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Technology as an enabler of sustainable well-being in the modern society

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Foreword

AS PART OF ITS WORK towards building a "Sustainable Well-being Society" the Finnish Innovation Fund Sitra has published a vision outlining the essential steps for leading a good life while remaining within the ecological boundaries of the planet. Sitra's efforts in building this vision have been based on intensive foresight, analysis and continual expert work, allowing the vision to be supplemented or renewed with new perspectives along the way.

In this report, Risto Linturi examines how technology development affects our vision: which technology trends support and enable sustainable well-being, and which trends threaten it? What are the roles of artificial intelligence, digitisation, biotechnology or nanomaterials in the pursuit of a sustainable future? How can society steer technological development in the desired directions?

Technology is so embedded in societal development that sometimes it is difficult to tell when technology development affects society or vice versa. In an open world, new technologies are present and spread throughout all societies, but the forms in which they manifest themselves differ between cultures. Accordingly, how technologies develop is not as essential as how societies use them.

As the author of this report emphasises, society can redirect its resources to support the development of technology, but it can also enable the adoption and spread of useful innovations, for example, by setting norms and standards, introducing incentives, investing in education, directing R&D funding and through communication.

In Finland, we tend to view ourselves as strong technology developers. Yet, only versatile and open-minded use of new technologies will enable us to prosper in the future too.

In order to be able to influence the technological developments made by a wide variety of decentralised actors, a shared direction – a vision – and co-ordination is needed. As a future-oriented organisation Sitra aims to strengthen societal debate on the future. Through its vision for a Sustainable Well-being Society it also aims to define the building blocks needed for a shared direction in society. Yet, as this report makes clear in relation to technology development, Sitra also wishes to test, challenge and refine its vision against important global development trends.

23 September 2015, Helsinki,

Eeva Hellström
Senior Lead, Strategy
Finnish Innovation Fund Sitra


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BAR
KELLOHALLI
LAPIN KULTA

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Executive summary

TECHNOLOGICAL PROGRESS has had a profound impact on our culture and economy throughout the whole of human history. Social and societal structures, even our values, have been affected by technological development. The impact varies from one area to another as different bases of social power and economic readiness create different dynamics within each culture.

Technological progress is escalating. The numbers of new scientific publications, references and patents are growing exponentially. Studies reveal an increase in the number of professions, businesses and public services that may soon become obsolete through this development. There is a growing urgency to understand this change, its threats, opportunities, and their inherent dynamism alike.

Society normally slows down adaptation of new technologies. Regulations might define how certain processes must be conducted and leave no room for innovative new technologies. Often the effect is more indirect and due to the systemic and interconnected nature of technology realms. Societal transition to new technologies commonly requires alterations in the respective technology regimes. Policy changes may also be required to solve chicken-and-egg-type diffusion problems even when there are no clear regulatory issues to be solved.

The majority of contemporary technological progress can be shown to fall under the following 10 titles: virtualisation and digitisation of data; artificial intelligence; instrumentation of everything; robotised transport and logistics; robotised production and services; nanomaterials; biotechnology and pharmacology; energy technology; digital crowd platforms; and globalisation of ICT structures. All these are advancing swiftly and are expected to have major societal impacts.

Sustainability and well-being are major contemporary challenges in Western countries. In its vision paper, Towards a Sustainable Well-being Society, Sitra promotes six principles and four example areas reflecting how ways of thinking and doing must change in Western countries. These principles and example areas have been used as a framework in this study to show how deeply short-term technology progress can affect the important goals and principles of our well-being and global sustainability.

When the sustainable well-being principles and their examples are considered jointly with the 10 key technologies, it becomes self-evident that many of the threats can be avoided and many opportunities pursued. Due to the dynamism of technology realms, the new practices are most malleable when new technologies emerge. Early adapters can steer the practices to their benefit and to the benefit of the whole of society through the principles of sustainable well-being. Businesses and policymakers will need to understand technology and embrace it rapidly in order to avoid being drowned by it.

Technological progress is escalating. The numbers of new scientific publications, references and patents are growing exponentially. There is a growing urgency to understand this change, its threats, opportunities, and their inherent dynamism alike.

1. Introduction: Technology and Society

1.1 Technological progress impacts societal development

The relationship between technological development and society is bi-directional. Our economic needs, cultural and individual values, organisational structures and educational practices all have influence on how we develop and utilise new technologies. Simultaneously however, each available and useful technology shapes our values, economies, organisations and education. Technological development is not in any way predetermined to yield optimal solutions for the society. There is a strong path dependency inherent in it that resembles biological evolution even if we forget the opportunistic tendencies of human individuals and their organisations. Development strives towards local maxima and the order in which innovations appear and the form in which society adapts to them determines the landscape and feasibility of the next steps.

Through technological progress, individuals become more capable of fulfilling their desires. Organisations must adapt to the empowered individual, but also to competing organisations. Individuals need to be educated, regulations and practices changed and motivational rewards rethought if we wish society overall to benefit from technological progress. In order to manage this challenge, it is important to understand the problems that we are facing today and equally important to understand what possibilities are open to us tomorrow. New tools become available that help solve existing problems. New problems also arise through suboptimal uses of new technology. Interventions are most effective when emerging technologies are in labile stages and their inertia is low. We need to use foresight in order to steer technological development and adaptation. We also need to understand what our options are related to what we consider beneficial to our society.

We can see a clear trend. Complexity has grown continuously throughout the evolutionary history of life and human history, excepting a few global catastrophes[1]. In socioeconomic terms this can be interpreted as increasing collaboration, growth in the volume and complexity of specialisation and exchange. This increasing collaboration seems to organise itself in a layered and modular fashion utilising autopoiesis and other copying mechanisms.

Many of the modular behaviours that social animals and especially human societies give rise to can be attributed to the use of social power. These social or societal structures are generally enabled and affected by technological development. This ongoing dynamism can be seen throughout history. One needs only to think about inventions and innovations such as farming, iron, navigation, the taming of horses, money, gunpowder, machine power, electricity, container shipping and computers. All of these inventions have fundamentally changed the way we organise our societies, businesses or our everyday lives and what inherent weaknesses our societies contain[2].

Complexity has grown continuously throughout the human history.

[1] Kauffman 1995; Wright 2000; Mithen 2004; Carroll 2007; Durkheim 1997
[2] Mann 1986; Wright 2000; Diamond et al. 1998; Diamond 2005; Beattie 2010

One might think that changes in culture and human values are independent of technological change. This is true only in the most limited sense. Technology does not completely determine our values. However, as technology enables new forms of means to ends, and as the sacrifices needed for each of the ends changes, so do our priorities and the relative order of our values. It is also common that means in organisations and cultures often become ends in themselves. Thus we get accustomed to giving value to those means that are useful for us and remain doing so even when those means no longer help us in attaining what might be considered our terminal ends. The growth in complexity through specialisation and exchange can by itself be shown to change our values[3].

Adam Smith showed great insight when he discarded money as the absolute value of things. He said instead: "The real price of everything, what everything really costs to the man who wants to acquire it, is the toil and trouble of acquiring it. What everything is really worth to the man who has acquired it, and who wants to dispose of it or exchange it for something else, is the toil and trouble which it can save to himself, and which it can impose upon other people"[4]. When we consider this statement, we see clearly how new tools and knowledge modify the "toil and trouble" that according to Adam Smith defines individual valuations. The needs, or more precisely the wants themselves, modified by cultures and power structures besides being based on human nature.

Most of our endeavours are but means to ends. As possession or ownership is a form of power over things and other people, power structures are very relevant to the means that are required to fulfil our needs. Power over other people comes in many forms and arises from different sources. Michael Mann divides this so-called social power into four categories: military power, ideological power, political power and economic power, and in his life's work he describes the emergence of each power structure related to the appearance of each new technology throughout human history. The impact of each new technology is different for each of these power bases. Differing power structures create differing dynamics in each culture, in spite of technology breakthroughs globally[5].

It is difficult to measure the growth of knowledge and complexity in our society. It has been claimed that the economy is becoming more volatile, interconnectedness and social networks now give rise to more nonlinear development than has ever been seen during human history[6]. The accumulation of knowledge seems however to be accelerating. It may be assumed that scientific knowledge somehow corresponds to it. Researchers have tried to estimate the growth in scientific knowledge and several studies indicate that the growth remains exponential and the volume of new scientific publications and references grow nearly 5 % yearly. Some studies have indicated a slowdown of this growth but they have erred in studying only traditional sciences or traditional science databases when it seems that majority of growth has happened in new fields and new science databases. The number of applied patents is also growing exponentially, indicating a correlation between scientific and technological complexity[7].

In their study, 100 Opportunities for Finland and the World[8], the authors foresee various technology-driven changes. The potential changes are grouped into 20 global value-producing networks and these value-producing networks are used to evaluate the presented 100 radical technologies based on their potential impact and the probability of their economic success in each value-producing network. Various other sources describe continuous technological advancements that have a major potential impact on our societies. There is constant discussion on how technological development enables new business models that may destroy old professions and challenge major established companies[9].

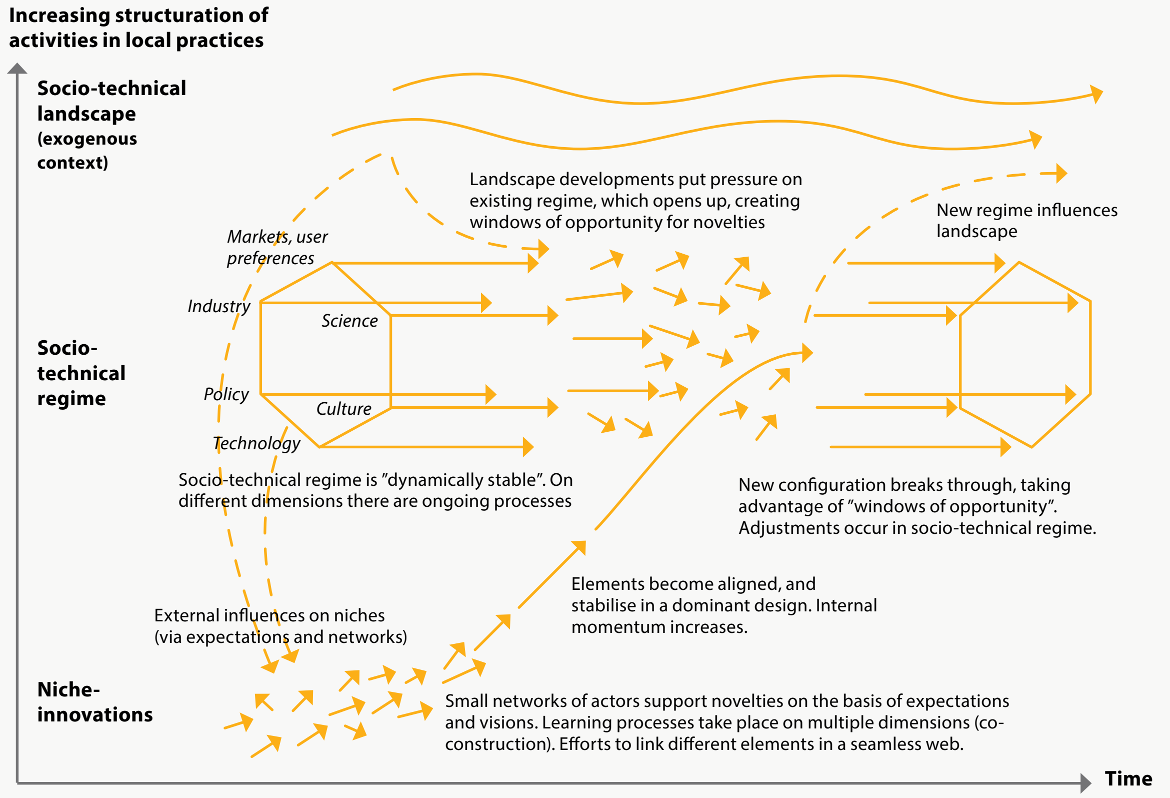
1.2 Socio-technical regimes; influencing technological development

If society does not adapt to new technology, it soon falls behind other societies that are more nimble. Productivity and well-being depend on using the correct tools to accomplish what we wish to be done. A society can increase its productivity briefly without renewing the technology it uses, but in the longer term this is not possible. Society however inevitably slows down the diffusion of new technologies because the laws, practices, education and values adapt to the existing mainstream technologies. New technologies face a hurdle and society can do much to speed up and steer emerging technologies especially in countries that are among the first to adapt and support new technologies. Later the inertia becomes greater.

