Bioprinters, resource-roundabouts and brainternet?

On how we produce, consume and redistribute in 2050

The Netherlands Study Centre for Technology Trends

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CONTENT

PREFACE

Anyone who follows the public debate, or even opens a newspaper from time to time, may feel that the future of the economy is very uncertain and is often described in black and white terms. Ominous headlines predict that robots will take our jobs, or even start to rule the world, while others appear to see many possibilities and opportunities. The same applies to the impact of climate issues and sustainability issues on the economy, as well as, for example, changes in the world trade system or the effects of Brexit. In all these cases, some seem to adopt gloomy and worrisome outlooks, while others see all kinds of positive assessments.

The future of the economy is inherently uncertain. The aim of this publication is not to try and formulate a single answer. Instead, the starting point is that, like the present and the past, the future will not be black and white. Yes, there is a lot going on, and yes, the world will look very different 20 years from now, in part as a result of technological developments, but that does not mean that people will become superfluous or have nothing to say about what that future should look like. If we want to be able to influence the future, it is important to discuss it in all its complexity, uncertainty and versatility. This foresight study on the future of the economy, carried out by the Netherlands Study Centre for Technology Trends, provides us with tools to help with that.

Photo: Christiaan Krouwels

The definition of economy we use in this foresight study is the way in which people produce, consume and distribute in the future, so the term is used in its broadest sense of the word. It is symbolic that these terms can also be applied to the activities included in this exploration: earlier studies and publications about the future have been studied, or, in other words, consumed. Subsequently, various instruments were produced: a trend overview, future scenarios, a serious game and, finally, this publication.

These tools are intended to facilitate the discussion about the future, or, in other words, to distribute the insights we acquired. And, although

this particular foresight study has reached its conclusion with this final publication, we hope that the process will continue, because organizations can continue to work with the results and with the instruments themselves. To discuss and make it clear where there is room for action to create the future that we have in mind.

This exploration would not have been possible without the efforts of many experts, stakeholders and other parties involved. Many have played a part in thinking about future developments and what they would mean for their company or organization, which already makes this exploration a success. I am grateful to those participants for their dedication and commitment. And I am convinced that, by preparing ourselves for the future now and making it open to discussion, we allow ourselves to assume the best possible starting position to start shaping that future, whatever it will bring.

Dr V.C.M. (Véronique) Timmerhuis
General secretary of the Social and Economic Council (SER)
Chairperson sounding board group STT foresight study into the future of economic

SUMMARY

How will technological developments affect the economy of the future? That question was the focus in the foresight study STT carried out between 2017 and 2019, which lead to this publication. The aim of the exploration is to inspire STT's stakeholders (policy makers, researchers, entrepreneurs) and other parties interested in the future; to inform, to advise on the possible influence of future developments, and to put the future on the agenda.

Anyone who delves deeper into the literature on the future of technology and the future of the economy will soon notice that there are some 'tall tales' about the future. Tales that create the feeling that we live in a time in which changes go faster and faster. A time of geopolitical tensions and trade wars. A time to think more seriously about climate change and making the transition towards a more circular economy. A time when, for the first time since WWI, we have a young generation that is worse off than generations before. A time in which the fourth industrial revolution is upon is, one that will have an even bigger impact than the three previous industrial revolutions. A time in which sectors, companies and jobs that are successful today, can be superfluous within ten years.

In this foresight study, we wanted to do more than merely focus on one of these tails and, instead, take a look at the role technology can play in all these developments and stories. That is why the term 'economy' has been broadly defined in this exploration, namely as the system that determines what is scarce, how we produce goods and services, how consumers make choices and how we distribute prosperity.

Each phase of this foresight study was in line with STT's main goals: to inspire, inform, advise and put the future on the agenda.

Trends

To be able to inform, making a trend overview was the most important activity. Based on literature research and expert interviews, we made a selection and description of trends that will have an impact on the economy of the future. These trends are:

Societal developments:

- Developments in the field of demography and the labour market
- Developments in the field of geopolitics and governance
- Developments in the field of ecology and climate

- Socio-cultural developments
- Financial and economic developments

Technological developments:

1. Robotics
2. Artificial intelligence
3. 3D-printing
4. 4D-printing
5. Big data
6. Blockchain
7. Internet of things
8. Quantum technology
9. Mixed reality
10. Autonomous vehicles
11. Small satellites
12. Digital twins
13. Biotechnology
14. Nanotechnology
15. Microrobots
16. Human enhancement
17. Brain-machine interfaces
18. Geo-engineering

The trend overview has been published online and can be downloaded at https://stt.nl/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf

Scenarios

To inspire, we worked on – and with – future scenarios. In various workshops involving experts, stakeholders and creative thinkers, the initial storylines for scenario's were developed. The four visions of the future are not intended as predictions, but as instruments to facilitate the discussion about the future. Each scenario focuses on a different set of technologies and on another aspect of the concept of economy:

Scenario A: Less is beautiful (2050)

In this scenario, scarcity of raw materials has led to a fragmented world and a desire for a large-scale behavioural change. Close-knit communities use information technology, 3D printing, big data, blockchain, biorefinery and autonomous transport to be as self-sufficient as possible. This

scenario focuses above all on how consumers make choices: There is an efficient use of raw materials and quality of life and solidarity have become more important than economic growth and material possessions.

Scenario B: Big government (2050)

In this scenario, globalization has continued, and strong international institutions focus on global sustainability, fairness and the importance of future generations. Thanks to advanced communication tools, based on technological developments like mixed reality, the Internet of Things and hologram technology, mobility has drastically reduced, and people work together virtually in teams from all over the world. Strong supranational organizations invest heavily in monitoring and regulation and force people to significantly reduce their ecological footprint. Government organizations determine much of what happens, while technologies like the Internet of Things and digital twins are used to make the most sustainable choices for us. In this scenario, the redistribution of wealth has been centralized, with sustainability and a sense of international justice being dominant values.

