SURVEY OF TECHNOLOGICAL INNOVATIONS IN THE LIVING ENVIRONMENT

JANUARY 2015

Rli
Council
for the Environment
and Infrastructure

About the Council for the Environment and Infrastructure

The Council for the Environment and Infrastructure (*Raad voor de leefomgeving en infrastructuur, Rli*) advises the Dutch government and Parliament on strategic issues concerning the sustainable development of the living and working environment. The Council is independent, and offers solicited and unsolicited advice on long-term issues of strategic importance to the Netherlands. Through its integrated approach and strategic advice, the Council strives to provide greater depth and breadth to the political and social debate, and to improve the quality of decision-making processes.

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In this publication the Council explores the possible impact of technological developments on the living environment and infrastructure. The focus is on so-called breakthrough technologies that can profoundly change the living environment due to their reach in different sectors. The Council specifically considers the technological developments in the subjects of healthy nutrition, smart buildings and efficient mobility and how they interconnect in our living environment.

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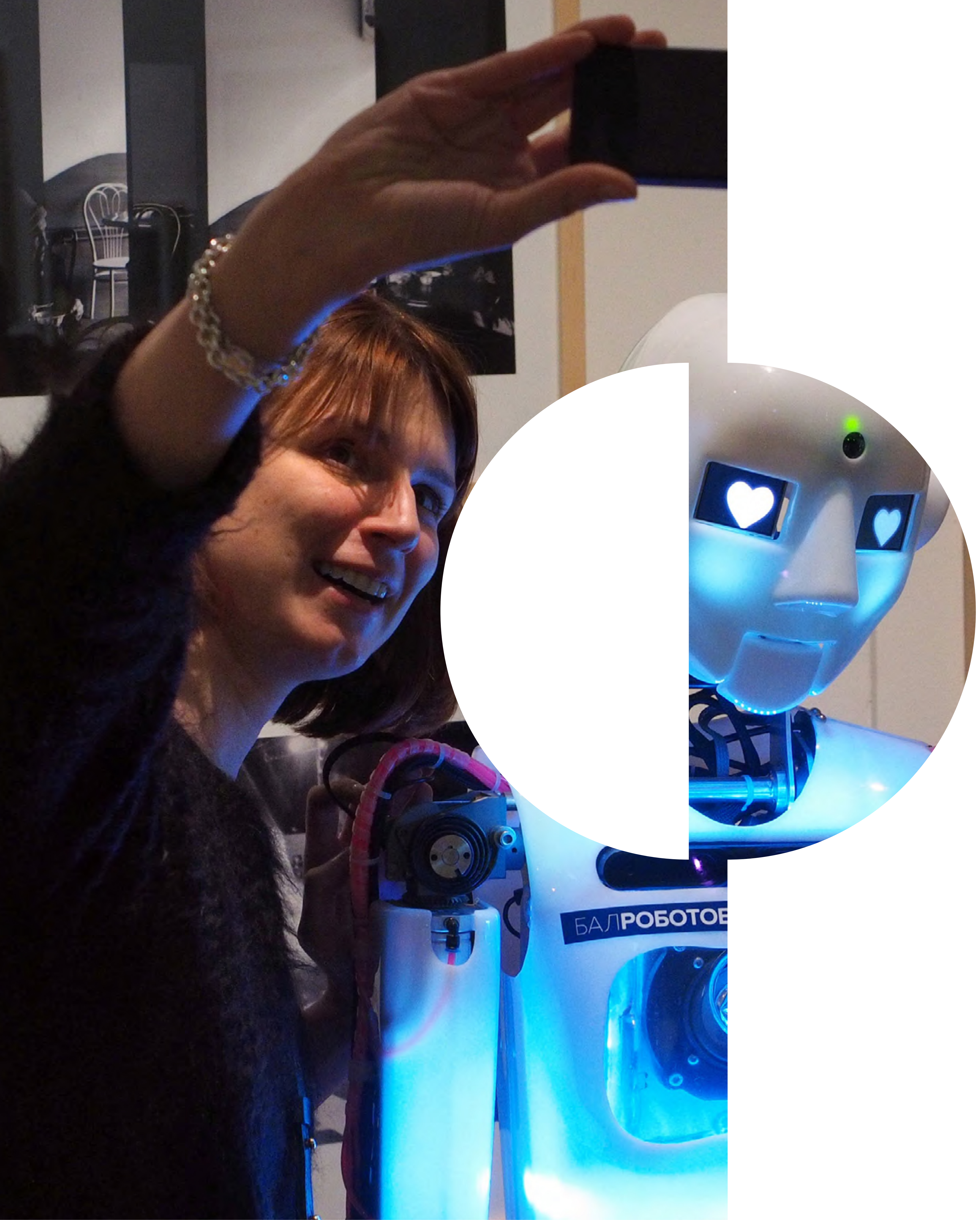


1

CLOSER INTERACTION BETWEEN TECHNOLOGY AND SOCIETY

1.1 Background and survey question

Technology is all around us. In the past, inventions like the axe, the wheel and the oven have influenced our way of life. Today, we connect with people all over the world through social media, we do our shopping from home and navigation apps guide us to our destination. Soon, nanoparticles will efficiently absorb solar energy for zero-energy buildings, kitchen robots will automatically recycle our waste and we will often share (autonomous) vehicles with others. In short, technology shapes our lives as well as our living environment.
Technological developments are succeeding each other ever more rapidly and are spreading across the globe at ever greater speeds. Furthermore, in our increasingly complex society, applications of technologies become more and more interdependent.

Many technologies that become important in the next thirty years are already available as prototypes or even already on sale. Autonomous vehicles, the intelligent home as part of the Internet of Things, 3D-printed food to our personal liking, artificial intelligence, bacteria as biofuel producers, faster charging batteries with the latest nanomaterials: it is no longer theoretical.

Which technologies will eventually find widespread application in the next thirty years and when, cannot exactly be predicted. After all, nobody knows precisely which new global or regional developments will occur or how social, demographic and socio-economic changes will influence our needs and choices for technologies. The period between the availability of a prototype, market introduction (time to market) and large-scale adoption (time to value) can vary greatly by technology. Moreover, the effects of technological innovations usually cannot be foreseen in advance. What is certain is that major differences exist and will continue to exist in expectations and opinions about the impacts of technological innovations.

The Council for the Environment and Infrastructure (Rli) is of the opinion that the acceleration and increasing complexity of technological developments make it more important to reflect more often on their impact and on any necessary conditions. Therefore, the Council has explored a number of technological developments and their possible impacts on society, both in a general sense and as regards their significance for the living environment and infrastructure. The central question is which impact technological innovations can have in both the public and private domain on healthy nutrition, efficient mobility and smart buildings. These three subjects have been selected in consultation with the Dutch Ministries of Economic Affairs, of Infrastructure and the Environment, and of the Interior and Kingdom Relations.

The purpose of the survey is to draw a picture of the developments that are associated with possible technological innovations in the three subjects. The Council directs his attention to technologies that may cause great changes in society through their many different applications in various sectors, so-called breakthrough technologies. The focus on technology in this survey provides insight into the new dynamics in technological developments and the closer interaction between technology and society. The Council is aware that the possible large-scale adoption of these breakthrough technologies strongly depends on additional social innovations, on their contributions to social challenges and on their inherent risks. The Council does not include any recommendations in this survey, but in Chapter 7 formulates a number of policy questions for the central government, which may give rise to an advisory report.

1.2 Key observations in the survey

Below, the key observations of the Council are explained briefly and then detailed in the subsequent chapters.

Acceleration of technological developments

Technological developments are accelerating. Individual technologies are converging and as a result are generating more and more innovations. Growing numbers of educated people in the world increase the combined knowledge and brainpower. Ever larger international digital networks enable them to share more knowledge and experiences, and work together on solutions to (societal) challenges.

Effects of breakthrough technologies on the living environment

The acceleration in technological developments increases the chance that in the coming decades numerous breakthrough technologies that can profoundly influence our living environment will appear simultaneously or in rapid succession, and as a result of which existing institutions could undergo significant changes. The Council refers to technologies like 4D printing, artificial intelligence, autonomous vehicles, quantum computers and next generation gene technology. The next generations of Information and Communications Technology (ICT) offer the infrastructure that is of great importance for further economic growth and social development.

The Council explores the possible effects of these breakthrough technologies on healthy nutrition, efficient mobility and smart buildings along four lines: the determining influence of new energy technologies, the possibility of multifunctional use of spaces and buildings, the emergence of more intelligent systems, and the interconnecting of our physical and virtual living environment. The technological developments within the three subjects also affect each other in the living environment.

Increasing importance of networks

Growing numbers of more diverse physical networks, social networks and data networks are being connected. Also to people: technology is getting closer and closer to us, even entering our body. Innovation processes, production processes, revenue models and the labour market are changing as a result of faster mobile communication technologies, smarter self-learning algorithms and increasing robotisation. Innovations are more and more emerging from networks. Companies with specialised knowledge operate in multiple networks and their knowledge is applied in multiple sectors. As technologies are becoming more and more complex and interconnected, the impact of their application is more difficult to understand, to predict and to control.

Innovations and values debate increasingly linked

To a significant extent, technological developments are driven by social values and by the challenges and wants in our society. But conversely, technology also influences social and moral values in society. Smart technology can increase our autonomy and freedom of choice, but can also give rise to questions about people's self-determination as regards their body and privacy, about responsibility and about digital security. When technological innovations put pressure on important values of people or groups of people, they will resist such innovations. At the same time, the use of technology is changing people's values and the importance that they attach to them. Thus groups of people have a different view on using mobile phones or on sharing private pictures on the Internet than fifteen years ago. If in due course people have become accustomed to the safety of autonomous vehicles, they might also change their view on drivers who still like to drive themselves. The Council observes that the focus on moral questions regarding technological innovations is increasing and that these questions are being debated more continuously.

Acceleration and complexity challenge adaptive capacity

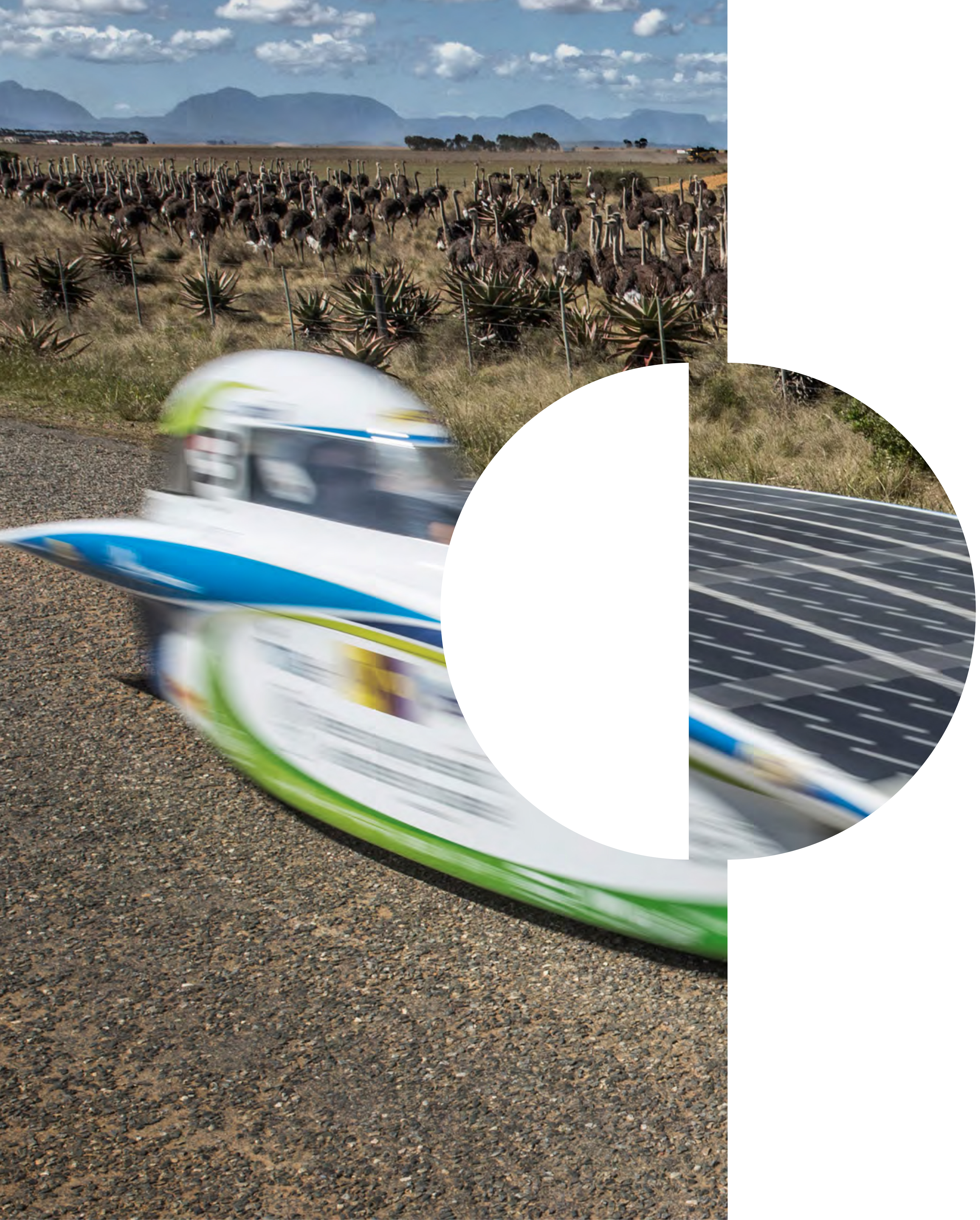
The impact of innovations, including changes in the meaning and importance of values, is increasingly felt, usually even before we have been able to reflect on them. For instance, smart phones have significantly changed our social interactions and it has become common for governments to extensively deploy digital resources for detecting things like fraud. In addition, unwanted effects can hit us harder because of the growing interrelation between human beings and technology. It may have greater consequences when someone's personally collected health data gets out in the public than when a passport photo is published without permission. The acceleration and complexity around technological innovations challenge our adaptive capacity. This applies to governments, as well as to citizens, companies and knowledge institutes. The Council sees examples of a new repertoire of strategies, interventions and instruments to handle the ever more complex society and the unpredictability of processes. This repertoire is often supported by technological possibilities, like big data, real-time monitoring and digital forums. In these examples, sections within government increase their adaptive capacity by continuously exploring (technological) developments, continuously adapting their role and actively engaging in networks.

1.3 Pressing questions of policy

The Council concludes that different dynamics and complexities are emerging around technological innovations. This requires a strengthening of the adaptive capacity within government as a whole. It needs a different type of government participation, in existing and new networks. After all, these networks give shape to the closer interaction between technology and society. Moreover, the Council considers it of great importance to organise broad debates on the impact of innovations on values, parallel to the technological development. In the opinion of the Council, this is pre-eminently a task for the government, as is the stimulation of life-long learning and the prevention of unwanted effects of new social divides.

In Chapter 7, the Council proposes five policy questions that the government should consider with urgency. They relate to the growing public importance of data infrastructure, to the impact on values of increasing use of data, to the organisation of public debates on technology, to the impact of technological developments on spatial planning and infrastructure and finally, to the changing role of government.

The chapters contain examples from the subjects of healthy nutrition, smart buildings and efficient mobility. In the thematic elaboration following Chapter 7, these examples and other possible effects of technological innovations are collected by subject.



2

ACCELERATION OF TECHNOLOGICAL DEVELOPMENTS

Our lives, our living environment and our behaviour are inherently connected with technology. A life without technology is completely unthinkable.

