628.htm

Recent vanguard product(s) or invention(s): Researchers are developing solutions with both carbon nanotubes and graphene. The results obtained in laboratories promise a tenfold yield of fresh water compared to energy used by conventional techniques. An expert of Lockheed Martin considers it possible to reach a hundredfold energy efficiency compared to earlier desalination methods. A Lockheed project is working on a prototype.

Application areas in 2030: Production of drinkable water from seawater or low quality fresh water.

Market development: 2, laboratory prototype

Scientific interest very high

Impacts on the value chains: 1.5, 1.8, 1.11, 1.13, 1.14, 1.17, 1.20

2.77. Nanocarbon as a reinforcement or as functional surface **

Ingress: Almost all artifacts built by people that are meant for long-term use are coated. It is usually not possible to incorporate the desired structural or functional properties into the property of the surface. Materials are also often mixed with each other, even though there is no chemical reaction. These mixes are usually called composites. Mixed materials can function as reinforcements, binders, electrical conductors, curing agents, adding or removing weight, porosity, flexibility or other material property. The many properties of nanocarbons make them functional surface materials and mix agents that change material properties in several ways. For example, graphene functions as an effective corrosion resistant surface and reinforcement, and nanotubes as electrical conductors and reinforcements. Due to their optical and piezoelectrical properties, nanocarbons have many uses in the modification of the touch sensitivity and look of surfaces and other functional surfaces.

Background information and examples:
http://media.uow.edu.au/news/UOW118285.html
http://www.futurity.org/science- technology/graphene-coating-stops-corrosion-100x-better/
http://www.rsc.org/chemistryworld/2012/10/graphene-lightest-framework-oil-clean-flame-resistant
http://news.discovery.com/tech/nanotechnology/top-10-uses-worlds-strongest- material-130212.htm
http://phys.org/news/2013-04-super-nanotubes-remarkable-spray-on- coating-combines.html
http://phys.org/news/2012-02-nanodiamond-coatings-safe- implants.html
http://pubs.acs.org/doi/abs/10.1021/nn800445z
http://www.nano.org.uk/articles/29/
https://machineslikeus.com/news/researchers-reach- ultimate-carbon-nanotube-goal
http://nextbigfuture.com/2013/06/high-strength-chemical- vapordeposited.html

Recent vanguard product(s) or invention(s): Nanodiamonds have proven their functionality in coatings and nanotubes are becoming more essential in reinforcements. However, the biggest promises seem to be related to graphene. If the problems related to the electrical conductivity of nanotubes are being resolved as reported, the use possibilities of nanocarbon will improve significantly.

Application areas in 2030: Increasing materials' strength and production of functional surfaces, industrial products, and electronics.

Market development: 3, close to commercialization

Scientific interest high, nanofibers are being actively studied

Impacts on the value chains: 1.3, 1.9, 1.10, 1.11, 1.12, 1.15, 1.16, 1.17

2.78. Cellulose nanofiber and microfiber ****

Ingress: Cellulose is made up of long fibers. By suitably cutting the fibers, one can produce so-called microfibers or nanocellulose, the properties of which differ fundamentally from conventional cellulose. It is significantly strong and light. The strength may equal that of Kevlar. The potential properties of nanocellulose include porosity, lightness, transparency, and the ability to reflect different wavelengths of light. Thousands of kilograms of nanocellulose is already produced daily, but many applications require such structures from nanocellulose that are so far only managed to be created in laboratory scale. It can be seen that nanocellulose could be used in, for example, building of car bodies and windows, display devices, filters, load-bearing structures, safety accessories, and completely new parts, which require flexibility, functionality, and strength, to be used in, for example, robotics.

Background information and examples:
http://www.newscientist.com/article/mg21528786.100-why-wood-pulp-is-worlds-new-wonder-material.html
http://gizmodo.com/5994113/7-incredible-uses-for-nanocellulose
http://www.theverge.com/2013/4/8/4195982/nanocellulose-wonder-material-produced-from-algae-solar-energy
http://www.aalto.fi/en/current/magazine/04/ever-finer_cellulose/
http://www.kcpk.nl/algemeen/bijeenkomsten/presentaties/20130130-nanocellulose

Recent vanguard product(s) or invention(s): Nanocellulose or microfibercellulose is produced by, among others, Stora-Enso and UPM, and its properties are studied widely around the world, including Aalto University.

Application areas in 2030: Machines and equipment, building, process industry, textile industry, furniture industry, robotics, electronics.

Market development: 3, close to commercialization

Scientific interest: High

Impacts on the value chains: 1.3, 1.5, 1.11, 1.12, 1.13, 1.15, 1.16, 1.17, 1.20

2.79. Materials that levitate on nanolevel *

Ingress: The Casimir Effect is one of the most acute fields of research in nuclear physics. Friction is one of its effects. On a very small scale, the Casimir Effect can be manipulated into thrust on specifically shaped surfaces and this can make an object levitate. This negative Casimir Effect has been demonstrated, but levitation based on the phenomenon has not been realized yet. The negative Casimir Effect is about a small force, which is significant in relation to gravity only on nanoscale, but in nanoscale machines it can help realize frictionless bearings and surfaces to nanoscale machines.

Background information and examples:
http://phys.org/news/2012-07-quantum-levitation-nano.html
http://www.sciencedaily.com/releases/2012/04/120418135132.htm
https://www.st-andrews.ac.uk/~ulf/levitation.html

Recent vanguard product(s) or invention(s): Japanese researcher Norio Inui has calculated that an yttrium sheet with a thickness of one nanometer levitates at the height of 0,5 micrometres from a gold surface beneath it. Federico Capasso has demonstrated that the negative Casimir Effect is measurable. Levitation has not been demonstrated in practice.

Application areas in 2030: Frictionless surfaces and bearings of nano-sized machines.

Market development: 1, scientific discovery

Impacts on the value chains: 1.11, 1.12, 1.16

2.80. Ultralight and strong materials ***

Ingress: The weight of used materials is an important constraint in the design of many machines and structures. For example, the lower floors of buildings must be able to bear the weight of the upper floors. In airplanes, the lift must be sufficient for the weight of the plane and its load to remain airborne. Material technology is producing even lighter materials and with their help such structures, machines, equipment, and other devices can be designed, that would not have been possible with earlier materials. Aerographite and aerogels are examples of such new, lightweight materials. At the lightest, these materials are equal to air in weight, i.e. about one gram per liter, but it must be noted that they are porous and, together with the air they contain, weigh two grams on sea level.

A piece of aerogel, which weighs two grams, can bear the load of a brick, which weighs two kilograms, without breaking. To the touch, aerogel typically feels like styrofoam. Aerographite was invented in 2012 and it weighs only 0,18 grams per liter. Aerographite consists of carbon nanotubes and is a better material than aerogels in many respects. These materials are especially promising as components of small aircraft and in small devices that people carry with them or that would have to be held or supported. For example, long suspension bridges would be quite problem-free in terms of their weight if they were made out of aerographite. Today, the wires of the elevators of high buildings

weigh significantly more than the elevator itself and there are lots of other similar weight-induced problems as well.

Background information and examples:
http://en.wikipedia.org/wiki/Aerogel
http://en.wikipedia.org/wiki/Aerographite
http://www.kone.com/corporate/en/Press/Releases/Pages/New-KONE-UltraRope(TM)-elevator-hoisting-technology-enables-the-next-big-leap-in-high-rise-building-design-2013-06-10.aspx
http://web.mit.edu/newsoffice/2013/how-to-make-big-things-out-of-small-pieces- 0815.html

Recent vanguard product(s) or invention(s): Aerographite has been developed in collaboration between Kiel University and Hamburg University and it is the pinnacle of current lightweight materials. Only a limited amount of the material has been produced so far. One of the applications is a supercondensator due to the material's electrical properties and large surface area.

Application areas in 2030: All light structures and devices that benefit from light weight as well as electrical devices, when it comes to aerographite in particular.

Market development: 3, close to commercialization

Impacts on the value chains: 1.2, 1.3, 1.6, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17

2.81. Spray-on textiles **

Ingress: Textiles are woven, cut, sewn, fitted, and bought. This is the typical process of ready-made clothing. Options are taking measurements, editing patterns, cutting fabrics, and fitting. Fabrics are fibers, and the development of fibers has enabled them to be sprayed. The fabric is not woven, but sprayed fabric has many of the woven fabric's properties. It can be sprayed on a mannequin or directly onto the user of the clothing. It would be practical for the process, especially with regard to clothes that are not skintight, if one would 3D print a mannequin in the shape of one's own body, and then the desired clothes would be sprayd on the mannequin. In addition to clothing, sprayable fibers can be used as bandages in health care and as coatings on machines and equipment.

Background information and examples:
http://www.youtube.com/watch?v=ScvdFeh1aOw, http://www.fabricanltd.com/

Recent vanguard product(s) or invention(s): Fabrican is the inventor of spray-on textiles. The patent was granted in 2000 and the technology is in commercialization phase.

Application areas in 2030: Clothing companies, fashion houses, health care, robotics, entertainment.

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.4, 1.8, 1.9, 1.11, 1.15, 1.17, 1.18. 1.19

Energy technology

This energy technology section includes radical technological solutions where the main functions concern energy production, storing or transmitting.

2.82. Rapidly cheapening solar energy ****

Ingress: Solar energy is not new invention. Already a long time ago, solar energy has been used for warming of water in southern countries and in places where the electric grid did not transmit cheap electricity. The production of early solar panels was, however, so difficult that solar panels did not produce as much energy during their life cycle as what was needed for their production. According to an US study of the DOE, the medium price of solar panels has decreased yearly seven per cent during last thirty years. It is expected that the trend will continue and it is anticipated that the production costs of the solar energy will be in 2015 lower than the local market price of energy in most sunny areas of the USA. In the whole USA, for the majority of electricity users in 2018, the price of solar panel electricity is anticipated to be lower than the grid electricity. It is expected that the decreasing price will continue also after 2018 because of the increased production, process improvements and already visible breakthroughs in production costs and the efficiency of the panels. The ground gets an energy flow of about 1 kW, when the sun is shining on the area of one quadrate meter. With recent technologies, it is possible to transform 10-50% to electricity from this energy flow. With the panel area of one quadrat kilometer, you can produce an electricity flow of about 100 MW if the panel efficiency is at 10%. When the cost of the solar panel electricity is less than the consumer price of electricity, consumers will place more and more solar panels on their roofs and gardens. This will considerably change the price of electricity. It seems to imply that that the price of electricity will decrease in 2020s and that it will make many recently planned power station investments unprofitable.

Background information and examples:
http://blogs.scientificamerican.com/guest-blog/2011/03/16/smaller-cheaper-faster-does-moores-law-apply-to-solar-cells/
http://www.nature.com/srep/2012/121123/srep00884/full/srep00884.html
http://solarroadways.com/intro.shtml
http://www.thelocal.de/20140619/germany-produces-half-of-electricity-needs-with-solar-power
http://costofsolar.com/cost-of-solar-is-2-100-times-cheaper-than-you-think/
https://www.indiegogo.com/projects/solar-roadways

http://www.extremetech.com/extreme/181389-japans-25-year-plan-to-put-a-gigawatt-solar-power-farm-in-space
http://www.iflscience.com/technology/solar-cell-material-moonlights-laser

Recent vanguard product(s) or invention(s): Solar panels are studied and developed continuously in many countries including Finland. The most cost-effective technology is still based on silicon, but a lot is expected from technologies based on nanocarbons. A Finnish company is producing solar panels that are integrated to outdoor walls. Solar Roadways is developing a solution in which roads are covered with solar panels.

Application areas in 2030: Energy production in power plants, in scarce populated areas and in buildings

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Many independent research paths

Impacts on the value chains: 1.1, 1.2, 1.3, 1.5, 1.11, 1.13, 1.14, 1.17, 1.18, 1.20

2.83. Efficient and light solar panels **

Ingress: It is not always practical that a mobile device carries its fuel or energy storage. Solar panel is an opportunity for such a device. The opportunity is relevant for devices carried by people, cars, boats and small flying vehicles and airplanes. When the area of a solar panel is limited, the efficiency of the solar panel is often more important than its cost. In many applications, the lightness is also an important property. New kinds of solar panels that use nanocarbons are flexible and light but they are not efficient enough. Basic research findings are, however, promising. We can expect, that nanocarbon based solar panels will be both effective and light in 2030. If needed they are also rollable or collapsible. Concerning boats and vehicles with wheels, the weight is not very essential issue and traditional silicon based panels seem to be cost-competitive still in 2030. In the longer run, nanocarbon based or other kinds of new solutions will probably replace them when they will pass silicon-based solar panels in efficiency. Latest in that stage, the roofs of cars will be commonly panelised, and flyers will collect the energy that they need when flying and the tents of wanderers will collect solar energy. There will be many kinds of solar umbrellas available and other collapsible surfaces that collect energy.

Background information and examples:
http://www.technologyreview.com/news/511751/research-hints-at-graphenes-photovoltaic-potential/
http://cleantechnica.com/2013/07/03/gaas-solar-cell-nanowires-could-boost-commercial-solar-module-efficiency-25/
http://phys.org/news/2013-06-future-bright-carbon-nanotube-solar.html
http://www.earthtechling.com/2013/06/mit-team-puts-super-thin-spin-oin-solar/
http://www.gizmag.com/spectrolab-solar-cell-efficiency-record/27000/

http://www.earthtechling.com/2013/06/mit-team-puts-super-thin-spin-oin-solar/
http://www.scienceworldreport.com/articles/8280/20130720/thinnest-light-absorber-record-new-tech-cleaner-energy.htm
http://www.economist.com/news/science-and-technology/21596924-way-double-efficiency-solar-cells-about-go-mainstream-stacking
http://www.gizmag.com/graphene-solar-cell-

Recent vanguard product(s) or invention(s): Besides other research groups, the research group of Peter Lund in Aalto university belongs to the developers of the nanocarbon based flexible solar panels. According to the evaluation of Lund, flexible and light panels will be bulk products during the next ten years. The Swedish Sol Voltaics promises to improve the energy efficiency of the recent solar panels 25% using a nanosurface material based on gallium arsenide.

Application areas in 2030: Electricity production in moving equipment, on breathing surfaces or on otherwise limited surfaces.