Scenario C: Survival of the most efficient (2050)

The battle for scarce raw materials has created international tensions and a world that is characterized by strong regional trade blocks. Highly urbanized, self-sufficient regions focus on high-tech solutions to deal with the scarcity of raw materials. Biotechnology, gene technology and quantum computing are used to develop new materials, while ecosystems are being restored, which has lead to a significant reduction of environmental pressure. 4D printers and bioprinters are available for the consumer market, which means people can make dynamic products and design new, sustainable organisms. In this scenario, the scarcity of raw materials is the most important driving force, and all kinds of technological developments are used to close cycles and develop alternative materials, crops and dynamic products.

Scenario D: I am technology (2050)

In this scenario, world trade has increased, and multinationals decide much, if not everything, in this future. Technological developments are fast and artificial intelligence is the key factor in production chains. There are completely autonomous companies and new jobs and tasks for people. We see the emergence of all kinds of applications in human enhancement: people use bionic prostheses and brain-chips to stay active for as long as possible and to compete with advanced robots and AI systems in the global labour market. Economic growth, individualism and freedom are important values. In this scenario, there is a whole new approach to the production process, and people seem to blend together with machines.

Serious game

To put the future on the agenda and advise organizations on how to prepare for an uncertain future, we have developed a serious game on the basis of which we have facilitated discussions with over sixty participants from fifteen different organizations about what the future may bring. The game, which is based on the trend overview and the scenarios described in this foresight study, invites participants to select building blocks for a fictional society. The game was an important tool in further clarifying the scenario stories. The game itself has also been developed further as a result of the game sessions.

Towards the future

The trend overview, the scenarios and the serious game were developed to place the future prominently on the agenda. Organizations can use these instruments to facilitate a conversation about the future. The final chapter provides tools and suggestions on how to use them, as well as providing additional 'what if' questions and statements that can be used to get the discussion about the future started.

See the list of the scenarios on page 29 and the summary of the scenarios op pages 76-77.

If you want more information about STT and this foresight study, visit www.stt.nl or contact project manager Silke den Hartog - de Wilde via denhartog@stt.nl

1. Introduction and approach

1. INTRODUCTION AND APPROACH

Will robots take over our jobs? Will crypto-currencies replace the money we use today? Are we in for a new economic crisis? Will we make a timely transition from a linear towards a circular economy? Will globalization continue or will an international trade war lead to increased protectionism? Will the European Union continue to exist? And is the Dutch social security system viable in the light of the country's aging population?

In recent years, there has been a great deal of attention in the Dutch media for these kinds of questions about the future of the competitiveness of the Dutch economy, the labour market, the social security system and the economy's vulnerability. These are not simple questions, and nor are the answers simple. They are (especially) complex in the sense that different experts provide different answers. It is not surprising, then, that the Study centre of Technology Trends (STT) started a foresight study about the Economy in 2017. When forward-looking questions are characterized by a high degree of complexity and uncertainty, we can no longer work with predictions or prognoses, and it makes more sense to explore the future in a more methodical way.

The purpose of studying the economy of the future is to inform policy-makers, strategists and decision-makers in the Dutch business community, knowledge institutions and the government about possible future developments that may affect the (Dutch) economy, and to help them discuss the future in all its complexity and uncertainty, and make strategic decisions about it. And while technological developments provide a central starting point for all the studies that STT conducts, it is also important to keep in mind that technological developments do not stand alone, but are influenced by – and in turn influence – other factors, such as demographic, ecological and political developments. That means that, in addition to the exploratory aspect, the interdisciplinary aspect is equally important when studying possible future developments.

Approach

Because the economy is a comprehensive and multi-interpretable concept, it is necessary to make a demarcation. This foresight study uses the following definition of economics:

Economics is about choices that people and companies make in the production, consumption and distribution of scarce goods and services.

The emphasis is on macro-economic trends, in other words on developments at an international and national level, trends that will affect the economy, although it is not yet exactly clear how. We decided to use a time horizon of about 30 years, which brought us to the year 2050, to help us get out of our comfort zone and look beyond our day-to-day concerns and examine large-scale changes. Because a lot can change in thirty years, that makes it worth exploring the future.

The following research question played a central role in this study:

What will the future economy look like as a result of technological developments?

The central research question is divided into five sub-questions:

1. What are the technological developments that will affect the economy between now and 2050?
2. What will be economically scarce in the future and how will technological developments affect that scarcity?
3. How will goods and services be produced in the future as a result of technological developments?
4. How do technological developments affect the way people consume goods and services in the future?
5. What is the influence of technological developments on people's income and wealth distribution?

To answer these research questions, the study was divided into three phases, each with a different activity:

Phase 1: Inventory and information

In the first phase, desk research and expert interviews were used to map the most important trends and developments that will affect the Dutch economy between now and 2050. The main findings of this phase are summarized in the digital publication *Looking ahead to 2050*, which can be downloaded at https://stt.nl/publicatie/voor-uitkijken-naar-2050/. This publication informs stakeholders about important trends and developments.

Phase 2: Imagination and inspiration

In the second phase, the emphasis was on imagining. The insights and issues that emerged from the first phase provided the basis for the development of future scenarios. In workshops involving experts, stakeholders and creative thinkers, the initial story lines were outlined for the scenarios. The scenarios, which are stories about possible future situations, are designed to inspire readers.

Phase 3: The strategic conversation

In the final phase of the study, I engaged with various stakeholders and experts via a serious game, in which the trend analysis and scenarios provided important input. The game challenged the participants to discuss the uncertain and complex future, and think about the possible implications of future developments for their own organization. This helped STT advise its stakeholders and put the future on the agenda.

The future of the fourth industrial revolution is being shaped by the cloud

By Ronald Teijken, IBM

It is no longer science fiction – the fourth industrial revolution, or Industry 4.0, has arrived. By merging all kinds of new technologies, including robotics, AI, 3D printing and the Internet of Things, our way of doing business changes completely, comparable to the changes caused by the Internet, smartphones and the PC in recent decades.