The Council observes that technological developments are accelerating. Various experts notice trends that demonstrate this acceleration, which can even be summarised in mathematical patterns (see paragraph 2.1). Firstly, there is an acceleration in the number and scope of breakthrough technologies that are created from the converging of technologies (see paragraph 2.2). Secondly, technological developments are occurring more and more in an international context, increasing the potential of available knowledge and brain power (see paragraph 2.3). People can share knowledge and experiences through international networks and work on solutions to (societal) challenges together. Growing numbers of educated people in the world increase the combined knowledge and brainpower. Thirdly, thanks to falling costs, technological innovations become available to more and more people. The speed with which consumers adopt innovations is growing constantly (see paragraph 2.4).

2.1 Mathematical patterns in the pace of technological developments

The acceleration of technological developments is creating a reservoir of technologies that could break through (Trendrede.nl, 2013). The acceleration for instance appears from the growing number of worldwide patents that are granted and the associated increase in the number of innovations. In 2010, 75% more patents were granted than in 2000, which is a higher growth than in the previous decade (30%) (Kurstjens et al., 2012).

Sometimes, the acceleration can be summarised in mathematical patterns, like Moore's law (the number of transistors on a chip doubles every 24 months) and the Carlson Curve (the cost and performance of DNA sequencing improves with at least a factor of two every two years). Ray Kurzweil (1999) extrapolated Moore's law to the past by looking at computational performance: the number of calculations per second per thousand dollars. For more than a hundred years, this computational performance has been showing an exponential growth, from analogue mechanical calculators to the later computers with vacuum tubes and today's semiconductor chips. He called it the Law of Accelerating Returns, which applies to many technological and biological evolutions (see example in Box 1 'Exponential growth of solar energy'). In these examples the accelerated development goes hand in hand with a decrease in scale: ever smaller products with ever higher performance.

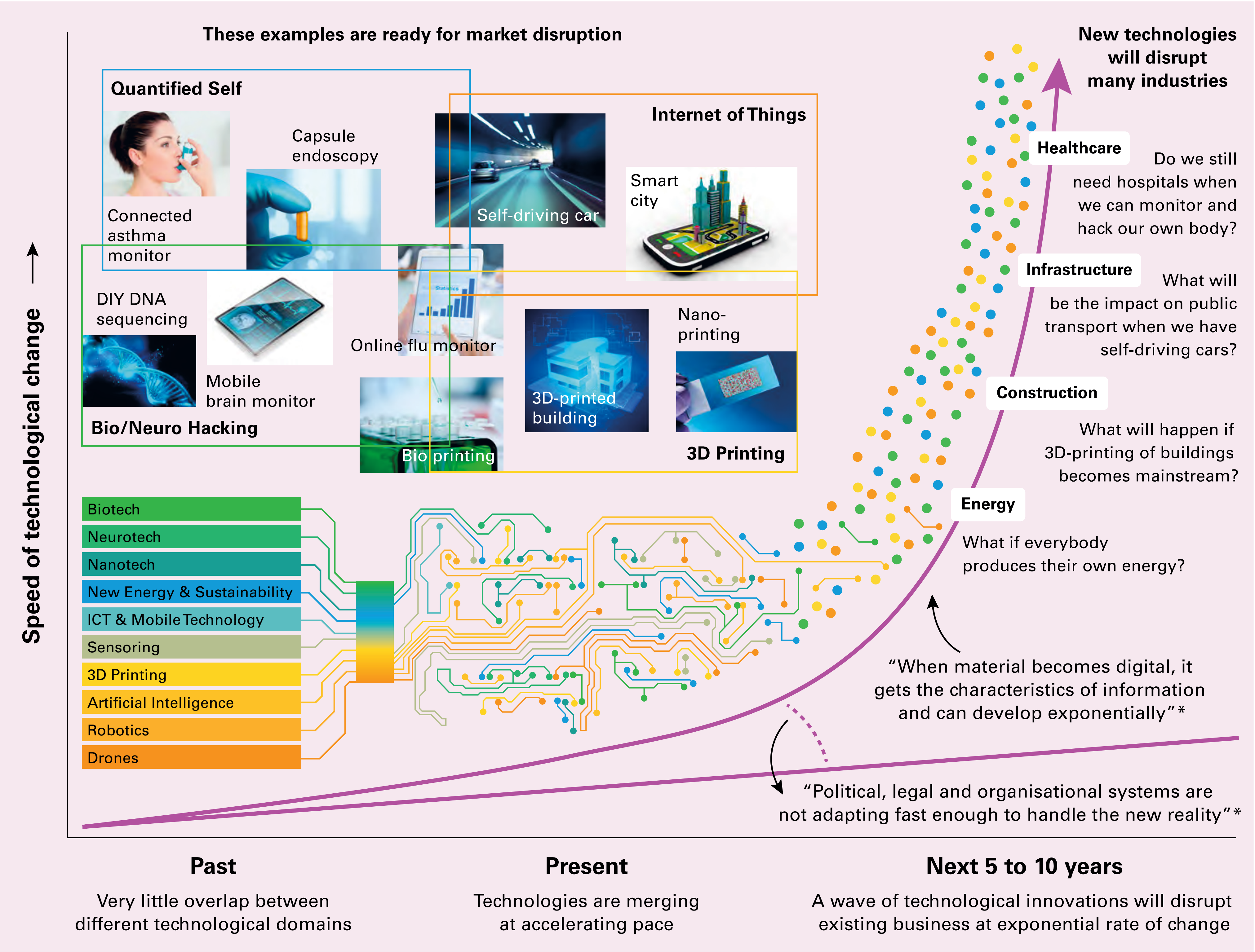
Box 1: Exponential growth of solar energy

These patterns also apply to the increase in worldwide energy production from solar cells and to the storage capacity for electrical energy, in particular through the application of nanotechnology. Worldwide, the installed solar cell capacity has increased from 23 gigawatts in 2009, to 71 gigawatts in 2011 to 139 gigawatts in 2013 (European Photovoltaic Industry Association, 2014). If this only covers 1% of the world's energy needs, but exponential growth applies, then the situation in which solar energy will meet the entire energy needs is only eight doubling steps away (1%, 2%, 4%, 8%, 16%, 32%, 64%, 128%). This situation could be reached within two decades (De Ridder, 2011).

For these patterns, technological acceleration is often preceded by a period of steady development. For instance, the first solar cell already dates from 1883 and the 3D printing technology is already thirty years old. In this initial stage, expectations are high and are usually perceived not to have been fulfilled, as a result of which the development is often no longer taken seriously. However, after a long initial stage, it shows that the application and the degree of use of these technologies are able to grow rapidly. Figure 1 shows that various technological developments are on or near the point of breakthrough. Bill Gates (1995) indicated that people always overestimate the change that will take place in the next two years and underestimate the change that will take place in the next ten years ("Don't let yourself be lulled into inaction", according to Bill Gates).

Some argue that exponential growth is limited to technological developments that go hand in hand with a decrease in scale of components (Kelly, 2010), like Moore's law. The acceleration in many other knowledge areas then piggybacks on the acceleration in ICT. Critics claim that the end of Moore's law is in sight, because a further reduction of the 'nanochip' is not possible (Kaku, 2011). Others think that the performance doubling will

Figure 1: Acceleration of technological developments



Source: Deloitte, 2013. * Quote: Salim Ismail, Global Ambassador & Founding Executive Director Singularity University continue because of the use of other concepts than the standard silicon chip (Huff, 2009), like stacking of chips, use of carbon nanotubes or quantum computers (one of the Dutch National Icons; see Rijksoverheid, 2014).

Whether it will come to a large-scale adoption of the technologies mentioned in Figure 1 depends on economic factors, like vested interests, existing standards, energy prices and availability of raw materials, as well as on social factors, like related social challenges (Scheerder et al., 2014), consumer needs and acceptance of effects on values.

2.2 Convergence accelerates breakthroughs

Innovations usually occur at the interface of knowledge areas and at the boundaries between sectors. In particular nanotechnology, biotechnology, information technology and cognitive sciences (NBIC technologies) are becoming increasingly interwoven in new technologies (Roco & Bainbridge, 2003). An example is the unmanned aircraft (drone). It uses energy-efficient batteries, light materials and small sensors based on nanotechnology, information technology for navigation and learning systems from cognitive sciences to relieve or even replace the pilot. It is this convergence that makes drones possible and accelerates their development.

Figure 2: Convergence of NBIC technologies

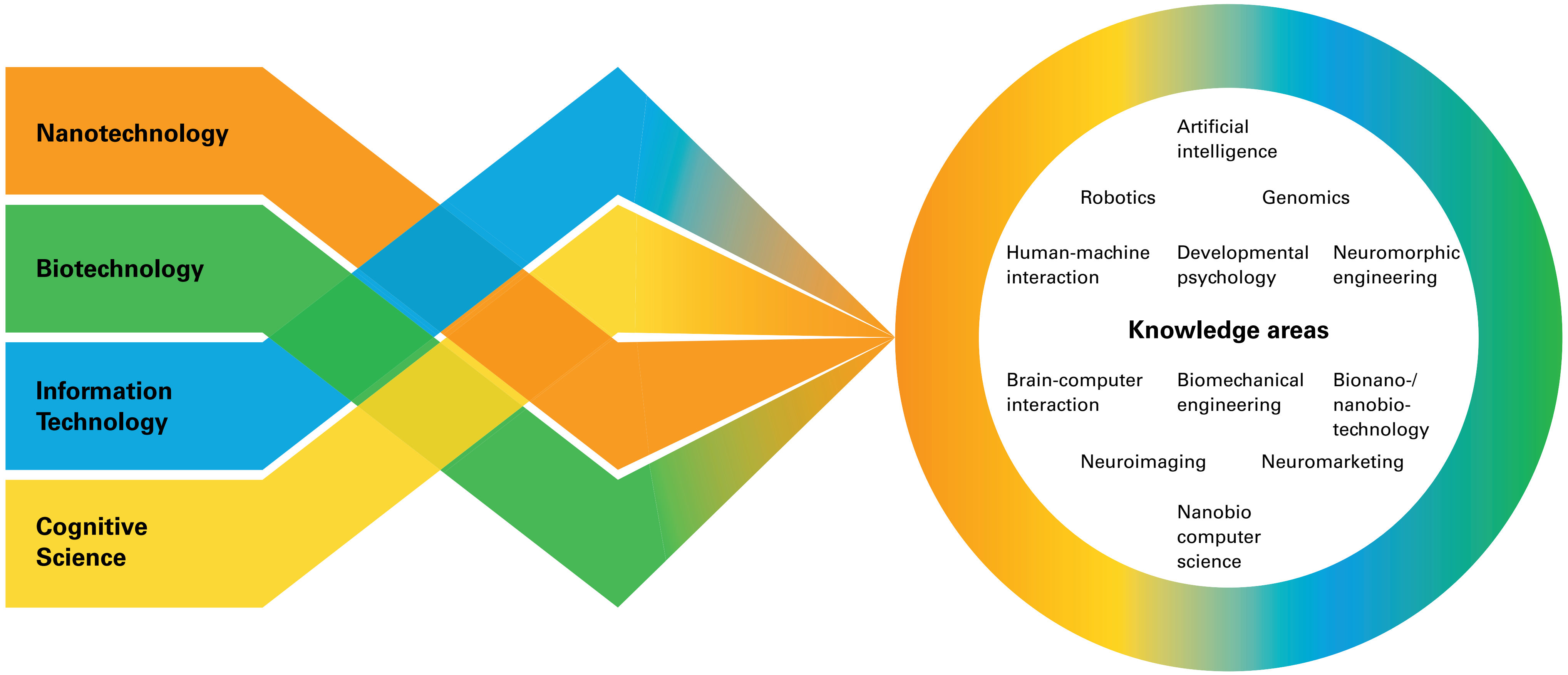


Figure 2 shows other examples where NBIC technologies meet and overlap. New knowledge areas emerge that are rooted in multiple NBIC sciences. For instance, ICT and cognitive sciences produce innovations in the field of artificial intelligence, which are used for the development of self-driving vehicles. From nanomaterials and biotechnology arise new production processes for foodstuff like the extraction and modification of vegetable proteins. In the cognitive sciences, ICT enables new imaging techniques, like neuroimaging. This technology is meanwhile being used to investigate why we prefer certain foods. Finally, based on the knowledge of nanomaterials, cognition and ICT, intelligent household systems are being developed.

2.3 More people with more knowledge connected in more international networks

The number of people with time and money to work on technology is increasing because of the growth of the world population and the world economy and as a result of emancipation, which allows more people to pursue a higher education (Kurstjens et al., 2012). Users are no longer just end-users, but participate in the innovation process (Slot & Frissen, 2007). Consequently, there is a larger global potential of manpower and brainpower available, leading to more rapid technological developments (see also Box 2 *'Expansion of interactive knowledge networks accelerates technology'*).

In addition, technological developments tend to accelerate if more interests are focused on a specific technology. In a rapidly flattening world, in which physical distances play less and less of a role because of digital connections (Friedman, 2008), this is going better and faster every day, also because of the creation of economic unions and international institutions. International social and economic networks are strengthened by the possibilities offered by ICT. People, time and money can then be specifically deployed at a higher scale with a shared objective: to develop this technology.

Box 2: Expansion of interactive knowledge networks accelerates technology

Metcalfe's law (founder of 3Com corporation and inventor of the Ethernet protocol) puts it that the value of an interactive network increases quadratically with the number of connected users. This may explain why Google invests a billion dollars to launch 180 satellites with start-up O3b Networks (the name refers to the three billion people who do not yet have Internet access). This is not Google's only plan to make mobile Internet available in larger parts of the world. With its project Loon, Google intends to transmit network signals to areas without Internet access with the help of balloons at a height of twenty kilometres. In addition, Google is planning fast Internet services in twelve cities in the United States via an optical fiber connection (fiber-to-the-home). Google has also recruited companies and experts that want to deploy drones for making the Internet broadly available.

In 2004, Charles Leadbeater published 'The Pro-Am Revolution', in which he described that people are increasingly pursuing amateur activities at a professional level. In the same year, James Surowiecki published 'The Wisdom of Crowds', in which he argues that large groups of people arrive at better solutions and insights than the cleverest individuals. Consumers or citizens go to the Internet for information about a subject (from the purchase of a car to the process of shale gas extraction) and regularly appear to have just as much or even more expertise than professionals.