The main concern of innovation theory is inertia. This is especially true when we talk about the diffusion of innovations. Many existing structures or attitudes slow down adaptation of both useful and useless inventions.

[3] Durkheim 1997; Ainslie 2001; Ariely 2009; Damasio 2003; Douglas 1966; Fukuyama 1999; Granovetter 1985; Lyons 2009; Mann 1986; Meier 2011; Urry 2000
[4] Smith 1776
[5] Mann 1986 1993; Lal 2006; Brand 2010; Bronowski and Mazlish 1975; Castells 1997, 2000a, 2000b; Friedman 1999; Lakoff 2006; Rheingold 2002; Simon 1997; Stiglitz 2002; Tahoor 2007; Tuomi 2002; Turkki 2009; Uzzi 1996; Vincent 2006
[6] Taleb 2007; Barabasi 2002; Tapscott and Williams 2008
[7] Larsen and Ins 2010; Kirshin 2014; Bornmann and Mutz 2015; WIPO 2014
[8] Linturi, Kuusi and Ahlqvist 2014
[9] Linturi, Kuusi and Ahlqvist 2014; Halal 2008; National Intelligence Council 2012

Figure 1. Illustration describing the role and change of socio-technical regime (Geels 2011)



The market by itself is usually incapable of radical change unless the incumbent companies become somehow vulnerable or motivated from the outside to drive paradigm changes. Even then, they generally succeed only in creating such new growth platforms where they have key competences from their earlier businesses[10].

Frank Geels (2011) has in his work concentrated in defining the realms that create coherence among systemic innovations. We can for example think about cars. They need roads, traffic regulations, petrol stations, a car manufacturing industry, driving tutoring, maps, road signs and provisions for pedestrians, parking and policing, among many other things. This socio-technical regime makes it difficult to gain acceptance even for relatively minor modifications like using an electric engine instead of a petrol engine to power the car.

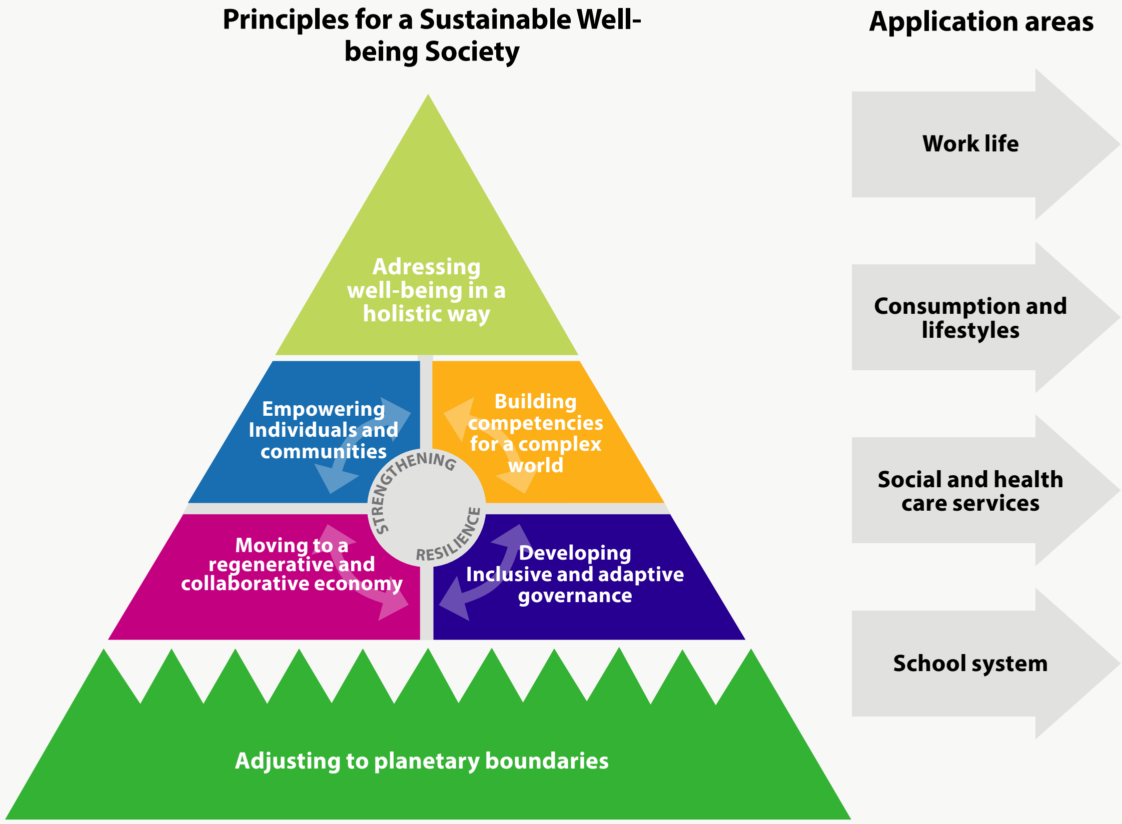
The dimensions of a socio-technical regime include policy, science, culture, technology, industry, markets and user preference. Tools that policymakers can use to influence socio-technical regimes are numerous. Regulations can be changed concerning the use, production and sales of technological devices, education policies can be changed, public funding of R&D can be initiated, government procurement can be progressive, public institutions can also encourage cultural and informational promotion of new technologies[11].

1.3 Purpose of the paper: Developing technologies for Sustainable Well-being Societies

Measured in terms of economic development and social justice, the model of Western welfare states has been one of the most successful societal models in the world. Many welfare states are now going through a historical transformation due to challenges that reflect a deep and long-term structural crisis of the 20th-century societal paradigm.

[10] Schumpeter 1942; Rogers 2003; Christenssen 2004; Laurie, Doz and Sheer 2006
[11] Geels 2011

Figure 2. Vision for a Sustainable Well-being Society (Hellström et al. 2015)



The Finnish Innovation Fund Sitra has published a working paper, Towards a Sustainable Well-being Society[12] calling for visionary thinking in order to find the new course for Western societies. The main challenges relate to public spending, required economic restructuring and adaptation to climate change. The vision aims to address how well-being needs have evolved and how the widening economic inequalities and diminishing social cohesion will be addressed.

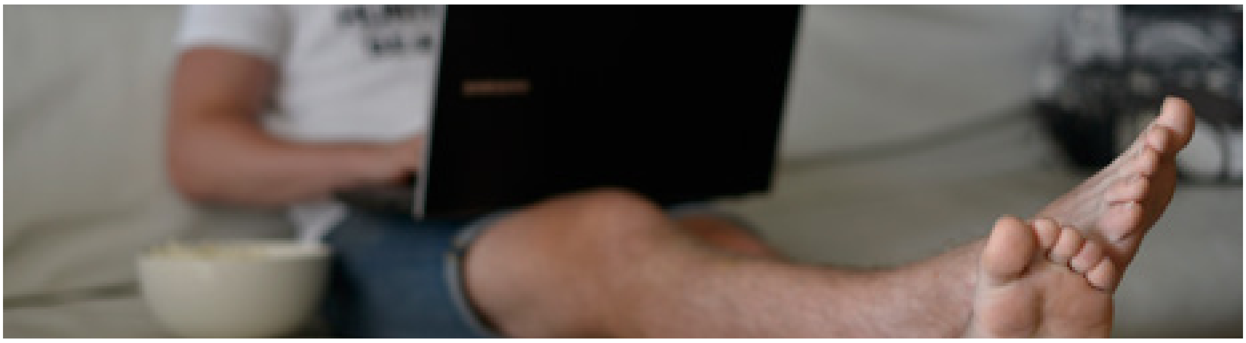
The working paper presents a vision containing six principles (Figure 2), which derive partly from the Bruntland Commission's work and which required such sustainable development that meets the present needs without compromising the ability of future generations to meet their own needs. Sitra's vision aims to lay out the present and future needs in order to evaluate how to meet them sustainably.

In addition to the principles, the working paper describes the potential effects of applying all the six principles simultaneously to four example areas of society and life. These are the work life, consumption habits and lifestyles, social and healthcare services and the school system (Figure 2).

As the previous chapters explained, technology development influences societal development in many fundamental ways. Accordingly, Chapter 1 drew general outlines of how technological development affects our societies and how society itself moderates and directs technological development. Next, this study describes 10 rapidly progressing realms of technology and their potential impact on society. Technological impact is first analysed from a technological viewpoint (Chapter 2). Observed threats and opportunities of these technologies are then further considered from the key viewpoints of the six principles of sustainable well-being and the selected application areas outlined in Sitra's vision paper (Chapter 3). The analysis aims to show how deeply the success in taking the selected principles into account depends on our understanding of the opportunities and threats that technological development brings forth. Finally, in Chapter 4, the findings are summarised, and discussed.

[12] Hellström et al. 2015

2. Key technology drivers



THIS CHAPTER DESCRIBES 10 technology realms which are in rapid development. The categories are selected to make the description of the technologies and their societal impacts as little redundant as possible while maintaining easily understandable characterisation. Practical technology often includes components of many of these categories. The comprehensiveness of this listing has been tested through comparing other studies that list emerging technologies, but naturally no list of future technologies and their impacts can be comprehensive. Source references are not mentioned in detail. The technologies referred to here are described in several documents and sites where hundreds of further references are given[13].

2.1 Virtualisation and digitisation of data

Throughout history, people have used words and pictures to transfer information, but we have not been able to produce communication that would easily simulate the reality. It has recently become common that we talk to each other from wherever we are and send our pictures or even videos to almost anyone via our mobile phones and post them on social media. But pictures or videos fall short of the real experience of being there. Since the 1970s visionary people have talked about virtual and augmented reality and some cumbersome products have emerged. Now Microsoft, Samsung, Facebook and Google have announced products and product platforms that enable 3D virtual reality and augmented reality experience. Testers agree that this can change the way we use computers and communications. Virtual reality feels like being in the place that one views.

Augmented reality allows computers to recognise what appears in one's natural field of vision and enables adding virtual objects to one's field of vision so that they appear realistic in three dimensions. Virtual reality facilitates easy interaction with remote tools like remote surgery robots, but also makes possible very realistic cultural and gaming experiences and telepresence. It also allows simpler features like virtual labels, direction pointers and other information from databases or computer heuristics added to things that one needs to use.

The first consumer-level devices in both categories have been brought to the market and the R&D efforts are increasing. Microsoft is promoting its Hololens to the media and seems to be readying itself for production. Google recently invested 500 million dollars in Magic Leap. Product demonstrations are enticing. Virtual reality and augmented reality glasses are not the only things being developed; haptic devices enable remote touching experiences. There are several technologies being developed, but few useful applications until virtual reality or augmented reality glasses are widely available.