Market development: 2, laboratory prototypes

Many independent paths of R&D

Impacts on the value chains: 1.2, 1.4, 1.6, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19

2.84. Artificial leaf and synthetic fuel from the sun light and carbon dioxide *

Ingress: Photosynthesis is the chloroform-based mechanism that transforms solar light, water and carbon dioxide to glucose and oxygen. In solar panels, the aim is to transform light directly into electricity. A problem is how to store electricity for those times when solar light is not available. The problem is solved if the solar light is able to produce storable fuel effectively. Nanotechnology based option is to use the electric energy generated inside solar cells to split water by means of electrolysis. The process yields free electrons that one can use for a storable fuel. Using this option, experiments are made to produce methane or ethanol beside hydrogen. Some of the solutions have combined production of the electricity and some storable fuel. In order to be competitive in sort-term storage with solar panels and batteries, improvements are needed in the efficiency and the price of these solutions. However, there are reasons to believe that the technology will already in 2020s be as cost-effective as energy plants. Synthetic fuel might be useful also in the long-term storage of the energy e.g. in Nordic circumstances where a lot of light is available in summer but little in winter.

Background information and examples:
http://www.wired.co.uk/news/archive/2011-03/28/artificial-leaf
http://phys.org/news/2013-06-polymer-coated-catalyst-artificial-leaf.html
http://cleantechnica.com/2013/05/17/new-artificial-leaf-concept-could-blow-up-fuel-cell-market/
http://www.tut.fi/fi/tietoa-yliopistosta/uutiset-ja-tapahtumat/vaitostiedotteet/bakteerit-tuottavat-vetya-ja-sahkoa-uusiutuvista-raaka-aineista-p040499c2
http://www.sciencedaily.com/releases/2013/07/130729111927.htm
http://news.stanford.edu/news/2014/april/ethanol-without-plants-040914.html

Recent vanguard product(s) or invention(s): Researchers at the HZB Institute for Solar Fuels have modified so called superstrate solar cells with their highly efficient architecture in order to obtain hydrogen from water with the help of suitable catalysts. These solar cells have produced a stable yield of approximately 3.7 percent sunlight when the cell's sensitive contacts are sealed to prevent corrosion. Stanford University researchers have built an electrochemical cell consisting of two electrodes that are placed in water saturated with carbon monoxide gas. When a voltage is applied across the electrodes of an oxide-derived cell, the oxide-derived copper produced ethanol or acetate with 57 percent faradaic efficiency from carbon monoxide.

Application areas in 2030: Energy production and storage, production of hydrogen.

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.5, 1.11, 1.12, 1.13, 1.14,1.15, 1.16, 1.17, 1.20

2.85. The production of biofuels using enzymes, bacteria or algae **

Ingress: Conventional biofuel production, such as the use of palm oil and the refining of ethanol from corn or sugar cane, has successfully displaced about 10 percent of the motor gasoline in the United States, about 5% in Europe and at times, depending on price, about 50 percent of the gas in Brazil. But first generation biofuels are also controversial for a variety of reasons, including that they divert grain and land from food production. The aim of many projects financed by EU has been to develop the 2nd generation production technology based agricultural and forestry residues for cost-effective production of biofuels. An important focus of these projects has been lignocellulosic biomass though US pilot producers that have used this raw material have been economic failures. There has been some progress in EU research efforts and cost-competitive production of biofuels might be possible in 2030 in suitable production environments but real technological breakthroughs based on used enzyme technologies seem to be unlikely. It seems that either radically new ways to use genetic engineering or the use of algae and other microbes e.g. electrofuel microrobes might open roads towards cheap biofuels in 2030. For example, Algenol Ltd. has developed a promising way to use algae beside the biofuel production to capture CO2. Algenol promises that using it patented technology it is able to produce four most important fuels (ethanol, gasoline, diesel, and jet fuel) for around $1.30 per gallon using proprietary algae, sunlight, carbon dioxide and saltwater.

Background information and examples:
http://cordis.europa.eu/result/rcn/140966_en.html
http://www.algenol.com/
http://www.mae.ucla.edu/news/news-archive/2013/wei-yu-raises-1.6-million-for-biofuel-startup-based-on-research-from-chih-ming-ho2019s-micro-system-laboratories
http://solazyme.com/innovation/?lang=en
http://news.nationalgeographic.com/news/energy/2013/06/130617-electrofuels-using-microbes-to-make-biofuel/

Recent vanguard product(s) or invention(s): Several EU research projects (e.g. Nemo, Disco and Hype) where Finnish researchers have been in leading positions have developed better ways to produce ethanol and other biofuels from lignocellulosic biomass developing more effective enzymes. Algenol Ltd. has developed a promising way to use algae. Algenol promises that using its patented technology, it will be able to produce four most important fuels (ethanol, gasoline, diesel, and jet fuel) for around $1.30 per gallon each using proprietary algae, sunlight, carbon dioxide and saltwater. Electrofuels microbes are derived from exotic bacteria that live underground or in other places (such as geothermal springs) where photosynthesis doesn't occur. In the wild, these organisms survive by "eating" electrons derived from minerals in the surrounding soil. To produce electrofuels, researchers feed carbon dioxide to microorganisms, and run an electrical current through the tank in which they are grown.

Application areas in 2030: Production of biofuels

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.3, 1.11, 1.13, 1.14, 1.16

2.86. Flying wind power and other new ways to produce wind energy**

Ingress: Changing winds are a big problem of the recent wind power. Winds at higher altitudes are steadier, more persistent, and of higher velocity. High-altitude wind generators can be adjusted in height and position to maximize energy return, which is impractical with fixed tower-mounted wind generators. High-altitude wind energy can be captured from the wind by kites, kytoons, tethered gliders, tethered sailplanes, aerostats (spherical as well as shaped kytoons), bladed turbines, airfoils, airfoil matrices, balloons, parachutes, drogues, variable drogues, spiral airfoils. Especially promising option for 2030, a combination of kite and airborne turbine will be developed by Makani Power. Recently, many new ways to use wind energy without blade turbines have been developed.

Background information and examples:
http://en.wikipedia.org/wiki/High-altitude_wind_power
http://en.wikipedia.org/wiki/Makani_Power
http://www.csmonitor.com/Environment/Energy-Voices/2013/0523/Google-kite-Tech-giant-buys-flying-windmill-firm-Makani
http://www.gizmag.com/saphonian-bladeless-wind-turbine/24890/
http://www.smithsonianmag.com/innovation/Massive-Flying-Wind-Turbine-Could-Offer-A-New-Path-To-Clean-Energy-180950509/?no-ist
http://www.alulaenergy.fi/
http://www.gizmag.com/invelox-wind-generator/27377/
http://www.gizmag.com/ewicon-bladeless-wind-turbine/26907/
http://www.awelabs.com/awelabs-awecs-proposal/

Recent vanguard product(s) or invention(s): Makani Power is an Alameda, California-based company that developed airborne wind turbines with the support of Google and the U.S. Department of Energy office of ARPA-E. The Makani airborne turbine takes off and moves like a plane, designed to reach winds that blow stronger and more consistently. The system bears an advantage over traditional wind turbines, unable to reach stronger winds that are over 300 meters above ground. The Wing 7 can reach heights of 450 meters. The Wing 7 has a wingspan of 8 meters, weighs 56 kg and has a rated power of 20 kW. Makani is developing a 600kW device that is planned to produce cheaper electricity than recent wind power or solar power. Altaeros Energies has used a helium filled tube shaped balloon to lift the turbine off the ground to a much higher height than conventional windmills. Tunisian green energy startup Saphon Energy has created a new bladeless wind turbine, which draws inspiration from the design of a ship's sails, and promises to convert the kinetic energy of the wind into electricity.

Application areas in 2030: Production of electricity

Market development: 3, close to commercialization

Impacts on the value chains: 1.11, 1.12, 1.13, 1.14, 1.17, 1.20

2.87. Piezoelectrical energy sources, harvesting of kinetic energy **

Ingress: There is a lot of kinetic energy in nature and the devices people use. Windmills convert the movement of air into electricity and turbines do the same to the movement of flowing water, but in many cases, such as in harvesting wave energy, traditional methods are ineffective. With the help of the piezoelectric phenomenon, even minor movement can be converted into electrical energy. The quartz crystal is the strongest known material that exhibits piezoelectricity, but researchers have succeeded in modifying graphene (quantum dots) in such a way that the piezoelectrical properties of graphene surface are on the same level as those of the quartz crystals. Graphene can be made to produce electrical current by bending it. In addition to conventional energy production, these techniques may have a crucial significance in the development of walking robots. When the kinetic energy that is created during the braking of a movement can be efficiently harvested, the walking or running of a robot consumed very little energy. These

techniques can also be used to harvest energy from roads and footpaths. In mobile devices, being able to convert a part of the body's movements into electricity is enough to fulfill the electricity requirement of many devices.

Background information and examples:
http://www.idtechex.com/research/reports/piezoelectric-energy-harvesting-2012-2022-forecasts-technologies-players-000320.asp
http://en.wikipedia.org/wiki/Nanogenerator
http://www.energyharvestingjournal.com/articles/piezoelectric-kinetic-energy-harvester-for-mobile-phones-00002142.asp?sessionid=1
http://www.electronicproducts.com/News/Nanotech_breakthrough_engineers_develop_piezoelectric_graphene.aspx

Recent vanguard product(s) or invention(s): A research group of Stanford University was able to achieve high piezoelectricity by modifying graphene surface.

Application areas in 2030: Harvesting of kinetic energy in mobile devices and in energy production, robotics.

Market development: 2, laboratorium prototype

Scientifically interesting

Impacts on the value chains: 1.1, 1.2, 1.6, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.15, 1.16, 1.17, 1.18, 1.19

2.88. Serial production of small nuclear reactors, fission and fusion *

Ingress: Today, nuclear power plants are designed and built individually, and the surveillance and control of their building and usage are also indivualized. Even though large nuclear power plants have their benefits, small nuclear power plants, which have been built and used for a significantly long time in, for example, submarines and icebreakers also have their own benefits. Small nuclear power plants can also be serial produced. The plants can be located in a safe environment, such as in caves or earth pits, which can easily be closed in case of an emergency. The emergency risk of a small-sized plant is also smaller because of lesser complexity and individuality, and easier comparability and controllability.

Other designs, such as the experimental fusion reactor project that's currently being built in France – called Iter – have to be much larger than the UW's because they rely on superconducting coils that circle around the outside of the device to provide a similar magnetic field. When compared with the fusion reactor concept in France, the UW's is much less expensive – roughly one-tenth the cost of Iter – while producing five times the amount of energy. Read more at: http://phys.org/news/2014-10-uw-fusion-reactor-concept-cheaper.html#jCp.

Background information and examples:
http://www.fusenet.eu/node/400
http://www.dvice.com/2013-2-22/lockheeds-skunk-works-promises-fusion-power-four-years
http://www.forbes.com/sites/uciliawang/2012/01/20/feds-to-finance-small-nuclear-reactor-designs/
http://phys.org/news/2013-09-chip.html Small accelerator

Recent vanguard product(s) or invention(s): The Department of Energy of the USA has announced a plan that will finance the development of a serial produced small nuclear power plant with the aim of starting production in 2022. Lockheed-Martin has announced a goal of developing of a functioning, small fusion reactor by 2017.

Application areas in 2030: Energy production

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.13, 1.14, 1.16

2.89. Rapidly charging light batteries and supercapacitors ****

Ingress: The low energy density and the long charging time of batteries have much restricted the use of batteries. Supercapacitors are used in applications that need short charging or discharging times. Rapid charging of batteries promotes the use of electric cars and also makes the use of mobile devices easier. Supercapacitors can store potential energy and kinetic energy in pendulum movements but supercapacitors can also replace batteries if their capacity is large enough. The charging of those "batteries" happens nearly without time delay. For example, superconductors of electric cars can charge themselves during the normal stop in a bus stop or in traffic lights. Using nanostructures, it is possible to increase radically the surface areas of supercapacitors and in that way their capacities. Combining graphene and carbon nanotubes, researchers at Rice University have innovated a new supercapacitor material. A single gram of the new material provides supercapacitor surface area of 2,000 square meters. The use of graphene and carbon nanotubes has also made possible to develop new kinds of batteries that are much more efficient than recent lithium batteries. The maximal energy density of IBM lithium-air batteries is theorized to be around 12 kWh/kg, some 15 times greater than li-ion batteries. This energy density it is comparable to gasoline. An analogous air oxygen reaction improving radically energy density has developed based on aluminum. In 2030, high energy density of supercapacitors will make feasible also especially small batteries. Already, available is a battery that's no bigger than a grain of rice.

Background information and examples:
http://www.extremetech.com/extreme/122763-graphene-supercapacitors-are-20-times-as-powerful-can-be-made-with-a-dvd-burner
http://www.bbc.co.uk/news/technology-22191650
http://www.extremetech.com/computing/141801-rice-university-creates-graphenenanotube-hybrid-material-that-could-redefine-electronics-and-energy-storage

http://www.extremetech.com/computing/126745-ibm-creates-breathing-high-density-light-weight-lithium-air-battery
http://spectrum.ieee.org/nanoclast/biomedical/devices/graphenebased-microbattery-ushers-in-new-age-for-biotelemetry
http://www.cbc.ca/news/technology/electric-car-with-massive-range-in-demo-by-phinergy-alcoa-1.2664653
http://phys.org/news/2014-01-energy-dense-sugar-battery.html
http://cleantechnica.com/2014/05/12/new-graphene-carbon-nanotube-supercapacitor/
http://www.extremetech.com/computing/163071-graphene-supercapacitors-created-with-traditional-paper-making-process-rivals-lead-acid-battery-capacity

Recent vanguard product(s) or invention(s): The team from UCLA has developed power-wise, LSG supercapacitors smearing graphite oxide — a cheap and very easily produced material — films on blank DVDs. The supercapacitors are capable of discharging at 20 watts per cm3, some 20 times higher than standard activated carbon capacitors, and three orders of magnitude higher than lithium-ion batteries. Energy-wise, it is about 1.36 milliwatt-hours per cm3, about twice the density of activated carbon, and comparable to a high-power lithium-ion battery. IBM's "air-breathing" battery has much higher energy density than conventional lithium-ion batteries around 12 kWh/kg, some 15 times greater than li-ion and comparable to gasoline. Lithium-air batteries aren't a new idea. They've been mooted since the 1970s, but just the recent material science with graphene and carbon nanotube membranes and the supercomputer-based design has opened possibilities to realize this option.