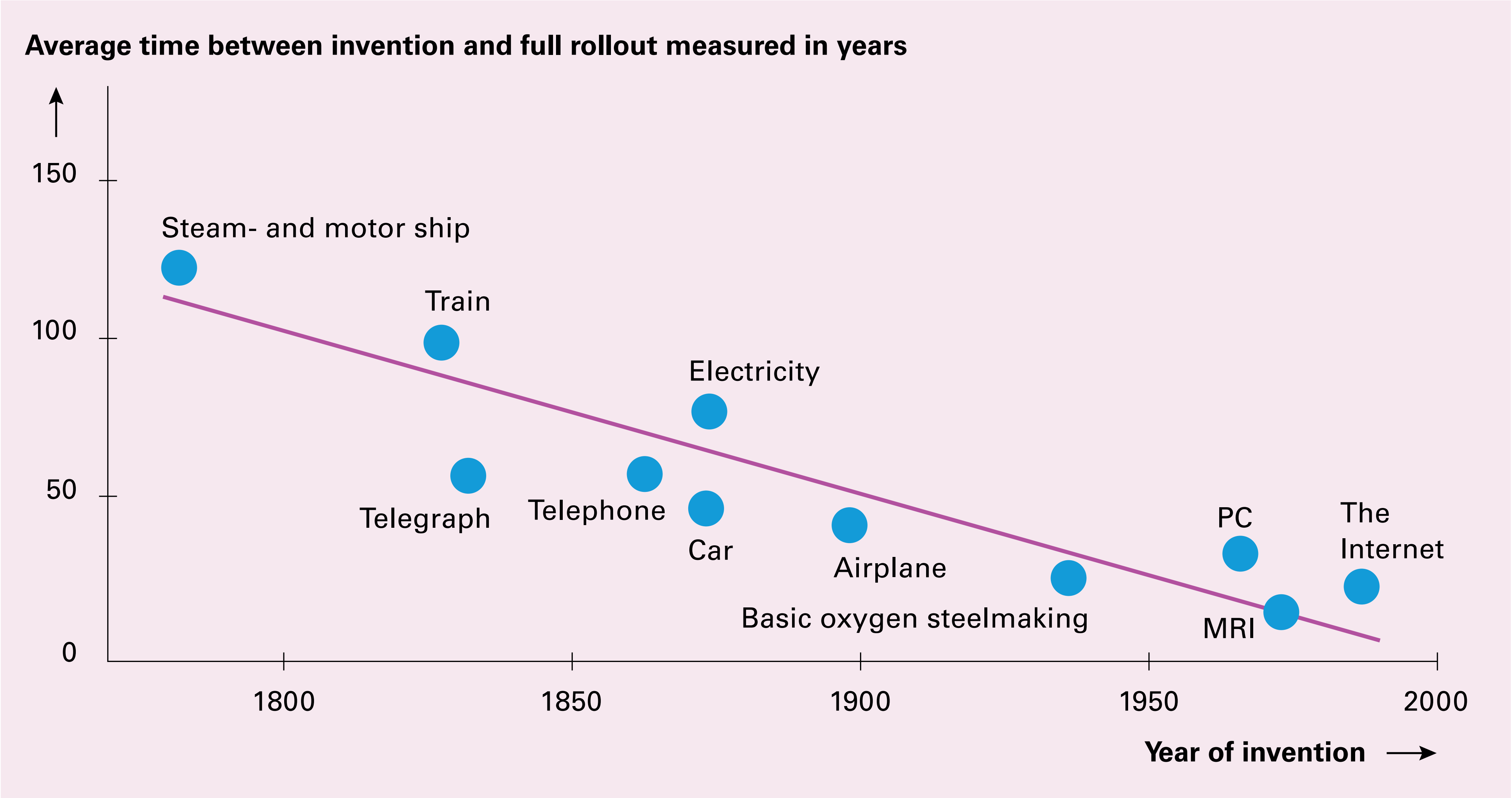
2.4 Acceleration of large-scale adoption of technology

A breakthrough technology only manifests itself truly when it has widespread application (Perez, 2002). Falling costs make new technologies available to more and more people. This in turn leads to new innovations. Cheap computing power, storage capacity and broadband Internet together explain the enormous success of YouTube. YouTube has been able to build on the availability of affordable computers with sufficient computing power to enable video processing by consumers (Montgomery, 2013).

Falling costs also enable cheaper production of customised products for individual customers. This trend is reinforced by the possibility of 3D printing to deliver small-scale customisation close to customers.

The speed with which consumers adopt innovations is also constantly increasing. Where the acceptance of the steamship took more than a century, the Internet changed the world in only a decade. Apple and Facebook made a revolution in less than five years. The time needed for the worldwide rollout of an innovation halves every fifty years (see Figure 3).

Figure 3: Increasingly rapid large-scale adoption of new technology



Full rollout takes place when the technology is used on a large scale for the production of (unfinished) goods or services. The figure shows an average for all relevant countries. Source: Kurstjens et al., 2012

3

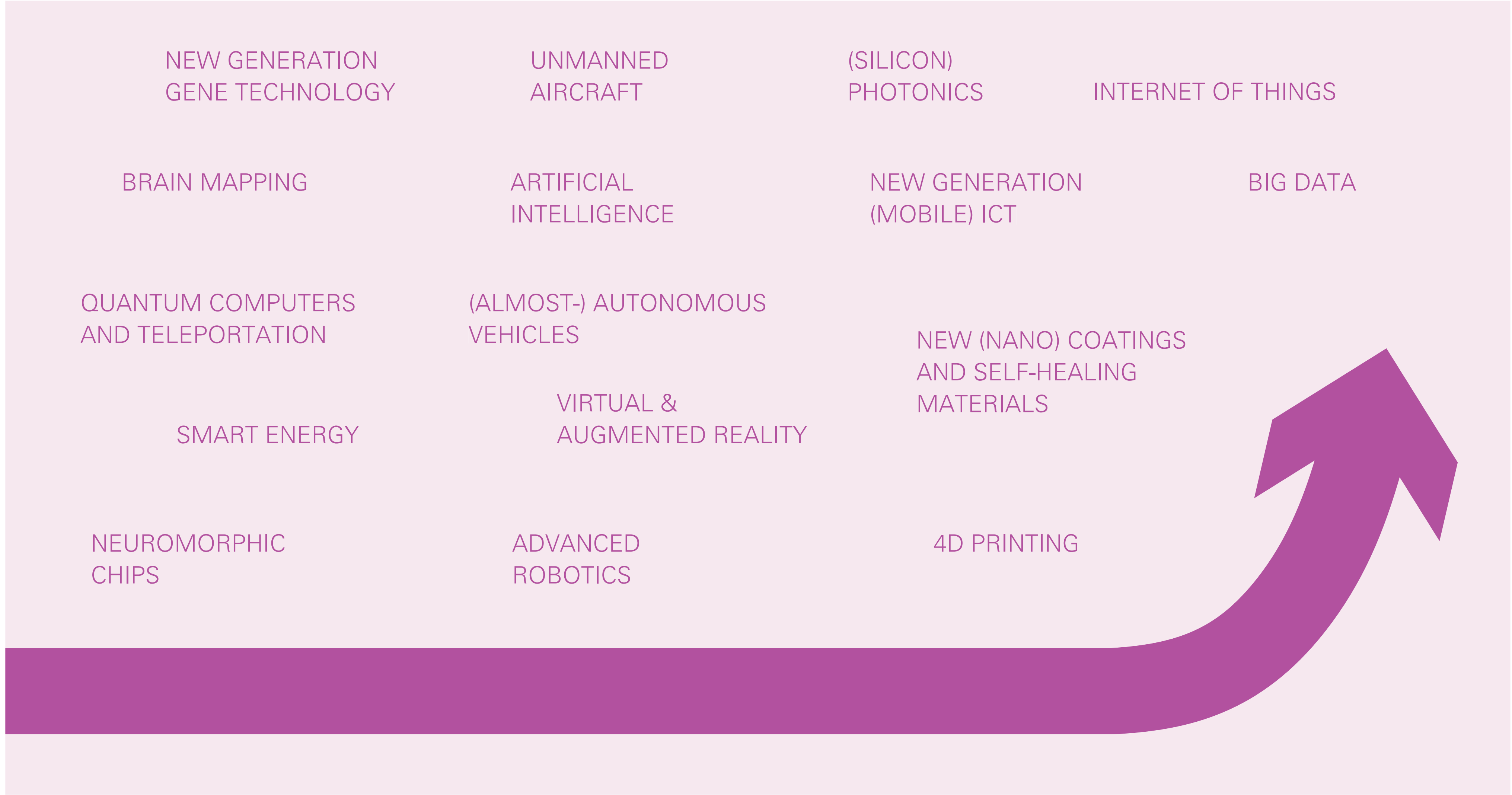
EFFECTS OF BREAKTHROUGH TECHNOLOGIES ON THE LIVING ENVIRONMENT

There are several ways in which technologies can constitute a breakthrough. They can offer new solutions to societal challenges, like a more efficient use of road infrastructure through autonomous vehicles or a more economic use of scarce resources through precision agriculture. They can also change social structures through market transformations (retail changes as a result of e-commerce; see Shopping2020, 2014), create new economic sectors (development of apps) or bring about changes in production chains (local production of spare parts with 3D printers). In this way they can significantly change existing institutions.

It is nothing new that breakthrough technologies change our daily lives and living environment. Steel-framed buildings and lifts transformed our built environment, which went skyward. Trains and cars enabled us to cover long distances faster; the required new infrastructures changed the design of cities. Containers and refrigeration were important for the development of a worldwide network of food chains and made products available independent of the season.

The previously discussed acceleration in technological developments increases the chance that in the coming decades numerous breakthrough technologies that can profoundly influence our living environment will appear simultaneously or in rapid succession. The list below gives an overview of possible breakthrough technologies for the coming decades. New generation ICT has a special place in this because it is really no longer an autonomous technology, but provides the infrastructure that is of great importance to further economic growth and social development.

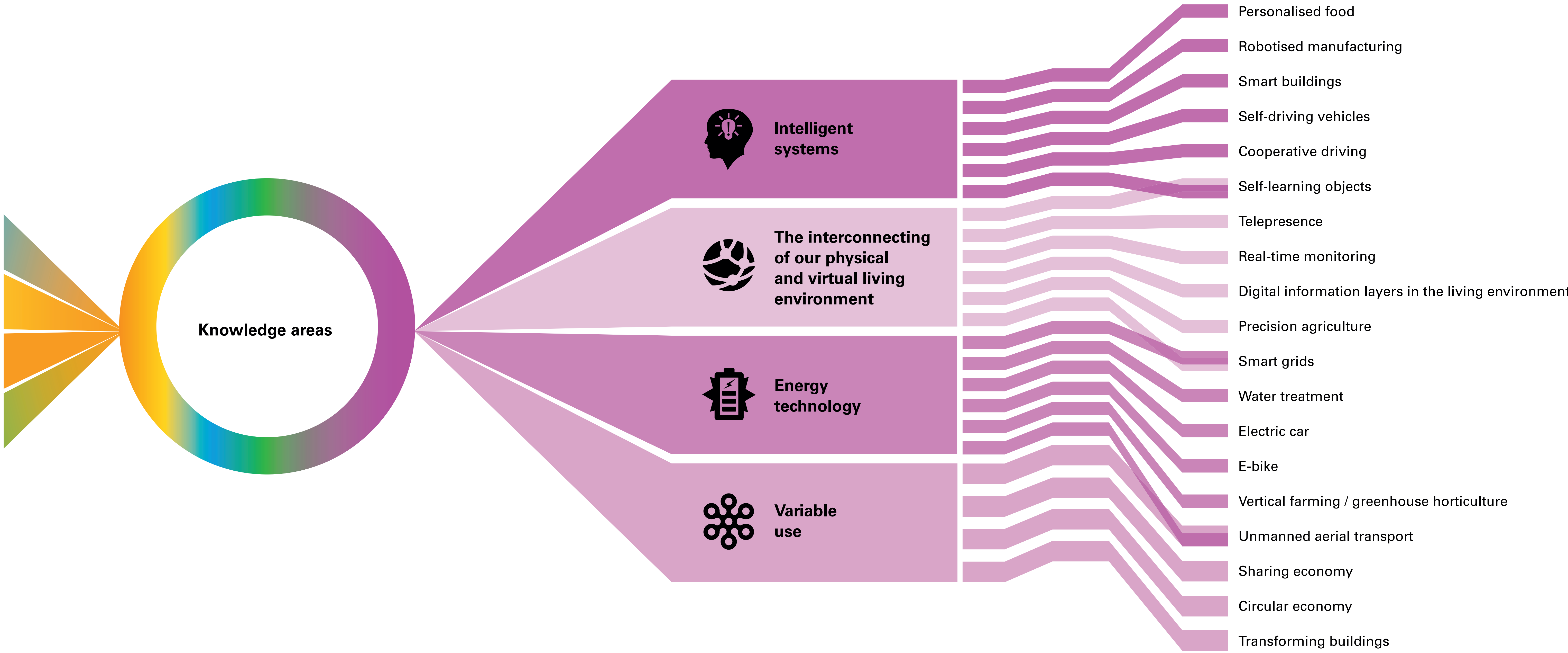
Figure 4: Possible breakthrough technologies for the coming decades



Sources: Manyika et al., 2013; Kurzweil, 2005; MIT Technology Review, 2014; Scheerder et al., 2014

The following paragraphs explore the possible effects of these breakthrough technologies on healthy nutrition, efficient mobility and smart buildings. This is done along four lines (see Figure 5): the determining influence of new energy technologies, the possibility of multifunctional use of spaces and buildings, the emergence of more intelligent systems and the interconnecting of our physical and virtual living environment. The technological developments within the three subjects affect each other and are irrevocably interwoven in their combined impact on the living environment.

Figure 5: The possible impacts of breakthrough technologies along four lines



3.1 Breakthroughs in energy technology are decisive for all sectors of the living environment

Breakthroughs in sustainable energy determine to a large extent the developments in nutrition, mobility and buildings. New nanomaterials enable breakthroughs in energy storage (larger storage capacity and higher charging speeds), which allow solar and wind energy to be used at a larger scale. Solar cells based on nanomaterials will be able to deliver more energy per square metre. Another possibility is the development of energy-producing nanocoatings for walls, roofs, cars and roads. Because they can cover large surfaces, efficiency does not have to be so high to be able to deliver a profitable amount of energy. Because of these and other developments, for instance in the field of insulation and new 4D-printed, reprogrammable building materials, buildings cannot only become energy-neutral, but also supply energy and even become self-sufficient.

Clean, affordable energy sources for transport can strongly reduce greenhouse gas emissions and improve air quality in our immediate living environment. When energy costs are no longer the determining factor for transport, mobility can increase strongly as regards volume and duration of traffic movements. In addition, new types of transport movements may develop, like individual transport by air or exoskeleton-supported race walking.

For the cultivation of crops in certain areas it could become profitable to turn saltwater into freshwater for irrigation and so provide more food security. It would also allow energy-intensive greenhouse cultivation or vertical farming in more places. The effects on agriculture and horticulture in the Netherlands are difficult to identify because cheap, clean energy will cause global shifts in agricultural and horticultural production.

More decentralised energy production and more intelligent energy use, like in buildings and exterior lighting, but also for instance by connecting electric car batteries to a smart grid, can drastically change the energy infrastructure. The combination of centralised and decentralised energy facilities can probably contribute towards a more robust energy supply by a much larger number of nodes.

The International Energy Agency expects that renewable energy sources will supply almost half of the global growth in electricity generation up to 2040, among other things as a result of falling costs. The demand for fossil fuels continues to rise, but the share of fossil fuels is decreasing and international energy prices are falling (International Energy Agency, 2014). So the question remains when energy costs for mobility, nutrition and buildings will be drastically reduced.

3.2 More multifunctional buildings

New materials, interactive OLED walls (organic light emitting diode), robotics, modular building units (Larson, 2012) and virtual, augmented and ambient reality allow spaces to be adapted to individual needs and preferences. Our personal preferences for design and atmosphere of a space (home or office) can be digitally transmitted and on arrival or even beforehand furniture, systems, walls, doors and decorations can be adapted to our specific requirements. This will make us feel at home in more places.

The same technology makes it easier to share buildings and homes, so that the number of spaces needed for various functions can be reduced. Depending on the need of the moment, a space can be used consecutively as a gymnasium, theatre or meeting place. New materials and building elements combined with 4D printers and construction robots enable us to construct, adapt or demolish buildings and recycle building materials faster than now. This makes the construction and renovation of buildings and offices more flexible.

When it becomes easier to transform spaces according to need, cities could be further densified. It is not so much that there will be more space, but that there will be more options for a variable use of space. This can have serious consequences for the existing practice of spatial planning and of structuring multi-functional living environments. The question is whether these possibilities will be quickly exploited in practice, as vested interests play a role in this, like right of ownership, agreed utilisation and land holdings. In addition, variable use of spaces and buildings can impact transport flows and the associated infrastructure.