Simultaneously with these virtual senses, tools that enable scanning our environment in detail and tools that are easier than ever for creating 3D models of our physical and imaginary surroundings are being developed. Within a few years it seems that materials and structural forms will be scanned in real time with consumer-level devices will allow realistic telepresence with touch and 3D vision. The augmented and virtual reality market is estimated to grow to 150 billion dollars by 2020, according to the market advisor Digi-Capital.

[13] The main sources used for this chapter are Linturi, Kuusi and Ahlqvist 2014; and Linturi and Kuittinen 2014. Additional sources are given as examples when they are considered useful extensions of the text to the reader.

Further reading and examples

- Article by Dean Takahashi describing the market estimate for virtual reality and augmented reality devices: http://venturebeat.com/2015/04/06/augmented-and-virtual-reality-to-grow-to-150b-by-2020-forecaster-says/
- Marketing video illustrating the use of Magic Leap augmented reality glasses: https://www.youtube.com/watch?v=kPMHcanq0xM
- Marketing video illustrating the use of Microsoft Hololens augmented reality glasses: https://www.youtube.com/watch?v=aThCr0PsyuA

Key impacts on societal development. Our physical world has a digital representation through geographic information systems (GIS). This data is constantly being enhanced and moved online combining it with detailed 3D models of our world. Sensors, embedded in our mobile phones, our vehicles and drones, feed real-time data to online databases continuously. All information about our physical world becomes remotely accessible. This remote access allows work to be organised independent of the user's whereabouts. Meetings, personal services, tutelage and computer-aided learning are among things whose online quality is greatly enhanced by this rich available data.

Augmented reality can easily add information to our vision helping us understand our surrounding environment and find what we are searching for, whether we do it remotely or physically. Online shopping also becomes easier than ever. Many tourist attractions and cultural experiences become available without travel. The economic value in these kinds of platforms may be distributed or concentrated depending on the commercial models that become popular, the competitive situation and regulations locally and globally. In the cloud services realm, if some actor gets people to contribute their information for others to view and consolidation of the information adds value, the winner often gains major market power.

Problems can be caused by the division of people into those mainly identifying themselves through spaces of flows and those connected mentally and physically to spaces of places[14]. Income differences between different areas will decrease while, within each area, these differences may increase because of this development. Transparency and productivity will increase, but only after major structural changes have taken place. Diffusion starts from games and professional applications, soon spreading to hobbyists, entertainment, education and everyday usage.

[14] Castells 2000a

2.2 Artificial intelligence

Throughout their history, computers have mainly been used to perform well-understood calculations, data storage and retrieval, classification and presentation of data. Today, computers are increasingly being asked to recognise patterns or shapes, make selections, decide or evaluate subject matters and predict probable outcomes of actions. Computers make stock market decisions based on press releases, select items for users to view based on their previous preferences, drive cars, find probable causes for diseases, reveal stolen credit cards and predict the weather.

Through 3D modelling, computers are becoming better and better at recognising objects in the physical world. They can also evaluate human behaviour in certain situations better than the average human. Simultaneous interpretation from speech between major languages is now adequate in many situations. Computers have surpassed humans in many cases. A good example is how computer software was able to learn dozens of video arcade games by itself and play them better than experienced humans. Computers also already play certain poker games better than human players. Learning algorithms allows computers to learn new skills. Big data and open data give them access to information in such volumes and at such speed that humans cannot compete. Computer chips are being developed specifically in order to perform well in those tasks that have previously been only handled by human brains.

Learning algorithms allows computers to learn new skills. Big data and open data give them access to information in such volumes and at such speed that humans cannot compete.

Further reading and examples

- Promotional material by IBM describing the methods used in their artificial intelligence product named Watson and its initial applications: http://www.ibm.com/smarterplanet/us/en/ibmwatson/what-is-watson.html
- A study by Youyou et al. showing that computer based personality judgements can be more accurate than those done by humans: http://www.pnas.org/content/112/4/1036.abstract
- Description by Microsoft Research on their machine translation research and applications: http://research.microsoft.com/en-us/projects/mt/

Key impacts on societal development. The most immediate result of increasing artificial intelligence is the automation of more and more tasks that were previously performed by humans. These include all kinds of work where people handle data. Many jobs do not get totally removed but less work is required. With the help of artificial intelligence, one person can handle the job that previously required several people. Computers take care of the easy tasks. This reduction of needed labour includes doctors, lawyers and stockbrokers, to name a few, and does not limit itself only to simple tasks. Artificial intelligence also assists in removing many blue collar tasks. Examples include many tasks in mining, logistics and manufacturing that were previously too difficult to automate. Simultaneously, as artificial intelligence destroys current jobs, it increases productivity and make new tasks profitable. New methods can greatly increase the volume of knowledge that can be economically processed. This makes new products and services possible and empowers those who have access to the required data and software. Even though new jobs will be created, structural unemployment and increasing income differences may result. Local structural rigidities and slow and passive adaptation will hinder the creation of new jobs while global competition will remove many current jobs independent of local decisions. Temporary and individual-level problems seem inevitable. Simultaneously, tech-savvy individuals become greatly empowered, productivity rises in small groups and the productivity gap between traditional and new ways of doing things increases.

2.3 Instrumentation of everything

Modern laboratories are quite capable of analysing materials and their weaknesses, testing blood samples for viruses or drugs, foodstuffs for bacteria or crime sites for DNA identification. Astronomers can deduce molecular structures of astral matter from the light that arrives to their lenses from hundreds of light years away. Now these capabilities are becoming cheap enough for consumer devices. We can even buy robotic vacuum cleaners that create 3D models of their surroundings with laser radars for careful, systematic navigation. Soon we will be able to purchase handheld devices that perform DNA analysis, or spectroscopes integrated into our mobile phones that analyse material composition of stuff that we hold in front of them. All this instrumentation will become mass-marketed and very cheap. It can be embedded in our environment or integrated to our mobile devices. The plentiful production of information enables us to design our processes, devices and structures quite differently from how we have acted before and makes many existing behaviours obsolete.

Further reading and examples

- Promotional video of SCIO, the consumer-level spectroscope: https://www.youtube.com/watch?v=ejl6gGgR9_g&t=59
- Marie Freebody's article on the potential of terahertz spectroscopy: http://www.photonics.com/Article.aspx?AID=56212
- Promotional material of a handheld DNA-analyser: http://www.quantumdx.com/devices.html
- Article describing 10 medical iPhone applications: http://internetmedicine.com/2012/12/14/top-ten-medical-uses-of-the-iphone/
- Overview by X Prize Foundation on their Tricorder competition: http://tricorder.xprize.org/about/overview

Key impacts on societal development. When sensory equipment becomes cheap, it effectively empowers the citizen, who becomes capable of laboratory-level analysis of indoor air quality, food, biometrics, DNA of other people, materials and their weaknesses, and also able to scan and automatically recognise events and patterns in their environment. This may result in huge increases of data volumes in collaborative user-supported databases. This will also limit privacy in many ways. Awareness of the environmental impact of our behaviour grows and consumption habits change.

2.4 Robotised transport and logistics

With the help of container shipping, ports have mostly been automated. This has greatly increased global trade and reduced overseas transaction costs. Employee wages in ships and trains are but a small portion when compared to the cost of transported goods or number of transported people. For road traffic the situation is different and driver cost forms a much higher percentage of all costs. When all driving is included, the numbers become staggering. In Finland people spend around one billion hours a year driving their vehicles. Major firms within the automobile industry and ICT industry have announced plans and demonstrated capabilities for driverless cars. Some driverless vehicles with limited capabilities are already on the market. Much of the scheduled transportation service on fixed routes could technically be driverless already by 2020. First, however, robotic assistance in preventing driver mistakes will cut down the number of accidents. By the early 2020s, many new cars will be able to drive by themselves to and from destinations if the routes are mapped in detail. By 2030 this will be routine.

Besides driverless cars, aerial drones such as quadcopters will develop rapidly. Drones are currently used mainly for aerial photography and military purposes. There are widespread experiments to use drones also for farming and logistics purposes and even for assembly work. The greatest limitation currently facing small drones is the small capacity of lightweight batteries. It seems however already practical to use drones when delivering small packages over distances ranging from hundreds of metres to tens of kilometres.

Besides driverless cars and quadcopters, other developments in logistics include robotic containers, robotic manipulative arms and two- or four-legged robots that can move on uneven terrain and stairs. In all these areas, robotisation appears to be developing quickly. Jointly, these developments enable fully a robotised logistics chain from door to door. Emerging major global interest in creating standards for the internet of things, and for accomplishing robotised logistics capabilities from door to door globally, may greatly speed up this development.

Further reading and examples

- Article by Felicity Capon describing the British testing of driverless vehicles: http://www.newsweek.com/green-light-tests-driverless-cars-britains-roads-306178
- A video illustrating Lockheed Martin's driverless vehicle projects and military applications: https://www.youtube.com/watch?v=NmwXy97CN8Q
- A report by DHL describing the potential of driverless vehicles in logistics: http://www.dhl.com/en/about_us/logistics_insights/dhl_trend_research/self_driving_vehicles.html

Key impacts on societal development. The robotisation of the logistics chain lessens the need for homogenous containers, therefore also lessening the economy of large stores. Heterogeneous packaging becomes cost efficient, as does the repackaging of containers. This reduces the economy of scale and adds to the long tail effect, which was initially enabled through online shopping and pull-type marketing. Even small manufacturers and marginal products can enter the global market and stay there without prohibitive marketing costs. Online shopping with home delivery becomes cheaper still. Instead of megatrends, microtrends[15] may become equally important as a larger-than-before share of profits will come from smaller production runs.

Through driverless cars, mobility becomes democratised. Mobility may become a service for most people and owning a car may no longer increase personal freedom or mobility. The number of cars can be reduced greatly, especially in Western countries where cars are very inefficiently used. In Finland one third of existing cars would be sufficient to provide immediate availability of cars, even during rush hours, if cars were robotised and provided as a service. Finnish car-related costs would thus be halved while increasing robotised mobility services. Driverless cars and robotised logistics will affect trade, urban environment and topology. Mobile robotised vehicles may also have major military consequences.

Mobility may become a service for most people and owning a car may no longer increase personal freedom or mobility.

[15] Penn 2007

2.5 Robotised production and services

Flexible, robotised production lines became common in the electronics industry in 1990s. This enabled small design-oriented firms to gain easy entry to product markets. For existing production companies it made decentralised production economically feasible in sites that are close to each specific market.

Today the price of automated production tools continues to decrease and their flexibility continues to increase. 3D printers are becoming more and more capable of producing all sorts of parts and devices for almost all industry sectors and all consumer segments, including medical field, construction, aeronautics, toys, etc. 3D printers are now able to print objects from most metals and industrial plastics, carbon filaments, numerous composites, ceramics and even biomaterials. Production speeds and prices are becoming competitive with earlier practices in several fields and they allow for high individualisation.

Robotisation enables services that are either fully automated or remotely operated. One driver could operate several snow ploughs or trucks, while taking personal care of only the non-trivial parts of the machines' operation. One operator could also service a large number of maintenance sites, if a remotely controlled maintenance robot were available in each site. The US Food and Drug Administration (FDA) has already allowed the use of a telepresence robot so that a doctor can do bedside visits and perform some tests remotely. This allows immediate specialist visits when needed and saves much transfer time, especially in rural areas.