Application areas in 2030: Electric cars, robotics, mobile devices, flyers, hoists, spying devices, high energy lasers and other high short time efficiency requiring devices

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.13, 1.14, 1.15, 1.16, 1.19

2.90. Massive storage of energy in high capacity batteries ***

Ingress: The electrical grid cannot tolerate large and sudden power fluctuations caused by wide swings in sunlight and wind. It is not yet a big problem in Nordic countries (with the exception of Denmark) though already now the price of kWh varies daily in the common Nordic energy market based on weather conditions. Typically, hydro energy that is used for the smoothing of the energy supply is much more expensive than other energy sources. When the share solar and wind's combined contributions to an electrical grid approach 20 percent, it is highly important to have energy storage systems that smooth out the peaks and dips storing excess peak energy and discharging when input drops. In 2030, an actor in the electricity market with high capacity battery will probably have nice trade options especially if the actor is able to anticipate the changes in supply and in demand of energy. Because the highest prices might be many times higher than the

lowest prices, it is enough for profitability that the yield of the battery is just moderate. A general target of the recent innovation activities is to develop batteries of about the size of 1-3 usual containers. Besides new ways to produce hydro energy, there seems to be two basic lines of innovations: a line is to develop so called flow batteries and the other approach is based on compressed gases. The main challenge of the battery approach seems to be still the price of the energy. The efficiency seems to be the main problem of the gas pressing approach. In some new technologies, the price of the electricity is already closing to the price of the hydro energy. Using high capacity batteries, households or small housing areas can smooth their solar energy production so that there is no need both to sell and buy energy from the grid.

Background information and examples:
https://www.youtube.com/watch?feature=player_embedded&v=Sddb0Khx0yA
http://www.33rdsquare.com/2013/04/new-battery-could-help-solar-and-wind.html?m=1
http://gigaom.com/2013/03/06/remember-the-artificial-leaf-startup-turns-to-making-a-flow-battery-instead/
http://www.greentechmedia.com/articles/read/LightSail-Gets-5.5M-from-Total-Thiel-Khosla-Gates-for-Compressed-Air-En
http://en.wikipedia.org/wiki/Flywheel_energy_storage
http://www.moraassociates.com/reports/0712%20Energy%20storage.pdf
http://en.wikipedia.org/wiki/Vanadium_redox_battery
http://www.powersouth.com/mcintosh_power_plant/compressed_air_energy
http://www.greentechmedia.com/articles/read/breakthrough-in-utility-scale-energy-storage-isentropic
http://www.greentechmedia.com/articles/read/eos-goes-global-with-new-utility-scale-energy-storage-partners
http://www.sciencedaily.com/releases/2013/08/130816094827.htm
http://www.treehugger.com/clean-technology/breakthrough-grid-scale-renewable-energy-storage-battery-made-gravel.html
http://cleantechnica.com/2014/06/09/solar-energy-storage-system-market-germany-approaching-boom/
http://blog.environmentalresearchweb.org/2014/04/19/undersea-energy-storage/
http://www.launchpnt.com/portfolio/energy/grid-scale-electricity-storage/

Recent vanguard product(s) or invention(s): There seems to be two basic lines of innovations: a line to develop so called flow batteries and the other is based on compressed gases. Flow batteries pump two different liquids through an interaction chamber where dissolved molecules undergo chemical reactions that store or give up energy. The chamber contains a membrane that only allows ions not involved in reactions to pass between the liquids while keeping the active ions physically separated. In MIT, Sun Catalytix has developed a prototype of flow battery. The end product is supposed to be a 1 MW flow battery that can last four to six hours and fit inside a 40-foot shipping container. The new Stanford/SLAC battery design uses only one stream of molecules and does not need a membrane at all. Its molecules mostly consist of the relatively inexpensive elements lithium and sulfur, which interact with a piece of lithium metal coated with a barrier that permits electrons to pass without degrading the metal. LightSail system is an example of the compressed gas approach. It captures and stores both the mechanical energy and the thermal energy used in compressing air. To do this, a water mist is infused into the compression chamber as the air is compressed. Isentropic, a young company from

the UK, has, perhaps, found even more effective approach. The company is working on a heat pump system that uses gravel (or more precisely, the thermal mass of small rocks).

Application areas in 2030: Storage of energy, smoothing of the energy supply.

Market development: 3, close to commercialization

Many independent research approaches

Impacts on the value chains: 1.3, 1.12, 1.13, 1.14, 1.16, 1.17, 1.18, 1.20

2.91. Solar heat and long-term storage of heat ***

Ingress: Converting solar energy into heat is significantly more efficient compared to current solar panels. Energy can be stored as heat for up to even six months. Typically, the heat is stored in isolated water or concrete but it can also be stored in native earth or bedrock. There are several techniques and they have been research mainly in relation to district heating and zero-energy houses. As heat pumps and drilling techniques develops, and the difference in the price of energy between wintertime and summertime possibly increases, and solar electricity increases, the significance of this technology may rapidly increase.

Background information and examples:
http://lms.epfl.ch/research/research-fields/energy-geostructures-thermal-piles
http://en.wikipedia.org/wiki/Thermal_energy_storage
http://www.anneberg.org/generell-information/sol-och-bergvaermesystemet

Recent vanguard product(s) or invention(s): There are several locations around the world, where the heat harvested in the summer covers all or most the winter's heating needs. Many different experiments have been done in Finland as well.

Application areas in 2030: Energy storage, heat production during the winter season.

Market development: 3, close to commercialization

Impacts on the value chains: 1.3, 1.13, 1.17, 1.18, 1.20

2.92. Inexpensive storage of hydrogen in nanostructures *

Ingress: Many different processes produce hydrogen, which can be efficiently converted into electric energy in fuel cells. However, there are challenges related to the storage of hydrogen. In gaseous form, hydrogen can easily explode, can also leak from its containers and it has to be compressed to a high pressure in order to make it fit into a small space. Researchers have attempted to develop alternatives in which hydrogen would absorb in a dense enough form into some structure in a way that the fore mentioned problems would become redundant. This would also allow the hydrogen to be release easily enough for re-

use. Promising nanostructures have already been found for this purpose. If a sufficiently safe and inexpensive structure for storing hydrogen is found, hydrogen can be produced at off-peak hours of energy and be converted back to electricity during the peak hours, or be used in some other way in fuel cells. One example of a challenge related to this technology are fuel cell cars that run on hydrogen, in which one question that needs to be solved is specifically the safety and efficient storage of hydrogen.

Background information and examples:
http://pubs.rsc.org/en/content/articlelanding/2013/CP/c2cp42538f
http://arxiv.org/ftp/arxiv/papers/1207/1207.5703.pdf

Recent vanguard product(s) or invention(s): The researchers of NEST have computationally shown different ways, in which graphene could function as an efficient and stable storage base for hydrogen. Practical tests have not been reported yet.

Market development: 1, scientific finding

Scientifically highly interesting

Impacts on the value chains: 1.1, 1.2, 1.3, 1.6, 1.11, 1.12, 1.13, 1.14, 1.18

2.93. Wireless electricity transmission (magnetism) for electric cars and other electrical devices **

Ingress: A change in the magnetic field induces the electrical current into a conductor that moves through the magnetic field. Transformers utilize this phenomenon and electricity transfer from one conductor to another without the conductors touching each other. The car company Tesla has been reported to have studied wireless electricity transmission over long distances, but the currently known efficient transmission distances are relatively short so that there is not too much of transmission loss. Wireless charging is becoming common in mobile devices in such a way that the charger is, for example, located underneath the table and the device that is charging is on the table. Electric cars would benefit significantly from wireless charging, if charging speeds were fast enough, so that the need for batteries would decrease. Wireless charging is significantly easier to implement in varied weather conditions than cable-connected charging, and it can be arranged into, for example, bus stops, traffic signals, and even on the surface of the road. The road surface could function simultaneously as a solar panel and an energy source for the cars that drive on it. In addition to these devices, wireless charging is essential to wireless sensors as well. For example, the RFID functions with the power transmitted by an antenna that reads a circuit. In interbody electrical devices, wireless energy sourcing is an important feature.

Background information and examples:
http://blog.ted.com/2009/08/25/wireless_electr/
http://www.geek.com/news/electric-cars-can-be-wirelessly-charged-through-10cm-thick-concrete-roads-1501535/
http://www.ted.com/talks/eric_giler_demos_wireless_electricity.html

http://www.npr.org/blogs/thetwo-way/2013/08/07/209855151/the-road-that-gives-electric-vehicles-a-charge
http://www.scienceworldreport.com/articles/12112/20140110/wireless-power-transfer-range-vastly-extended-with-superlens.htm

Recent vanguard product(s) or invention(s): Japanese professor Takashi Ohira has developed an inductive coupling, through which a system beneath the road surface is able to charge a car via its tires with a 60-Watt power at a 90% efficiency. According to Ohira, efficiency can be increased enough for the system to be practical.

Application areas in 2030: Mobile devices, means of transport, wireless sensors.

Market development: 4, market growth

Breakthrough growth rate 2014-2030 yearly over 15%

Impacts on the value chains: 1.1, 1.2, 1.6, 1.10, 1.12, 1.13, 1.14, 1.17

2.94. High-performance lasers, wireless power transfer, laser weapons *

Ingress: Laser consists of beams of light, which are precisely in phase with each other. Because of this, the laser beam travels coherently over a long distance as opposed to a regular beam of light. Laser beams are used for many different measurement purposes, because much more can be concluded based on the reflection of an in-phase light compared to that of normal light. Higher performance lasers are used for cutting material, heating and lighting. The US army has developed a laser weapon, the power of which is about one hundred kilowatts and it is capable of destroying military drones and weakly protected boats. Even more powerful weapons are being developed, but according to a military officer, one ”projectile” of this weapon costs one dollar, and therefore it is very inexpensive and quick to destroy, for example, a large amount of offensive drones, which regular weapons are not very well equipped for. Producing one hundred kilowatts of power for the laser pulse requires a quite large generator or high-performance condensator. In addition to destroying a target, high-performance lasers can be used to transmit power to, for example, an airplane or drone in a way that it does not need to land for refueling or charging. High-performance lasers can also be used for creating electromagnetic pulse (EMP), which destroys unprotected electronic devices in its proximity.

Background information and examples:
http://www.wired.com/dangerroom/2013/04/laser-warfare-system/
http://www.techhive.com/article/259225/lockheed_martin_recharges_flying_uavs_with_freaking_lasers.html
http://en.wikipedia.org/wiki/High_Energy_Liquid_Laser_Area_Defense_System
http://www.lle.rochester.edu/media/publications/high_school_reports/documents/hs_reports/2007/Tait_Alexander.pdf
http://www.gizmag.com/cota-ossia-wireless-charging-microwave-phased-array/29217/

Recent vanguard product(s) or invention(s): Israel and the US Ministry of Defense are the primary sponsors in the development of laser weapons, and the key developers are Kratos Defense & Security Solutions and Lockheed Martin. The latter has also developed a system with which an airborne military drone is charged with a laser beam.

Application areas in 2030: Monitoring drones, continuously airborne base stations, military technology, terrorism.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.2, 1.6, 1.11, 1.13, 1.14, 1.16

Messaging technology and protocols

This group consists of those radical technological solutions where the main functionality is related to inter machine communication with the help of electromagnetic radiation and related protocols.

2.95. Nanoradio *

Ingress: As minituarization technology advances, wireless communication is being developed to fit smaller devices. Radio transmitters are now attempted to be reduced to nanoscale. A nanoscale radio transmitter can be located into sensors that travel in the blood vascular system without disturbing organ functions. This enables real-time interbody monitoring. Nanoradios can also be controlling tool in many processes and, if their production cost can be lowered enough, they can be added to materials and together with nanotransmitters and receivers, can create intelligent materials. Therefore, materials such as liquids could control their environment based on their condition or history. Combined with DNA memory and other nano-level technology, nanoradios could be imagined to advance effective structures that assemble independently from liquids, but there are no concrete concepts for these yet.

Background information and examples:
http://en.wikipedia.org/wiki/Nanoradio,
http://www.physics.berkeley.edu/research/zettl/pdf/350.PSS(b)245.10-Weldon.pdf

Recent vanguard product(s) or invention(s): The device was first described by Alex Zettl, and so far, only the nanoscale radio receiver has been proven functional.

Application areas in 2030: Intelligent environment, intelligent materials, medical science, entertainment, spying.

Market development: 1, scientific finding

Impacts on the value chains: 1.5, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.15, 1.16, 1.19

2.96. LED "radio" *

Ingress: We are increasingly dependent on our mobile devices and their wireless connections. Due to the limitations of radio frequencies and increasing communication needs, the radio frequencies used in the traditional manner are running out. In addition, in many environments, such as in hospitals and airplanes, radio frequencies disturb sensitive measurement devices and other connections. The development of LED lights has opened the opportunity for inexpensive use of the frequencies of light. The wavelenght band of light is ten thousand times larger compared to radio frequencies. With current technology, the amplitude of an LED light can be directed so fast, that for example the transmission speed required by an HDTV level television image can be easily achieved. Due to the high frequency, this can be done without a person noticing any change in the lighting conditions. In practice, this means that any lit space, in principle every base of a lightbulb can be transformed into an LED radio that transmits a broadband signal, which can be received with a very inexpensive sensor in good conditions. If the receiver can filter the frequencies, in theory there can be a large amount of transmitters functioning in different frequencies of light within the same space. In addition to being disturbance-free and having a high transmission speed, a benefit compared to current wireless solutions is that the signals don't disturb each other and they are not readable through visual barriers.

Background information and examples:
http://www.ted.com/talks/harald_haas_wireless_data_from_every_light_bulb.html
http://spie.org/x93593.xml?highlight=x2414&ArticleID=x93593
http://www.greentechmedia.com/articles/read/the-ipv6-addressable-light-bulb-goes-on-sale

Recent vanguard product(s) or invention(s): Professor Harald Haas of Edinburgh University has demonstrated a functioning LED radio with HDTV transmission speed. At the same time, LED lights that can be assigned IP addresses have come on the market, for which more traditional communication features have been planned.

Application areas in 2030: Wireless data communication in interior spaces.

Market development: 3, close to commercialization

Impacts on the value chains: 1.4, 1.6, 1.17, 1.9, 1.10, 1.12, 1.15, 1.17, 1.19

2.97. Wireless transmission 2.5 terabytes per second (vortex beam) ***

Ingress: Traditionally, the maximum rate at which information is transmitted over a data communication channel has been calculated based on a specified bandwidth according to the Shannon-Hartley theorem. Data transmission speeds are now slowly reaching these theoretical calculations. Researchers have found an OAM property (Orbital Angular Momentum) in electromagnetic radiation. By modifying the OAM, the same radio frequency can be utilized many times over without the signals disturbing each other. Therefore, in theory, the capacity of radio frequencies can be even multiplied many times.