3.3 Increasing intelligence in nutrition, mobility and building technology

Next to new energy technology and materials, another important development is the growing use of artificial intelligence in nutrition, mobility and buildings. Mobile phones, cars and production robots already contain artificial intelligence: they make simple choices through pre-programmed algorithms, like which twitter messages appear on someone's timeline. Meanwhile, the first applications of self-learning algorithms already exist. These algorithms learn to perform on the basis of measuring signals from sensors in an unknown and changing environment, like army robot mules carrying equipment. Neuromorphic chips, designed on the basis of neurological structures instead of digital logic, are becoming suitable for processing complex sensory information like images and sounds (Human Brain Project; see Europese Commissie, 2014). Some researchers think that artificial intelligence may match or even exceed the intelligence of the human brain.

Vehicles are becoming more and more intelligent. Planes are perfectly capable of taking off, flying and landing on autopilot. Cars are using computers to control fuel consumption, to keep distance to the car in front, to calculate the fastest route based on actual traffic information and to park automatically. Several companies are working on their own versions of increasingly autonomous cars.
Roads can be used more efficiently by the use of real-time information on road use through traffic regulation and through information to road users. Communication between vehicles and between vehicles and traffic infrastructure allows 'cooperative driving' one behind the other in a 'train'. However, this would mean a more intensive use of the road surface, causing maintenance to be needed sooner. The next generation of road surfaces can self-repair smaller cracks and can transfer data on the condition of the road surface for preventive maintenance. The connection of autonomous vehicles to public transport will also set requirements for the arrangement of areas around for instance railway stations (Jansma, 2014).
If autonomous vehicles can drive by themselves and if there is a shift towards car sharing, a lot of parking space could be freed up. Space that can be used to improve the quality of the living environment.

Artificial intelligence, next to big data and DNA sequencing, can also help us achieve a healthier diet. Nanobiosensors in for instance smartphones or smart bands or embedded in clothing can measure biomarkers through the skin. They can also collect and analyse movement patterns. Based on those measurements, individual combined nutrition and exercise advice can be given that is suited to the situation. People are already experimenting with these possibilities for collecting information about themselves and learning from it (Quantified Self). Cognition research, among other things through neuroimaging, can give more insight into the effects of nutrition in combination with exercise, on someone's health and mental wellbeing. On the basis of the required nutrients, measured by sensors, and our own taste preferences a computer can devise a recipe that combines these two aspects (IBM, 2014). A robot can then automatically prepare the desired recipe. Such robots are currently under development, as is the 3D food printer. More knowledge about personalised healthy dietary patterns could result in breakthroughs in the treatment of specific diseases, but is also important for elderly care and for the promotion of general physical and mental health. If on average this would help us to grow older healthier, it would in turn influence people's mobility patterns and housing and recreational preferences.

High-tech agriculture under controlled conditions with the help of for instance sensors, LED lighting (light emitting diode) and local administration of water and other nutrient delivers higher yields per square metre and enables food production in the built environment. This could create shorter, more recognisable food chains.
The development towards a biobased economy, supported by gene technology and biocatalysis, combined with vertical farming, can simplify the use of waste flows within cities. For instance the use of waste flows for the production of raw materials for bioplastics, which 3D printers can use for the local production of all sorts of products. This can contribute to the closing of material flows within cities. As a result, great changes may occur in the local, national and international flows of goods.

3.4 Physical and virtual living environment increasingly interconnected

Not only utensils, but also our living environment and infrastructure will contain more and more intelligence. Homes become smarter with home automation, which controls the living environment, communication, entertainment, security and energy consumption in interaction with the residents. One step further, the home automation system controls robots that provide care, like shopping and preparing meals, and ensure that we get enough exercise. New types of telepresence (in addition to telephone and Internet), virtual reality and telerobotics make it possible to communicate and gain experiences - for instance travelling to other countries - without leaving our home. Thanks to this kind of technologies more people may be able to live at home longer independently (Raad voor de leefomgeving en infrastructuur, 2014a).

Also when it comes to mobility, the physical and virtual environment will increasingly merge. The mobility system of the future will be almost entirely controlled by self-learning algorithms that respond to various data flows that produce a current picture (real-time monitoring) of the traffic situation. As a result, traffic jams and accidents can be minimised, even in mixed traffic consisting of autonomous trucks, almost-autonomous vehicles and people-driven vehicles. Consequently, the role of data infrastructure will become at least as decisive as that of road infrastructure. They merge into a single mobility infrastructure.

RFID chips (radio-frequency identification) and nanosensors yield information about the origin, quantity and quality of foodstuff. Thanks to a good ICT infrastructure combined with smartphone apps and smart bands, this information can be easily shared within the entire chain, including consumers.

The origin and composition of foodstuff becomes more transparent, so that people are much more able to follow their own preferences, including customised products from 3D printers. This in turn creates opportunities for primary producers in the area or further away, because these technologies enable them to enter into a direct relationship with their customers and to respond to their needs and preferences.

4

INCREASING IMPORTANCE OF NETWORKS

Growing numbers of ever more diverse physical networks, social networks and data networks are being linked. Also to people: technology is getting closer and closer to us, even entering our body. Innovation processes, production processes, revenue models and the labour market are changing as a result of faster mobile communication technologies, smarter self-learning algorithms and increasing robotisation. Innovations are more and more emerging from networks. Companies with specialised knowledge operate in multiple networks and their knowledge is applied in multiple sectors. As technologies are becoming more and more complex and interconnected, the impact of their application is more difficult to understand, to predict and to control. This chapter describes these four effects of new technologies on society.

4.1 Technology creates numerous connections

ICT establishes connections within and between various types of networks: physical networks, like energy infrastructure, waterways, roads and districts; social networks, both face to face and virtual, and data networks. Developments in ICT stimulate globalisation through fast, almost immediate communication and document sharing on the Internet. Distances have been radically reduced, and information and experiences are disseminated ever broader and faster. The growing number of connections between networks strengthens the correlation between economic sectors and between social issues. The next generation of mobile ICT will also increasingly connect people and organisations to artificial intelligence in computers, robots and mobile phones (see paragraph 3.3). Nicholas Carr (2011) commented that in addition to advantages, like far greater access to information and help to solve problems, there could be adverse effects, like a reduction of concentration, reflection and creativity.

With ever smaller sensors, increasingly smarter electronics and new nanocoatings, technology is getting closer and closer to us, even entering our body (Van Est et al., 2014). We are already used to carrying our mobile phones with us all the time. The first smart bands are already on the market. Prototypes of shirts with integrated sensors and electronics also exist. The next step is more technological artefacts inside our body, not only to treat diseases, but also to support us in our daily life. In other words: technology is changing from carryable, wearable and nearable to insideable (Engelen, 2014). There are already people with implanted RFID chips that give them access to their homes, offices or clubs, where they can then pay with the balance on their chip.

4.2 Innovations are more and more emerging from networks

Because of a growing number of networks with an ever greater diversity, societies are being organised differently in a fundamental way (Castells, 2005). Technological capabilities allow the creation of self-managing networks of large and small companies, knowledge and research institutes and consumers. In the further evolution of the knowledge economy, this makes the triple helix (cooperation between business, knowledge institutes and government) an outdated concept and obliges us, following on from among others the European Commission, to talk about the quadruple helix: in the knowledge economy, citizens join the interplay of forces between governments, the research community and businesses as an important source of experience, knowledge and interests.

Self-managing networks help to develop innovations that yield economic and social returns, as they facilitate the close interaction between actors from different sectors and knowledge areas. The power of networks lies in the creation of new connections, which in turn lead to new insights and discussions, also about standardisation, intellectual property and mechanisms for conflict resolution. This interaction thrives in physical networks like brainparks and tech labs and in digital networks like open innovation platforms (see Box 3 'Knowledge economy in networks').

Which digital networks are involved in these processes varies per issue and depends on the moment. A process of active exploration can start in a broad network to gather many ideas and values. It can then be continued in a smaller and differently composed part of the network to work on solutions, which are then again broadly disseminated to generate feedback. If an issue can best be addressed and solved locally, the necessary knowledge and best practices can be derived from a much larger (inter)national network.

Box 3: Knowledge economy in networks

At the High Tech Campus in Eindhoven, businesses and research institutes are working together in open-innovation processes. The people working for these organisations meet each other on campus, but are also connected with other people in worldwide digital innovation networks. Crowdsourcing platforms like Quirky help to accelerate product development. Because of the success of crowdsourcing, GE company has opened its patent portfolio to the Quirky community to develop more new products per year. In the past few years, the Internet has enabled local companies to rapidly develop into multinational enterprises (e.g. Uber, Facebook, Google). In the future, such trends will only become stronger because of more and faster (wireless) connections, more intelligent mobile devices and because more and more people will have access to the Internet.

4.3 Specialised companies in multiple networks

Faster mobile communication technology, smarter self-learning algorithms and further robotisation not only result in new products. In addition to innovation processes they also change production processes, revenue models and the labour market. Business becomes more dynamic, while the downward trend in the average lifespan of companies continues. Only companies that can adjust their production capacity, product type and business model more rapidly than others will remain competitive in the knowledge economy (Kurstjens et al., 2012).

The great importance of knowledge will often require further specialisation, with specialised companies in multiple networks and sectors operating in a larger international market. Small companies can make money by working together with other small and large companies on the basis of highly specialised knowledge. A company like KPN commits itself to the supply of connectivity, realising content and applications together with other larger and smaller companies (De Jager, 2014). ASML has a network of hundreds of smaller companies that not only supply specific components, but are also continuously developing them, in consultation with ASML.

Companies that grow rapidly internationally through large-scale adoption of innovative products can determine new international standards. This can provide entrepreneurs with a platform for offering new products, like new apps (Kreijveld et al., 2014). On the other hand, the more we use Google's products and services, the more information Google can gather about us (to 'google' has become a verb). Google can use this information for the development of new services in for instance the insurance, the tourist and the credit industry. Meanwhile, new innovation dynamics have developed, in which specialisation (in the case of Google the collecting, combining and interpreting of data) in fact leads to business activities in multiple sectors. Through this combination of business activities, companies can obtain an almost monopolistic market share, which can cause distrust among consumers and governments. For instance, on 27 November 2014, the European Parliament adopted a motion that urges the European Commission to separate search engine activities from other commercial activities within companies.

As a result of the greater dynamism in business, jobs could disappear, for instance in production, services and transport. On the other hand, new jobs could be created, for instance in maintenance, recreation and algorithm development. There will then probably also be a greater demand for specific human qualities: critical thinking, creativity, (empathic) communication and cooperation. The precise effect on the labour market is as yet impossible to predict.

4.4 Increasing complexity, decreasing predictability

Not only technologies are becoming increasingly more complex and interconnected. Networks that apparently have nothing to do with each other, can when connected form a complex organised system with new properties and functionalities (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2014a). Such complex systems are difficult to understand and control, but have always surrounded us in nature. For instance, our own body is a complex biological system, of which the components and their interrelations are increasingly better understood by scientists, although not yet entirely unravelled. What is new is that as regards complexity, technological systems are beginning to look like biological systems. The increasing technical complexity and the increasing social complexity of our society go hand in hand. There are increasing differences in the way in which people deal with policies or available technologies. Thus developments in high tech (3D printing) and low tech (food from your own kitchen garden) continue to exist side by side and their interaction produces new possibilities.

In general, all kinds of previously separate developments are influencing each other, both reinforcing and counteracting each other and because of this causality is increasingly less linear. This makes processes more difficult to predict. It is difficult to look many steps ahead at the possible effects of technological developments if they influence both each other and social developments. These social developments can in turn influence technological developments. The only thing certain is that unexpected positive and negative effects will occur (Van der Steen & Van Twist, 2014).

There are also corrective mechanisms. Innovations in one area can have negative effects in other social fields. In interconnected networks these negative effects will be noticed sooner by people concerned about them. They also have immediate access to network forums for turning the spotlight on these effects and discussing them.

5

INNOVATIONS AND VALUES DEBATE INCREASINGLY LINKED

To a significant extent, technological developments are driven by social values and by the challenges and wants in our society. But conversely, technology also influences social and moral values in society. Smart technology can increase our autonomy and freedom of choice, but can also give rise to questions about people's self-determination as regards their body and privacy, about responsibility and about digital security. When technological innovations put pressure on important values of people or groups of people, they will resist such innovations. At the same time, the use of technology is changing people's values and the importance that they attach to them. Thus groups of people have a different view on using mobile phones or on sharing private pictures on the Internet than fifteen years ago. If in due course people have become accustomed to the safety of autonomous vehicles, they might also change their view on drivers who still like to drive themselves. The Council observes that the focus on moral questions regarding technological innovations is increasing and that these questions are being debated more continuously.

Our morals, the actions and behaviour that we see as correct and desirable, are determined by traditions and values that exist within society: on them we base our rules of conduct (standards). Our values are not a given: they are influenced by the spirit of the age and by the use of technologies. People and technology mutually shape each other. Because of the increasing interrelation between human beings and technology, technological innovations are increasingly influencing our morals (Verbeek, 2014).

Some values are fundamental and universal in their nature, like safety, equality and freedom (see also Universal Declaration of Human Rights). Other examples of values are politeness, creativity and trust (see Figure 6). Based on these shared values we agree on standards, for which we are mutually accountable. Thus from the value of safety follows the standard to wear seat belts in cars. The police can fine people who are not wearing their seat belts. Values therefore precede standards. When the meaning and importance that we attach to values change, the associated standards will change with them.

Figure 6: Examples of values

Which values individuals or groups of people consider important and which standards they derive from them, can vary greatly. If people find the same values important, there may be differences in which situation they find which value the most important. Or they translate the same value into another standard. Partially as a result of this, there are great differences in expectations and opinions about the effects of technological innovations. These differences may increase as a result of the growing influence of technological innovations on our morals.

5.1 Technology changes values, but also puts pressure on them

In addition to science driven by wonder, there are also social and economical motives for technological development. Consumers get ideas about what would be fun to have (a fridge that orders your groceries), or which problems have to be solved (being able to go up the stairs to the bedroom despite a physical disability). Companies and investors weigh market opportunities and thereby control the direction of research and innovation. Among other things, governments help define technological developments by linking innovation policies and the granting of subsidies to societal challenges and the associated values. By means of these technologies they want to strengthen these values in society.

Assessment frameworks for technological innovations are often limited to specific measurable values, like effects on the environment, health and safety. However, innovations also have an effect on social and moral values, like freedom of choice and transparency, which are less easy to measure. Sometimes intentional and sometimes unintentional, as appears from the example in Box 4 *'Values and the OV-chipkaart'*. These effects are often forgotten (Swierstra, 2011).

Box 4: Values and the OV-chipkaart

The *OV-chipkaart* (Dutch public transport chip card) enables public transport companies to deploy their resources and staff more efficiently. It makes the distribution of revenues between the companies faster and fairer. The *OV-chipkaart* is convenient for travellers because it offers access to all public transport in the Netherlands (Translink, 2014). Following the transfer from the old bus and tram card to the *OV-chipkaart* it is no longer possible for two persons to travel on the same card. The first train journey with an *OV-chipkaart* requires an initial investment of 27.50 euros. New rules were introduced for seeing people off at the platform. In short, by selecting a set of values, the *OV-chipkaart* has an impact on other social values in the field of mobility. Thus, during the introduction as well as later on the basis of user experiences, a public debate was held about the weighing of values that had been strengthened and values that had come under pressure. As a result, usage rules and conditions have been adjusted gradually. Minister for the Environment Mansveld intends to develop the *OV-chipkaart* further with the help of local pilots. These also offer room for experiments with for instance the use of smartphones and other new methods of payment.