Further reading and examples

- An article by Lucas Mearian covering HP's plans to enter the 3D printer market: http://www.computerworld.com/article/2841414/hps-move-into-3d-printing-will-radically-change-manufacturing.html
- An article by Hannah Devlin describing new, accurate and extremely fast 3D printing technology: http://www.theguardian.com/science/2015/mar/19/scientists-create-terminator-2-inspired-3d-printer
- A video illustrating a robotic snow plough: https://www.youtube.com/watch?v=tPg1ZMiC9pA
- A video illustrating the capabilities of Honda's Asimo robot: https://www.youtube.com/watch?v=FShZddlsjkA

Key impacts on societal development. As the maintenance and production of rare items become cheaper through 3D printing, this aids the long tail effect. Product versatility will grow. As production becomes more and more flexible and automated, production facilities come closer to the customer. Many future products will be made by specialist shops and services using 3D printing and other robotised production tools. Current industrial practices with mass production, shipping to warehouses and distribution through delivery channels will suffer. Some technically easy products will be made by consumers themselves or hobbyists. The increasing flexibility of 3D printing and robotics will cause the lessening of international specialisation and decrease physical trade between countries. It will also cause a reduction in hierarchies and possibly also the lowering of income differences. Intellectual property rights become more difficult to control as the world becomes filled with 3D copy machines. Work becomes more holistic and meaning-driven, the economy more turbulent, and in many cases production will have near-zero marginal costs. This all encourages a sharing economy.

Peer production may become commonplace in physical production and instrumentation. Social commons may become important in this area. Wikipedia-like effort might bring about free production recipes or printable 3D models for all common 3D printable things. Peer production models could then easily create these things locally. There are already hundreds of thousands of free 3D models available online. Within the next decade we may see hundreds of millions of free or almost free printable 3D models and other data that enables robotic production of useful objects.

Controlling robots remotely may have various effects on how we work, where we live and how we fight our wars. These effects add to complexity, may strengthen globalisation of many services and support the economies of scale, contradicting the trend in physical production expected to arise from flexible robotised manufacturing.

2.6 Nanomaterials

The invention of plastics changed many industries. There are new materials brewing in scientific laboratories that have the potential to cause much greater change to industry and even to our everyday lives compared to the changes plastic brought about. We might even imagine as big a change as that brought about by iron or electricity. Graphene was first isolated in 2003 and it now has over 20 characteristics by which it can be considered as a super material. Graphene is almost two orders of magnitude stronger than steel, electrically and optically active and consists of carbon only. It has potential uses in almost all industries including electronics, optics, processing, manufacturing, construction, medicine, energy and food.

Fewer than a thousand tons of graphene are now being produced annually, but new production lines are emerging quickly and new cheaper production methods are published constantly. As the raw material of graphene is carbon or carbon dioxide with almost unlimited supply, and the potential uses seem without limit, R&D interest is immense. New potential applications for graphene derivatives are invented and published almost weekly.

Other carbon-based materials besides graphene, such as carbon nanotubes, continue to show important potential in electronics and for use as extremely strong and light materials.

Nanocellulose is another promising material. Some forms of nanocellulose are extremely strong and comparable to Kevlar, for example. Other forms are more easily manufactured from cellulose and can be used to produce plastics, textiles and composites for various uses. Nanocellulose can be used to replace several widely used materials like cotton, whose production has severe environmental side-effects.

There are a large number of nanomaterials which have electrical, optical, or medical uses, that increase energy efficiency, self-clean or otherwise benefit the end products that utilise them.

Individual biometrics and home farming may change consumer behaviour.

Further reading and examples

- An article by Katherine Noyes analysing the business potential of graphene: http://fortune.com/2014/05/12/the-business-potential-of-amazing-wonderful-futuristic-graphene/
- Wikipedia article describing nanocellulose: http://en.wikipedia.org/wiki/Nanocellulose
- A collection, edited by Earl Boysen, describing several promising nanomaterial applications: http://www.understandingnano.com/nanomaterials.html

Key impacts on societal development. Due to the large number of new materials that have both extraordinary characteristics and potential for high volumes, challenging times can be seen ahead for several different industries. New materials could possibly replace major existing materials such as metal and plastic. This would lead to a turbulent transfer from products based on existing materials to new products using new materials in several industry sectors. There is potential for a major impact on industries including packaging, textiles, plastics, concrete, steel, other metals, electronics, optics, etc. Due to the materials having extraordinarily flexible characteristics, this is not just a question of one material replacing another, but instead the new materials may lead to totally new possibilities in products that could not have been realised using conventional materials. The change brought about by these new materials may equal the change brought about by iron and electricity together. The transition may take two or three decades before it begins to shake whole industries. Already now however, graphene is enabling the development of products that surpass their predecessors.

2.7 Biotechnology and pharmacology

Our whole existence is based on the cultivation of plants. As a result of increasing populations and higher protein consumption we must continuously find new and more productive plants and farming methods, since we can no longer expand the farming area. Biological products are also utilised for various purposes other than food, including chemical processes, textiles, medicine, manufacturing and construction. All these uses benefit from different characteristics of our ecosystem, which could be enhanced by mutations. Genetic manipulation is becoming easier and more precise than ever. Computer simulation of cellular metabolism enables all kinds of virtual tests and even the simulation of specific DNA sequences and their effects on the ecosystem. Simulating the effects of synthetic DNA at the cellular level and in specific environmental conditions is a first careful step in constructing completely synthetic life. It is a step presently being taken by the world famous geneticist Craig Venter's team.

DNA can be designed and produced precisely and the metabolism of cells with specific DNA can be predicted with increasing accuracy and tested in simulation before real-life experiments. Viruses can also be extremely useful in biotechnology. Professor Angela Belcher's team at the Massachusetts Institute of Technology has been able to direct viruses to produce functioning solar panels and batteries. This has required no other intervention other than the mixing of viruses and appropriate chemicals together and sending biological messages to the viruses to change their coding for each specific layer to be produced. It can be said that the viruses have become programmable production tools. Biotechnology now allows, both in theory and in practice, the production of very strong and delicate materials and complex devices, at room temperature with very low energy consumption.

Plants contain very valuable chemical substances and various filtration methods have been developed to separate those substances from things like wood pulp. Farming methods are facing changes too. Developments in energy technology have opened possibilities for indoor farming with artificial lighting. LED lights are quite efficient and if they use only the most optimal frequencies and target light at only the leaves at the most optimal intervals, the energy required for artificial lighting does not exceed what can be captured from the same area with high efficiency solar panels. The water consumption is radically lowered, heating costs are non-existent and production does not cause pollution of the environment.

It is becoming more and more probable that most major illnesses could be cured and the healthy human lifespan could be lengthened by tens of years. Currently, the only crucial and positive clinical proof from longevity research is from experiments on mice, but the ageing mechanisms are somewhat similar and many of the experiments seem promising. Personalised medicine and nutrition can also bring major benefits when individual DNA sequence and cell level metabolism information is available, and when cell simulators are tuned to individual DNA. Pharmacology also changes when a full map of cell signalling is available.

Further reading and examples

- Wikipedia article on the first synthetic genome: http://en.wikipedia.org/wiki/Mycoplasma_genitalium
- TED talk by Angela Belcher on making viruses build things: http://www.ted.com/talks/angela_belcher_using_nature_to_grow_batteries
- Monica Kim's article featuring an indoor, LED-illuminated salad farm: http://modernfarmer.com/2014/12/salad-inc/
- An article by George Dvorsky describing current results and expectations of longevity research: http://io9.com/do-these-startling-animal-studies-mean-your-lifespan-co-486041314

Key impacts on societal development. Increased complexity will lead to the restructuring of the food industry. With instrumentation and artificial intelligence, it is possible that many households could start farming their own food indoors in the future. Individual biometrics and home farming may change consumer behaviour. Due to forthcoming cheap solar electricity and increased turbulence from climate change, indoor farming probably will become more popular also in the food industry. In Finland, indoor farming can take place underground, where heating cost is minimal.

A major change in behaviour may take place when individual DNA and cell level metabolism information is available. Life will change into a game where everyone sees how they score, how they might end up if they continue their current paths and how they might fare if they changed their behaviour. Currently people have a very general understanding of statistical outcomes but as the correlations are too weak, invisible or long-term to be convincing, they have failed to change many people's behaviour.

A breakthrough in longevity research could have extremely complex effects including psychological, economic and cultural aspects. These should be studied. We have already seen some effects as life expectancy has doubled during the past 100 years. Life is more valuable to people whose probable life expectancy is long. Thus we may expect people behaving more rationally as their life expectancies grow.

2.8 Energy technology

The installation costs of both solar and wind energy have decreased quickly. From 2006 until 2014 the decrease in installed solar energy cost has been 16 % yearly in Germany, according to a Fraunhofer Institutes study. Deutsche Bank estimates that the cost of solar energy will drop by a further 40 % by 2020, or faster in many countries like the USA, and reaches network parity with existing electricity prices in 80 % of countries studied by 2017. Several research institutions, including Fraunhofer, estimate that by 2050 the cost of solar electricity will drop to 2-4 cents per kWh, and may thus undercut the current transmission cost of electricity in places like Finland. Laboratory experiments show that this radical price reduction may be possible through thin and flexible efficient solar panels made from cheap materials, which can be integrated into common construction elements. Extensive reliance on solar power and wind will require large energy storage facilities or alternate power sources when there is no wind or sun available. Storage technologies are developing rapidly and daily fluctuation can already be handled economically. Storage technology prices are expected to fall steadily and "flow batteries" may solve the problem of longer-term energy storage. Another new option for longer-term storage involves converting energy into hydrocarbons and using them for electricity production in fuel cells or in conventional engines when stored energy is needed. Fuel cell development is also making rapid progress due to new materials.

Small serially manufactured atomic power plants may be another way to bring down the cost of electricity. There is also a serious attempt by Lockheed to build a functioning prototype of a small fusion reactor within a few years.

Further reading and examples

- A Fraunhofer Institute report on photovoltaics in Germany: http://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf
- A Fraunhofer Institute report on the German "Energiewende" providing long-term scenarios on the development of photovoltaic systems: http://www.agora-energiewende.org/fileadmin/downloads/publikationen/Studien/PV_Cost_2050/AgoraEnergiewende_Current_and_Future_Cost_of_PV_Feb2015_web.pdf
- Lockheed Martin's promotional pages on their fusion project: http://lockheedmartin.com/us/products/compact-fusion.html

Key impacts on societal development. It seems very probable that energy prices will fall as a result of quickly decreasing prices of solar power. According to Gaia Consulting[16] it is already now cost efficient for many users in Finland to produce solar electricity for their own consumption. When costs continue to fall and rooftop solar becomes popular, energy producers and electricity network operators are challenged. The electricity grid is basically fixed cost. For many energy plants the capital cost of the production facility is a major consideration too. When the market becomes volatile, fixed costs are more difficult to cover.

Energy companies face a turbulent road ahead. They will need to change their pricing to compensate for their obligation to supply energy at those times when solar power is unavailable. This may lead to the situation where more and more users decide to produce and store their own electricity, in the same way they now produce their own heat. Many may disconnect themselves completely from the grid if solar power and storage technology development makes it economically feasible. The energy sector will face a major restructuring in such a situation. Due to rapid technology development, visibility is not good enough for riskless long-term investments and profitability should either be calculated using short payback times or high discount percentages.

If solar power becomes the dominant energy form, Finland may lose much of its energy-intensive industry. If solar power wins globally, energy will inevitably be cheaper in southern countries where winter is not so dark and excessive energy storage costs or alternate energy sources are not required. If the price of nuclear power in the form of serially produced small power plants can be reduced enough for it to compete with the falling price of solar energy, the impact of cheap solar energy will be mitigated.

2.9 Digital crowd platforms

There are now over one billion active Facebook users. Facebook and other social media compete evenly with traditional media on many fronts. Wikipedia, MOOC (Massive Open Online Courses) education, open data, open code, online machine translation, search engines and easily accessible and free applications bring forth unseen transparency and the democratisation of knowledge. Uber, Airbnb, eBay, Paypal, Bitcoin, Kickstarter, Shapeways, Linux, Wikipedia and other creative online tools are but a few examples that show how the internet enables a sharing economy, peer production, flash mobs, crowdfunding, crowdsourcing and other sorts of collaboration.