Background information and examples:
http://www.extremetech.com/extreme/131640-infinite-capacity-wireless-vortex-beams-carry-2-5-terabits-per-second
http://www.extremetech.com/extreme/120803-vortex-radio-waves-could-boost-wireless-capacity-infinitely

Recent vanguard product(s) or invention(s): American and Israeli researchers of NASA, University of South California and University of Tel Aviv have managed to transfer OAM modulated waves wirelessly with 2.5 terabyte speed. A Swedish and Italian research group proved the existence of the possibility in practice in 2012 by sending and receiving two separate broadcasts over the same frequency at the same time.

Application areas in 2030: Wireless data transmission primarily, but the technology might have applications also in measurement devices and wireless data communication.

Market development: 2, laboratorium prototype

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.7, 1.9, 1.10, 1.12, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20

2.98. Multi-channel communication and software-based controlling of information networks **

Ingress: Data communication links are vulnerable, easily spied on and traditional means of protection are difficult to verify. An even clearer understanding of the massive, concentrated information gathering and storage by actors of nation states and an even greater dependency on the reliability of data communication connections creates space for new solutions. Multi-channel issues in data communication have been discussed for a long time as an improvement to the certainty of the functioning of both information security and data communication. Multi-channel communication is based on the simultaneous use of many channels and routes in communication, and the message is divided into packages among them. The message becomes whole only when all of the packages are received and put together. If there is an error in one of the used channels, other leftover routes are used instead. Data communication can also be intensified by choosing the route for the message through a programme. Depending on the protocol, this can be done through optimization by an application, administrator of the network, or the network itself.

Background information and examples:
http://tools.ietf.org/html/rfc6182
http://en.wikipedia.org/wiki/Multipath_routing
https://www.usenix.org/legacy/event/osdi10/tech/full_papers/Koponen.pdf
http://www.technologyreview.com/news/515966/the-internet-of-cars-is-approaching-a-crossroads/
http://www.scienceworldreport.com/articles/8272/20130719/faster-internet-designed-computers-tcp-protocol.htm

Recent vanguard product(s) or invention(s): IETF has attempted to standardize multichannel communication and many actors have shifted to software-defined networking (SDN).

Application areas in 2030: Improving of information security and reliability and utilization of ad-hoc networks in data transmission, data centers, mesh-networks, MTCP.

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.4, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.14, 1.15, 1.16, 1.18, 1.19, 1.20

2.99. Electronic money, time banks ****

Ingress: A large part of trades happens on the Internet. By paying small amounts through the systems of banks and credit card companies takes a part of the payment, monitoring systems and currency risks are related to state currencies. Paypal is a good example of the numerous payment systems based on cash and credit cards that have been developed specifically for trading on the Internet. In terms of use, Paypal seems to be a safer and handier option than a credit card. It is easy to create a Paypal account online and no personal identification is needed for it. Money can be transferred onto the account and payments can be performed from the account in normal, exchangeable currency, and one can also receive payments from others on the account, therefore the money can be transferred onto one's own credit card account. The online earnings and payments can be kept secret from everyone who doesn't spy on network traffic. Today, eBay owns Paypal, which conveyed money transfers worth about 100 billion euros in 2012 through more than 100 million active accounts. Bitcoin is a state independent cryptomoney created by a community. Suppliers of server capacity who join the service according to their capacity create the money. Many commercial actors now accept bitcoins as payment and in currency exchange. Bitcoin is also an investment object and its value fluctuates sharply. Due to difficulties in monitoring Bitcoin, it is also considered a means of money laundering and drug trafficking. A Bitcoin user can create one or several digital wallets. At the current rate, the total amount of Bitcoins equals about one billion euros and Bitcoins exchange owner 30 times per day on average. Time banks are regional systems that support exchange, and they can be considered as electronic money. The significance of time banks is increasing.

Background information and examples:
http://www.hongkiat.com/blog/digital-wallets/
https://www.paypal.com/fi/webapps/mpp/home
http://en.wikipedia.org/wiki/Bitcoin
http://www.youtube.com/watch?v=0b99MUlFBR4

Recent vanguard product(s) or invention(s): Bitcoin and Paypal are the fastest change agents on the Internet money market, and time banks are shaping regional cooperation.

Application areas in 2030: Internet payments and money transfer, anonymous banking activity and investing regardless of state, regional exchange outside of monetary economy.

Market development: 4, market growth

High growth rate 2014-2030 yearly 5-15%

Impacts on the value chains: 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.15, 1.16, 1.18, 1.19, 1.20

2.100. Internet for robots **

Ingress: Robots require information from a database to function automatically and they are also controlled via telecommunication networks. The Internet's protocols are not very well suited for this and the content of the Internet is not designed for the use of robots. As robots move and function in a large area, also outside of Earth and out of reach of normal telecommunication connections, controlling them through telecommunication that happens via satellites is under development. NASA and ESA have experimented with using the Disruption-Tolerant Networking (DTN) protocol for interplanetary Internet to control a robot on Earth from the International Space Station (ISS). Services have also been developed on the Internet for the use of robots when they encounter previously unknown situations. The more robots connected to the Internet, the greater motivation there will be to create common cloud services for robots for the exchange of learned and gathered information, and algorithms. Rapyuta is a device-independent, European project that aims for this.

Background information and examples:
http://www.bbc.co.uk/news/technology-21714191
http://www.bbc.co.uk/news/technology- 20270833

Recent vanguard product(s) or invention(s): European Rapyuta is a cloud service designed for robots for their common exchange of information and for offering algorithms for the common good of robots.

Application areas in 2030: Robotics, remote-controlled devices.

Market development: 3, close to commercialization

Impacts on the value chains: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.9, 1.10, 1.12, 1.14, 1.15,1.16, 1.17, 1.18, 1.19, 1.20

3 Skills and the Access to the Emerging Markets of Radical Technological Solutions

The previous chapters described 20 globally important value-producing networks and introduced one hundred technologies that seem to change value production in a radical manner. In this chapter, we shortly discuss how to combine these global opportunities to available resources of various potential users of the Radical Technology Inquirer.

In the pilot project, the evaluation of the role of available resources was made in the national frame of Finland. In the Chapter 2, we did not mention these evaluations. In this chapter, we will shortly describe how we made the evaluations and what kind of role these evaluations had in the summary indicator that defined the arrow classes 1-4 of the radical technological solutions. The impact of the Finland specific resources is visible in the appendix 1 where the importance orders of 100 radical technological solutions are given with and without these Finland specific evaluations. After the Finland specific discussion, we will shortly generalize the available resources discussion to all kinds of actors that might use the Radical Technology Inquirer tool e.g. other nations, EU and companies that make choices concerning their technology portfolios.

Finland is a small country in a continuously specializing world. In order to finance its vital import, Finland cannot manage without the successful export. Since the 1990s, Finnish decision makers have considered that if Finns have special skills or knowledge in some areas, then those areas are also the most promising for export. Based on this interpretation, the special focus of the technology policy has been to increase knowledge of research institutes and researchers. This focus has not, however, been very successful for the development of national strengths in emerging technologies. Public or explicit research knowledge transfers across borders rather easily. The success depends more on how easily the Finnish actors access the tacit knowledge of other technology developers and potential customers of new technologies.

In his book, National Competitive Advantage, professor Michael Porter of Harvard University crystallized the main message of his very covering study in the "National Diamond" that predicts the competitiveness of the firms of a nation. The famous Diamond consists of four necessary factors of the competitiveness:

1. Firm strategy, structure and rivalry (e.g. good leadership, good organizational frames, competent national competitors),
2. Factor conditions (capital resources, knowledge resources, physical resources, infrastructure),
3. Demand conditions in the home market,
4. Presence of related and supporting industries.

In Finland, the National Diamond received common interpretation where the role of home market demand was essentially removed. The conflict with Porter's proven model is obvious. Finnish previous big strength in exports, the fast adaption of innovations in Finland, was sidelined even though Porter's study confirmed it as important. The

underlying assumption in the commonly used cluster model was that Finland should aim directly to international markets using our special skills and knowledge, because our home markets rarely fulfill the conditions set by Porter. Successful internationalization, however, still seems to comply with Porter's model, at least when adapted to present day situation. Success seems to be difficult to achieve without easy access to demanding clients.

In international business, the developer of a product gets typically a relatively small compensation for his/her invention and knowledge compared to those companies, which have the easiest access to potential clients. If the access to customers and other relevant stakeholders is not readily available, the access owner is typically able to hire researchers and to buy relevant patents at a much lower price than what the product's developer would spend to get access to the client interface. Therefore, presence at the client interface explains success better than research knowledge.

Porter noted that when the headquarters or R&D division of a company makes decisions and choices, it understands the needs of the home market best because of its understanding of close social networks, the culture of the physical environment, and local media influence the decision-makers more than distant markets. According to Porter, the situation is favorable to internationalization, if the home market fulfills these conditions:

- The structure of the home market is similar to that of the international markets
- Clients are quality conscious
- Client needs are equal to those of the market leaders
- There are several independent clients
- Markets are large enough for economies of scale
- Early demand
- There are multinational clients in the home market
- Other market areas can be influenced via the home market

Globalization and the development of information networks have changed the world since Porter's book. Geography has more limited role than in those times that Porter have analyzed. Therefore, Porter's conclusions must be considered critically. However, the most important message seems to be still valid. There must be easy access to clients who are market leaders. Exports are most likely to succeed if the home market adapts new technologies fast, or if there is an otherwise well-functioning connection to the international clients. This ensures easy transfer of knowledge from the clients who are market leaders to the product developers and decision-makers, and important client references and experiences are obtained among the early adopters. It is very difficult to compensate for the lack of customer knowledge and it is typically very expensive to compensate for it or to buy access to the clients. On the other hand, a research knowledge transfer from one country to another is more effortless than when Porter developed his Diamond.

The above reasoning explains a choice made in the Finnish pilot study of the Radical Technology Inquirer. The client interface or access got higher weight as the criterion of

potential success than special Finnish skills and knowledge. In the summary indicator that defined the 1-4 arrows of the radical technological solutions, the scale of the indicator that described the Finnish national access to relevant application areas of the breakthrough got values 1-3. The Finnish national competence indicator got just values 0-1.

Let's proceed from the Finnish pilot study to general conclusions concerning the potential users of the Radical Technology Inquirer. Its seems that other players besides public policy makers on local, national or EU level, but also medium size companies can get benefit from the tool. When a company realizes from the Inquirer that it should focus more on some radical technological possibility, it might develop a role of an early adopter. But probably the more typical situation is that it cannot get that type of role. In that kind of situation, the company can seek to lean on other companies' ready export channels and their client relations, whenever new technologies are tangent to the client needs that the existing channels fulfill. Small companies, however, rarely have these channels through which radical technologies are usually adopted. On the other hand, large companies are mainly too rigid and radical technologies are typically too marginal for them in the beginning. The Inquirer might help medium size companies to find niche markets that might later challenge the established large firms.

4 Scientific basic research promoting technological breakthroughs

In this chapter, we will shortly discuss the opportunities that the basic research is opening for various technological breakthroughs. The main aim of the discussion is to motivate the indicator that we have used when we evaluated the basic scientific interest in radical technological solutions. We will also describe the main data source of the evaluation: Science Map studies made in Japanese NISTEP (The National Institute of Science and Technology Policy).

In the past, the time delay between a breakthrough in science and its technical applications was rather long. The delays have, however, shortened and a target of the science and technology policy has been to further shorten the delays promoting the interaction between basic researchers and developers of technological applications. In Finland, SHOKs or Strategic Centres for Science, Technology and Innovation have been a way to carry out the long-term cooperation between the scientific communities and product developers in fields most crucial for the future. The aim has been to promote breakthrough innovations of global importance, which can be agilely transformed into growth in business life and wellbeing in society.

In practice, however, it is not easy to motivate university researchers to cooperate with companies because the success criteria in science differ much from the profit targets of companies. Two features are especially relevant for basic research that promotes technological breakthroughs:

- The science that promotes technological breakthroughs is global activity. Its results use to diffuse rapidly in the global networks of basic researchers.
- The basic science proceeds typically following its own principles that differ from the incentives of companies. The science is developing on the one hand cooperating and on the other hand rivaling research communities. The research communities define their own research questions and acceptable research methods. The role of appreciated and much cited journals is especially central because the articles published in those journals use to be the most important factor that defines the carrier of the basic researcher. The most appreciated technology relevant scientific journals publish articles are just in English.

Two main roles of the university researchers are the scientific research and the teaching. In Finland, the so-called “third function” of universities or the social/economic impact of the research has very limited role when the staff of the basic research oriented universities is selected. Two main criteria for professorships in the basic research are peer-reviewed articles in appreciated journals and how much the books or papers of the person are cited by peers.

The global orientation is the common starting point of high quality basic research in technology relevant areas and of the business applications of the emerging technological breakthroughs. However, in the interaction between companies and university researchers it is also important to realize the differing values and incentive systems. It is important that companies motivate basic researchers with research problems that are

scientifically interesting. On the other hand, researchers should be ready to point to their students or junior researchers study problems that opens them to opportunities in the business life. If the differing values and incentives are taken into account in this way it increases the amount of those who are able to work both in the basic research and in social/business activities related to radical technological breakthroughs.

From the point of view of both the scientific and the technological breakthroughs, research problems that belong to the border areas between different fields of science have been especially important. For example, the use of the new information technology for the reading of the genetic code improved radically the possibilities for the genetic engineering. It was a big step forward for both the basic science and for the technological applications of the biotechnology. As we will see, the closing of the nanotechnology and the biosciences is now an especially interesting development from the point of view of both scientific and technological breakthroughs.

When the applications based on results of the science are more important for the international competitiveness of firms and for the export of countries, the autonomy of the basic science is in risk. This concerns especially countries like Finland that have lost a lot from their international competitiveness. In Finland, this tendency is visible in the financing principles and discussed themes of the SHOKs. For example, this tendency is visible in the SHOK Summits that gather every other year different industry segments' influencers and innovators together to discuss common challenges and opportunities (http://www.shok.fi/en/shok-summit/). The presentation themes of the 2014 SHOK summit are all focused on technological innovations. No presentation looked at any SHOK from the perspective of the basic researchers.

If the special incentives of the basic researchers in the SHOKs are not taken into account there is the risk that though basic researchers in their speeches stress the practical applications of their research activities their real activity is anyway focused on their basic research oriented targets. If their achievements are criticized they might totally lose their interest in the common efforts of the SHOK. The controversy between the basic science and application oriented development work might even increase instead of better interaction. The contradictory objectives of the SHOKs was also remarked and stressed by the evaluation study of the SHOKs published in 2013
(http://www.tekes.fi/u/Licence_to_SHOK.pdf).