These new technologies have the potential to improve products, to provide people with a customized experience, to increase productivity, improve safety and reduce costs, in ways that will affect different sectors, from production to retail, and from healthcare to transport. But how will business react to the opportunities and challenges of this new landscape?

The fourth industrial revolution

The term 'fourth industrial revolution' refers to the coming together of a number of so-called 'disruptive' technologies that will change the world in the coming decades.

Technologies that are often mentioned in relation to the fourth industrial revolution include artificial intelligence, robotics, the Internet of Things, 3D printing, drones and autonomous vehicles.

The first industrial revolution (18th century)
Mechanical production by steam and water power

The second industrial revolution (19th century)
Mass production through electrical energy and the division of labour, the emergence of cars, steel and oil

The third industrial revolution (20th century)
Electronics and ICT lead to the further automation of production processes

The fourth industrial revolution (21st century)
Further automation and hyper-connectivity though cyber-physical systems (combination of ICT, data and physical elements)

Source: Schwab, K. (2016), The Fourth Industrial Revolution. Switzerland: World Economic Forum, 2016

Strengthening human capacities with sensors that can see and hear

Industry 4.0 will not replace people, but focuses on improving and broadening human capacities, to reach a degree of efficiency that was never possible before. One of the best examples of Industry 4.0 in practice is the production sector. Within this context, sensors are placed in the production line that send information to the cloud, where the information is analysed and provides practical insights.

Examples of this include the detection of defects and preventive maintenance, made possible by powerful data analysis that far exceeds human capabilities. Cognitive Visual Inspection while spraying cars, for instance, detects faults that are too small for the naked eye, thus saving hundreds of hours of inspection time.

In addition, it is possible to monitor acoustic and visual signals with sensors. By monitoring sound, the quality of products can be improved in a non-destructive and non-disruptive manner, avoiding expensive down-time. The technology is designed to distinguish known 'good' from 'bad' sounds, which could indicate a malfunction. After installation in the factory hall, the same technology recognizes audible sounds as well as sounds people cannot hear.

Predicting problems before they occur

One of the most exciting applications of sensors and data analytics is the concept of 'digital twin' or virtual modelling. Based on information provided by sensors, a digital model of a system can be built. With that digital system, tests and 'what if' scenarios can safely be performed, without putting the actual physical system at risk, making it possible to predict what is likely to happen in a given situation and to anticipate potential problems.

Together with the Port of Rotterdam and the leading technology partners Cisco and ESRI, IBM is working to build a digital twin of the port. Unlike the model that is normally used for 'digital twins' in the context of Industry 4.0, these twins include an exact replica of the operational activities, reflecting all of the port's resources. Ship movements, infrastructure, weather, geographic data and water conditions, they are all mirrored with 100% accuracy.

As part of this project, the port digitizes a number of crucial objects, such as mooring posts and quay walls. These objects will generate data about their status and environment, complete with timestamp. For example, digital bollards will give us insight into the status and use of a berth, and in the water and weather conditions in its neighbourhood, so that the harbour masters can determine what the optimal time and place is to moor a ship. Using machine learning increases our knowledge based on data patterns, allowing the port operators to rely on 100% accurate, real-time data about the port infrastructure.

By predicting the water and weather circumstances, it is also possible to determine how easy it will be for a ship to enter the port. A more efficient operational management should make it possible for the port to increase the volume

and the efficiency of the transhipment of goods and reduce the environmental impact.

Data are the engine of the next revolution

None of these innovations would be possible without the cloud. All of the sensors involved collect enormous amounts of data about the most diverse issues, from the factory floor up to the vibrations of equipment, from the audio output of machines to their temperature, and much more. It is expected that, by 2020, there will be about 31 billion IoT devices in use[1]. This represents a truly staggering quality of data, much of which is stored in the cloud, analysed in real-time and then used to gain insight into ways we can improve activities and make them more efficient.

This article has been published online: https://www.ibm.com/blogs/think/en-and/

1 Statista: https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide

Towards a circular economy?

By Tara Jansen and Karolina Ryszka, RaboResearch Netherlands

What is sustainability?

Sustainability is a broad concept with many different definitions. This article focuses on the environmental aspect, which includes two major challenges: climate change, due to too much greenhouse gas (GHG) in the atmosphere, and the unsustainable consumption of (scarce) raw materials. The Paris Agreement is an important milestone in terms of the reduction of greenhouse gas emissions. A transition towards a circular economy affects both challenges. The impact can be both positive and negative, depending on the specific situation.

Climate change

Because of the increasing amount of greenhouse gases in the atmosphere, the earth's atmosphere is warming (Anderson, 2016), basically because more greenhouse gases are emitted worldwide than the earth can reabsorb. These gases retain the heat of the sun, which thus cannot leave the ozone layer again (EPA, nd). In the past 800,000 years, the concentration of CO_2 in the air has never been as high as it is now. It is a clear consequence of the industrial revolution, in which not only prosperity, but also the use of fossil fuels and other raw materials has increased enormously, resulting in a considerably larger so-called carbon footprint[1], as we know by now. If this process were to continue, that can have major consequences for the quality of life in many regions (WRI, nd), which could even go beyond what the Intergovernmental Panel on Climate Change (IPCC) has included in its new report (IPCC, nd), which indicates that global warming in excess of above 1.5 degrees centigrade will already have enormous consequences.

Exhaustion of raw materials

Raw materials can be divided into two categories: renewable and non-renewable. For example, fossil fuels[2] are not renewable, while vegetable fuels are. The current use of non-renewable resources creates two problems. First of all, the world's population is growing and prosperity is on the increase, making it all the more challenging to meet everyone's future needs with regard to raw material (WorldBank, nd). In addition, it is not sustainable because we are removing more and more raw materials from the earth. Eventually, it will all run out.