[16] http://www.sitra.fi/artikkelit/aurinkoenergia-nyt-kannattavaa-myos-taloyhtioille

Through increasing innovativeness, robotics, data standardisation and artificial intelligence, the internet enables continuously new and more extensive forms of self-organising behaviour. We have seen how collaborative grass-roots movements can create computer operating systems and encyclopaedias. We will most probably see them changing production, logistics and many parts of trade and professional services. Existing organisations are an expensive way of co-ordinating behaviour that could as easily be self-organised with the help of suitable software. It is not really the software that does the organising. It merely catalyses and provides an automated platform for exchange and self-co-ordination. People are generally both willing and capable of self-organising behaviour if a suitable structure for transactions is provided and easily accessible.

Further reading and examples

- Farhad Manjoo's article about the Uber business model: http://www.nytimes.com/2015/01/29/technology/personaltech/uber-a-rising-business-model.html
- Website of the 3D printing service Shapeways: http://www.shapeways.com/
- Website of the crowdfunding Kickstarter: https://www.kickstarter.com/hello?ref=footer

Key impacts on societal development. Self-organised work when combined with the global network and performed remotely makes it very hard for governments to collect income taxes or VAT. When production becomes collaborative and the produced utility is shared between those who made it, we must ask: should the time used for it be considered work or a hobby? Many simultaneous developments like artificial intelligence, robotics, biotechnology, new energy forms and these self-organising social innovations make it relatively easy to leave the monetary economy mostly aside and rely generally on other types of collaboration. This potential change may cause very fast collapses for businesses and whole industries, if self-organising movements can finance themselves and organise work, production, marketing and distribution of their products all through voluntary collaboration. It has become easy to understand how this can happen with virtual goods. Many however struggle to understand that this can happen with physical goods and services too. We must remember that 3D printers and robots are becoming widespread and we should realise the implications

Self-organised work when combined with the global network and performed remotely makes it very hard for governments to collect income taxes or VAT.

of their marginal costs being close to zero when compared to the value of the things they are able to produce. Airbnb and Uber already rely on this kind of near-zero marginal cost effect. Society will not stop with these. We may see peer-produced cars in the 2020s as we already today see peer-produced toys, and we will certainly see remote work where robotic services are directed over the network. The change will be greater than we can imagine.

Loosening of the contemporary key power structures by increasing the availability of self-organising platforms will create turmoil in the economy and in society overall. Citizens will become empowered and this new self-organising dynamism may change whole industries without any help from governments, financial institutions or industry heavyweights. It becomes difficult to influence society without intensive involvement in social media. It will be difficult to predict the effects of this change on existing governance models while they try to fight the inevitable and maintain old paradigms. The longer we wait, the stronger the turbulence will be.

2.10 Globalisation of ICT structures

The internet of things, modularisation of robotics, crowdsourced and open data, self-organising platforms and several other developments require de facto standard interfaces for physical hardware, software, data and communications. Many of these de facto standards come in the form of cloud services or popular physical devices and their interconnections. Some of them are official standards; others are popular products or services that facilitate collaboration and sharing. Some de facto standards are in the form of open source software or open source hardware and these spread throughout their respective ecosystems freely through copying. When a proprietary interface becomes popular and a large number of devices and third-party services connect to each other via the proprietary interface, it yields much power and possible great profits to those who control the interface and hence the ecosystem that builds around it. Whether the popular interface is proprietary or not, it may create rigid structures that stop evolving while simultaneously speeding up development within its boundaries[17].

Further reading and examples

- An article by Alasdair Allen comparing 36 electronics boards for robotics and the internet of things: http://makezine.com/magazine/make-36-boards/which-board-is-right-for-me/
- An article by Michael deAgonia et al. describing the main personal technology ecosystems: http://www.computerworld.com/article/2483616/personal-technology/battle-of-the-media-ecosystems--amazon--apple--google-and-microsoft.html

Key impacts on societal development. As the structures become more and more open and interconnected, new applications within their boundaries arise faster and become more powerful than ever, as do new powerful players and global industry heavyweights like Google. Popular platforms become difficult to modify or switch as users tend to get connected to the whole ecosystem and often even separate third-party products are not interoperable with more than one popular platform or ecosystem.

As software APIs (application programming interfaces), global data, cloud services and robotic devices all become interconnected and available for third-party applications and services, this will lead to a major development surge. This was seen with the microcomputer revolution of the 1980s, then with internet websites and recently with mobile apps. A myriad of internet-connected devices will become available as well as applications that can use them to manipulate the physical world in any number of ways. Due to their global integrating nature and positive effect on productivity, successful platforms and ecosystems can enforce practices that local legislators are unable to oppose. This in a way makes them stronger than local laws, and the local laws must yield unless major economic powers such as the US or the EU take a stand.

A myriad of internet-connected devices will become available as well as applications that can use them to manipulate the physical world in any number of ways.

[17] Katz and Shapiro 1985

3. Technology impacts for Sustainable Well-being Societies

IN THIS CHAPTER, the potential impacts of the 10 described areas of rapid technology development are analysed, listing the key threats and opportunities which the forthcoming technologies may bring forth. This analysis is performed for each of the principles for building a sustainable well-being society and the application areas described in Chapter 1.3. Here, only the potential impacts of technological development on the principles and example areas are described. The principles and application areas themselves are described in more detail in Sitra's working paper Towards a Sustainable Well-being Society.

3.1 Addressing well-being in a holistic way

Key technology impacts: threats. All the technologies described in chapter 2 may add to the complexity, hidden interdependencies, rapid change and turbulence that makes coping with one's life more difficult. This turbulence may make it difficult to connect causes with effects, may increase the feeling of meaninglessness of one's own deeds, lessen trust and increase moral dilemmas, causing severe life-management problems. Economies of scale and an increasingly transparent global economy may lead to swift appearances and disappearances of huge hierarchical structures, whose collapses may cause unexpected changes to people's lives.

Key technology impacts: opportunities. While adding to the problems of coping with one's life, technology also provides tools that make it easier to manage everyday problems. Social networks provide easy access to virtual communities or individuals online with similar problems to one's own. Artificial intelligence can be embedded into software applications and cloud services in order to reduce the technological complexity of available tools and services. Virtual reality interfaces and computer simulations give room to easy experimenting. Gamification, game-like scoring of one's actions, makes learning easier by showing when and how preferred goals get closer if complex interactions and numerous variables make comprehension of system dynamics otherwise difficult. Networks of trust assist in selecting products that other people in similar circumstances have been satisfied with. My Data-based services help maintain focus on meaningful personal issues.

Local production with robotic tools, such as 3D printers, fosters small-scale jobs where work is not as abstract or fragmented as in large hierarchies. These kinds of new jobs require a more holistic approach in each assignment than most jobs in large hierarchies. It is also easy to see the need for and

Robotisation opens up great potential for strengthening local communities and creating meaningful small-scale jobs.

the results of one's work when customers are close by.

If technology allows energy, food, clothing and machinery to be produced locally in each town with the help of robotic tools, local identity and social cohesion may strengthen and people may get respect from their neighbours by being directly useful to them. Technological progress may give rise to optimism. As the capabilities increase to locally provide and produce almost all physical necessities and niceties of life, decision-making may become more decentralised.

Suggested development opportunities. Robotisation opens up great potential for strengthening local communities and creating meaningful small-scale jobs. ICT empowers individuals to cope with their life in an increasingly complex society. This should be supported.

3.2 Adjusting to planetary boundaries

Key technology impacts: threats. Automation makes it ever easier to harvest and mine the earth's resources. Mining is now cheaper than ever. Even shale oil can be recovered and oil drilled from the Arctic. Fishing has become so efficient that large areas no longer have any fish. Human productivity increases continuously. Our consumption has reached unsustainable levels. When resources are depleted or spoiled, the resulting economic, environmental and psychological shocks add to the global and local socioeconomic turbulence, causing depressions, famines, terrorism and war. Growing complexity and connectivity make it possible for minor players to cause major problems. It is difficult to prevent these problems beforehand without simultaneously hindering the economy and causing political upheaval.

Key technology impacts: opportunities. Virtualisation enables replacing atoms with bits. It also moderates the need for transport and logistics. Artificial intelligence helps to optimise production and logistics to save energy. Instrumentation can be used to monitor and preserve nature, prevent environmental catastrophes and optimise production. Robotised transport reduces the need for vehicles and also makes it easier to adopt energy-efficient electrical vehicles. Through local robotised production and global digitisation, added value can arise from increased complexity and individualisation of products instead of material excess. Robotisation also increases the competitiveness of local production and thus reduces the need for global logistics, large warehouses and excessive marketing.

Nanomaterials like graphene and other new materials like nanocellulose make it possible to have mode durable products from less environmentally harmful materials. New materials may also enable more recyclable products or provide for easier chemical filtering and thus enable wider industrial symbiosis – using one company's or citizen's waste for another's resources.

Biotechnology can help produce various substances or materials and even whole products at room temperature with very little energy required. LED technology enables indoor farming that consumes very little water and does not create pollution from fertilisers. Indoor farming may in many areas become mandatory with climate change.

The rapidly falling cost of solar energy, new forms of wind energy or serially produced cheap atomic power plants promise to radically reduce the price of non-carbon-based energy. It might be economically possible within a few decades to replace most fossil fuels. Renewable energy is commonly decentralised, and requires energy storages that are often also decentralised. National electric grids may become unnecessary, reducing centralised vulnerabilities, if local production and storage become efficient. Sustainability can be supported by a private and public display of gaming-style sustainability scores. This increased transparency can create peer and customer pressure, encouraging the movement towards sustainable practices. Simulations help in understanding the complex interdependencies in the energy market and in achieving public support for sustainable designs.

With sufficiently cheap solar power, carbon- and nanocellulose-based materials and indoor farming, the earth could well support several times its current population sustainably.

Suggested development opportunities. Resource sharing, renewable materials, renewable energy, local production, indoor farming and virtualisation should be encouraged. Local solar power-based, off-grid-type lifestyles should be studied. Gamification of sustainability should be encouraged.

With sufficiently cheap solar power, carbon- and nanocellulose-based materials and indoor farming, the earth could well support several times its current population sustainably.

3.3 Empowering individuals and communities

Key technology impacts: threats. The globalisation of ICT structures, the virtualisation of services and evolving artificial intelligence may each make it harder for local communities and individuals to influence society. A winner-takes-it-all-type world and its consequent inequalities creates frustration and increases the feeling of powerlessness. The division between people who identify themselves with virtual communities and those who still maintain strong local identity may cause rifts in local communities and society overall[18]. These rifts are not easily mended by increasing automation in governance, since this usually leads to mechanical decisions disregarding individual needs and wants.

Key technology impacts: opportunities. Virtualisation and open data enable even the smallest communities to enjoy high-quality services regardless of locality. Social networks let people of all ages and hobbies find like-minded people with similar interests. Collaboration opportunities include business activities, third sector positions, study groups, hobbies and political interests. Digitisation favours social cohesion based on interests instead of locality. This can be seen both as a risk and an opportunity.

Virtualisation and open data enable even the smallest communities to enjoy high-quality services regardless of locality.