Though the SHOK development projects might be reasonable for other countries beside Finland, we consider that in the Radical Technology Inquirer it is highly important to look towards the scientific interest related to radical technological solutions from the genuine perspective of the basic researchers and their incentives. We consider that global basic research based interest in some radical technological solution will have in average more impact on the future prospects of the radical technological solution than global R&D activities focused specifically in the realized applications of the radical technological solution. The global general scientific interest towards radical technological solution is taken into account in the summary indicator with special indicator having values 0-2 and the global R&D focused on specified applications with an indicator having value 0-1.

But how to evaluate the global general scientific interest towards a radical technological solution? Very much peer cited articles belong to the achievements that basic researchers appreciate. These have been the main focus of the Science Map studies made in Japanese NISTEP (The National Institute of Science and Technology Policy). Since 2002, its Science Map project has used bibliographic methods to repeatedly study global changes in the field of science. Each of the studies that were conducted at an interval of two years focused on over five million scientific articles published in the last six years preceding the study. The studies have been based on the Thomson Reuters Science Citation Index (SCI), which has monitored publishing in about 1500 scientific journals. The most recent Science Map report focuses on the development between years 2003 and 2008 (Saka et al. 2010). The development of different fields of research has been evaluated as follows:

- The significance of the research areas and their relations among each other have been examined using the top 1 percent of highly-cited papers during each year in each of the 22 examined fields. In Science Map 2008, there were included approximately 56,000 papers in total.
- A measure has been created that describes the reciprocal closeness of the fore mentioned, highly-cited papers. ”Co-citation” occurs when two notable scientific papers are both cited by another scientific paper. Further, the so-called co-citation analysis (the number of scientific papers that cite two papers divided by the square root of the product of papers that cite only one of the two papers) describes the closeness of two scientific papers. Papers that were very close to each other were interpreted as belonging to the same research area. The clustering of scientific papers obtained 647 research areas in total. Therefore, each research area had about 8 top articles on average and about 800 published articles in total.
- The closeness based on the fore mentioned analysis has been visualized on a map. ”Hot” areas, which are clusters of research areas/especially many articles, are formed on the map.
- The ”hottest” 121 research areas were subjected to content analysis.

As is distinctly manifested in the following table copied from the research report by Saka et al. (2010), most of the research areas that came up in the clustering belong in the life sciences cluster, even though their portion has reduced slightly from the year 2002. The research areas in the computer science cluster have increased relatively much in the time period between 2002 and 2008. The increase in scientific interest in this field can be considered genuine. Other fields of science, which seem to have received increased interest, are engineering, environment/ecology, geosciences, materials science, psychiatry/psychology, and mathematics. However, in the case of these fields, the result might be due to a measurement bias caused by changes in the range of monitored journals. Based on the consistent annual increase in growth, it could be concluded that at least materials science and psychiatry/psychology have been subjected to genuinely growing scientific interest.

Table of the Science Map's clustered fields of research in the 22 fields of science (Saka et al. 2010).

	All research areas in Science Map 2002	All research areas in Science Map 2004	All research areas in Science Map 2006	All research areas in Science Map 2008
Agricultural Sciences	111	131	56	106
Biology & Biochemistry	992	963	763	713
Chemistry	2245	2353	2286	2376
Clinical Medicine	3402	3471	3351	3458
Computer Science	122	157	335	350
Economics & Business	152	166	109	125
Engineering	735	729	730	971
Environment/Ecology	293	322	309	364
Geosciences	392	395	381	503
Immunology	310	287	254	259
Materials Science	494	545	606	597
Mathematics	139	155	142	218
Microbiology	291	247	319	289
Molecular Biology & Genetics	663	563	494	555
Inter-/Multi-disciplinary Research Areas	69	63	36	27
Neuroscience & Behavior	633	457	432	444
Pharmaceutical Science/Toxicology	175	134	134	103
Physics	2395	2644	2692	2742
Plant & Animal Science	1008	923	979	849
Psychiatry/Psychology	150	195	234	233
Social Science, general	323	304	193	177
Space Sciences	316	327	330	367
Total	15410	15531	15165	15826

Number of core papers in life science	7735	7371	7016	7009
Number of core papers other than life science	7675	8160	8149	8817
Percentage shared by life science	50.2%	47.5%	46.3%	44.3%
Percentage shared by fields other than life science	49.8%	52.5%	53.7%	55.7%

Note: In the table, colored fields indicate life science.
Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Reuters' "Essential Science Indicators."

Figure 1 shows the Science Map 2008 (Saka et al. 2010), with the positions of the hot research areas. The brown and yellow areas in the image are the areas, in which the most cited scientific papers were published.

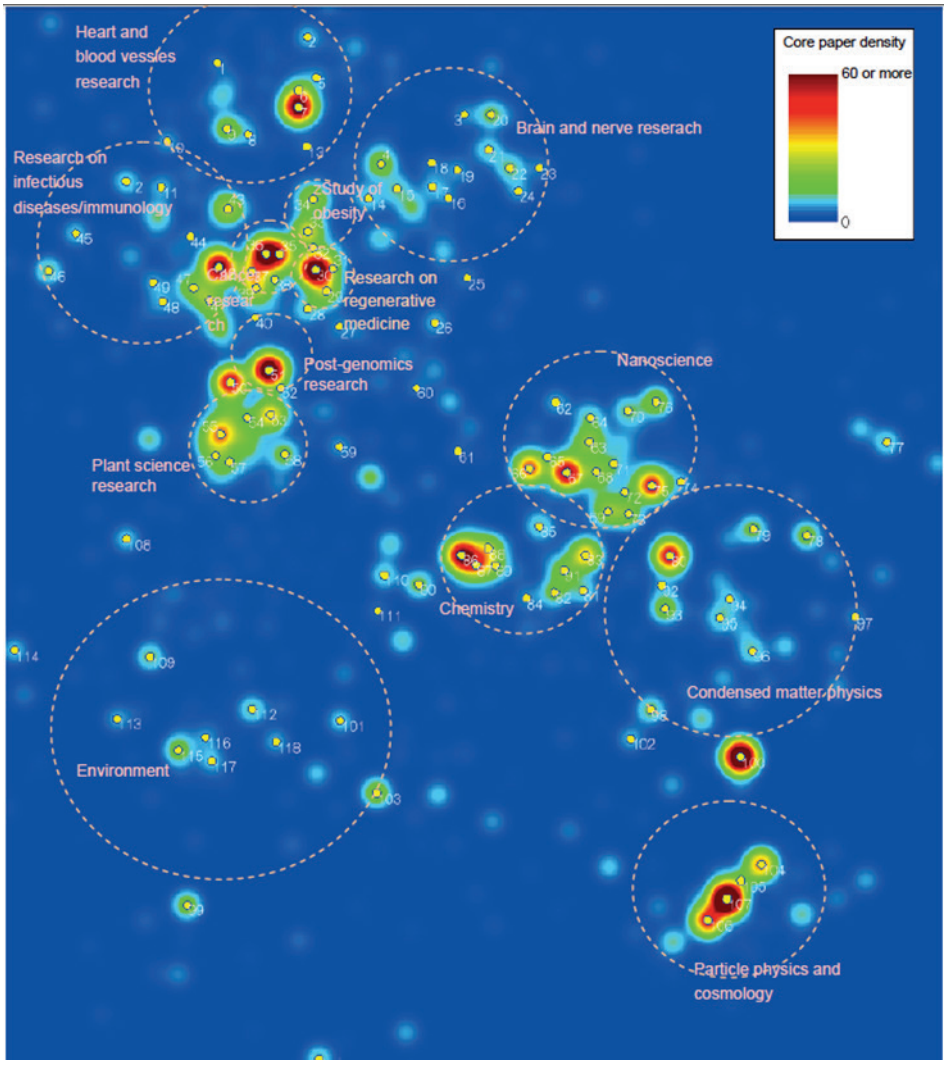


Figure 1. Science Map 2008 (Saka et al. 2010)

The Science Map shows four hot areas of scientific development that are clearly mutually distinct.

The hottest area builds around research of genetics and regenerative medicine. The hottest point is cancer research and neurodegenerative diseases in its proximity including obesity related problems and Alzheimer's disease. Fields at the edges of the cluster are heart and blood vessels research, and research of contagious diseases and immunology. Plant and brain research are positioned at the edge of the cluster as well.

Nanoscience, condensed matter physics, and nano and catalytic chemistry form another strong area of research. The "hottest" area forms around nanoscience. An area, which Saka et al. (2010) call post-genomics research, forms between this area and the life sciences area. The name refers to the general research of the modes of action of genes, which started after the DNA of organisms was learned to read around the year 2000.

The third area of research, which is developing strongly, is the area of particle physics and cosmology. The area between this field and the nanosciences cluster, which contains, among others, optics and strongly interacting many body systems (ID 100), seems especially interesting in terms of long-term technology development. A connective field of research in this area is the research of quantum phenomena, which is not acknowledged by Saka et al. (2010).

The hottest point of the fourth cluster is formed by environmental research and especially research based on climate change and its effects. An area of bioenergy and environmental chemistry research connects this cluster to the nanosciences cluster.

Taking into account the fact that a significant part of scientific research is conducted within methodological sciences, social sciences, and humanities, their part of the recognized key research areas is very small and their relation to the forementioned hot areas of research is not depicted in the map. It can be concluded from the previously presented table that the Science Citation Index does not handle these fields as fields of science. Therefore, only the research areas of "Corporate governance" (ID 119) and "New trends of economic geography" (ID 121) are on the Science Map's list of especially hot research areas. We can conclude the weak position of methodological sciences from the fact that only one area has made it to the list of hot areas from purely mathematical sciences, even though the number of mathematical journal articles appears to have been increased more recent basic data of Thomson Reuters.

One fundamental problem in the research methods used by the Science Map is that highly-cited articles are in a way lagging behind by one generation from where the vanguard of science is. Because of the delays in publishing, the scientific community cannot prove the most recent scientific breakthroughs as important through citations. Because of the corresponding problem, in the case of patents, it is preferable to use so-called bibliometric coupling (clusters of patents that cite the same patents) instead of co-citation analysis as a method (Kuusi and Meyer 2007). However, when clusters consisting of scientific articles are used to analyze scientific breakthroughs that enable radical technological solutions, this problem cannot be considered very serious. Technological breakthroughs are typically based on bit older and secured breakthroughs than the vanguard of science. For this reason, the following does not refer to the research by Saka et al. (2010), in which experts were asked to supplement the promising fields of research that were formed by clustering.

The fields of research considered as most promising can be divided into the fore mentioned clusters in the way that is presented in Table 2. The research areas have been ranked into the same group based on both the closeness based on co-citation as well as the ”heat” that describes the article denseness of the area they form. We don’t follow the division suggested by Saka et al. (2010) entirely. We have ranked each of the 121 research areas that were considered important into one or more groups. Five areas of research, which differed significantly in nature from the other areas, were group under ”Other important research areas”.

Mentioned sources:

Kuusi, Osmo.; Meyer, M. (2007), Anticipating Technological Breakthroughs: Using bibliographic coupling to explore the Nanotubes paradigm. Scientometrics, 70 (3) 759-777.

Saka, Ayaka , Masatsura Igami andTerutaka Kuvahara (2010): Science Map 2008, Study on Hot Research Areas (2003-2008) by Bibliometric Method, Nistep publications 139, www.nistep.jp.

Table 2. Research areas in Figure 1 and their groups

Groups	Research areas
Heart and blood vessels research	1 Critically ill patient management (Particularly in cases of acute respiratory distress syndrome) 2 Effects and prognostics of device therapy for advanced heart failure 5 Clinical research on the control of cardiovascular incidents by antihypertensives and their impacts on diabetes 6 Coronary CT (computed tomography) 7 Treatment of acute coronary syndrome using antiplatelet drugs 8 Research on adverse effect of COX inhibitors 9 Mineral and bone metabolism disorders in chronic kidney disease 10 Prostate cancer/endocrine therapy/radiotherapy/effect and adverse effect 13 Effect and adverse effect of hormone replacement therapy (HRT) Aivotutkimus
Brain research	3 Medical therapy for neuropathic pain and fibromyalgia syndrome 4 Physiological function of endogenous cannabinoid system in central nervous system 14 Research on physiological role of peptide hormone in the brain 15 Molecular mechanism of the onset of Alzheimer's disease and the development of ways of prevention and treatment of the disease 16 Clinical research for Parkinson's disease 17 Neurogenesis in adult hippocampus (the understanding of phenomena and the development of clinical application) 18 Genetic research on schizophrenia and molecular pathogenesis investigations developed from the research 19 Brain-derived neurotrophic factor/brain morphology in schizophrenia/mood disorder 20 Clinical research on treatment of schizophrenia and bipolar disorder 21 Molecular neuroscience of emotion and its pathological conditions 22 Research on higher brain functions unique to humans using functional brain imaging 23 Brain neural mechanisms for decision-making 24 Neural mechanisms for emotion/empathy and imitation/context
Contagious diseases and immunology	10 Prostate cancer/endocrine therapy/radiotherapy/effect and adverse effect 11 Pathological condition and treatment of bronchial asthma 12 Clinical research on early diagnosis, prevention and treatment of deep mycosis 41 Production of interferon by innate immunity 42 Differentiation mechanism of T cell subsets and their role in disease 43 Control of autoimmune disease by immunoregulatory mechanism of biological drugs 44 NK cell receptor and its ligand that inhibits activation 45 Development of human papillomavirus vaccine 46 Development of drug resistance in Staphylococcus aureus and ways to cope with it 47 Process of early infection with Hepatitis C virus and its treatment 48 Control of HIV infection 49 Research on anti-HIV drugs
Stem cells and regenerative medicine	27 Hydroxylation modification of HIF and HIF and regulation of mitochondrial function 28 Molecular mechanism of apoptosis (cell death) 29 Role of autophagy in health and disease 30 Research on regenerative medicine and stem cells 31 Research on aging-suppression and longevity-control factors in individual and organ stem cells