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1 Carbon footprint is the total amount of greenhouse gases for which an individual, company, event, product, and so on, are responsible.

2 Fossil fuels are also renewable, technically speaking, but it takes millions of years for plants to become coal, oil or gas again.

Secondly, many products are not used or consumed, but discarded, which is not only a waste of the raw materials, it often also pollutes the environment. The problem here is that air, water or soil usually do not belong to someone, and it is difficult to limit their use, which means people can easily pollute water, air or soil. This is also called the ' tragedy of the commons' .

Renewable raw materials sometimes provide an alternative to non-renewable resources, like bio-plastic made from plants instead of petroleum. However, bio-plastic is not a sustainable alternative if we use up plants faster than they can grow, which means that renewable is not always the same as sustainable.

What is circular economy?

The circular economy is about reusing resources, creating multiple values, and achieving a complete system change and different way of thinking and working. The raw materials represent the most tangible aspect, and mapping their flow is often a good starting point, which requires cooperation within and between sectors. The circular economy is more than 'recycling 2.0', it's about recovering as much of the value of raw materials as possible. Figure 1 shows that reuse, for example, has a higher value than recycling. There are various business models within the circular economy aimed at recovering these values, which also have a – positive and negative – impact on the emission of greenhouse gases.

These days, the circular economy is a hot topic among companies, and one would expect circular business models to play a major role in that. But how well are Dutch companies actually doing in practice? Radboud University Nijmegen, in collaboration with Rabobank, has examined that question and concluded that companies find it difficult to close cycles, and

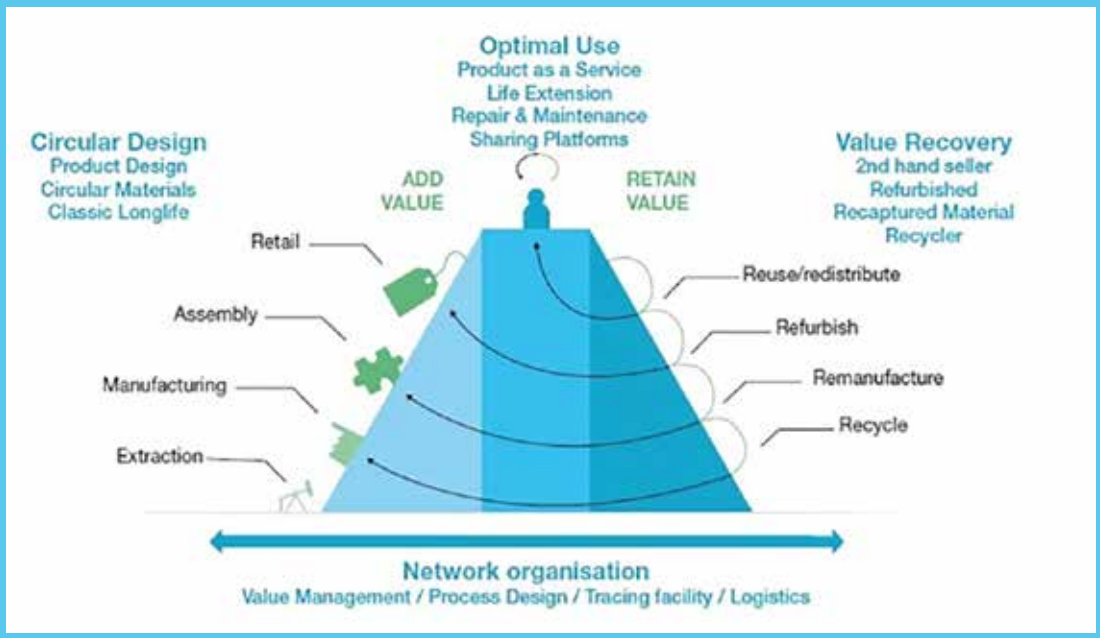

Figure 1: Circular value hill. Source: Achterberg et al., 2016

are often working together with parties that they already know. The research also showed that the circular economy they try to achieve is often based on existing business models.

Examples of this include more recycling and using less energy and raw materials. As such, although a lot is happening, much of it takes place on a small scale and within existing companies, with a few front-runners who pioneer with more drastic changes.

Circular economy in thirty years

Although it is difficult to predict where the circular economy (CE) will be thirty years from now, this article makes an attempt by looking at the current barriers for CE. If those barriers are likely to disappear in years to come, it stands to reason to assume that CE will grow.

Research by Radboud University Nijmegen shows that, at the moment, there are four major barriers: customer attitudes, regulations, (pre-) financing and a lack of budget. This is in line with what other studies tell us: De Jesus and Mendonca (2018) drew similar conclusions concerning CE barriers. Kirchherr et al. (2018) interviewed a large number of stakeholders (208 stakeholders from industry and politics, 47 semi-structured interviews). The most important barriers they identify are a lack of interest and consumer awareness and a hesitant corporate culture. These cultural barriers are driven by market barriers, which in turn are caused by a lack of government policy designed to accelerate the transition to a circular economy. The studies also indicate that there are no serious technological barriers.

Developments in the barriers for CE

Consumer attitudes: people increasingly make sustainable choices (Thijssen, 2018). For example, more people take the train rather than fly when travelling short distances and demand for meat substitutes has been growing considerably. These developments can have a positive effect on the circular economy, because it means people are generally more open to new circular and sustainable products.