Robotisation radically lowers the transport costs for people with disabilities and democratises mobility for them and others without a car. Robotised logistics and needs-based, pull-type marketing open up possibilities for small producers and remote local communities to participate in global commerce on an equal footing. Individuals are no longer meaningless parts in large machines but instead they can have an active role. Combined with robotised logistics, the robotisation of services and production will give small one-person shops an efficient means with which to enter the global market. It will also enable local players to produce high-quality items for local needs, thus reinforcing local identity and cohesion. Indoor farming adds to the local capabilities as well as solar energy and local energy storage.

Technological advances enable efficient local services that rely on rather moderate levels of exports and imports, where society is built from smaller modules, the functioning of one's own community is easier to understand and the meaningfulness of one's own role is clear. Technological development gives room for positive, convincing and inspiring visions that can overcome disease, poverty and environmental crises.

Suggested development opportunities. Virtualisation and robotisation should be used to empower individuals or small firms and their collaboration regardless of their location. Studies should be carried out into how these and other new technologies could enable societies that are founded on smaller, more human-sized modules based on a greater interaction and cohesion between each part of the society, rather than on the current striving towards economies of scale.

3.4 Moving to a regenerative and collaborative economy

Key technology impacts and threats. The slow-paced European economy and increasingly bureaucratic tendency means that Asia and the United States are the main beneficiaries of the market for new technologies and new business models. The USA and Asia hold a large majority of all new patents[19]. New business practices and paradigms are being defined by their pioneering efforts. Europe is being left behind and is either filling up smaller niches or protecting the old structures that support the old work places. This works against the renewal of the economy. If robotised production advances slowly in European local markets while the automation of logistics proceeds swiftly, Europe will end up importing most new technology. Without speedy adoption of new technologies and their best usage models, Europe will lose the possibility of contributing to its design and fail to capture new markets.

Key technology impacts: opportunities. Virtualisation, cloud services, instrumentation, 3D printers and open data all make collaboration possible regardless of

[18] Castells 2000b
[19] WIPO 2014

the location of the collaborating parties. Services can be provided by remotely controlled robots, 3D models can be sent over the internet to be printed locally and language problems can be solved with machine translation.

Robotisation enables flexible production in small runs. Even individual production is efficient and practical. Added value will be gained more often from the fulfilling of individual needs. The value of each product could mostly reside in their individual designs or modifications, not in the brand or other replicated design characteristics. This individual value can most naturally be produced locally, as it requires understanding the specific customer's needs and their local culture. It may also require taking the customer's measurements or modelling their existing artefacts in order to create new things that truly fit their needs.

New robotic tools and 3D printers enable manufacturing models which resemble those of medieval times, where masters would craft bespoke items for their customers. In the near future, networked guilds will share collaborative knowledge in the form of commercial or open designs. Robotic tools and applications that assist in the work may be sold globally but their yields will increasingly be produced locally.

The rapid emergence of environmentally sustainable materials, biological processes and renewable energy production will all yield numerous new business opportunities while restructuring whole industries. Often these new businesses can be started up locally without any major capital investment. This can happen quickly if the market is well aware of the opportunities. Emergence of these new business models can be encouraged through government action: public institutions can create early market demand for novel products and focus attention on decentralised production, environmentally sustainable materials, solar energy and local production of local goods by means of new technology. The business environment can also be renewed by embracing new business models such as social commons, the sharing economy, crowdfunding, peer production and the opening to businesses of existing government monopolies.

Suggested development opportunities. The sharing economy should be supported where near-zero marginal cost situations occur. Socio-technical regimes should be changed to favour business models that use new technologies. Structural dynamism in the economy should be increased to lower income differences. Social commons should be favoured where it helps local production models, individual added value and business concepts that rely on new technology.

3.5 Building competencies for a complex world

Key technology impacts: threats. Non-linear, inherently complex and uniquely interlinked phenomena will more and more common due to virtualisation, artificial intelligence, robotisation and self-organising social innovations supported by globalised ICT structures. However, both our education system and governance model maintain traditional beliefs in how knowledge is structured. Mistaken beliefs result in inadequate or even poor changes being celebrated as big advances while society continues to deteriorate.

We are mainly taught hierarchical paradigms and reductionist thinking throughout school curricula. This makes it very hard to understand the new basics of self-organising behaviours and holistic thinking in the complex world.

The methods used to teach and learn new skills are outdated and the new tools are mostly only learned through each student's individual motivation and individual pursuit of relevant knowledge. As technology progress gathers pace because of the exponential growth of knowledge, and as most people try to comprehend the change through old paradigms, they and their teachers are not even aware of what understanding they are missing. Due to outdated paradigms they see chaos in development instead of complex order and they may lose faith in their ability to comprehend the larger picture in spite of the wide availability of ever better tools that they could use if they only knew how.

Key technology impacts: opportunities. Virtualisation, digitisation of data and artificial intelligence make it easier than ever to learn skills through simulation. Simulations can be multidisciplinary, combining natural sciences and life sciences, providing platforms for learning practical skills, psychological insight, strategy, and business skills in realistic situations. Prototype building is related to simulations. Complex, nonlinear systems can really only be learned and understood through simulations and prototype building. Both practices transform cognitive knowledge into skills and reveal misapprehensions.

Simulations in the form of multidisciplinary strategy games and gamification of work and life create opportunities for collaborative learning and may help challenge existing beliefs while maintaining a holistic approach. Through computers, we have the opportunity to teach how to understand the big picture and its complex dynamism. There are numerous different tools with which the big picture can be viewed from various angles and with which specific knowledge can be mined and used. When facing problems it is easier than ever to find answers, use applications that utilise big data, artificial intelligence and collaboration. Instrumentation yields data from within ourselves or our environment or whatever aspect of the world we need. My Data-based applications assist in finding the data most relevant to each individual and can offer help in interpreting that data.

3D printers and other robotic tools enable wide-ranging experimentation. Social networks help in finding collaboration opportunities in almost any field while simultaneously maintaining a multidimensional approach. History, language skills, medical knowledge, natural sciences and maths are all at our fingertips if we only know how to use the tools and understand the right crucial paradigms. New tools such as Wikipedia help break silos in our thinking; online educational material exists in nearly every field of knowledge at every level and helps in making a quick assessment of what knowledge is available and how it could help.

Suggested development opportunities. We should assess the key paradigms and teach the skills that are important instead of outdated paradigms and skills that have become useless.

3.6 Developing inclusive and adaptive governance

Key technology impacts: threats. Our current governance model has become very good at maintaining itself in spite of a growing need to adapt to a changing society. Our collaborative structures are derived from times before ICT technology made distances irrelevant for most bureaucratic functions. This is typically the situation in Europe. Immense numbers of detailed regulations exist, supporting socio-technical realms that are suboptimal compared to the attainable technological potential.

This technology gap is widening due to the exponential growth of technological knowledge and slow productivity growth in Western nations. An increasing number of opportunities are being wasted. Most regulators, politicians and even business people are blind to the opportunities, as they see the world through the paradigms supported by the current structures and it is often those very structures that cause the stagnation.

One major impediment in the governance model is that democracy is locality-based while technology allows collaboration independent of locality. Another problem is that governments strive to organise themselves as hierarchical structures that are divided into local monopolies even though that is by no means the only way to organise public services. While corporations specialise and exchange to gain efficiency, municipal governments try to do everything by themselves, and what they are unable to do they still need to understand in order to handle the purchase procedures. The more complicated this world comes, the more mistakes will be made when governments are not allowed to rely on trust, are forced to organise detailed competitive bidding and are prevented from using historical information when selecting the winners of tendering processes.

Key technology impacts: opportunities. Virtualisation and the digitisation of data, and instrumentation and robotised logistics and services disconnect most aspects of governance and collaboration from the restrictions of time and place. The subsidiarity principle did not originally require physical vicinity. According to the subsidiarity principle, social problems should be dealt with at the most immediate level, consistent with their solution. As communications technology has removed most limitations of distance, the most immediate level is determined by the issues at hand and the interests of the stakeholders instead of physical proximity. If the subsidiarity principle was understood along these lines major problems could be solved, but it would require a radical restructuring of public services. Municipal governance could yield most of its responsibilities to specialised institutions that have their own governance structures run by specialists in their respective topics and elected by those their decisions concern.

The subsidiarity principle is dysfunctional in its contemporary form. Our common interests no longer depend on our physical vicinity but more often on our special interests themselves. People on the opposite sides of the globe

One major impediment in the governance model is that democracy is locality-based while technology allows collaboration independent of locality.

might have stronger common interests that many neighbours. This is really new. Before the internet this was very rare and the physical vicinity strongly defined our common interests. As a result, we have started to feel alienated from the decision-making on those issues that mean most to us. Instead of a single monopoly organisation for each locality, these new and specialised organisations could be national or even transnational and there could be several of them competing for members. This approach would increase democracy by allowing freedom for citizens to select the most suitable groups and thus also allow for competition within governance while still increasing economy of scale and specialisation compared to existing practices.

These specialised bodies could be elected democratically by their members and they could have independent authority to create regulations within their jurisdiction. If such subject areas that affect only a limited number of people were regulated by the affected people themselves, this would lead to better evolutionary development and the reconsideration of decisions or ideas if they prove to be ill-advised.

Competitive bidding, which currently causes severe inefficiency and problematic supplier selections, could be optional instead of mandatory. It could be replaced by a complete transparency of all discussions and decision-making on any transaction. Trust would be taken into account when full transparency is in effect. This would greatly simplify many transactions and lead to responsible services when buyers are not experts.

Artificial intelligence, instrumentation and robotised services could make huge gains in productivity possible in most administrative functions. They would also enable greater gains in service quality. The regulative environment could be revised in a way where methods are not governed at the technological level but at the level the technology might have, in order to open up all these opportunities.

Open Data and My Data may open up dynamic and efficient new practices for governance, markets and individuals. These new practices could be boosted by being accepted as the ruling principles of governance. My Data could be regulated in such a manner that each holder of an individual's private data would be obliged to transmit it to the trusted third party of that individual in machine-readable form when required. Self-organised behaviour like crowdfunding and creative commons could also be fully supported, and networked virtual operations could be fully and officially recognised practices designed to promote efficient practices.

Suggested development opportunities. The principle of subsidiarity should be re-examined. It was not originally understood as physical proximity but rather as what is more immediate (not more local) level. Competitive bidding practices should be re-examined. Open Data and My Data should be embraced.

3.7 Work as a source of sustainable well-being

Key technology impacts: threats. Artificial intelligence, virtualisation and robotisation continue to replace existing jobs. New technologies in nanomaterials, biotechnology, energy technology and ICT continue to replace old industries. If Finland has lost the capabilities for renewing its public and business structures and technology regimes, local productivity will decrease while areas of high productivity are grabbed by foreign players. This leads easily to a simultaneous lowering of profits, lowering of wages and increased unemployment. Due to rigid structures, this may also lead to increased income differences, high taxes and a turbulent work life. If this kind of development is caused by bad governance, many talented and business-oriented people may leave the country.

Key technology impacts: opportunities. Even though new technology will replace existing jobs, it will also create new opportunities. There are several technological advances that may lessen income inequalities, enable new meaningful jobs and assist in the learning of new skills. Virtualisation and robotisation make remote work easier than before. Therefore people do not need to move from their homes even though they work or sell services to companies that reside far away. Robotisation creates new opportunities fulfilling local needs with local production. Higher local wages can be compensated with better recognition of local needs, creative commons-based global designs, robotised individual production and fewer storage, logistics and other transaction costs. 3D printers and other flexible robotised production tools are already, for many purposes, relatively inexpensive and enable versatile production capabilities.

Robotised logistics, search engines and 3D printers enable small-scale production for niche markets globally. Networked learning materials make it possible to learn new skills. Social media, crowdsourcing, cloud services, peer production, social commons, open data and crowdfunding – among other new technologies – make it easier than ever to set up meaningful collaboration and business practices, but also to provide for one's own needs. Solar energy, indoor farming, service robots and 3D printing are examples of new technologies where relatively small investments enable production of energy, food and services for oneself and those living nearby.