If face recognition with a smartphone, glasses or in social media is possible, the question is not just whether this will be a threat to the value of privacy, but also in particular how as a result our values and standards on privacy will change and how boundaries between private and public will shift. The values with which we assess Google Glass and its successors are influenced by the glasses themselves and by the possibilities that they offer (Verbeek, 2014).
Young people who have grown up with mobile phones have no qualms discussing their love life with a friend in a full train compartment. Other passengers may take offence. If as a result of future technologies energy should become much cheaper and more sustainable, our attitude towards energy efficiency could change. Smartphones provide us with ever more intelligent features, but also collect increasing amounts of data about us, thereby compromising our privacy. Technologies can therefore make a positive contribution to values, but can also put pressure on them (see also Box 5 ‘Resistance to privacy invasions’).

In an environment where we are surrounded by smart technology, freedom of choice and autonomy can increase. Someone who is housebound may for instance be less dependent because of Internet shops, may use social and virtual media for contacts and may independently search the Internet for information about possible treatments. In the future, his or her autonomy will continue to grow thanks to care robots and autonomous vehicles.
Meanwhile, we are getting used to not having to type in our passwords every time, to search engines presenting interesting products to us on their own accord and to social media proposing new contacts that fit our profiles. We often carelessly agree to privacy statements on websites without actually reading them. The question is whether and to what extent people can oversee the consequences of their consent for the use of personal information, even after reading such statements.

The Council observes that more and more businesses extensively explore the impact of their innovations on values by first announcing products to provoke a discussion, by actively engaging with consumers on digital forums and by releasing more intermediate versions of products to gain user experience. In this way, companies get an idea of how products are being received and how they may influence values in practice. By communicating more widely about products, a discussion can arise about if and how

Box 5: Resistance to privacy invasions

“Don’t put anything on paper and certainly not on a computer or mobile phone. Keep everything in your head. It’s the only place with privacy that we still have.” (Forsyth, 2010). At least eight hundred Dutch are trying to obtain 500 euros compensation from social media giant Facebook for invading their privacy. The Dutch civil rights movement Bits of Freedom and specialised legal consultancy ICTRecht of Amsterdam believe that Facebook is deliberately breaking European rules because they are using tracking cookies for following the surfing behaviour of users without their permission. For instance, they are said to be tracking which Internet pages users do and do not ‘like’. All these data are then sold on to business customers. Since the ruling of the European Court of Justice on the ‘right to be forgotten’, Google has been struggling to process the huge flow of requests. To prevent fake profiles, Facebook asks you to use your real name, otherwise your account will be blocked. This has had unexpected effects for drag queens and transgenders. As a result, the new Ello network was all of a sudden receiving thirty thousand requests a day from people wanting to switch in protest against Facebook.

values can be guaranteed under existing or future legislation, for instance liability for autonomous vehicles or for moving home robots. Google has deliberately refrained from introducing face recognition in Google Glass to first allow its social discussion.

5.2 More ongoing attention to moral questions about technological innovations

The result of the personal choice between values that are strengthened or put under pressure by a new application of a technology is different for everyone. The question whether a technology is desired or not is therefore difficult to answer. More and more technology is coming closer to us or is even entering our body (see paragraph 4.1) and is increasingly affecting our lives and our values. People have also become more articulate and can more easily disseminate their opinions through digital forums (Stikker, 2013). In addition, the impact is increasingly difficult to predict in advance because of the increasing complexity (see paragraph 4.4). As a result, the Council observes that in various places the focus on moral issues concerning a technological innovation is increasing and more often takes the form of ongoing debates instead of one-off discussions before or after its implementation.

More and more often, moral questions about technological developments are already getting attention in an early phase of research and development. In 2006, the three technical universities of the Netherlands strengthened the knowledge base about this subject by founding the Centre for Ethics and Technology. In the NanoNextNL research programme (2011), 15% of the budget is allocated to research into risks of nanoparticles and into the social embedding of nanotechnology.
The European research and innovation programme concentrates on the development of the concept of responsible innovation, where the public debate about technological innovations forms an intrinsic part of the innovation process (European Commission, 2014). The Responsible Innovation programme of the Netherlands Organisation for Scientific Research (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2014b) finances and stimulates research in which researchers from various areas of science right from the start examine ethical and social aspects when designing new technology.
Companies are increasingly communicating with their environment (governments, consumers, neighbours, NGOs) about the underlying values of their actions and of the products that they sell, both before and during the development process and afterwards.
In this way, companies account for sustainability in reports on corporate social responsibility or privacy in transparency reports. In particular for digital products like search engines and social media, companies are clearly aware that customers can easily switch to other providers if they cross ethical boundaries too far.

The meaning and role of technological developments cannot be assessed apart from the social context of technology. The social context changes because of new legislation, new activities, new international trends, new technologies et cetera (see example in Box 6 ‘Robots that make moral choices for us’).
Through use in combination with new technology, existing technology can have new uses and as a result have different effects than before. According to the Council, the greater speed with which technological developments succeed each other requires a different, more ongoing reflection on the possible meaning and role of these developments. The example of the *OV-chipkaart* in Box 4 illustrates how usage rules and conditions were gradually adjusted through experiences with the card and its public debate.

Box 6: Robots that make moral choices for us

Robots, in the broadest sense of the word, are intelligent systems that are capable of making 'moral decisions'. This is not science fiction. If a child crosses the road in front of an autonomous vehicle, a choice has to be made: make an emergency stop, drive on because there is a bus full of children behind the vehicle, swerve left where an adult is standing? Nowadays, cars with adaptive cruise control can intervene when we get too close to the rear of the vehicle in front of us. The question is how this system determines whether braking hard will not endanger the safety of traffic behind. Algorithms increasingly determine what we are shown in for instance Google, Facebook, Twitter, but are also increasingly making moral choices for us. How are we going to deal with this? Who designs this machine intelligence, how are moral choices captured in algorithms and how is the transparency of these choices guaranteed?

Bryant Walker Smith outlines a similar process for the development of regulations and conditions for the use of autonomous vehicles. In various states of the United States, current legislation allows self-driving vehicles, provided that a driver is present to take control of the vehicle if needed. However, it is unclear what this driver is allowed to do and what not when driving or how well in advance the vehicle must send a signal to the driver to safely take the wheel again (Walker Smith, 2014). In view of the available room for experiments and public debates about experiences in various networks, continuing insights will provide the answers to these questions.

Because of further internationalisation, developments will inevitably affect Dutch society. An example are innovations in the field of genetic modification. In the European Union (EU), the application of these technologies is limited by strict rules regarding the cultivation and import of food and animal feed (Europees Parlement, 2001). The same rules apply to industrial and medical applications, but result in far fewer restrictions. Outside the EU, for instance in the United States, Brasil, Australia and China, genetic modification is applied on an increasing scale, also for food.

In the course of the years, technologies for modifying genetic material have greatly improved. New opportunities are arising, not only in the production of food and animal feed, but also for the biobased economy and for medical applications. New technologies for genome editing, like CRISPR–Cas (clustered regularly interspaced short palindromic repeat - associated protein), allow changes in the genome to be carried out with much greater precision. In addition, breeding techniques are being developed in the EU that apply gene technology, but do not produce species transgression. There is debate whether the products created by these techniques, like cisgenesis for potatoes, are genetically modified or traditionally bred crops. These products no longer show the route along which the modified hereditary characteristics have come about. If these breeding techniques are seen as traditional breeding, they would not fall under EU regulations for genetically modified organisms (GMOs) and consequently not be subject to the more rigorous risk analysis for these products.

Recently (January 2015) the EU decided upon new legislation that gives individual member states opportunity to deviate from an authorisation of the cultivation at EU level giving reasons (Europees

Parlement, 2014). Member states can thus impose stricter requirements for the growing of genetically modified crops within their own borders. The Dutch Committee on Genetic Modification (COGEM) previously noted that EU regulations fail to take proper account of new developments in among other things genome editing. It proposes to focus regulation on the safety of products instead of on production methods as in the current regulations (COGEM, 2014a en 2014b). The question remains whether at international level, the EU will again make a broad assessment between the social and economical pros and cons of the current rules.

6

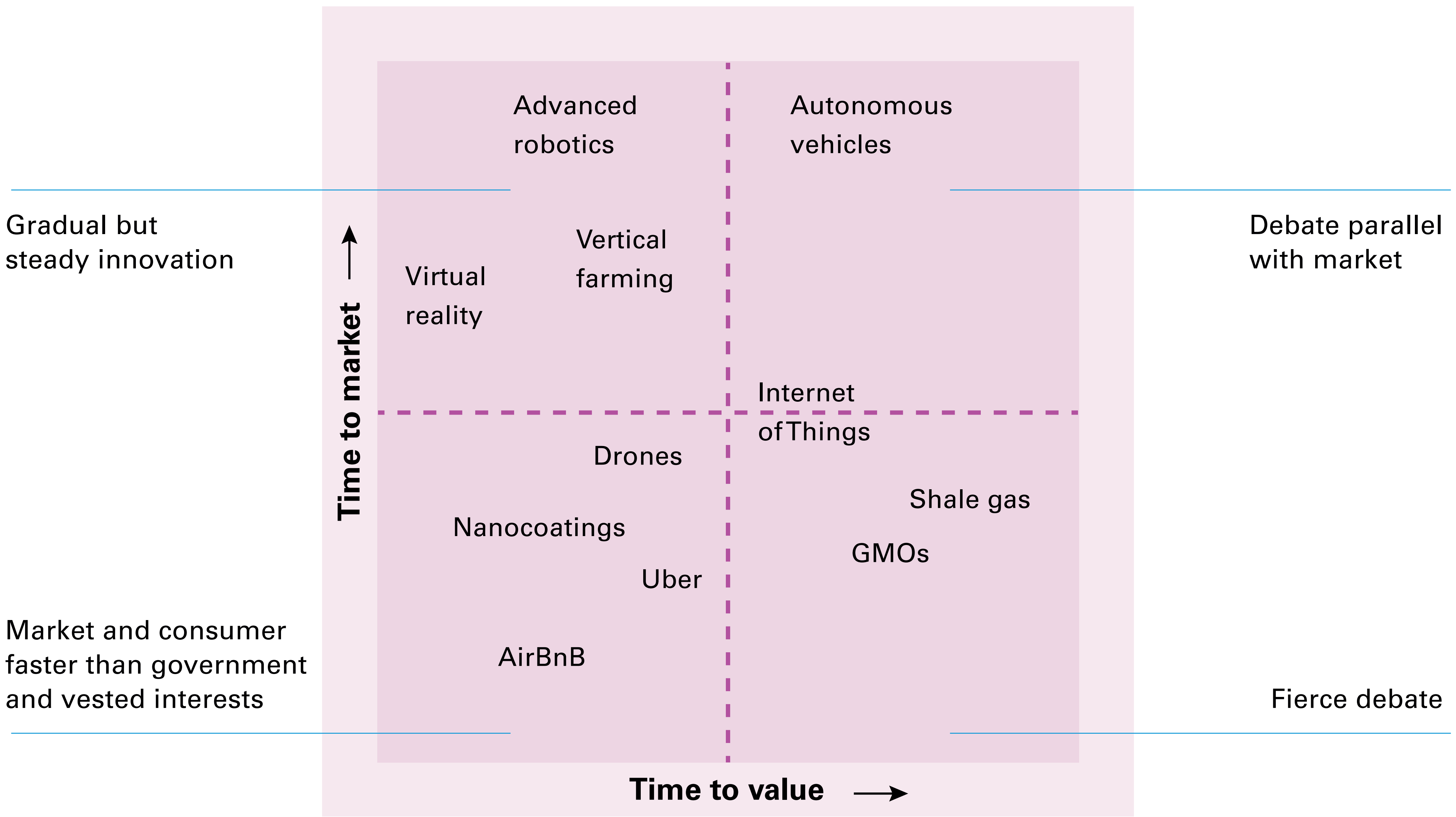
ACCELERATION AND COMPLEXITY CHALLENGE ADAPTIVE CAPACITY

The impact of innovations, including changes in the meaning and importance of values, is increasingly felt, usually even before we have been able to reflect on them together. For instance, smartphones have significantly changed our social interactions and it has become common for governments to extensively deploy digital resources for detecting things like fraud. In addition, unwanted effects can hit us harder because of the growing interrelation between human beings and technology. A leaked personal health profile may have greater consequences than a passport photo published without permission. The acceleration and complexity around technological innovations challenge our adaptive capacity. This applies to governments, as well as to citizens, companies and knowledge institutes.

The Council sees examples of a new repertoire of strategies, interventions and instruments to handle the ever more complex society and the unpredictability of processes. This repertoire is often supported by technological possibilities, like big data, real-time monitoring and digital forums. In addition, the Council observes that sections within government are increasing their adaptive capacity by actively engaging in networks (see paragraph 6.1), by continuously exploring (technological) developments, by continuously adapting their role and thereby becoming more agile (see paragraph 6.2).

Adaptive capacity means the ability to respond continuously to new developments and adapt to them in time. Roles, objectives, activities and strategies are continuously adjusted. As a result, the direction of the technological development itself can be influenced.

Figure 7: Time to market versus time to value and the public debate



6.1 Governments more often participate in networks

The acceleration in technological development is in particular reflected in faster market introductions: a shorter time to market. At the same time, broad public acceptance (time to value) is more irregular as the public debate about the values involved is more complicated. Figure 7 gives a number of examples of innovations with the various relationships between the period before market introduction and the period up to and including broad public acceptance (if it eventually comes). If the impact of an innovation affects multiple sectors and parties involved, and if over time the debate in society also changes, the difference between the two periods may become greater.

The Council observes that parts of governments are actively and honestly prepared to cooperate with others, discuss matters and arrive at joint solutions. In doing so, they are increasingly switching between their various roles (legislator, financier, promoter, mediator et cetera.) and operating in and between various networks of parties involved. In this interaction in networks between governments and parties in society, processes seem to be progressing better, support for the adjusted roll-out of innovations seems to be stronger and as a result the time to value of projects can even be speeded up (see the example in Box 7 'Public participation in networks'). Governments can no longer control the dynamics of networks and the versatility of complex issues through a top-down approach. Their standard procedures and efficiency standards are not always already geared to rapid technological developments. The Council notes that various parts of governments are as yet inadequately equipped for an adaptive role in a network environment. For instance, they do not yet involve citizens or consumers in these networks or do not link their problems to other issues. They base themselves mainly on their permanent place in the old network, work according to known rules and stick to the current working culture.

Debates on technological developments are usually conducted in existing networks. As a result, new players have difficulties in gaining access to these networks. In other words: networks (social, physical and digital) not only connect, but also exclude newcomers. In this way, they also regularly ignore ideas for removing barriers to innovation and for solving societal problems. Often, vested interests

Box 7: Public participation in networks

Within the 'The Living Wall' project, residents and entrepreneurs brought in an alternative plan to that of Rijkswaterstaat and the municipality of Utrecht. To limit noise pollution from the widening of motorways near the Lunetten district of Utrecht, an acoustic barrier was to be installed between the road and the district. However, in addition to noise pollution, some residents were also worried about air quality. They set up a residents' committee to develop an alternative that would solve both issues. The 'Living Wall' is a higher acoustic barrier to further limit the noise, which simultaneously filters the air because the barrier is covered with plants. To cover the higher costs, they developed a business plan to link other objectives to the initiative, like use of space over the road and less heavy goods traffic trough the district. What started as a standard process with a formal information and consultation session, ended in a dynamic process with all parties involved, making other options conceivable, logical and feasible (Van der Steen et al., 2014).

of companies, citizens or governments are used as arguments for delaying or blocking developments. This may be legitimate, but it could also point to a blind spot for new opportunities and for the risks involved when clinging to the present moment.

Not everybody finds it easy to play a role in public debates or to join new networks. Unequal access to new technologies can lead to new forms of division in society or to a strengthening of existing divides. It is a self-reinforcing process, because individuals and groups that are not involved in the debate are unable to bring their influence to bear, so that they become even more excluded.