Regulations: The European Commission (EC) has set clear targets in the area of waste, indicating, for example, that, in 2030, seventy percent of all waste has to be recycled. To realize those objectives, the EC has made a circular action plan (European Commission, 2015), which outlines how to remove obstacles to the circular economy at a European level. For example, a campaign to improve the recycling of plastic, facilitating more legal transport of waste within Europe, and a directive to improve the reuse of demolition waste in construction. The EC focuses especially on waste, but not on the broader context. Because waste is relatively easy to quantify, there is much potential profit to be gained in some European countries. The Netherlands has a similar plan (Dutch Central Government, nd) to stimulate the circular economy, but it goes beyond merely focusing on waste, for instance stating that laws and regulations must be adjusted to make it easier to reuse waste and that the Dutch government will invest in companies that are active in the areas of energy generation, energy saving or the reduction of CO_2 emissions. However, although these are positive developments, entrepreneurs indicate that laws and regulations continue to

stand in the way of improvements. That may change in the future, but at the moment, there are serious barriers.

Financing: the circular 'pay-per-use' business model tends to be difficult to finance, and there are other business models that provide a better match with the current financing model. Financial institutions are looking for ways to make pay-per-use models easier to finance in the future, which is another positive development for the circular economy.

There is movement on all the major barriers to the circular economy, which is a positive development for the circular economy and will allow it to go much further. However, we see that current developments with regard to CE are by and large developments that also fit within the linear economy, including recycling and the use of biological materials. In thirty years, the circular economy is likely to play a bigger role in society, but probably still in ways that fit the existing linear economy, and a real system change is not expected to take place in the medium term. That would require a new tax system, other forms of chain collaborations, new laws and regulations, other business models, and so on.

The effects of technology on the circular economy

Technological development is a prerequisite and one of the main drivers for the further development of the circular economy. Knowledge about where raw material flows go and what the composition of products is, facilitates recycling and reuse. Blockchain is a technology that can be used to keep track of information about a product, from production to consumption reliably and accurately. For instance information about the raw materials and associated carbon footprint of the screws that are used in a chair you may buy from IKEA, creating a raw material passport for every product. Innovations in different areas make it possible to recover raw materials, use new raw materials and design and construct products in a circular way. For example, new and existing techniques are needed to develop innovative applications for biological raw materials. Technological developments make it possible to convert various renewable raw materials to biofuel. Or to produce food in different ways. In addition, technological developments can make the new circular production methods cheaper and, therefore, more competitive.

How does all this affect the Dutch economy?

At the moment, the question of how CE will affect the Dutch economy is surrounded with great uncertainty. We can only make predictions that are based on a lot of assumptions, in fact, nobody knows what the economic costs and benefits of CE will be. We do, however, see major movements in CE that affect the Dutch economy.

To start with, when it comes to raw materials, the Netherlands is a net importer, which means that, should we manage to use raw materials for longer, we need less of them and, consequently, they will costs us less, while our ability to recycle, repair and reuse them will increase the

benefits. The more expensive raw materials are, the greater the corresponding benefits of circular alternatives will be.

Secondly, because of the circular economy, there will be a growing demand for people with a vocational training. It is, however, not easy to predict where those people will end up working, so that does not necessarily result in additional employment in the Netherlands. When demand for repairs increases, it ca6n be more efficient, for example, to outsource the work to a country with lower labour costs. This depends partly on the state of the Dutch labour market itself. At the moment, for example, unemployment figures are low, which means that it is more likely that that type of work will be outsourced to other countries, but the situation could be different when unemployment is on the rise. Overall, odds are that the additional employment will go to other countries.

Another expected development in this context is the export of CE-related knowledge. If the Netherlands manages to become a front runner, there is money to be made, similar to the current situation in relation to water management.

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About economic laws and the future

By Patrick van der Duin (STT)

Anyone who studied economic science even a little is familiar with the law of supply and demand, the law of Say, and the Philips curve, all of which relate to different aspects of the economy. They sate that if the price of a product goes up, demand for it drops (and vice versa), that every supply creates its own demand, and that there is a correlation between inflation and unemployment.

But can we really speak of economic laws or principles? There are products for which demand falls when the price falls. These are called 'inferior goods' that have a negative price elasticity, for example cheap meat and second-hand clothing. And it remains to be seen whether every supply creates its own demand. The money with which a new supply is financed and produced can 'leak away' and be spent elsewhere. And, finally, the correlation between inflation and unemployment appears to apply only in the short term.

Economic laws are, therefore, not absolute laws as they are in the natural sciences. A natural law like the law of gravity applies always and everywhere, as does Archimedes' principle and the four laws of thermodynamics.

When it comes to the economy, it is better to speak about 'forces' or 'tendencies', as the philosopher Roy Bhaskar calls them. So, although demand for a good does not always go up when its price drops, it will often have a tendency to do so, and although supply does not have to fully create its own demand, it can contribute to it. And inflation and unemployment are linked, but not forever. The effect of 'tendencies' can be seen as pulling a rope. If two people pull equally hard, there is no movement in the rope, although the forces are there. If one of the people pulling the rope is a little stronger, there will be movement, but of course not so much when only one person pulls. So, for example, demand for a good depends not only on its price, but also on the price of a competitive good.

Another, comparable approach is the one proposed by the economist Nicholas Kaldor, who speaks of 'stylized facts' (inspired by Jan Tinbergen's 'stylization'), which refers to a 'simplified representation of an empirical fact' (see Wikipedia). An example is the claim that education increases income (learning is earning). Kaldor formulated six facts in relation to economic growth, one of which is that the role that labour and capital play in long-term income

are constant, and that real wages increase in the long term. Although Kaldor uses the word 'facts', again, they are not cast in concrete, but more 'directions' in the economy. So the proposition that real wages increase over time does not mean that they literally always do. It is better to say that real wages tend to rise.

The question then arises as to why the economy, and (therefore) economic science, has no laws or principles. The most important explanation is that the economy is not a closed, but an open system. It is not a laboratory, which means it is not possible to examine the economy in a laboratory setting. Economic assumptions, such as the one that people are rational and selfish (the 'homo economicus'), in practice turn out to be more nuanced: consumers do not automatically buy more of a good when it is cheaper. And, because the propensity of consumers to buy something not only depends on its price, but also on their disposable income, the direct link between price and demand is disturbed. And besides, our economy does not stop at our borders, so an increase in supply in The Netherlands can also create greater demand elsewhere, while the occurrence of 'stagflation' shows that high unemployment and high inflation can indeed happen simultaneously, because employers and employees take account of (future) inflation, which they negotiate in employment contracts.