Groups	Research areas
Neurodegenerative diseases and their prevention	15 Molecular mechanism of the onset of Alzheimer's disease and the development of ways to prevent and treat the disease 16 Clinical research for Parkinson's disease 32 Metabolism control through PGC-1 and insulin resistance 33 Genetic epidemiologic research on complex genetic disease 34 Elucidation of pathogenic mechanism of lifestyle-related diseases resulting from obesity
Cancer research	28 Molecular mechanism of apoptosis (cell death) 35 Development of drug therapy/genome sequencing technology for breast cancer 36 Molecular biological approach to human malignancies 37 Multiple myeloma/new medicament 38 Research on the development of molecular targeting anticancer drugs including HDAC inhibitors 39 Activation of tyrosine kinase and its drug resistance 40 Role of ubiquitin modification system in NF-kB activation
Post-genomics research	25 Molecular mechanisms for excitatory synaptic plasticity 26 Biological implication of protein aggregation from the viewpoint of common denominators in transmissible aggregate "prion" and amyloid-like 27 Hydroxylation modification of HIF and HIF and regulation of mitochondrial function 28 Molecular mechanism of apoptosis (cell death) 50 Network science 58 Microorganism ecosystem 59 Systems biology/synthetic biology 60 Structure and functions of G-protein-coupled receptor 61 Analysis of dynamic behavior of proteins
Plant research	51 Gene silencing/plant hormone 52 Redox control 53 Environmental responses of plants/metabolome analysis/proteome analysis 54 Mechanisms for generation of nitric oxide in plants and its physiological role 55 Defense mechanism of plants against infection 56 Plant-microorganism interactions/strigolactones 57 Plant developmental genetics/carbohydrate metabolism
Nanosciences	62 Microchannel device 63 Semiconductor-spintronics material/magnetic semiconductors 64 Research on creation and application of nanofibers 65 Development of nanostructure using nucleic acid 66 Living radical polymerization/click reaction/molecular machine 67 Synthesis, function and toxicity of sensors/SWNTs/functional DNAs/nanoparticles, etc. 68 Bioapplications of gold nanorods 69 High-efficiency electroluminescence (EL) element 70 Superhydrophobic surface 71 Mesoporous material/silica, carbon and metal oxide 72 Nanomaterial synthesis in ionic liquid/hollow and mesoporous material 73 Ionic liquid 74 Development materials from carbonate following the examples of nanocar-bons and living organisms 75 Organic/organic-oxide semiconductors - Photo- and electro-functional materials and elements 76 Solid macromolecule type fuel cell

Groups	Research areas
Condensed physical matter research	77 Formation of bulk metallic glass/transformation of metal glassy alloys 78 Ferroelectric property in new materials such as multiferroics, etc. 79 Metal-based spintronics 80 Physics and chemistry of molecular substance 92 Electromagnetic response of surface plasmon in artificial structures 93 Meta material 97 Novel electronic order in high-temperature superconductivity
Nano and catalyst chemistry	81 Nanochemistry of gold 82 New-generation density functional theory for large-scale molecular calculation 83 Design and functions of configurational space and coordination lattice 84 Research on hydrogen bonding 85 Anion sensors 86 Catalytic asymmetric synthesis 87 Molecular conversion reaction using transition metal catalyst 88 Synthesis of N-Heterocyclic carbene (NHC) and its application to catalytic reactions 89 Direct carbon bond formation through transition metal catalytic reactions
Quantum phenomena, inc. optics	94 Optical quantum information/communication, optical nanoscience 95 Qubits using semiconductor quantum dots/electronic charge, electron spin and nuclear spin 96 Quantum information science using atomic system/photons 98 Ultrafast and ultraintense optical science 100 Strongly interacting quantum many-body system 102 New technologies related to solid oxide fuel cell (SOFC)
Particle physics and cosmology	104 Gauge/gravity theory correspondence and black hole solutions 105 Gamma-ray burst 106 Elementary particle physics/elementary particle astrophysics 107 New developments in cosmology and elementary particles theory owing to advancement in precise observation of space
Bioenergy and environmental chemistry	90 Microbial fuel cells/microbial cells/enzyme-based biofuel cells 91 Complex hydrides associated with hydrogen production and storage and fuel cells 110 Environmental chemistry of bromine flame retardant 111 Environmental burden of drugs and other industrial chemicals and technologies to reduce the burden
Environment and especially climate change	101 Studies on the evolution of air and living organism in early earth and its analytical approach 103 Earth in the Precambrian era 109 Warming impact/bio- and eco-systems 112 Organic aerosol 113 Observational studies on carbon balance in continental ecosystem 114 Stability discrimination/stabilizing control of delay system using matrix inequality 115 Atmospheric composition and minor constituents 116 Climate change simulation including aerosol effects 117 Sea level fluctuations/seawater density/ice sheet/water circulation 118 Restoration of the past global environmental change

Groups	Research areas
Other important research areas	99 Limitation and application to signal processing/information theory using "sparse" property of source 108 Emergence process of Homo sapiens 119 Corporate governance 120 New asymptotic expansion method for nonlinear differential equation and its application 121 New trends in economic geography - Evolutionary economics and relational logic

By comparing the cluster images from research of the years 2002 to 2008 (Figure 2), we can see that the cluster structure has remained quite similar. Saka et al. (2010) recognize the following changes:

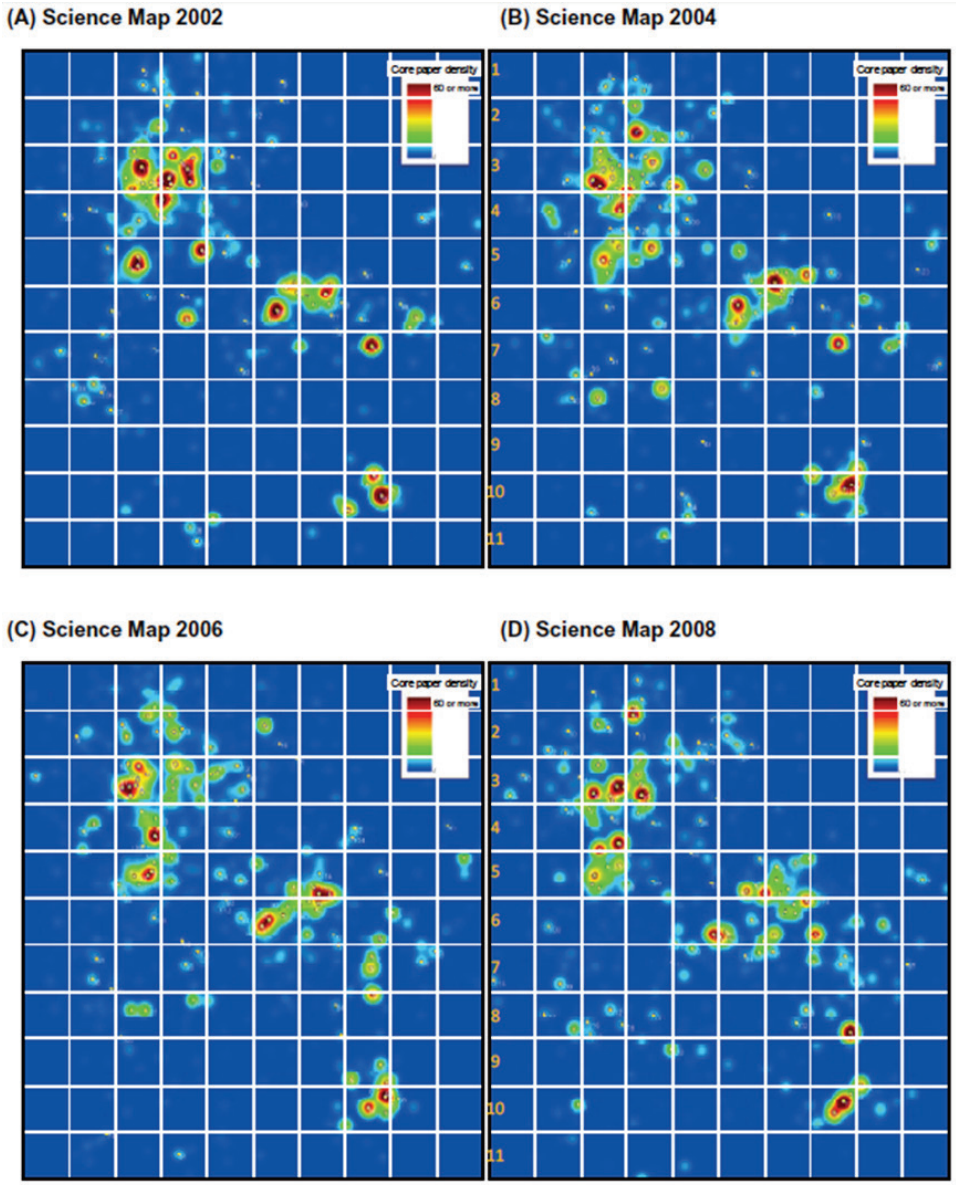
The key hot areas of the research have become closer to one another. This indicates a sort of an integration of sciences toward a kind of universal science. The mutual approaching of the clusters is seen especially in the approaching of biosciences and nanosciences as well as the approaching of condensed matter physics, particle physics and cosmology. The expert evaluations collected by Nistep also support this conclusion. The research areas considered especially interesting by the experts were typically multidisciplinary or interdisciplinary.

More significantly than before, the 2008 research shows post-genomics research and especially the use of microbiochips in gene silencing that is at its core, as sort of a link between biosciences and nanotechnology. From the direction of nanotechnology, the connecting area of research was ”Microchannel devices”. In previous studies, the connecting area of research was more clearly protein research. Saka et al. (2010) note that the new connecting areas of research are related to the fast and inexpensive reading of DNA. On the other hand, microchannels are essential in directing all kinds of nanoscale chemical reactions.

In the Science Map of 2008, the research area ”Strongly interacting many body systems” functioned as the connecting link between condensed matter physics, particle physics and cosmology. Still in the Science Map of 2002, quark research, Bose-Einstein Condensate (BEC) phenomenon research and superconductivity and superfluidity occurred as separate. In 2008’s research there were close to each other in the way that the quark and Bose-Einstein Condensate research had moved closer to the condensed matter physics and superconductivity and superfluidity had moved closer to particle physics and cosmology.

In 2008’s research, the United States held the clear lead position as the producer of the most highly-cited scientific articles. However, the portion reduced from 51,8% in 2002 to 43,5% in 2008. A bit surprisingly, Europe’s largest countries, namely Germany, France, and Great Britain, held their portion at approximately the same level (18,2% in 2008) or even clearly increased it from 2002 to 2008, when another calculation method was used that favors articles with multiple authors. China’s portion increased very quickly as was expected reaching almost the same level with Japan in 2008’s research (5,2% and 5,4%).

However, compared to East Asia's position as a producer of industrial commodities, its portion in scientific research is very modest. This disproportion is especially clear in the case of South Korea. Its portion of the most highly-cited articles was only 1,0% in 2008's research.



Note: The yellow circles indicate the center location of hot research areas. The numbers next to the yellow circles are the hot research areas' ID numbers.
Data: Tabulated by the National Institute of Science and Technology Policy based on Thomson Reuters' "Essential Science Indicators."

Figure 2. Comparison of the cluster images from year 2002 to 2008 (Saka et al. 2010).

Conclusions

The development in highly-cited scientific papers highlights two interfaces of ”hot research areas”. These are the interfaces between life sciences and nanotechnology and between condensed matter physics and particle physics. The former interface is characterized by the area of post-genomics research, which connects the research areas. Saka et al. (2010) highlight especially one key technological solution in this area: the microbiochip. If one wants to pick up one especially promising path of global scientific development in 2003–2008 from Thomson Reuters' material, it could be the application of microchip technology or below 100 nanometer tubes/filters in genetic information. It seems that the Finnish scientific community has observed this challenge, considering that the Academy of Finland's Research Council for Biosciences and Environment pointed out the lack of experts in bioinformatics as a key challenge in the SWOT analysis presented in its 2012 report on the review of the state of scientific research in Finland. Another path of development that appears very promising would seem to be related to the development of elementary particle physics, which makes quantum phenomena more controllable than before.

Besides the Science Maps of NISTEP another useful source for the scientific interest evaluations has been the Towards 2020 Science report and Road Map of the Technical Research Centre of Finland (VTT 2006:4). The Road Map included e.g. the following table that evaluated the scientific interface between the information technologies and biotechnology.

Table 3. Goals of Scientific Research for the year 2015 and 2020 (VTT 2006:4)

	State-of-the-art	2015	2020
Goals	• LHC preparation • Systems biology emerges as new discipline • Ex vivo molecular-computer diagnosis • LHC switch-on • Automated remote species-identification • Reliable global warming, natural disaster and weather-prediction models • Keystone-species identification	• Systems approach to biology becomes mainstream • In vivo molecular-computer diagnosis • Comprehensive biological data integration: majority of 'omes co-analysable • Individualised medicine • Modelling based vaccines • Finding the Higgs boson? • Predictive models of: effects of rainforest destruction, forest sustainability, effects of climate change on ecosystems, effects of climate change on foodwebs, restoration ecology planning, global health trends, sustainable agriculture solutions • Full model of a single cell	• Full model of a multi-cellular tissue/organ/organism • Foundational theory of Global Ecosystems • First purely in silico developed drug comes to market • Personalised in situ molecular-computer 'smart drug' • Verifiable global ecosystem models • Verifiable global epidemic models • Predictive model of effects of human activities on Earth's life support systems • Predictive models (mathematically precise, definitional, verifiable) of biological systems (cells, organs, ecosystems) • Understanding complex biological systems, from cells and organisms to ecosystems • Comprehensive codification of biological knowledge • Understanding the make-up of the Universe • Understanding of Earth's life support systems

5 Conclusions and Results

Methodological Choices of the Inquirer and the Special Features of the Finnish Pilot

In this concluding chapter, we will summarize the discussion of the previous chapters. We will focus on the benefits that the Radical Technology Inquirer would provide to various actors from EU level to single companies. On the one hand, the Inquirer is a huge source of recent information. The about one thousand Internet sources related to the 100 Radical Technological Solutions (RTS) that were reviewed give an updated overview of possible technological breakthroughs. What is especially important is that the Inquirer suggests a practical way for the evaluation and for the continuous updating of this whole picture of the technological progress.