6.2 Governments are becoming more agile

Paragraph 4.4 described that the complexity and interdependence of new technologies makes it more difficult to predict their effects on individuals and society, and that the unpredictability becomes even greater because in turn individuals and society react to these new technologies. Because the effects are difficult to assess, it is problematic to set frameworks for the application of new technologies in advance. Existing rules and regulations, as well as their absence, can limit the adaptive capacity (Pelkmans & Renda, 2014). Governments that opt for an approach of active exploration and experience are gaining new knowledge and experience at every step and are therefore able to adapt to developments. This increases their adaptive capacity. It means that governments adapt their role to the times, depending on the process, to the cooperation partners and to the stakeholders. By using ideas of relevant organisations and citizens and making agreements about the inclusion of progressive insights, all parties are able to adapt faster. This increases the agility of governments for responding to new developments (see Box 8 'Agile municipalities'). This could mean taking a step back at the right time. For that purpose, Great Britain's Localism Act includes the Right to Challenge: local communities and citizens can propose to take over public tasks (United Kingdom, 2011).

An example is the development of autonomous vehicles. The Dutch government wants businesses to

Box 8: Agile municipalities

Instead of resilience against the impact of changes, municipalities can also focus on agility to respond to changes fast and to adapt to them. There are municipalities that in their strategy for the three decentralisations in the field of care, youth and work assume that things will go differently than planned. On an experimental basis they have already adopted the new rules within these policy areas to experience their effects. These municipalities focus on the resilience in the local community. To realise maximum learning potential, some municipalities are investing in connections with other municipalities, citizens and professionals. These municipalities are particularly concerned about the degree in which the central government continues to offer space to trust on resilience, instead of framing it again (Van der Steen & Van Twist, 2014). By expanding the network in which the municipality operates and by connecting with other parties as new nodes in the network, in emergency situations other solutions or routes in the network can be used (temporarily). In anticipation of the entry into force of the Dutch Environment and Planning Act in 2018, legal possibilities have been created to already start experimenting with this act.

develop knowledge and gain experience in this area to strengthen their competitiveness. The government then does not express an opinion, but investigates the possible positive and negative effects of autonomous vehicles. It does this together with stakeholders. Under current legislation room has been created for experiments, however, rather than already drawing up a whole new legislation, the umbrella legislation for liability and privacy continues to apply. The government also plays a mediating role by ensuring that road users, behaviourists, citizens, interest groups, experts and other stakeholders have the most current information at their disposal. In this way all parties involved can continuously help thinking about the way in which autonomous vehicles can be integrated in our daily lives, in our living environment and in our set of values. Depending on the way in which technology, its use and our set of values develop, the government can lay down rules to protect public values, like safety and privacy.

The Council notes that governments can increase their adaptive capacity if there is room for experiments, as well as a culture that tolerates errors to learn from them. Within such room for experiments the parties involved can try out and experience the social impact of technological innovations and together weigh the effects on various values. The introduction of nanotechnology in the Netherlands seems to be based on a similar approach (Raad voor de leefomgeving en infrastructuur, 2014b). With room for experiments, governments are increasing their own learning potential, but also that of citizens, companies, knowledge institutes and social organisations (Wetenschappelijke Raad voor het Regeringsbeleid, 2006).

Learning also takes place by exploring the future and by backcasting. The government of Singapore for instance applies this way of learning, which enables them to anticipate new possibilities of technologies and changing economic revenue models, using small steps. However, the Council notes that the impact of breakthrough technologies is only included in horizon scans and trend analyses in a limited way (for example through what-if scenarios), because they are accompanied by great uncertainties (Planbureau voor de Leefomgeving i.s.m. Centraal Planbureau, 2013).

According to the Council, technological developments also require a greater adaptive capacity in education. Energy efficiency will become a requirement in the construction sector, but are we training enough pupils and (lateral entry) students? When finally the influx of exact sciences students into colleges of higher education increased, no quick switch was made to enable this, but a numerus fixus was instated. Tomorrow's employees will increasingly be asked to quickly access information, to handle large amounts of information, to bring together and evaluate information from various backgrounds, and most importantly: to add new knowledge themselves. Tomorrow's labour market wants people who can think critically, understand algorithms (European Schoolnet, 2014), are creative and have good communication and cooperation skills.

7

PRESSING QUESTIONS OF POLICY

The Council concludes that different dynamics and complexities are emerging around technological innovations. Technological developments are accelerating and can have a major impact on nutrition and buildings as well as on mobility. Technological innovations create new economic, social and ethical questions and can significantly change existing institutions. This requires a strengthening of the adaptive capacity within government as a whole. It needs a different type of government participation, in existing and new networks. After all, these networks give shape to the closer interaction between technology and society. Moreover, the Council considers it of great importance to organise broad debates on the impact of innovations on values, parallel to the technological development. In the opinion of the Council, this is pre-eminently a task for the government, as is the stimulation of life-long learning and the prevention of unwanted effects of new social divides.

Below, the Council proposes five policy questions that the government should consider with urgency. They relate to the growing public importance of data infrastructure, to the impact on values of increasing use of data, to the organisation of public debates on technology, to the impact of technological development on spatial planning and infrastructure and finally, to the changing role of government.

7.1 How can the increasing public interest of data infrastructure be guaranteed?

The data infrastructure becomes associated with all sorts of new functions, like the Internet of (Living) Things in buildings and production chains, dynamic mobility systems and precision agriculture. Because it plays an ever greater role in living, working, caring, producing and recreation, the data infrastructure is becoming a crucial part of the living environment. Socially and economically, data use and access to data traffic is becoming increasingly important and as a result becomes a public interest through values like open access, transparency, safety, privacy and robustness. This raises the question how public and private responsibilities need to be allocated for promoting the public interest of the data infrastructure. In addition, public responsibilities are also divided between the central government, local and regional authorities, the European Union and wider international forums. How can these authorities maintain an overview of data infrastructure developments in the various sectors and the resulting changes in the public interest?

Important aspects are accessibility, reliability and connection speeds. Compared to neighbouring countries, the Netherlands has an extensive data infrastructure, but a lasting lead is not self-evident. When sectors become increasingly dependent on data infrastructure, its reliability in situations that are very different from normal conditions, also becomes important. For example, think of redundancy in the system in the event of local outage or vulnerability as a result of dependency on one or more large market parties.

Technological development is an important factor in the dynamics of society, as a result of which earlier guarantees of public interests could no longer be effective and would have to be revised. If the public interest of the data infrastructure for society changes, it may be appropriate to look again at how it is guaranteed. The Scientific Council for Government Policy (Wetenschappelijke Raad voor het Regeringsbeleid, 2000) distinguishes four mechanisms for guaranteeing public interests: rules, competition, hierarchy, institutional values. The Netherlands Senate published a decision framework to support decision-making on privatisation of tasks (Eerste Kamer, 2012).

7.2 How can governments guarantee values like transparency, accessibility, privacy and trust when data use increases?

The growing number of connections and the inclusion of intelligence in appliances or even inside our bodies creates new data streams. This in turn leads to questions about who may use which data, for what purpose and under which conditions, like transparency, privacy, reliability of data and digital security.

To make best use of the advantages of big data, it is important to recognise privacy issues, the correct use of data and transparency about its application. Consumers and citizens should be able to inspect and correct data stored about themselves (Bloem et al., 2014) and be allowed access to it for their own use. This requires that central governments have effective privacy laws and recognisable monitoring of infringements. In addition, governments can include clear relevant requirements in invitations to tender.

It is likely that in the future the demand for symmetry in data use will become more imperative. Symmetry means that people can download and upload their data at the same speeds and can also use and modify their data. This depends on the architecture of databases (Munnichs et al., 2010). Symmetry also determines whether digitisation not only makes our life easier but also really increases our autonomy (see example Box 9 'Smart cities design together with citizens'). Perhaps trust, autonomy and the creation of room for manoeuvre with insight into and grip on the functioning of algorithms is more important than absolute protection of personal data. This is an important subject, as appears from the suspension of the general statutory introduction of the electronic patient record in the Netherlands, which was ultimately due to worries about the ownership of medical data and about patient privacy. Evgeny Morozov (Martijn, 2014) said that if we all control our own data, this does not mean that our privacy is safe. He indicated that this even has a downside: nobody would have to contribute to public interests that can be realised with big data.

Because 93% of Internet users do not read general terms and conditions before they click 'Agree', the Nationale DenkTank 2014 is introducing the *DataWijzer*: terms and conditions simplified by means of recognisable icons (2014). The think tank proposes to use four icons, so that users can see at a glance what happens with their data: how long their data is stored, which data is actually stored, whether their data can be sold on to third parties and whether or not the terms and conditions fall under Dutch law.

Recently, the Dutch cabinet initiated a cabinet vision on the phenomenon of big data and profiling in the private sector, in relation to the right to privacy and the right to equal treatment. The cabinet acknowledged the increasing social and economic potential for the use of data. The cabinet also observed that the impact of the technology and associated developments in the markets could breach the trust of citizens in the way in

Box 9: Smart cities design together with citizens

Municipal authorities tend to look at technological possibilities for the development of smarter cities from a government perspective and based on current public interests. In this type of plans it is important that citizens play a clear role, in order to create more reciprocity in interests and possibilities. This involves questions like: how do citizens benefit from a development, how do the plans contribute to their social relationships, which values do the plans strengthen for them, how are they allowed to use the generated data?

which their data is handled. Existing legislation on protection against invasion of privacy and against unequal treatment is not always in line with the changes in the use of data (Tweede Kamer, 2014). In the intended approach, the cabinet recognises that on account of the increasing complexity, in addition to legislation or the laying down of standards by the government, multiple tracks are required, like stimulation of the privacy by design principle and organisation of an expert group with a broad representation from the society. The technological developments described in this survey strengthen the importance of such a cabinet vision. After all, it concerns developments that affect our (personal) living environment via different sectors (and therefore departments).

The increasing demand for symmetry raises a number of questions. Will governments and companies soon pay extra or give discounts for our personal data on account of its great value? Or will so much data be created that its price will only go down?
Will organisations that can build a reputation in offering valuable services where personal data is handled reliably have an advantage on account of the confidence they inspire?

Because of technological developments this will become topical questions as regards nutrition, buildings and mobility. How can various sections within government maintain an overview of the differences and similarities between various sectors when developing policies for these questions?

7.3 How can the government broaden social debates on technology as regards time, parties involved and consequences?

The Council sees reason to synchronise the processes of technological developments more with debates on their broad impact. Because of this broad and hard to predict impact, progressive insights has to be included and all parties need to be involved.
A more parallel process of technological development and ongoing debates on the impact offers more possibilities for adapting the technology to values that we find important as a society. The Council believes it is important to make implicit choices explicit, so that defaults (standard values) in innovations become visible. For instance, the default that the appliance cannot be opened for repairs or that GPS locations are always sent on to the supplier or that the autonomous vehicle should always swerve for dogs. Social and moral values have then been included in the development and design process.

The Council observes that this broadening of debates requires a new repertoire of strategies, interventions and instruments to realise this in the ever more complex society. Sometimes, this can be supported by technological possibilities, like big data, real-time monitoring and digital forums. However, in the opinion of the Council active research remains necessary to understand what is going on, otherwise monitoring is reduced to combating symptoms.

7.4 How can the government take account of effects of technological innovations on spatial planning and infrastructure?

In Chapter 3 the Council identified possible effects of breakthrough technologies for the living environment along four lines. These four lines offer clues that should be taken into account in spatial planning, but that also raise questions.

Technological developments are changing the use of public spaces and the use of buildings. Spaces, buildings and road sections can be used more easily for different functions. Soon, buildings and spaces can be built or transformed quicker (see paragraph A2 below). If developing and building will soon be even faster, what will this mean for the decision-making processes for spatial planning? How can zoning plans become more flexible? What does it mean for securities for investment decisions and for the depreciation period of investments?

The living environment itself will become an intelligent system. Who will be controlling parts of this intelligence? To what extent will intelligent systems be allowed to take their own decisions in the future? How dependent will we be on those systems or their suppliers? Which values are included in those systems? What timing is appropriate to respond to a different spatial planning that is suited to more intelligence in buildings, production processes, roads and vehicles?

Finally, breakthroughs in energy technology may be reflected in spatial planning. More decentralised energy production and more intelligent use of energy can drastically change the energy infrastructure, for instance to enable each party to supply energy to the network. With more buildings producing their own energy, the role of the current energy network could also change significantly. More different carriers of energy may emerge, as well as other methods of storage or transport.

For policy development on spatial planning, governments base themselves among other things on horizon scans and trend analyses. This survey shows the increasing interconnection of physical and virtual space, the determining influence of new energy technologies, the development of variable use of buildings and spaces and the increasing intelligence in technical systems around us. The Council sees reason to reflect on the structural exploration and further inclusion of technological developments in usual exploration methods to connect these developments better to current and future social challenges.

7.5 The changing role of government

As the influence of technology in our daily lives is growing, it is in the interest of citizens to play a greater role in its development and application. Paragraph 6.1 indicated that not everybody can easily play this role, with the possible consequence of new or stronger divides in society. Networks can provide platforms for these debates, but among other things this requires network neutrality and inclusiveness.
Frances Brazier (2014) concluded that other paradigms are needed to structure the network functions in such a way that people become empowered to participate and to take responsibility for their own behaviour in complex dynamic systems. Participation promotes transparency and trust. The Council is of the opinion that an even more important role of government will be to facilitate access to networks and to guarantee that groups will remain broadly involved in debates.

Technological developments also change markets and institutions, where existing policies and legislation usually guarantee the interests of existing market players and institutions more than those of new players. In a short time, new players can have an impact on public interests and values, in a positive but also in a negative sense. What type of rules and regulations or which additional tools are better geared to the introduction of new technologies, so that also when technological innovations accelerate opportunities for challenges in the living environment are not wasted and risks are limited?

The internationalisation of technological developments through innovation processes in international networks and the more rapid global spread of innovations, is also changing the playing field in the Netherlands. Think for instance of standards that are developed elsewhere and that are coming our way. Sometimes these are public standards and sometimes private. How does the role of government change if the standard is more difficult to determine, given the increasing interrelation of technology in networks and increasing complexity? Will governments participate in the network in which standards are developed, because the standardisation process also determines the defaults for technological innovations? Is standardisation even more a task for the European Union and other international networks because of the global scale on which technological developments occur?

Not only the role of governments is shifting, the same applies to companies, knowledge institutes and citizens. Governments can and should leave more room to these parties to assume their responsibilities and to pick up ideas, while in other cases more control and vision on the part of the government remains necessary. The question is how more parts of government can incorporate an approach of active exploration and learning by experiment in their way of working and participate more in networks, involve multiple parties at an earlier stage and think cross-sectorally. Institutes like the Rathenau Instituut can play a role in this. No single model can be identified for this and therefore in the next few years a lot of experimental daring and trust in parties will be required from governments.

THEMATIC ELABORATION

Without being exhaustive, the following paragraphs give a brief impression of what the technologies from the 'Possible breakthrough technologies for the coming decades' overview in Chapter 3 could subsequently mean for the subjects of healthy nutrition, smart buildings and efficient mobility.

A.1 Technology for healthy nutrition

The production of food is a concatenation of applied technologies. Technologies that increase production volume, technologies that ensure hygiene, technologies that influence taste, texture and bite and technologies that change the nutritional value of food. Technologies are being developed that can greatly change our food and dietary patterns. The Netherlands Study Centre for Technology Trends has compiled a number of these technologies in an overview and explained them in their publication *'Toekomstverkenning Agro & Food'* (Stichting Toekomstbeeld der Techniek, forthcoming).