The fact that there are no economic laws does not mean that there are no 'constants' in the economy or that we always see completely different phenomena emerge. An economic phenomenon like unemployment is a fixed feature of our economic system (i.e., the free market). In the 1930s and 1980s, there was mass unemployment, while there was also unemployment in the period in between, although on a smaller scale. That means that the cause of unemployment does not have to be constant or or follow a certain principle. Naturally, unemployment arises when the supply of labour is greater than demand, but that is a definition, not an explanation. Unemployment always has a different cause. In the 1930s, it was caused by too little demand for goods and services, and in the 1980s, it was caused by the far-reaching automation of work processes. A constant explanation is the qualitative mismatch between supply and demand of labour, so that there are always people who do not (yet) have a job.

To think about the future of the economy and the extent to which economic science is able to describe or characterize it, we have to look at the social and technological changes that affect the economy.
This directly opposes the views of a very important classic economist, Karl Marx, who stated that the economic balance of power forms the basis of social relations. Our current society is firmly commercialized and economized by now, but an important (social) development is that companies are increasingly guided by social, sustainability considerations and even ethical considerations. Just think of corporate social responsibility and 'responsible research and innovation'. Apparently, the economy follows society in this respect.

Because there are so many social and technological changes taking place, we cannot be

complete. That is why it is more effective to adopt the perspective of a number of economic 'laws' or principles by which we can trace possible economic changes. To that end, we examine the insights of a number of recent Nobel Laureates.

For example, in 2002, the psychologist (!) Daniel Kahneman won the Nobel Prize for his research into the integration of psychological insights into economic science. Kahneman actually demonstrated that Homo Economicus does not exist. It turns out that, in their economic behaviour and decisions, people have, among other things, a preference for maintaining the status quo, while any losses they may experience weigh more heavily than any increase in value, and that they find it difficult to analyse and handle complex situations properly, especially if the future consequences are uncertain.

A Nobel Laureate in the field of economics who is working on the same subject, is Richard Thaler (2017), who has shown what effect 'limited rationality, social preferences, and lack of self-control' have on individual decisions and on the outcomes of markets (see Wikipedia). In particular, he developed the concept of 'nudging', which refers to the effective and inexpensive influencing of people's choice-related behaviour by providing them with certain stimuli.

In 2008, it was Paul Krugman's turn. He won the Nobel Prize for economics for his research in the field of trade, he concluded that countries with small economic differencestrade. While accepted wisdom argued that economically different countries act together, he concluded that countries witrh small economic differences trade with each other. Krugman also examined the location of economic activity, arguing that labour was probably the most important factor. In 2009, Elinor Ostrom showed that the communal use of natural resources does not have to lead to excessive use. She did this by looking at small groups where that does not occur, on the basis of which she developed eight design principles, including joint decision-making by owners and clarity what are the commons, and who are its owners. Finally, also in 2009, Oliver E. Williamson received the Nobel Prize for his research in the field of transaction costs, which has to do with the extent to which transaction costs affect negotiations, or – the best-known application – with the formation of companies. Depending on the transaction costs, it may or may not be useful and efficient to set up an organization or work with separate contracts and agreements.

The theories mentioned above are, in essence, critical about the neo-classical economic theory that is considered to be the standard theory. Many economists, policy-makers and politicians base their ideas, and especially their expectations, on this theory. It is the prism through which they look at the (or rather their) economic reality. However, when new scientific insights emerge, it is time to take another look at the economy. Looking at a new, future economic reality with outdated insights will detract from our ability to formulate 'future proof' economic policy.

On the basis of a number of new economic insights like the ones described above, we must take account of the following 'tendencies' in the

economy of the future.

1. Economic decisions are not made on the basis of self-interest and rationality, but on the basis of societal criteria and intuition.
2. Economic behaviour can be directed and it will have to be clear who is going to provide and check the incentives, and on the basis of what information (data) that happens.
3. Economic traffic will to a large extent take place within clusters of comparable countries and the labour market will become the most important location factor for companies.
4. Economic activities will take place on an ever smaller scale, because it is more efficient, more effective and better to manage.
5. We cannot simply assume that businesses will remain the dominant economic form of organization. The diversity of forms of organization will increase and their lifespan will decrease.

The question now is whether we can also locate these tendencies in the scenarios of this exploration. This proves to be possible: Tendency 1 fits best with scenario A of this publication, because it revolves around quality of life and solidarity. Not everything is decided on the basis of rationality and there is a lot of room for the human dimension. Tendency 2 also fits well with scenario A, because behavioural change is the driving force there. Scenario B is also a good candidate, because it also involves making choices based on a large amount of data, although the (international) authorities in this area are particularly active. Tendency 3 fits in well with scenario C, where the world economy consists of regional trading blocks, and trade takes place mainly between like-minded people, which is to say between economically similar countries that are often geographically close to each other. Trend 4 fits with scenario A, because of the small scale involved. However, scenario C is also a candidate for this trend, because of the emphasis on scarcity, where greater efficiency and effectiveness can make a positive contribution. Tendency 5 appears to be reasonably in line with scenario D, where economic activities are not all organized in the same way, but respond instead to market requirements.

So anyone who wants to consider the future of economics must not think in terms of laws, but of tendencies. And they should not think in terms of one future, but of several possible futures. This publication helps with that.

2. A LOOK INTO THE FUTURE: SCENARIOS

Scenarios are fictional storylines about the future that help us think about what the future may bring. They are not predictions, but a brainstorming tool, and they are intended to allow organizations to consider the opportunities and risks that the future may bring.