It is extremely important to realise the similarity of these new technologies to the microcomputer revolution of the 1980s and 90s. Microcomputers enabled the production and publication of media content, even entire movies like Star Wreck without major investment. Many forthcoming technologies will enable similar developments to happen in the world of material things, since efficient production no longer requires an economy of scale in each case. This will change working life, creating many new jobs, if only people can realise the new opportunities. Unless we open up to the new possibilities, our productivity will suffer compared to more nimble economies and jobs will disappear. There are currently too many regulations and the whole socio-technical regime favours large hierarchies. This can be changed.

Suggested development opportunities. The potential of new technology to create new jobs through increased productivity should be promoted. Small-scale local production fulfilling local needs and using robotised procedures should be encouraged. New business models including the promotion and use of social commons, crowdsourcing, crowdfunding and peer production should be supported. Solar energy, indoor farming, new materials and other new technologies should be promoted as sources of new potential jobs.

3.8 Consumption habits and lifestyles to support sustainable well-being

Key technology impacts: threats. Robotisation makes production ever cheaper. Online shops make us aware of all that we could purchase. Social media promotes consumerism based on not only our conscious or subconscious needs but also on our wish to impress friends and colleagues. Businesses create products that cannot be fixed when they break and products that intentionally stop functioning no longer damage the brand. Driverless cars, language translators, global collaboration and social commons may lead to increased travel. The internet of things and increased connectivity may create wide-ranging ecosystems that force us to swap our fridges, other household appliances and even our cars if we wish to change brand; for example, from an Apple ecosystem to a Google ecosystem. These kinds of domino effects seem unavoidable unless we succeed in creating interoperability between the various ever-extending ecosystems.

Crowdfunding and creative commons can help organise resources and collaboration to create products and services that support sustainable lifestyles.

Key technology impacts: opportunities. Virtualisation and social media can be utilised to promote values that are less materialistic. People might gain status from the virtual realm and this might reduce their need for material status symbols. Added value and displays of wealth could also be realised through designing individual forms and intricate details instead of adding plain material functionality or increasing the volume of material consumption.

Through gaming-style public displays (gamification) of resource efficiency, social pressure can direct us towards sustainability. The sharing economy, value through immaterial consumption and sustainable lifestyles can all create status value and make us influential among people who support the movement into more sustainable lifestyles. The instrumentation of everything, artificial intelligence, big data, open data and transparency in general can give rise to awareness and empower consumer movements against ill-behaved companies, voter revolts against politicians who act against sustainability and peer pressure towards other individuals who seem to lead a carelessly wasteful life.

Crowdfunding and creative commons can help organise resources and collaboration to create products and services that support sustainable lifestyles. These can range from Wikipedia-like knowledge production to full designs and peer production of devices like solar panels or indoor farming, which may be necessary for some people's sustainable lifestyle choices. Collaborative consumption becomes increasingly easy through transparency, instrumentation, social networks, crowdfunding, peer production, cloud computing and robotisation of logistics and services. Through this kind of work, villages may become nearly independent of any physical interchange with the outside world and still maintain a high quality of life in a sustainable way. This kind of lifestyle would make it possible to use renewable resources such as solar power or wind when they are available and to perform less energy-intensive tasks when renewables are not available, instead of running energy-intensive production tasks even through the darkest months of the year.

Robotised production removes much of the need for specialisation and exchange as robots can download new talents from the internet when needed. Human beings are not competitive in highly specialised tasks but have the need to gain more holistic and empathetic capabilities. Instead of specialising in a narrow task, an increasing number of people should learn to use their time freelancing in different tasks, fulfilling other people's needs and collaborating in development tasks or providing for one's own needs when one's time is not required by other people.

Modularity, social commons, and standardisation may help to build more sustainable systems through making various ecosystem parts interchangeable. 3D printers and modular open design principles certainly promise to make things easier to maintain. Maker-type behaviour where people enjoy creating their own things through 3D printing or craftsmanship and individualisation of products create a culture where products are not easily discarded, and where people also participate in their design before they are produced.

Suggested development opportunities. Gaining status through the virtual realm should be supported. Gamification of resource efficiency should be made mandatory for all organisations and public officials. The sharing economy should be supported and legal barriers removed. Self-sustainable lifestyles and freelance work should be promoted and platforms facilitating them should be supported.

3.9 Sustainable well-being implies comprehensive social and healthcare services

Key technology impacts: threats. The growing complexity and information bubbles induced by social media and personalised information services make people vulnerable to irrational beliefs. Vaccinations are being avoided as one example; alternate medicines and ill-advised diets lead to many problems. The increasing complexity of treatments raises the costs of available medical procedures. The availability of very advanced medical treatments and diagnostic procedures combined with the increasing number of old people with complex symptoms place increasing pressure and stress on the medical profession who have to cope with insufficient resources. This stress is worsened by an increasing number of patients who have searched for their symptoms and possible cures from the internet and face doctors with demands that can often not be met.

The inefficient competitive bidding procedures and inconsistently fragmented medical organisations have led to increasingly ill-suited ICT systems being used by medical organisations. It may be that these discrepancies will only worsen due to the rapid progress of technology and an exceedingly slow reaction to the change by the public sector and legislature.

Social problems will continue to increase due to increasing complexity; exclusion and increasing income inequality will arise if technological change is not embraced; and the growing tension between out-of-date structures and technological development will lead many to experience ill-effects.

Key technology impacts: opportunities. Virtualisation, robotisation and instrumentation jointly enable virtual clinics. They also empower people diagnosing themselves in many cases with the help of cheap add-ons and applets to their mobile phones. There are an increasing number of cheap devices accepted by the Federal Drug Administration in the USA that can do retinal scans, photograph the ear drum, diagnose several diseases, predict heart failure, etc. The X Prize Foundation is running a competition with 10 finalists, each of whom has designed a device that can diagnose 16 different diseases. The devices are handheld and intended for layman's use.

Automated transport can greatly lower the cost of ambulances and taxis. Support for elderly people in their homes can be enhanced with telepresence robots besides robotised food delivery and cleaning. Medical facilities and other social and healthcare institutions can also benefit from robots doing routine cleaning, logistics and transport tasks and many administrative tasks. Robotised exoskeletons are already practical in helping people to their own feet from wheelchairs. They and other prostheses enable elderly or handicapped people to cope on their own instead of being reliant of constant help. Eye prostheses can help the blind to see. The newest hand prostheses have touch sense and can be controlled by the brain. Many 3D printed organs will soon be installed to replace those destroyed by illnesses or trauma[20].

Pharmacology and other treatment options show great

[20] Linturi, Kuusi, Ahlqvist 2014

Artificial intelligence reveal relationships between symptoms, diseases, genetics and the environment. New knowledge in the field of medicine will emerge faster than in most other fields.

promise in solving severe illnesses like Alzheimer's and various types of cancer. Anti-ageing drugs and other life extension procedures already seem functional with mice. It may not take more than one or two decades before we have procedures that postpone age-related illnesses by one or several decades compared to existing practices. These developments should at least temporarily ease the burden of the medical profession.

Artificial intelligence like IBM's Watson and increasing volumes of big data reveal relationships between symptoms, diseases, genetics and the environment. They lead to machines being both capable of preliminary diagnosis and extremely helpful in medical research. New knowledge in the field of medicine will emerge faster than in most other fields.

Personalised monitors displaying the medical effects of our deeds – or in other words the gamification of health, combined with instrumentation, genetics and social media – create good possibilities for self-organised preventive medicine. Combined with My Data architecture, this could lead to an easy integration of personal medical information and lifestyle choices. This integration will not however happen widely or easily enough without legislative changes.

When considering the social problems, social networks can be of a great assistance. Along with many emerging new technologies they can provide meaningful tasks through virtual collaboration to all kinds of people, depending on their interests. Gamification of social problems has shown promising results. Many problems can also be solved in support groups of one's peers.

Suggested development opportunities. Self-diagnosis and virtual clinics should be promoted and modern self-diagnostic tools should be tested and promoted and the medical culture changed in a way that enables doctors to better cope with patients who have diagnostic tools and online information but no experience in interpreting the results. Artificial intelligence should be embraced. Robotised exoskeletons and other prostheses should be recommended. Gamification of health and quantified self-movement should be supported.

3.10 School as an engine for achieving a Sustainable Well-being Society

Key technology impacts: threats. Virtualisation and artificial intelligence give pupils and students easy access to information, tutelage and learning tools that surpass quickly most teacher's capabilities in any subject matter. As the curriculum in school consists mostly of topics that no longer represent the proper foundations of our modern society, no change in teaching methods is enough to remove the discrepancy that young people see between what they are required to learn and how they themselves regard the problems. Why learn languages when you have machine translation? Languages do open a window to respective cultures, but for most pupils this is pure theory for the third and fourth languages. Why learn calculus, when computers never use it? Why learn details of history when you can get any fact at your fingertips whenever you need it?

Youngsters seem to learn more practical things from their peers and the internet than they do from school and their teachers. The faster technology develops the larger this gap becomes unless schools are fundamentally reformed. Teachers are now ill-equipped, since they often know less about the modern tools for learning than their pupils. This change however is difficult as teachers' lobbies, the educational bureaucracy and older people's understanding is based on the old paradigms, and very few people in responsible positions seem to realise the falsity of how our contemporary school functions.

We have talented teachers and many schools that do their best. However, without a complete reorganisation of job descriptions, curricula and national final exams, changes will only be incremental and insufficient compared to the needs. The system is stuck without a major revision of the vision for schools. Meanwhile, the tension between the existing practice and modern expectations or needs grows continuously.

Key technology impacts: opportunities. Virtualisation enables reverse teaching or the "flipped classroom", where students learn the basics of each topic online and the teacher mainly assists in motivation, discussions and problem-solving. Problem-solving can consist of emulating real-life situations through simulations with the help of computers and artificial intelligence. As data is abundant and freely available, students can be taught the real fundamentals that modern society requires. These fundamentals do not contain things that can quickly be found and understood from information easily available online. Fundamentals consist of tools that can be used to find detailed knowledge and understanding, which is required to gain a holistic picture of the complex cross-disciplinary interactions of various phenomena. If cheating were allowed at every level and each topic, this would quickly steer the attitudes of teachers towards exams that measure skills, which need teaching and learning, instead of trivia that can easily be found online.

The curriculum needs revision to reflect the skills and knowledge that presently can be considered as foundations for understanding the modern society where everything is digital.

The material for reverse teaching could be produced collectively by teachers. Khan Academy's[21] brilliant teaching material for mathematics, chemistry and physics classes, from the foundation to college level, were produced practically by one person, Sal Khan. This method could be copied from the Khan Academy, but content needs re-evaluation. In mathematics for example, more emphasis could be put on topics such as discrete mathematics, algorithms, simulation and complexity theory. Similar revisions should be done in all topics.

A number of technologies can be used for collaboration, simulation, gamification of education, experimenting and evaluating learning. When the learning materials are appropriate, the learning methods optimal and the topics relevant, student motivation is good and the teacher's role corresponds better than it does nowadays, emphasising more what a human teacher can do better than a computer. We should not however expect contemporary teachers to understand this.

Creativity can be induced by giving the students 3D printers, building blocks of robots, new materials and other enabling technologies with whose help the students can feel they have the opportunity to do things that their parents could not accomplish.

The interlinked nature of the world can be learned through simulations, educational games and strategy games where groups in various schools play against others. This kind of platform encourages learning and creativity while adding to the understanding of the interlinked nature of our society and technology.