Technology can completely change the network of chains in the food industry. Some chains may disappear, but new chains are also created that overlap with other sectors, like the chemistry sector. Trade agreements and other economical and political partnerships also have a great influence on technological innovations and on chains in the food industry. The Scientific Council for Government Policy advocates a change from an agricultural policy to a food policy, among other things because the network of food chains ('food net') has greatly changed as a result of the greater role of non-agricultural businesses in this network. This is causing concern about the robustness of the food system, also because a large part of the markets has come into the hands of a small number of companies (Wetenschappelijke Raad voor het Regeringsbeleid, 2014).

Retail

As a result of ICT, RFID chips (radio-frequency identification), nanosensors in smart packaging, smart bands and all sorts of apps, the food chain is generating ever more data that can be exchanged ever more easily throughout the entire chain, up to and including with consumers. Tracking and tracing makes it increasingly easy to monitor the origin of products, which helps to ensure food safety, sustainability and fair trade. More and better information enables consumers to adjust their buying behaviour for food more accurately to their personal preferences. The increasing interrelation of physical and online shopping makes it easier for consumers to shift between suppliers. Online, suppliers can more easily be compared and products can be delivered to the home or to a collection point. Supported by technologies like 3D printing, primary producers, in the area or further away, can together with consumers better anticipate their preferences. As a result, the type and role of retail and distributive trade could greatly change. It is as yet unclear what these changes will entail and how significant they will be. The many types (for instance local and global, small and large-scale, short and long production chains) may continue to coexist. Innovative retail channels like online subscriptions to regional products or supermarkets without disposable packaging are already appearing.

Precision agriculture

Precision agriculture can greatly increase yields, which has a positive effect on food security. Unmanned aircraft, mini-satellites and sensors can be used to collect more and more targeted information. Robotics, for instance, enables the precisely targeted administration of water, nutrition and (biological) pesticides. Crop yields vary per square meter and per year, because it concerns biological systems, but with precision agriculture, variations will become smaller.

In addition, targeted administration of pesticides reduces their use, resulting in a lower environmental impact. Improved monitoring and control increases the predictive value of production models and increases transparency within the entire chain.

The development of the biobased economy (from an economy based on fossil resources to an economy based on biomass), with contributions from gene technology and biocatalysis, stimulates the development of agro-industrial parks. The combination of high-tech agricultural production and production of biomass in the urban environment, for instance through vertical farming, aquaponics and urban aquaculture, can have great effects on the length of food chains, on circular material flows and on the application of biobased products like bioplastics in 3D printers. The question is whether high-tech agricultural production will take place in existing businesses that are using new knowledge or in new businesses that are competing with traditional agriculture.

Figure 8: Examples of technologies in healthy nutrition

Substitutes for current animal proteins in food

All over the world, increasing prosperity causes a growth in the consumption of animal proteins. That does not seem consistent with what we consider to be a healthy dietary pattern. Because of the increasing consumption of animal proteins, the relatively great ecological disadvantages of the current production methods for animal proteins are also becoming greater. Therefore, technology that enables a healthy and ecologically responsible substitution of animal proteins in dietary patterns is interesting.

There are different ways in which technology can produce tasty and easy substitutes for animal proteins in food, for instance through vegetable proteins from seaweed as meat substitutes. Together with VION (an internationally operating food company), McDonald's is developing hamburgers based on proteins from tomatoes. Various technologies, like 3D printing, are helping to create an attractive texture or bite that resembles meat. Another development is cultured meat based on stem cells, in other words meat production without living animals. Finally, it is being investigated how technologies could be used to add insect proteins to Western foodstuff. In large parts of the world insects are a traditional part of the diet, but in Western Europe this is unusual. Incidentally, in countries where this tradition exists, the consumption of insects seems to be partly displaced by the consumption of meat.

Synthetic biology and genome editing

Also as a result of convergence between ICT, nanotechnology and biotechnology, the technologies for modifying genetic material have been strongly improved. New opportunities are arising, not only for the production of food and animal feed (green biotech), but also for the biobased economy (white biotech) and for medical applications (red biotech). New technologies for genome editing, like CRISPR–Cas (clustered regularly interspaced short palindromic repeat - associated protein), allow much greater precision in altering the genome (COGEM, 2014a). In addition, breeding techniques are being developed that use gene technology, but do not produce species transgression. An example is cisgenesis for potatoes, where species-specific genes from wild potato varieties are used for increasing resistance against phytophthora (potato blight).
Synthetic biology goes beyond changing hereditary characteristics and develops building blocks for the design, modification and control of biological systems (Rerimassie & Stemerding, 2014). These building blocks can be used as switches for activating or deactivating genes, as a storage medium for data, or to control the metabolism of microorganisms. Meanwhile, DNA strands can be ordered through the Internet in any desired composition at low prices, as a result of which the application of this technology has also become accessible to relatively small businesses.

Synthetic biology supports the development towards a biobased economy, because it allows the substitution of fossil resources in production processes. Meanwhile, there are possibilities for faster and very targeted growing of products that make specific desired substances, like spider silk (useful as extremely strong textile fibre) from goat's milk (Lewis, 2014). Further experiments are being performed with the production of cow's milk and even breast milk from modified yeast. Large-scale application of such technology can have major implications for the dairy sector. Work is also underway on the development of antibiotics that considerably reduce the risk of resistant bacteria, so-called lantibiotics.
In addition to questions about safety and security, the developments around genetic modification and synthetic biology also involve ethical, legal and

social issues. There is for instance a discussion about patenting. A new development is the databank of the BioBricks Foundation, offering free access to developed biological building blocks to help accelerate innovation within synthetic biology (Rerimassie & Stemerding, 2014).

Personalised food

Technology extends the food chain to the individual: individual body measurements by ever smaller and cheaper sensors that can be translated into individual nutritional needs through data analysis. Both in medicine and in food, knowledge based on statistics (epidemiology) is shifting towards knowledge based on individual features: the quantified self leads to personalised medicine and personalised food. Through the application of nanobiosensors in a lab-on-a-chip, or soon even easier by using light to measure through the skin, various biometric features can be measured. This produces fast feedback on somebody's lifestyle and nutritional needs.

Cognition research, among other things through neuroimaging, increasingly provides us with knowledge about the impact of nutrition on health and spiritual wellbeing, and about the synergy between nutrition and exercise. This knowledge is used in playful games for health, which train people on a scientific basis in making healthy nutrition choices.

Nutrigenomics studies the interaction between someone's personal genes and nutrition. A person's microbiome, the whole of micro-organisms in his or her body, like intestinal flora, is increasingly easy to map. A disturbed microbiome can then be repaired through fecal transplantation, phage therapy or 'yogurt on prescription'.

Mobile information services and big data will make this knowledge increasingly better and easier to use. Personalised information is created through smart bands, smart packaging and smart drinking cups. Food supplements, possibly produced through synthetic biology, can be chosen on the basis of all collected data. In addition, 3D food printers will make it possible to create tasty, attractive personalised food from individual components. Personalised food is already being produced in hospitals and care homes to prevent malnutrition and food waste. Application in the broader consumer market is being studied. Personalised food can have effects on the physical and mental health of larger groups of people and on prevention in healthy people, which in turn leads to higher labour productivity, lower healthcare costs, more mobility et cetera.

A.2 Technology for smart buildings

Buildings are linked to various networks: sewer systems, mains water supply, gas networks, electrical power networks, road networks, waterways networks and various communication networks, like telephone, cable and optical fibre. Drones enable buildings to also become linked to the air traffic network. This development may lead to an increased use of roofs as landing pads and as access to buildings to receive packages or to step out of your own larger drone and enter the building. This calls for a different design. With the advent of Internet and appliances with various sensors and processors (the Internet of Things), buildings will be getting some form of intelligence. Various technologies can greatly change this part of our living environment.

Domotics

Often, smart electronics enter our living environment unseen. Today, buildings frequently contain smartphones, tablets, smart TV's, smart kitchen appliances, smart energy meters, game consoles and simple robots, like vacuum cleaning robots.

Through such domotics, the smart home or office is developing into an automated building in which electronics interactively control the living environment, communication, entertainment, security and sustainable energy consumption. Sensors are used to monitor temperatures, the amount of light, ventilation, the layout of the room and its objects and the presence of residents. On the basis of knowledge about users, smart appliances set values for the indoor environment. With even further developed technology, the smart home may also be involved in lifestyle and care tasks, like supported cooking to a greater or lesser degree, food management and making sure that we get sufficient exercise. Sensors can also be used in locks, where they can recognise residents by a chip implanted in them or by biometric features, like fingerprints, facial features or a heartbeat pattern. Perhaps technology will enable more people to live at home independently for longer. Robots can help with this by keeping people company and if they speak another language, talk to them in their mother tongue. Of course, a home full of sensors does affect our privacy, which may have effects on our social behaviour, our living and our autonomy.

Technology also opens new ways to keep in touch with others, without physical proximity. In addition to telephone and Internet, virtual reality, telerobotics or telepresence and brain-to-brain communication could become serious and sometimes necessary alternatives for physical proximity, mobility and contact. Telepresence and virtual reality enable us, as it were, to take along the personal furnishings of our home or office in a digital form, so that we can feel at home everywhere. This could also be done physically. New materials and robotics will enable fully transformable spaces. As a result, this could reduce the number of spaces needed to support different functions for each person. Past experience with urbanisation and vested rights to space, like homeownership or land holdings in cities, has shown that cities are usually not keen on using less space for buildings. Urbanisation will continue as long as it improves meeting opportunities, provides economic conurbation advantages and the net result is less pressure on the environment. On the other hand, we are sharing our buildings and homes more and more. The interrelation between virtual and physical buildings is changing the boundaries of what we perceive as our personal living environment.

Construction methods and systems: flexible and sustainable

4D printing can be used to make the construction of homes and offices more flexible. 4D-printed components can be designed so that they very easily disintegrate into recyclable elements. Sensors can indicate when parts of a building have to be replaced or need maintenance or repair. General insurers are already experimenting with 3D-printed components for repairing minor damage to homes. In addition, new materials, modular construction elements and virtual reality make it possible to construct, adapt or demolish buildings and recycle building materials ever faster. Elements in buildings (systems, furniture, walls, doors) are increasingly easy to change to suit specific individual requirements. Circular design opens the door for replacing or renewing parts of for instance a high-efficiency boiler instead of installing a whole new boiler. Building elements are designed that temporarily support care duties and that can be easily removed and used again later. Nanotechnology makes solar panels more effective and enables them to be incorporated in building elements like roof tiles, windows and wall coverings. Plants in and around the house can also supply energy. Nanotechnology, sometimes combined with biotechnology, is also developing capabilities for

Figure 9: Examples of technologies in smart buildings

cost-effective energy storage in homes or cars, thereby reducing dependence on central energy generation.

The free availability of professional design software, like WikiHouse and open source design, make it easier for end users to participate in both the design and construction process. As a result, buildings are increasingly being developed by end users. This can lead to more variation in buildings and lower costs. This trend, evidenced for decades by the growing number of do it yourself shops, to build your own home partially or entirely by using 3D printers, will probably continue. This may have consequences for the roles of professionals like architects, contractors and installers, in particular in existing buildings. Building zero-energy buildings is also in the interest of end users, because they have to bear the costs after completion. If energy production and storage should lead to abundant and cheap energy, this could have a huge impact on buildings.

Flexible buildings also require a different design. To make functions and systems truly flexible, the design should already take into account that tubes, pipes, panels and cables should be easy to remove and/or install. Circular building can extend the life of buildings, provided that the supporting structure is maintained and that only the layout and use of other components is changed. This requires different building materials and methods that in addition shorten the building process and limit nuisance from building activities. New building blocks that make this possible could reduce costs by 70% and shorten construction times by 80% (Farnsworth, 2014). In China, houses have already been printed for 4,800 US dollars a piece. One of the biggest delaying factors for these innovation opportunities is the lack of trained staff who can build and install in this way.

Technology would make it possible to form buildings and spaces to what is needed at that moment. Making buildings more flexible for change, demolition or replacement can be done by using new materials, new modular building techniques (Larson, 2012) and by deploying 4D printing. These technologies could cause great changes in construction. The 'form follows function' concept would then to a lesser extent apply to the building itself and consequently to the design.

A.3 Technology for efficient mobility

The Netherlands has nearly 140 thousand kilometres of public roads, of which around 5,800 kilometres are managed by the central government. Every year, the Dutch spend altogether 62 million hours stuck in traffic. The economic costs of this are estimated at between 2.4 and 3.2 billion euro per year (Rijkswaterstaat, 2014). In addition to the construction of roads, extra lanes and reinforcements around nodes, policy is aimed at influencing the behaviour of travellers, so that they make efficient use of the existing infrastructure and public transport facilities. Technology is not only indispensable for optimum generation and use of traffic information, but also for presenting behaviour options for travel outside the rush hour or by public transport, or for not travelling at all and working from home. Traffic management (ramp metering, dynamic maximum speeds, rush-hour lanes and traffic information on panels over the road and through other channels), helps the utilisation of infrastructure by influencing road behaviour. Implementing traffic policies requires a lot of information about current road use, for instance from detection loops, cameras, information from telecom providers and app service providers about the number of mobile phones on the motorway whose users are not moving, but also about the possibilities and arguments of road users for adapting their behaviour. Technological innovations are being developed for more efficient use of the existing infrastructure, for instance through personal travel information and driver assistance, but also in the form of incentives to avoid the rush hour. In this way, the use of different modalities, networks and infrastructures, but above all the behaviour of their users, can be optimised. New vehicles like e-bikes, drones and autonomous vehicles will also raise new issues about adaptation of the existing infrastructure, about the construction of new infrastructure or about an entirely new traffic system to properly manage the new aircraft and road vehicles.

Autonomous vehicles

Today, a new car contains some seventy mini computers; more than NASA used at the time to take astronauts to the moon (Timmer et al., 2013). At this moment, aspects of autonomous driving are already being sold in the higher end of the car market. In the coming years more and more driving tasks, in particular on motorways, will become autonomous. Google's prototype of the autonomous car from 2014 seats two people and only has a start and stop button, so no steering wheel and no pedals. Google will market this car in 2020, but other experts say that the fully autonomous car will not be a reality before at the earliest 2030. Until that time, autonomous vehicles will not be able to drive independently on all roads and under all weather conditions. For the time being, some situations will still be too complex for a computer. Nevertheless, the development towards autonomous driving does mean that in fifteen years' time employment for taxi and truck drivers could be drastically reduced. If autonomous vehicles prove to be safer, perhaps we will have a different view on the freedom to be able to drive your own vehicle.

Sensors, big data, communication and energy technology and the increasing intelligence in vehicles and infrastructure enable an ever richer exchange of information between means of transport, between means of transport and their environment and between users and their 'digital travel advisor'. The Dutch government classifies this exchange under the heading Talking Traffic. There are also systems where sensors register whether you are about to fall asleep at the wheel, where the car 'feels' how the driver is feeling and communicates on this with the driver or intervenes itself (automatically). These sensors are even already being used for controlling the entire car (mind-controlled car) or for using neurofeedback to ensure that drivers are optimally concentrated. A digital travel advisor can already make travel proposals on the basis of someone's agenda, behavioural profile and preferences, together with current information from the environment.

The automotive industry is developing standards for communication between cars and between cars and the road infrastructure. This communication is intended to achieve optimum cooperation between vehicles. Cars that 'talk' to each other learn more accurately from each other how fast they are driving and when they are going to brake or make a turn. The road infrastructure knows where vehicles are and where they are going. Communicating vehicles can also drive cooperatively by together forming a kind of train. This improves the flow of traffic and increases safety. Pressure on the environment may also decrease. Communication standards are part of Talking Traffic and therefore of the development of autonomous vehicles. Autonomous vehicles are also being developed that only optimise their own driving behaviour and route and cannot communicate with other vehicles and the road infrastructure (Timmer & Kool, 2014).