Scenarios outline possible, surprising future images of the (international) context in which, in this case, the Dutch economy could function in 2050. A decision was made to adopt a set of four scenarios, because that is a number that can be processed during work sessions. The scenarios are based on important insights from existing national and international scenario studies. Relevant components from more than twenty studies were combined, and supplemented with insights from expert interviews and workshops, to generate the scenarios. In consultation with the sounding board group for the foresight study, a number of key variables were identified that are addressed in the different scenarios. Together, these key variables make up the scenario framework:

The degree of globalization:

- To what extent is there an open economy with a lot of international cooperation (and competition) in the future, or instead, a situation where many countries close their borders and take protectionist measures?
- What is the level of competition for raw materials and natural resources? Could there even be international conflicts?

The speed, acceptance and application of technological developments:

- Will there be a breakthrough of a new general purpose technology (GPT)?
- Will the development of the current GPT – ICT – continue in the direction of IT (information technology) or CT (communication technology)?

General purpose technology (GPT) is a term that has been coined to describe a new method of production and invention that is important enough to have a broad, long-term impact. The term is used for technological changes that affect both our daily lives and the way companies do business. For instance, steam, electricity, internal combustion and information technology (IT) are often classified as GPTs. (Jovanovic, Boyan & Rousseau, Peter L., 2005) & Rousseau, Peter L., 2005)

What are the dominant values in society:

- Is there more individualism or more solidarity in the future?
- Will sustainability be the norm, or are economic growth and freedom more important?

In addition, a different combination of technological developments is highlighted in each scenario. That does not mean, however, that any given technology occurs in only one scenario.

Scenario A: Less is beautiful

- 3D printing
- Big data
- Blockchain
- Biorefining
- Autonomous transport

Scenario B: Big government

- Digital Twins
- Internet of Things (IoT)
- Nanobots
- Mixed reality
- Hologram technology
- Robotics

Scenario C: Survival of the most efficient

- Biotechnology
- Gene technology
- Metamaterials
- Quantum computing
- Geo-engineering
- 4D printing
- Bioprinters

Scenario D: I am technology

- Human enhancement
- Brain-machine interfaces
- Artificial intelligence
- Nanomist (utility fog)
- Brainternet

In addition, it was decided to emphasize a different aspect of the concept of economy (scarcity, production, consumption and prosperity) in each scenario. In scenario A, for example, the focus is on a different approach to consumption; in scenario B, we look at the way we (re-)distribute prosperity; in scenario C, everything revolves around the scarcity of raw materials and our production methods; and, in scenario D, a whole new way of producing and working is described. To further elaborate on these lines of thought, the scenarios are illustrated with possible future vacancy texts: examples of jobs that do not exist at the moment, but that may be created in the future. Similarly, advertisements for fictitious products and services were added that fit within the scenario in question.

Finally, at the end of each scenario, 'building blocks' are included from the serious game that was developed. For each scenario, there is an overview of the building blocks that best march the relevant storyline. A more extensive description of the serious game is included in chapter 4.3.

Summary of the scenarios

Scenario A: Less is beautiful

Focus on information technology and data analysis – Conflict over raw materials: international tensions between largely self-sufficient regions – Strong role for regional authorities and civil society – Behavioural change leads to less consumption – Sustainability, solidarity and quality of life are priorities

3D printing • Big data • Blockchain • Biorefinery • Autonomous transport

Scenario B: Big government

Emphasis on communication technology; virtual collaboration – Internationalization and strong international institutions that monitor and regulate – Fair distribution of prosperity leads to a strong state and little individual freedom – Global sustainability, international justice and the importance of future generations are paramount

Digital Twins • Internet of Things (IoT) • Nanobots • Mixed reality • Hologram technology • Robotics

Scenario C: Survival of the most efficient

Biotechnology, gene technology and quantum computing are new GPTs – Conflict over raw materials: international tensions between largely self-sufficient regions – Scarcity leads to high-tech solutions and new applications designed to manipulate the environment – Techno-optimism, self-sufficiency and safety come first

Biotechnology • Gene technology • Metamaterials • Quantum computing • Geo-engineering • 4D printing • bioprinters

Scenario D: I am technology

Bio-en neurotechnology as a new GPT – Internationalization and powerful multinationals – Production is highly automated and people adopt human enhancement to stay productive – Techno-optimism, market forces and individualization are important

Human enhancement • Brain-machine interfaces • Artificial intelligence • Nanomist (utility fog) • Brainternet

2.1 SCENARIO A: 2050 – LESS IS BEAUTIFUL

Focus on information technology and data analysis – Conflict over raw materials: international tension between largely self-sufficient regions – Strong role for regional authorities and civil society – Behavioural change leads to less consumption – Sustainability, solidarity and quality of life are priorities

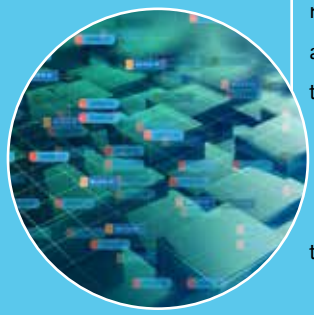
3D printing • Big data • Blockchain • Biorefinery • Autonomous transport

3D printing is a production technique in which a 3D model is created by applying material layer by layer on the basis of a digital design. Striking examples of products that are 3D-printed: a gun, a piece of skull, organs, houses and a bridge.

Autonomous vehicles are vehicles that, after a destination is provided, can take part in traffic by themselves (i.e. without the person in the car being involved in the process).

Big data refers to the large quantity of data being generated by people and sensors, which is available online – often real-time.

Biorefinery is the process by which biomass is converted into fuel, electricity, heat and chemicals, and which can help realize a society without waste. Converting industrial waste into chemicals and fuels reduces waste and pollution.



A **blockchain** is a long chain of virtual blocks to which a new block is added regularly, in which the most recent changes to the database are included as a list of transactions (SURF, 2017). A blockchain protocol creates consensus within a network by verifying each transaction against previous transactions. Block-chain technology makes secure transactions possible without having to trust either the sender or the recipient (Ortt & Drees, 2018).