Suggested development principles. Material for all courses on reverse teaching should be provided on a national level. Teacher responsibilities should be reorganised to reflect the flipped classroom model. Cheating should be allowed in all exams. All school topics should be redesigned to reflect the needs of modern society. UNESCO's Kronberg Declaration should be followed and all degrees should be based on exams performed independently of the place where one has studied.

[21] Khan Academy offers practice exercises, instructional videos, and a personalised learning dashboard that empower learners to study at their own pace in and outside of the classroom. For more information: https://www.khanacademy.org/

4. Conclusions

THE NEWEST TECHNOLOGY already available on the market today enables major productivity increases that have not yet been realised even by the most advanced societies. Many of the technologies described here are still under development, but will be widely available in the near future and they will open up even larger opportunities. These potential productivity increases have both positive and negative impacts on our society. Existing institutions can slow down the change, but in so doing they increase potential turbulence. Much that might be valuable is then only gained by a small minority. Many ill-effects will spread across borders and by slowing itself down a society loses its capability to endure the challenges of the new technologies.

Table 1 summarises the opportunities and threats opened up by each of the 10 key technologies to each of the six principles and four application areas of Sitra's model for sustainable well-being societies.

From Table 1 and Figure 3 we can conclude that there are more opportunities than threats in each topic area. However, while embracing the opportunities, we must simultaneously accept the ominous understanding that a chain needs only one weak link to break the whole chain. Single threats can cause a catastrophe, while bringing about a paradise requires a horde of successful developments.

Opportunities arise from all key technologies (Figure 3) and their potential benefits spread rather evenly to all analysed sectors (Figure 4). Possibly the most important opportunity arises from renewable energies and new materials as they form the economic basis of sustainable well-being. On the other hand, all the technologies that create opportunities for efficient small-scale production and human-scale cohesive communities are important building blocks for a meaningful life and stabile society.

Major threats can be seen to arise from artificial intelligence, nanomaterials, biotechnology and globalisation of ICT structures (Figure 3). The target of these threats is usually the individual, his empowerment, well-being and work (Figure 4).

From both the opportunities and threats we can conclude that the spread will grow between the technologically most productive ways of doing things and common

Figure 3. Average impacts of individual key technologies on the vision for Sustainable Well-being Societies. Average impact level (-3 … +3) for all principles and application areas presented in Table 1

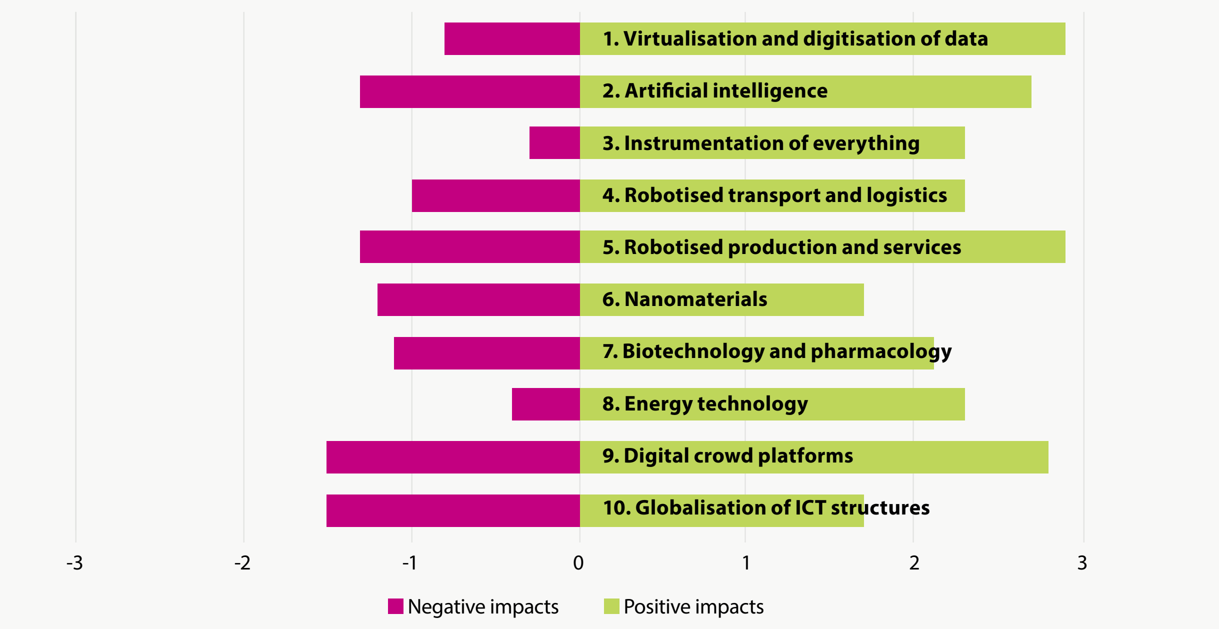
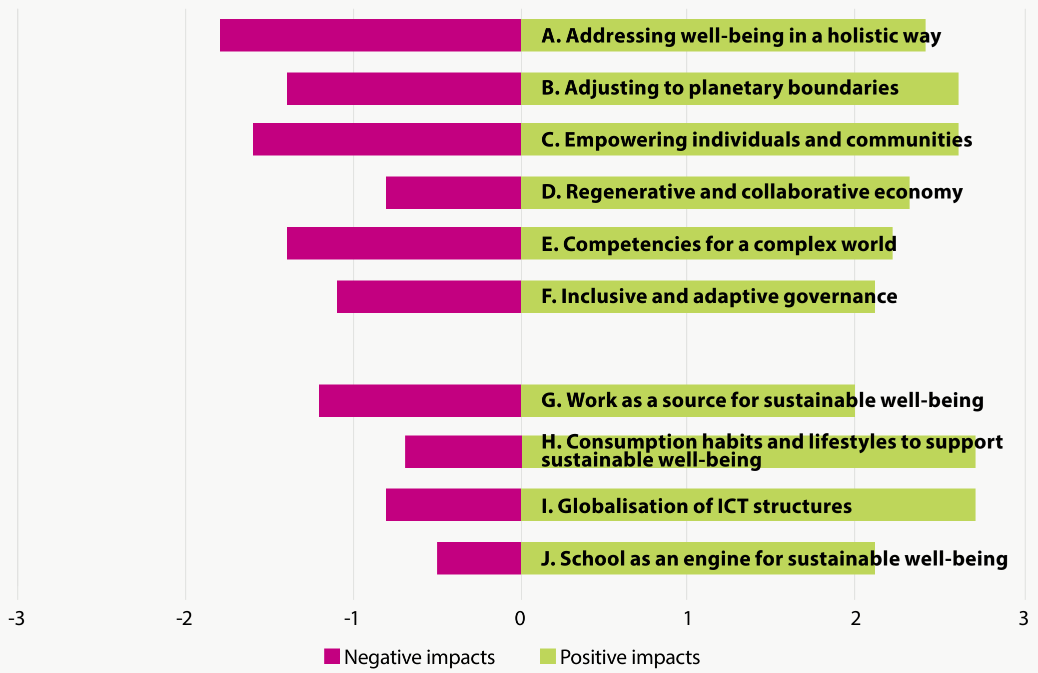


Figure 4. Average impacts of individual key technologies on various elements of the vision for Sustainable Well-being Societies. Average impact level (-3 … +3) for all key technologies presented in Table 1



contemporary practices. The digital divide may grow due to the fast pace of technological development and slow adaptation of societal structures. Simultaneously it is possible through empowerment of individuals and self-organising behaviour that income differences related to power hierarchies and economies of scale could shrink.

When the policy recommendations for each 10 topic areas of Sitra's model for sustainable well-being are considered, there are a few underlying themes. Consideration should be given to digital platforms that empower citizens to better cope with their lives and small virtual and physical communities to produce goods and services competitively disregarding the economy of scale. Sharing economy and social commons should be promoted. Various socio-technical regimes should be renewed to better support new technologies that favour the principles of sustainable well-being. Artificial intelligence and gamification should be increasingly used to encourage holistic thinking in an increasingly complex world.

The overall conclusion must be that there exists a major challenge to society. There are enormous opportunities, but these may turn into threats if our structures are too rigid and we are unable to adapt quickly enough. Turbulent times are ahead, especially if radical opportunities are taken by the nimblest societies and their speediest individuals while the majority of people get left behind. Society needs to guarantee swift progress for the large majority of people in order to avoid the problems arising from increasing inequalities.

Table 1: Positive and negative impacts of the selected technologies on the 10 topic areas of the vision for Sustainable Well-being Societies.

Key technologies	Principles for a Sustainable Well-being Society						Application areas of the principles				Average
	Addressing well-being in a holistic way	Adjusting to planetary boundaries	Empowering individuals and communities	Regenerative and collaborative economy	Competencies for a complex world	Inclusive and adaptive governance	Work as a source for sustainable well-being	Consumption habits and lifestyles to support sustainable well-being	Comprehensive social and healthcare	School as an engine for sustainable well-being	All principles and application areas
Average, all key technologies	++ --	+++ -	+++ --	++ -	++ -	++ -	++ -	+++ -	+++ -	++ -	++ -
1. Virtualisation and digitisation of data	+++ -	+++	+++ --	+++	+++ --	+++ -	++ -	+++ -	+++	+++	+++ -
2. Artificial intelligence	+++ -	+++	+++ ---	++ --	+++ --	+++ --	+ ---	+++	+++	+++	+++ -
3. Instrumentation of everything	+++ -	+++	++ -	+	+++	++	+ -	+++	+++	++	++
4. Robotised transport and logistics	+++ --	+++ --	+++	++ --	+ -	++	++ --	+++ -	+++	+	++ -
5. Robotised production and services	+++ -	+++ --	+++ --	+++ -	++ -	+++ -	+++ --	+++ --	+++ -	+++	+++ -
6. Nano-materials	+ ---	+++ -	++ --	++ -	+ --	+ -	++	++	++ --	+ -	++ -
7. Biotechnology and pharmacology	++ ---	+++ -	++ -	++	+ --	++ --	++	+++ -	+++ -	+ -	++ -
8. Energy technology	++ -	+++	+++	+++	+++ -	+	+++	+++	+ -	+ -	++
9. Digital crowd platforms	+++ --	+ -	+++ --	+++	+++ --	+++ -	+++ --	+++ -	+++ --	+++ --	+++ --
10. Globalisation of ICT structures	+ ---	+ -	++ ---	++ --	++ -	+ --	+ -	+ -	+++ -	+++	++ --

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Risto Linturi is a serial entrepreneur, a futurist and the chairman of one of the largest Finnish ICT-training companies, Sovelto. Many of his ideas and innovations have spread globally and his interviews have been published by dozens of major newspapers and TV channels all over the world.

Linturi has been a board member or a chairman of several successful technology companies, influential national and international committees and an advisor or consultant to both multinational and national institutions, including academic institutions. In 2007, the Director-General of UNESCO invited him to become a member of the UNESCO High-Level Group of Visionaries on ”The Future of Knowledge Acquisition and Sharing”.

Recently, Linturi has co-authored several reports on technology development and its impact on our society. These include ”100 Opportunities for Finland and the World”, published in 2014 by the Parliament of Finland.

Technological progress is escalating. Studies reveal an increase in the number of professions, businesses and public services that may soon become obsolete as a result of this development. Nevertheless, many of the threats can be avoided and many opportunities pursued. There is a growing urgency to understand this change, its threats and opportunities and its inherent dynamism.

In this study, Risto Linturi examines how deeply short-term technological progress can affect the important goals and principles of our well-being and global sustainability. It aims to answer the question: how can technology act as an enabler of sustainable well-being in the modern world?

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