The main elements of the Inquirer/tool are illustrated in the picture 1 on the page 10. We can summarize the methodological choices of the Inquirer and its Finnish pilot as follows:

1. Candidates for 100 Radical Technological Solutions (RTS) and important Internet sources that motivate the importance of the RTSs are found crowdsourced. In the Finnish pilot study, crowdsourcing has happened as a facilitated Facebook discussion. In summer 2014, about 600 persons were registered to the discussion pages. In practice, the most valuable contributions of the crowdsourcing have been suggestions of interesting Internet sources of RTSs.
2. The final choice of the 100 RTSs described in the Chapter 2 was made by three futures researchers who are the authors of the Finnish report. They have long careers in the anticipation and evaluation of technological development. Typically, the accepted Radical Technological Solution does not refer to a single technology but a cluster of technologies that aim to meet some shared challenge. A metaphor of the RTS is the forest that recently includes just small trees or saplings or in some cases just seeds. The future value of the "radical technological solution forest" is evaluated based on the heights of its highest trees in 2030. The minimum requirements of the acceptable RTS candidate are that some technological solution should be available in the global consumer or the user market by 2020 at the latest, and there are reasons to expect vast global use by the year 2030. It is also required that the principles of the possible solution are already published in a peer referred scientific publication.
3. The authors of the report defined 20 Global Value-producing Networks (GVPN) combining global megatrends, changing consumption patterns and technological opportunities. The GVPNs are described in the Chapter 1. GVPNs

were chosen from the Western developed country perspective and they are areas of technological and societal change based on global demands. The list was aimed to cover the most important sources of added value for a country like Finland in the period 2014-2030. In the Finnish pilot, the criterion was the high potential added value of GVPN candidate for Finland in the period 2014-2030. The futures researchers considered that in 2030, Finnish people will fulfil most of their needs in the selected 20 GVPNs. When EU, other countries or other actors e.g. companies will use the Inquirer, the recent list of GVPNs is at least useful reference list for new GVPN lists.

4. The systematic evaluation of the future prospects of Radical Technological Solutions are based on 25 indicators summarized below. The indicators are motivated in Chapters 3 and 4 and in the beginning of the Chapter 1 and 2. In this English edition, the main function of the Chapter 3 and Chapter 4 is to motivate indicators related to the R&D activities in the universities and in the business sector as well as provide indicators related to the access of companies and other actors to emerging markets of radical technological solutions. The evaluations of this report are collected in a table that can be found in the attachments. The points of evaluation are the following:

    - The maturity of the solution is evaluated on a scale from 1 to 4. The value 1 is given when the solution seems possible based on a scientific, peer-reviewed report. The value 2 is given when a prototype developed in a research institution exists, and value 3 is given when several mutually independent, well-funded institutions have prototypes and invest in further development of the solution. The maximum value 4 for maturity is given when some version of the solution is on the market and the market seems to grow in such a way that further development is worth the investment for commercial reasons. For this English edition a further choice was made concerning the stage 4 radical technological solutions. The average yearly market growth 2014-2030 is divided in two categories 5-15% (high growth) and over 15% (breakthrough growth). The breakthrough growth means that the market in 2030 will be at least 8 times the recent market. If the average yearly growth rate is evaluated to be less than 5%, meaning that the market is 2014-2030 less than doubled, it is evaluated that the radical technological solution is not feasible for the list of 100 radical technological solutions. In this report, this addition has not, however, changed numerical summary evaluations.
    - The scientific interest is evaluated on a scale from 0 to 2. The value 1 is given when such scientific research is widely conducted that is on tangent with the solution and advances its development. The value 2 is given when a vast amount of research is conducted on the solution.
    - The scope of independent paths of R&D is evaluated on a scale from 0 to 1. The value 1 is given when product development related to the solution is done widely on commercial markets, public administration or hobbyist markets and in user communities.

- Finland's know-how is evaluated on a scale from 0 to 1. The value 1 is given when there is significant R&D know-how or research know-how in areas related to the radical technological solution in Finland.
- Finland's access is evaluated on a scale from 0 to 3. The value 1 is given, if we have a clear connection to such a global clientbase, which could use the examined solution in its own operational area. The value 2 is given, if the connection is of such nature that the examined solution could be supplied to products that are currently being sold or it is directly related to them. The value 3 is given, if the above-mentioned terms are fulfilled and the position in the entire potential market segment is strong.
- The potential of each radical technological solution is evaluated separately in each value-producing network on a scale from 0 to 20. The value 1 is given, if the successful solution can be seen to produce some added value from the point of view of the main value produced in the network. The value 3 is given, if the produced added value can be significant if it succeeds, i.e. at least tens of millions of euros in Finland's scale or it would have a vast impact on people's everyday lives. The value 5 is given, if the potential added value is worth over a hundred million euros or the impact on people's everyday lives is vast and significant. The value 10 is given, if the potential impact is over one billion euros or the impact on people's everyday lives is vast and crucial. The value 20 is given, if the solution is necessary for the main described development of the value-producing network.

5. The summary promise of the radical technological solution is calculated by first summing the potential of the solution in different value-producing networks, summing the readiness of the required inputs, and then multiplying these two values with each other. Maturity is pressed in the readiness of the required inputs in such a way that it is given double weight when calculating the sum compared to scientific interest, the scope of independent paths of R&D, Finland's know-how, and Finland's access.
6. In the Finnish pilot study, the evaluations of 100 radical technological solutions in 25 indicators related to Global Value-producing Networks (2500 parameters) were made by the authors of the Finnish report and the adviser of the Committee for the Future Olli Hietanen. Impacts on 20 Global Value-producing Networks (2000 parameters) were evaluated in face-to-face sessions of four evaluators. Other 500 parameters were evaluated by Risto Linturi and Osmo Kuusi. Their expertise complements each other in that way that Kuusi has more expertise in bio- and material technologies and Linturi in information and electric technologies.

Some Results of the Pilot Study

The summary promise values of the radical technological solutions are presented in the appendixes 1 and 2. In the appendix 1, the values are presented in the Finnish specific order taking into account the Finnish specific know-how and access. The most promising 25 solutions in this summary indicator get ****, the next 25 ***, the next 25 ** and the rest ones *. These stars are also presented in the Chapter 2. In the appendix 2, the values are in the order where the Finnish specific variables are not taken in account. In this list, every radical technological solution gets the value 0 both in the Finnish specific know-how and in the Finnish specific access. For comparison, the ranking values in the global list are mentioned in the Finnish specific list and the ranking values of the Finnish specific list in the global list.

In the global list, the highest summary promise value gets "Extremely dense processors that take quantum phenomena into account"(2.72). Its ranking in the Finland specific list is 5. This radical technological solution is related to the famous "Moore's law". Intel's Gordon Moore estimated in 1965 that the number of transistors in inexpensively produced integrated circuits would double about every two years. This has since proven to be rather accurate prediction and there are now several billions of transistors in the densest integrated circuits. The number of transistors has a direct impact on the size of memory circuits and an essential significance for processing power as well. The continuation of Moore's Law has required ongoing innovation. Many experts have suspected that development would come to a halt in the 2010's due to quantum level phenomenon, as the size of transistors will have shrunk close to their area of impact. Several new inventions demonstrate that the barriers are solvable and development can advance as per Moore's law for at least a decade. This means about one hundred times the transistor density compared to current circuits. The means are new carbon based materials, three-dimensional transistors, deference to quantum phenomenon, spintronics, and logic based on light. Increasing density is required in very many new applications.

In the Finnish specific list, the highest summary promise value gets "Open data and big data" (2.17). In the global list its ranking is 2. Open data implies that data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents or other mechanisms of control. On the other hand, Big data is looking for effective ways to handle information when world's technological per-capita capacity to store information has roughly doubled every 40 months since the 1980s. Big data uses statistical and system analysis methods e.g. genetic algorithms, machine learning, natural language processing, signal processing, simulation, time series analysis and visualization in order to infer relationships, dependencies and perform predictions of outcomes and behaviors. It has been realized that Open data is a key for trustful and sustainable Big Data. Besides volume (amount of data), Open data seems to be not only sustainable but also effective way to manage two other aspects of Big data: velocity (speed of data in and out), and variety (range of data types and sources).

The third in the global list and the second in the Finnish specific list is "Freely organizing remote work and organizations that form on the Internet" (2.13). Like the open data, it is at least as much social than technology based option. Many different forms of collaboration and sales of work deliverables are created on the Internet. Earlier, remote work has been suitable only for tasks in which the deliverable is intangible, but with the help of remote controlled devices and remote presence techniques, remote work can have a physical dimension as well. Free organizing enables the emergence of trust and working without the organizer or payer knowing the worker or even his/her location. Only the result and peer reviews matter. Such a way of organizing the exchange of work and services, which is independent from the traditional ways of organization, easily bypasses state borders, authorities and traditional financing and decision-making mechanisms as well as liability issues. At the same time, however, they may offer very low transaction costs, a significant improvement to the equality of resources and attainability of services. The birth of the Linux operating system is one of the best-known examples of the benefits of these new ways of organization.

The highest ranked radical technological solutions use to be those that are already well noticed. It is important to follow how they develop and to take them into account for example in the occupational education. For the companies, however, most interesting are those options that are not yet widely recognized or used. Based on the used ranking systems weighting the anticipated impacts on Global Value Producing Networks, some still rather poorly recognized innovations e.g. 2.40 "Material Radar" gets four stars. Its ranking in the global list is 16. From the business point of view also very interesting "Quadcopters"(2.47) or drones got three stars and their ranking on the global list is 34. Some very promising options do not yet, however, belong to the high -evaluated. An example is 2.6 "Longer life time and slower aging processes". It is evaluated to deserve two stars. If the control of the aging based on SIRT2/SIRT1 genes will realize this might huge impacts on the life of people. For the further use of tool, it is highly important the update the list regularly and to monitor still uncertain and low-ranked opportunities or opportunities that are still out of the list of 100.

How the International Community Can Benefit from the Radical Technology Inquirer?

The key feature of the Radical Technology Inquirer is its flexibility. This concerns the choice of its main elements: the Radical Technological Solutions (RTSs) and the Global Value-producing Networks (GVPNs). Though it is useful that there are reference lists of RTSs and GVPNs in a national level or for example on the EU level, every user of the Inquirer can define the lists from its special perspective. A company might take the GVPNs from the reference list and evaluate technologies of its technology portfolio in the frame defined by the GVPNs. The company might realize that some RTS of the reference list is reasonable to add now or in the future to its portfolio. Related to this kind of choice, the company should think about the following questions:

- Is it reasonable to invest on a radical technological solution and on its some execution option(s)?
- Is it reasonable to wait and just follow the developments related to a radical technological solution and its execution options?
- Is it reasonable to abandon some investment option because of emerging radical technological solutions?
- Is it reasonable to abandon some recent activity because of GNVP or RTS options?

Some actor, e.g. an educational institute, might focus its interest just on one GVPN. It might take the reference list of RTSs and evaluate how to teach the skills needed for the use of the most relevant RTSs. Or it may construct a new GVPN that is more relevant from its point of view.

The recent reference list of the RTSs and the GVPNs are made from the Finnish perspective though both lists are in principle global. Surely however, a country that differs much from Finland has to check both GVPNs and the list of 100 most promising RTSs and not only the country specific know-how and access.

We consider that the basic structure of the evaluation formula of RTSs is reasonable though the weights of its different elements are intuitively selected. It is reasonable to sum resource or input elements on the one hand and on the other hand the GVPNs based impact or output elements and to multiply the inputs and the outputs. Instead everyone interested in the subject can try different weights for different indicators and their impacts on the order of the listing.

What could be the next effort that in the best ways helps the international community to get benefit of the Inquirer? We consider that there are at least two good options:

- Some other country beside Finland makes its own version of the Inquirer. After this effort, available are two reference solutions for various users of the Inquirer
- A consortium from many countries makes the reference solution to EU. This seems to be an especially promising possibility for Europe.

Thanks

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Attachments

Four-level model, TOP 100 – Global

		Global	Finland	Special Finnish focus
****	2.72 Extremely dense processors that take quantum phenomena into account	1	5	-4
****	2.19 Open data and big data	2	1	1
****	2.13 Freely organizing remote work and organizations that form on the Internet	3	2	1
****	2.22 Glasses of augmented reality	4	3	1
****	2.12 Schools in the cloud	5	6	-1
****	2.20 Gamification	6	4	2
****	2.02 Biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms	7	8	-1
****	2.28 Cloud computing	8	10	-2
****	2.56 3D printing of goods	9	9	0
****	2.45 Self-driving car	10	7	3
****	2.82 Rapidly cheapening solar energy	11	12	-1
****	2.01 Routine and complete DNA sequencing	12	14	-2
****	2.43 Printed cheap biosensors	13	11	2
****	2.07 Continuously monitored personal health	14	13	1
****	2.53 Modular robotics	15	17	-2
****	2.40 “Material Radar”	16	15	1
****	2.99 Electronic money, time banks	17	23	-6
***	2.31 Effortless 3D imaging of parts	18	32	-14
****	2.09 Drugs that prevent dementia	19	16	3
****	2.32 Real-time 3D modeling of the environment	20	20	0
****	2.89 Rapidly charging light batteries and supercapacitors	21	18	-1
****	2.21 Interfaces reacting on movements	22	22	4
****	2.70 Robotic legs and the exoskeleton that reinforces movement	23	24	-1
****	2.74 Antibacterial and other dirt repellent materials and surfaces	24	19	5

		Global	Finland	Special Finnish focus
***	2.30 Pattern recognition and pattern search services	25	27	-2
***	2.04 Drugs based on genetically modified organisms	26	30	-4
***	2.54 A walking robot with hands	27	26	1
***	2.38 Cheap Lidar	28	35	-7
***	2.17 Automatic speech recognition and translation	29	34	-5
****	2.23 Interfaces based on feeling of touch	30	21	9
****	2.78 Cellulose nanofiber and –microfiber	31	25	6
***	2.14 Human recognition systems	32	31	1
***	2.39 Lenseless camera and image construction based on data analysis	33	28	5
***	2.47 Quadcopters	34	39	-5
***	2.16 Capturing and content searching of personal life	35	40	-5
***	2.15 Emotion management in robots and automatic recognition of emotions	36	42	-6
***	2.61 Sensitive robot fingers and hands capable of remote work	37	43	-6
***	2.71 Genetically modified organisms as producers of multi-use materials	38	38	-6
***	2.24 Large haptic screens	39	44	1
***	2.68 Artificial cell and simulating life on cell level	40	37	3
***	2.91 Solar heat and long-term storage of heat	41	36	-4
***	2.46 1 or 2 wheeled vehicles for personal or good traffic	42	45	6
***	2.52 Light continuously flying equipments	43	33	10
***	2.41 Cheap gas sensors	44	46	-2
**	2.26 Thoughts monitored from brain and action based on them	45	52	-7
***	2.36 Simulation and mapping of brain	46	48	-2
***	2.44 Graphene based terahertz devices	47	50	-3
***	2.29 Grid computing	48	49	-1
***	2.97 Wireless transmission 2.5 terabytes per second (vortex beam)	49	29	20
***	2.80 Ultralight and strong materials	50	41	9
***	2.90 Massive storage of energy in high capacity batteries	51	47	4