Through the use of self-driving motor bikes, bicycles and other small vehicles, multiple vehicles can drive next to each other in a 'classic' lane, requiring less space per passenger. Because these vehicles can drive by themselves and because of a shift towards car sharing, a lot of parking space could be freed up that can be used for the improvement of spatial quality. Shared use of vehicles also changes which cars are still being bought, because it is no longer necessary to own a car that is suitable for every application. Cars for daily commuting can be a lot smaller, because 80% of car journeys only includes one passenger. Lanes that are reserved for self-driving vehicles can dynamically change direction of travel to provide space for the busiest direction at different times.

Public transport can be made more attractive with better and up-to-date travel and seat information, indeed, autonomous vehicles can also become part of public transport. A Personal Rapid Transit system uses small driverless vehicles that literally deliver you to the front door, like a kind of horizontal lift. Transitions between an autonomous vehicle and for instance a train require a new arrangement of areas around railway stations (Jansma, 2014). Such optimised use of space, existing road infrastructure and travel information contributes positively to all forms of mobility. Whether or not shifts will occur between competing alternatives for road transport (including public transport) and in mobility behaviour and patterns is impossible to predict. Scenarios are conceivable where traffic with autonomous vehicles grinds to a halt because communication between the vehicles does not function properly because of the use of different standards (Townsend, 2014). The self-driving car combines some of the advantages of driving and public transport, but e-bikes can also be a good alternative for short public transport and car journeys. This competition with new modalities introduces a new uncertainty that is relevant for the basis of investment choices for infrastructure and public transport, including the ones reserved up to 2028 in the Multi-year Programme for Infrastructure and Transport (MIRT). Present choices for infrastructure have effects that will last until after 2050. By that time, autonomous transport could be just as normal as the self-driving driver of the past decades.

New materials, sustainable energy and faster production

Thanks to (nano) materials science, cars and trucks will be made from ever lighter, stronger materials for lower energy consumption and more safety. Improved batteries will increase the radius of action. New lithium batteries with carbon nanowires or titanium oxide

Figure 10: Examples of technologies in efficient mobility

gels (Phys.org, 2014) can be charged super-fast and could be available in a few years. Also a lot of cheaper batteries are being developed on the basis of algae, which have a hundred times more capacity and can also be charged faster than current batteries. The vehicle itself can be made from material that generates energy through solar cell technology or artificial photosynthesis. Wireless charging will be available in places where your vehicle happens to stand still or where it can drive to itself when it is not in use, on roads of self-repairing material with inbuilt solar cells (Solaroad, 2014). Public roads will become part of the energy infrastructure.

Means of transport can be made faster and in greater varieties with the help of new production processes like 4D printing, perhaps no longer in factories, but partially or completely in a garage round the corner. Sensors could be printed in the material. As a result of programmable materials that can change form and function after manufacturing by for instance an electric signal, contact with water or exposure to light, our means of transport will contain more adaptive systems. For instance the exterior layer may change colour for improved visibility in snow, tyre rubber could adapt to driving conditions, or there could be an extra chair that is easily folded out and hardly takes up space. The materials of the means of transport can be easily recycled by taking this possibility into account in the design.

Virtual transfer: virtual reality and telepresence

Virtual reality creates a lifelike sensation of physical presence in a location where you currently are not, with the use of all your senses: hearing, sight, feeling, smell and taste. The first signs of what virtual reality glasses will bring us are impressive, but at the same time they are probably only a hint of how immersive virtual experiences will eventually be. Telepresence allows people to be remotely present and communicate through robots. The person in question then observes the surroundings through the cameras and sensors of the robot. It is difficult to predict to what extent we will experience this type of presence as 'real' and whether it will replace, or in particular change, many forms of physical contact and mobility. Telephony and the Internet can be a good alternative to visiting someone. They also help to improve contacts and make new contacts, as a result of which more visits are paid to people at greater distances.

Faster, further, cleaner, higher

Drones are as yet not allowed to fly everywhere, but Internet company Amazon is preparing for forthcoming legislation in the United States, which would allow them to use drones for delivering packages through the air in the second half of 2015. Intensive use of drones in an urban environment, for instance for delivering packages or providing security, requires consideration of the possible impact on the living environment and security, but also on people's privacy and liability in air traffic. Drones could be vital for delivering relief supplies to inaccessible areas, as in the case of floods, or for the fast delivery of medical aid. For instance, the Delft University of Technology is developing an ambulance drone that can quickly deliver AEDs (automatic external defibrillators).

In Germany, drone technology is applied to a new type of helicopter with eighteen electrically driven rotors. This device flies safer, quieter, cleaner and more economical than normal helicopters, making passenger air transport more accessible. A prototype of a hoverbike has already been developed that will probably be on the market in 2017. Air traffic becomes more attractive through the development of supersonic aircraft that can fly twice as fast as today's planes.

2015 sees the first test flight of a type of 'space shuttle' that makes it possible to fly from Amsterdam to Sydney in two hours. In addition, aviation can become cleaner, like the Swiss plane that flies only on solar power and that will fly around the world in 2015. Trains can continue to compete with planes on speed, by whizzing through tubes under vacuum conditions at eight thousand kilometres per hour. This will take you from New York to London in one hour. Technology also brings clean, individual, flying transport closer for both goods and people. NASA is already developing a traffic management system for flying transport (Ackerman, 2014). Busy air traffic over cities can also take place only with self-flying aircraft to guarantee safety.

New battery technology may soon have major consequences for mobility and for how we organise mobility. If in addition to lower fuel emissions, electric cars would also outperform combustion engines in the field of price and sustainability, our stock of cars could rapidly become greener. Electric trucks would again be permitted in environmental zones. A move towards more shared cars could also structurally accelerate the replacement of the stock of cars. Under the current rules, fuel and road tax revenues would then fall. The environmental space of rush-hour lanes would improve and maximum speeds limited by emissions could be increased. Governments could already require self-driving vehicles or specific shared cars to be electric. Technology is getting cheaper and Well-to-Wheel (emissions from the vehicle itself, Tank-to-Wheel, as well as emissions released during extraction and the refining process or the production of electricity, Well-to-Tank, are included) is becoming more sustainable. As a result, the risk that the popularity of self-driving vehicles will result in an increase in or extension of the environmental problems of combustion engines is getting smaller.

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APPENDICES

GLOSSARY

3D printing The manufacture of products or components that are built up layer by layer with a greater three-dimensional freedom of form than for other manufacturing techniques.

4D printing 3D printing where the product can change shape three-dimensionally in time under the influence of a change in its environment, like water, heat or electricity.

Algorithm A finite series of instructions that lead to an intended goal through a number of steps.

Aquaponics A method for growing food, where conventional aquaculture (culturing fish, crustaceans and shellfish) is combined in a symbiotic way with hydroculture (growing plants in water).

Artificial intelligence The science that deals with the realisation of intelligence in objects, like reasoning, learning or understanding speech.

Artificial photosynthesis The use of sunlight for a more efficient conversion than plants to other energy carriers like hydrogen and ethanol.

Augmented reality Computer-created information in video and audio that supplements the real environment.

Backcasting Reasoning backwards from a desired future image to know which policy options or actions could realise that future image.

Bacteria as biofuel producers A colony of bacteria, kept together in a container or petri dish, which converts substances into biofuel like bioethanol.

Big data A large, complex, changing collection of data that can be searched and analysed with new data analysis techniques, on the basis of which (statistical) data on and patterns in phenomena can be obtained.

Biocatalysis The use of enzymes for biochemical conversions on an industrial scale, for instance for food and animal feed, for the biobased economy and for medical applications.

Brain mapping The mapping of brain functions by measuring activities in the various brain regions to understand the relationship between structure and function of the human brain.

Cisgenesis A form of genetic modification where DNA is inserted that comes from the same species or from a crossable relative (COGEM).

Cold nuclear fusion The fusion of nuclei of different atoms into an element with a heavier nucleus at a relatively low temperature, during which energy is released.

CRISPR-Cas This system (clustered regularly interspaced short palindromic repeat - associated protein) can recognise specific DNA sequences for targeted changing of heritable material. This system makes it possible to regulate gene expression, remove (parts of) genes, introduce new genes or DNA fragments or make visible locations of specific sequences within the genome.

Crowdsourcing The obtaining of services, ideas or knowledge by asking contributions, usually online, from a large group of not pre-specified individuals.

DNA sequencing The determination of the sequence of building blocks (nucleotides) in a DNA strand.

Domotics Appliances and infrastructure in and around buildings that electronically register, communicate and control, to regulate functions like lighting, heating, care duties and entertainment, for instance for improving comfort, energy-saving and security.

Drone An unmanned aircraft that flies autonomously or by remote-control.

Ethernet protocol A communication protocol for exchanging data between computers.

Fecal transplantation The transfer of bacteria from the feces of a healthy person to a recipient.

Genetically modified organism (GMO) An organism of which the genetic material has been changed in a way that is not possible in nature through reproduction or natural recombination and which has the ability to reproduce or transfer that genetic material (COGEM).

Gene technology Refers to techniques that cause changes in the genetic material (COGEM).

Geothermics The energy that is stored under the earth's crust in the form of heat.

Internet of Things The concept that ever more objects, data, processes and people are connected to the Internet and therefore to each other. As a result, all kinds of objects will be able to communicate with people and with other objects and make autonomous decisions on the basis of this.

Lab-on-a-chip The technique for integrating various laboratory functions on a small surface. For the analysis of liquids, very small volumes are needed compared to regular laboratory techniques.

Lantibiotics A collection of peptides with a length that varies between twenty and forty amino acids. They derive their name from special amino acids that are linked to each other through a so-called thioether bridge (one sulphur atom): the lanthionines.

Nanobiosensor A sensor that can detect a small quantity of analyte with the help of nanotechnology and a biological element, like an enzyme or an antibody.

Nanoparticle A particle the size of 1 to 100 nanometres, where different characteristics of the material can occur than for larger sizes.

Neuroimaging A technology for depicting the structure and characteristics of a human brain.

Neuromorphic chip A microprocessor designed on the basis of neurological structures instead of digital logic, suitable for processing complex sensory information like images and sound.

OLED (organic light emitting diode) A light-emitting diode (LED) is a light source based on semiconductor materials that produce light when an electric current runs through them. Organic LEDs consist of organic materials like polymers, that can easily be applied to large surfaces.

Phage therapy The therapeutic application of bacteriophages (viruses that infect specific bacteria or groups of bacteria and multiply in them) for the treatment of bacterial infections.

Photonics The study and technique of the conversion of light to electricity and the other way around (like solar cells, light sensors and lasers), the transport of light and light as an information carrier.

Quadruple helix A school of innovation that is based on cooperation between government, business, knowledge institutes and citizens.

Quantified self A concept in which people collect information about themselves with the help of technology with the aim to learn from this.

Quantum computer A computer architecture based on properties of quantum particles, with a potentially much higher calculating rate.

Responsible innovation A transparent, interactive process in which innovators, users and social parties arrive at a shared image about the (ethical) acceptance, sustainability and social desirability of the innovation process and the saleable products.

RFID chip (radio-frequency identification) A chip that can be read remotely and wirelessly via radio signals to identify an object or to read or store information.

Smart band A wrist band that collects information about the degree of activity of a person and about body values like heart rate. This data is shared with an app, so that the person can later read how long he has slept or how many steps he has taken.

Smart grid An electricity network where the demand for electricity is geared to the use of centralised and decentralised energy optimised over time, with the help of digital intelligent network management. Appliances like electric cars or washing machines can consume electricity at times with lower demand, possibly at a lower rate.

Stem cell A cell that can develop into any type of body cell and from which any type of blood cell can be created.

Superconductivity The transport of electrons without electrical resistance in a specific group of materials, usually at very low temperatures.

Synthetic biology A field of study that focuses on changing existing organisms with the aim of obtaining useful features, and on designing and synthesising artificial genes and complete biological systems (COGEM).

Technology The systematic application of (exact) scientific knowledge for practical purposes (Stichting Toekomstbeeld der Techniek).

Teleportation The direct transfer of objects or information from one location to another, without the object or the information having to physically traverse the space between the two locations.

Telepresence A collection of technologies that gives the user the feeling to be somewhere else or that realises a form of presence of the user in another location than the user himself is in.

Telerobotics The remote control of robots where physical actions of the controller are copied by the robot.

Transistor An electronic semiconductor component that is used for amplifying or switching electronic signals.

Triple helix A school of innovation that is based on cooperation between government, business and knowledge institutes.

Urban aquaculture The artificial keeping of fish, crustaceans and shellfish in ponds and basins in an urban environment.

Value A meaningful ideal or motive.

Vertical farming A form of agriculture where use is made of stacked (artificially lighted) growth layers in buildings or multi-storey buildings situated in cities, so-called vertical farm towers.

Virtual reality A computer-simulated environment that people can visually and auditorily experience as real, sometimes supplemented by smell and touch.

Well-to-Wheel An arithmetic method in which both emissions from the vehicle itself (Tank-to-Wheel) and emissions released during extraction and the refining process or the production of electricity (Well-to-Tank) are included.

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OVERVIEW OF PUBLICATIONS

2014

Managing surplus national real estate ['Vrijkomend rijksvastgoed, over maatschappelijke doelen en geld']. December 2014 (Rli 2014/07)

Risks assessed. Towards a transparent and adaptive risk policy ['Risico's gewaardeerd, naar een transparant en adaptief risicobeleid']. June 2014 (Rli 2014/06)

Recovering the costs of environmental damage: Financial indemnity to be provided by high-risk companies ['Milieuschade verhalen, advies financiële zekerheidsstelling milieuschade Brzo- en IPPC4-bedrijven']. June 2014 (Rli 2014/05)

The future of the city. The power of new connections ['De toekomst van de stad, de kracht van nieuwe verbindingen']. April 2014 (Rli 2014/04)

Quality without Growth. On the Future of the Built Environment ['Kwaliteit zonder groei, over de toekomst van de leefomgeving']. April 2014 (Rli 2014/03)

Influencing behaviour, more effective environmental policy through insight into human behaviour ['Doen en laten, effectiever milieubeleid door mensenkennis']. March 2014 (Rli 2014/02)

Living independently for longer – a shared responsibility of the housing, health and welfare policy domains ['Langer zelfstandig, een gedeelde opgave van wonen, zorg en welzijn']. January 2014 (Rli 2014/01)

2013

Sustainable choices in the implementation of the common agricultural policy in the Netherlands ['Duurzame keuzes bij de toepassing van het Europees landbouwbeleid in Nederland']. October 2013 (Rli 2013/06)

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Safety at companies subject to the Major Accidents Risks Decree: responsibility and effective action ['Veiligheid bij Brzo-bedrijven, verantwoordelijkheid en daadkracht']. June 2013 (Rli 2013/04)

Dutch Logistics 2040: Designed to last ['Nederlandse logistiek 2040, designed to last']. June 2013 (Rli 2013/03)

Nature's Imperative. Towards a robust nature policy ['Onbeperkt houdbaar, naar een robuust natuurbeleid']. May 2013 (Rli 2013/02)

Room for Sustainable Agriculture ['Ruimte voor duurzame landbouw']. March 2013 (Rli 2013/01)

2012

Keep Moving, Towards Sustainable Mobility. Edited by Bert van Wee. October 2012 (Rli/EEAC)

Original title
Verkenning technologische innovaties in de leefomgeving

Editors
Catherine Gudde, Paradigma Producties

Photo credits
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Page 45: GE Japan Corporation

Graphic design
2D3D Design, The Hague, The Netherlands

Rli publication 2015/01
January 2015

Translation
Hans van Leeuwen, Blue Chip

Digital magazine
This survey is in a shorter version available
as a digital magazine via www.rli.nl.
Text: Joost van Kasteren. Translation: Balance2, Amsterdam.

ISBN 978-90-77166-58-1
NUR 740