		Global	Finland	Special Finnish focus
**	2.25 Digital mirror	52	64	-12
**	2.60 Robotic surgery and other cutting of biological objects	53	53	0
**	2.93 Wireless electricity transmission (magnetism) for electric cars and other electrical devices	54	58	-4
**	2.06 Longer life time and slower aging processes	55	56	-1
**	2.51 CubeSat and other minisatellites	56	55	1
**	2.08 Brain implants that restore or develop brain functions	57	59	-2
**	2.83 Efficient and light solar panels	58	62	-4
**	2.35 Universal memory based on new materials and solutions	59	65	-6
**	2.27 Flexible and transparent screens using cheap materials	60	61	-1
**	2.87 Piezoelectrical energy sources, harvesting of kinetic energy	61	51	10
**	2.98 Multi-channel communication and software-based controlling of information networks	62	54	8
**	2.18 Crowd funding and micro finance	63	74	-11
**	2.57 3D printing of buildings	64	57	7
**	2.77 Nanocarbon as a reinforcement or as functional surface	65	60	5
**	2.34 Predictive analytics based on self-organizing data	66	67	-1
**	2.100 Internet for robots	67	68	-1
**	2.81 Spray-on textiles	68	73	-5
**	2.65 Artificial muscles	69	66	-6
**	2.86 Flying wind power and other new ways to produce wind energy	70	71	4
**	2.10 Repairing and regrowing of human organs, (stem) cell cultivation	71	75	-6
*	2.73 New building materials that replace reinforced concrete	72	77	-8
*	2.84 Artificial leaf and synthetic fuel from the sun light and carbon dioxide	73	80	2
**	2.85 The production of biofuels using enzymes, bacteria or algae	74	63	11
**	2.42 Very sensitive camera sensors based on nanocarbons	75	69	6
**	2.75 Carbon nanotube yarn or thread	76	70	6

		Global	Finland	Special Finnish focus
*	2.33 Self-organizing virtual world from the 3D data of the Internet	77	76	-1
*	2.03 Small portable magnetic resonance imaging scanner	78	78	2
**	2.58 3D and 4D printing of material	79	72	7
*	2.50 Magnetic or superconductor based levitation	80	83	-3
*	2.05 Nanorobots (nanobots) in the health promotion	81	79	2
*	2.96 LED "radio"	82	81	1
*	2.88 Serial production of small nuclear reactors, fission and fusion	83	82	1
*	2.63 Nanosurfaces that convert air moisture to water	84	87	-3
*	2.37 Quantum computers	85	88	-3
*	2.62 Robo-tailoring	86	90	-4
*	2.48 On-demand personal aviation services	87	84	3
*	2.76 Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons	88	85	3
*	2.64 Biobots	89	86	3
*	2.94 High-performance lasers, wireless power transfer, laser weapons	90	93	-3
*	2.67 DNA memory	91	95	-4
*	2.55 The cyber insect	92	91	1
*	2.92 Inexpensive storage of hydrogen in nanostructures	93	97	-4
*	2.66 Artificial, self-renewing skin	94	94	0
*	2.11 Synthetic cartilage in human joints	95	92	3
*	2.59 3D printing of organs	96	89	7
*	2.49 High-performance lasers, wireless power transfer, laser weapons	97	99	-2
*	2.69 In-vitro meat and meat-like plant protein	98	96	2
*	2.95 Nanoradio	99	98	1
*	2.79 Materials that levitate on nanolevel	100	100	0

Four-level model, TOP 100 – Finland

		Finland	Global
****	2.19 Open data and big data	1	2
****	2.13 Freely organizing remote work and organizations that form on the Internet	2	3
****	2.22 Glasses of augmented reality	3	4
****	2.20 Gamification	4	6
****	2.72 Extremely dense processors that take quantum phenomena into account	5	1
****	2.12 Schools in the cloud	6	5
****	2.45 Self-driving car	7	10
****	2.02 Biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms	8	7
****	2.56 3D printing of goods	9	9
****	2.28 Cloud computing	10	8
****	2.43 Printed cheap biosensors	11	13
****	2.82 Rapidly cheapening solar energy	12	11
****	2.07 Continuously monitored personal health	13	14
****	2.01 Routine and complete DNA sequencing	14	12
****	2.40 “Material Radar”	15	16
****	2.09 Drugs that prevent dementia	16	19
****	2.53 Modular robotics	17	15
****	2.89 Rapidly charging light batteries and supercapacitors	18	21
****	2.74 Antibacterial and other dirt repellent materials and surfaces	19	24
****	2.32 Real-time 3D modeling of the environment	20	20
****	2.23 Interfaces based on feeling of touch	21	30
****	2.21 Interfaces reacting on movements	22	22
****	2.99 Electronic money, time banks	23	17
****	2.70 Robotic legs and the exoskeleton that reinforces movement	24	23
****	2.78 Cellulose nanofiber and –microfiber	25	31
***	2.54 A walking robot with hands	26	27
***	2.30 Pattern recognition and pattern search services	27	25
***	2.39 Lenseless camera and image construction based on data analysis	28	33

		Finland	Global
***	2.97 Wireless transmission 2.5 terabytes per second (vortex beam)	29	49
***	2.04 Drugs based on genetically modified organisms	30	26
***	2.14 Human recognition systems	31	32
***	2.31 Effortless 3D imaging of parts	32	18
***	2.52 Light continuously flying equipments	33	43
***	2.17 Automatic speech recognition and translation	34	29
***	2.38 Cheap Lidar	35	28
***	2.91 Solar heat and long-term storage of heat	36	41
***	2.68 Artificial cell and simulating life on cell level	37	40
***	2.71 Genetically modified organisms as producers of multi-use materials	38	38
***	2.47 Quadcopters	39	34
***	2.16 Capturing and content searching of personal life	40	35
***	2.80 Ultralight and strong materials	41	50
***	2.15 Emotion management in robots and automatic recognition of emotions	42	36
***	2.61 Sensitive robot fingers and hands capable of remote work	43	37
***	2.24 Large haptic screens	44	39
***	2.46 1 or 2 wheeled vehicles for personal or good traffic	45	42
***	2.41 Cheap gas sensors	46	44
***	2.90 Massive storage of energy in high capacity batteries	47	51
***	2.36 Simulation and mapping of brain	48	46
***	2.29 Grid computing	49	48
***	2.44 Graphene based terahertz devices	50	47
**	2.87 Piezoelectrical energy sources, harvesting of kinetic energy	51	61
**	2.26 Thoughts monitored from brain and action based on them	52	45
**	2.60 Robotic surgery and other cutting of biological objects	53	53
**	2.98 Multi-channel communication and software-based controlling of information networks	54	62
**	2.51 CubeSat and other minisatellites	55	56
**	2.06 Longer life time and slower aging processes	56	55
**	2.57 3D printing of buildings	57	64

		Finland	Global
**	2.93 Wireless electricity transmission (magnetism) for electric cars and other electrical devices	58	54
**	2.08 Brain implants that restore or develop brain functions	59	57
**	2.77 Nanocarbon as a reinforcement or as functional surface	60	65
**	2.27 Flexible and transparent screens using cheap materials	61	60
**	2.83 Efficient and light solar panels	62	58
**	2.85 The production of biofuels using enzymes, bacteria or algae	63	74
**	2.25 Digital mirror	64	52
**	2.35 Universal memory based on new materials and solutions	65	59
**	2.65 Artificial muscles	66	69
**	2.34 Predictive analytics based on self-organizing data	67	66
**	2.100 Internet for robots	68	67
**	2.42 Very sensitive camera sensors based on nanocarbons	69	75
**	2.75 Carbon nanotube yarn or thread	70	76
**	2.86 Flying wind power and other new ways to produce wind energy	71	70
**	2.58 3D and 4D printing of material	72	79
**	2.81 Spray-on textiles	73	68
**	2.18 Crowd funding and micro finance	74	63
**	2.10 Repairing and regrowing of human organs, (stem) cell cultivation	75	71
*	2.33 Self-organizing virtual world from the 3D data of the Internet	76	77
*	2.73 New building materials that replace reinforced concrete	77	72
*	2.03 Small portable magnetic resonance imaging scanner	78	78
*	2.05 Nanorobots (nanobots) in the health promotion	79	81
*	2.84 Artificial leaf and synthetic fuel from the sun light and carbon dioxide	80	73
*	2.96 LED "radio"	81	82
*	2.88 Serial production of small nuclear reactors, fission and fusion	82	83
*	2.50 Magnetic or superconductor based levitation	83	80
*	2.48 On-demand personal aviation services	84	87
*	2.76 Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons	85	88

		Finland	Global
*	2.64 Biobots	86	89
*	2.63 Nanosurfaces that convert air moisture to water	87	84
*	2.37 Quantum computers	88	85
*	2.59 3D printing of organs	89	96
*	2.62 Robo-tailoring	90	86
*	2.55 The cyber insect	91	92
*	2.11 Synthetic cartilage in human joints	92	95
*	2.94 High-performance lasers, wireless power transfer, laser weapons	93	90
*	2.66 Artificial, self-renewing skin	94	94
*	2.67 DNA memory	95	91
*	2.69 In-vitro meat and meat-like plant protein	96	98
*	2.92 Inexpensive storage of hydrogen in nanostructures	97	93
*	2.95 Nanoradio	98	99
*	2.49 High-performance lasers, wireless power transfer, laser weapons	99	97
*	2.79 Materials that levitate on nanolevel	100	100

High and Low Special Priority Radical Technological Solutions (RTS) from the Finnish perspective

(if the difference 1 or 0, RTS is not mentioned with two exeptions)

	Radical technological solution	Finnish ranking	Global ranking	Finnish priority
***	2.97 Wireless transmission 2.5 terabytes per second (vortex beam)	29	49	20
**	2.85 The production of biofuels using enzymes, bacteria or algae	63	74	11
***	2.52 Light continuously flying equipments	33	43	10
**	2.87 Piezoelectrical energy sources, harvesting of kinetic energy	51	61	10
****	2.23 Interfaces based on feeling of touch	21	30	9
***	2.80 Ultralight and strong materials	41	50	9
**	2.98 Multi-channel communication and software-based controlling of information networks	54	62	8
**	2.57 3D printing of buildings	57	64	7

	Radical technological solution	Finnish ranking	Global ranking	Finnish priority
**	2.58 3D and 4D printing of material	72	79	7
*	2.59 3D printing of organs	89	96	7
****	2.78 Cellulose nanofiber and –microfiber	25	31	6
***	2.91 Solar heat and long-term storage of heat	36	42	6
**	2.42 Very sensitive camera sensors based on nanocarbons	69	75	6
**	2.75 Carbon nanotube yarn or thread	70	76	6
****	2.74 Antibacterial and other dirt repellent materials and surfaces	19	24	5
***	2.39 Lenseless camera and image construction based on data analysis	28	33	5
**	2.77 Nanocarbon as a reinforcement or as functional surface	60	65	5
****	2.89 Rapidly charging light batteries and supercapacitors	18	22	4
***	2.90 Massive storage of energy in high capacity batteries	47	51	4
**	2.65 Artificial muscles	66	70	4
****	2.45 Self-driving car	7	10	3
****	2.09 Drugs that prevent dementia	16	19	3
***	2.68 Artificial cell and simulating life on cell level	37	40	3
*	2.48 On-demand personal aviation services	84	87	3
*	2.76 Nanocarbons in salt or bacteria removal and other separation techniques based on nanocarbons	85	88	3
*	2.64 Biobots	86	89	3
*	2.11 Synthetic cartilage in human joints	92	95	3
****	2.20 Gamification	4	6	2
****	2.43 Printed cheap biosensors	11	13	2
**	2.86 Flying wind power and other new ways to produce wind energy	71	73	2
*	2.33 Self-organizing virtual world from the 3D data of the Internet	76	78	2
*	2.05 Nanorobots (nanobots) in the health promotion	79	81	2
*	2.69 In-vitro meat and meat-like plant protein	96	98	2
****	2.19 Open data and big data	1	2	1
*	2.03 Small portable magnetic resonance imaging scanner	78	77	-1
****	2.28 Cloud computing	10	8	-2

	Radical technological solution	Finnish ranking	Global ranking	Finnish priority
****	2.01 Routine and complete DNA sequencing	14	12	-2
****	2.53 Modular robotics	17	15	-2
***	2.30 Pattern recognition and pattern search services	27	25	-2
***	2.41 Cheap gas sensors	46	44	-2
***	2.36 Simulation and mapping of brain	48	46	-2
**	2.08 Brain implants that restore or develop brain functions	59	57	-2
*	2.49 High-performance lasers, wireless power transfer, laser weapons	99	97	-2
***	2.44 Graphene based terahertz devices	50	47	-3
*	2.50 Magnetic or superconductor based levitation	83	80	-3
*	2.63 Nanosurfaces that convert air moisture to water	87	84	-3
*	2.37 Quantum computers	88	85	-3
*	2.94 High-performance lasers, wireless power transfer, laser weapons	93	90	-3
****	2.72 Extremely dense processors that take quantum phenomena into account	5	1	-4
***	2.04 Drugs based on genetically modified organisms	30	26	-4
***	2.46 1 or 2 wheeled vehicles for personal or good traffic	45	41	-4
**	2.93 Wireless electricity transmission (magnetism) for electric cars and other electrical devices	58	54	-4
**	2.83 Efficient and light solar panels	62	58	-4
*	2.62 Robo-tailoring	90	86	-4
*	2.67 DNA memory	95	91	-4
*	2.92 Inexpensive storage of hydrogen in nanostructures	97	93	-4
***	2.17 Automatic speech recognition and translation	34	29	-5
***	2.47 Quadcopters	39	34	-5
***	2.16 Capturing and content searching of personal life	40	35	-5
**	2.81 Spray-on textiles	73	68	-5
****	2.99 Electronic money, time banks	23	17	-6
***	2.15 Emotion management in robots and automatic recognition of emotions	42	36	-6
***	2.61 Sensitive robot fingers and hands capable of remote work	43	37	-6

	Radical technological solution	Finnish ranking	Global ranking	Finnish priority
***	2.24 Large haptic screens	44	38	-6
**	2.35 Universal memory based on new materials and solutions	65	59	-6
**	2.10 Repairing and regrowing of human organs, (stem) cell cultivation	75	69	-6
*	2.73 New building materials that replace reinforced concrete	77	71	-6
***	2.38 Cheap Lidar	35	28	-7
**	2.26 Thoughts monitored from brain and action based on them	52	45	-7
*	2.84 Artificial leaf and synthetic fuel from the sun light and carbon dioxide	80	72	-8
**	2.18 Crowd funding and micro finance	74	63	-11
**	2.25 Digital mirror	64	52	-12
***	2.31 Effortless 3D imaging of parts	32	18	-14

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