The increasing demand for scarce raw materials has led to a fragmented world. In addition, growing sentiments for earlier times have generated large-scale behavioural change. Close-knit communities use information technology, 3D printing, big data, blockchain, biorefinery and autonomous transport to be as self-sufficient as possible. The way consumers make choices is a central element in this future. Efficient use is made of raw materials; quality of life and solidarity have become more important than economic growth and material possessions.

Driving forces

Due to increased prosperity in emerging economies and rising commodity prices, fierce international competition over raw materials has arisen, which has led to a closed economy and little international trade and cooperation. Raw materials are scarce and expensive, and people have to deal with water and food shortages on a regular basis. There is increasing resistance among the population against globalization, and against the power of multinational companies that consider economic gain to be more important than people and the environment. After a period of social unrest, people have taken a step back, and quality of life and solidarity have become more important values. Due to the slower economy and the desire for sustainability, people focus strongly on their own immediate environment. Cooperation within the EU is strong. In this scenario, people are cautious about new technology and innovation takes place incrementally. ICT is still the dominant general purpose technology. Many investments are being made in information technology, including applications like big data and machine learning. More stringent environmental taxes in the EU, consumers with a growing preference for sustainability and more expensive traditional production techniques have sped up the transition towards a circular economy. Strong efforts were made to realize local production chains, re-use and recycling. The emergence of the 3D printer has been a decisive factor in that process.

Restlessness and economic insecurity

Emerging economies have created an increasing demand for natural resources in the first decades of the 21st century. The prices of natural resources and energy have increased, creating international tensions between countries that are rich in natural resources and those that lack those natural resources. In part as a result of globalization, the recent economic crisis and terrorist attacks in Europe, more and more Dutch people felt that their economic and physical security was under threat. This was especially so for those with a lower education and for the elderly, and it led to a rise of nationalist sentiments and a focus on national sovereignty. It put enormous pressure on the support base for the principles of economic solidarity, like, for example, a tax system focused on income equalization. This reinforced the feelings of economic insecurity among certain population groups even more.

– Advertisement –

Trash engineering

Do you want to learn how to
transform discarded products
and packages into great
new products and materials?

Next Friday starts our course

trash engineering

for beginners.

Bring your own
garbage bag!

Closing recycling processes

In addition to the economic insecurity, the consequences of climate change in the twenties and thirties of the 21st century were clearly noticeable. In the Netherlands, the weather became increasingly extreme and sea levels rose faster than expected. There were major problems with infrastructure and other facilities during the hot summers and severe winters. Drinking water shortages, power failures and several floods in large cities had such an impact that citizens and politicians decided it was time for a change. There was a strong tendency to look to the past, when people were careful with their things and there was no waste. The feelings of nostalgia reinforced the pursuit of self-sufficiency, sustainability and the desire to close resource cycles.

Technology designed to realize behavioural change

In this scenario, there is little need for radical new technologies, since people prefer behavioural change to solve problems. The technological innovations that do take place relate to the self-sufficiency of regions, particularly the smart handling of raw materials and waste. Information technology helps with this: big data and machine learning give people and communities insight into their consumption patterns and how they can live as sustainably as possible.

Circular and local production

In this circular economy, production takes place locally and for the local market. Companies provide as much customization as possible. 3D printing has proved to be the answer to many problems: it is an efficient production method that helps relieve the pressure on ecosystems: there is less residual material compared to traditional production methods, it uses less energy, and less transport is needed, because production takes place locally. Thanks to applications of 3D printing, companies can produce many varieties, tailored to local requirements, which fits well in a world where people are very critical of globalization and focus more on their own immediate environment, and on their regional and national identities.

Thanks to the emergence of 3D printing, reduced demand for (new) products and the realization of local return flows, the global flow of goods is falling drastically, compared to 2020. We have accepted that certain goods, like exotic fruits, are no longer (continuously) available, and that we no longer buy a new phone every year. Production chains are closed at as low a level as possible. The fear of shortages of energy, food and water has led more and more Dutch people to realize self-sufficient systems in their homes, neighbourhoods or cities, making them less dependent on central supply or import.

– Advertisement –

Of course, you want to know your neighbourhood's ecological footprint, but you may not have the time to integrate and analyse all datasets. With our community eco-trackers, you can see the ecological footprint of your neighbourhood in real-time at any time of the day. Residents can choose a tracker in the form of a watch, earring, bracelet, chain or bandana. The impact of all human activities on water, air and soil are collected in real-time and are available online immediately.

Consuming less and using instead of owning

The prices of products have fallen over the last two decades, thanks to more efficient production methods and a reduction in demand. Goods also last longer and have to be replaced less quickly. Locally, all kinds of new markets have arisen for small-scale production (small-scale manufacturing and crafts flourish), agriculture, refurbishment, recycling, etc. Demand for energy and raw materials has also fallen sharply. In 2050, people grow their own vegetables as much as possible, install their own windmill park and neighbourhood battery and share products and capacities in their community. In many kitchens, microwave ovens have been replaced by 3D food printers. Neighbourhood-food printers are shared in many neighbourhoods. Many people use smart apps to follow a personalized diet tailored to their age and lifestyle. Vertical urban agriculture is crucial for the food supply of cities. In particular, dairy and meat have become so expensive that, by 2050, people consume more meat substitutes and alternative dairy products, while Supermarkets are filled with insects, soya and seaweed products. (Erasmus University Rotterdam, 2018).

Tailor-made production

3D printers have turned the business world completely upside down. 3D printing is no longer only used for making prototypes, but for all kinds of applications, and it has transformed the entire production landscape. Production processes have been

sped up, because objects can be made in smaller numbers, without the need to re-set a machine or to have a mould made. For parts of production processes that used to be labour-intensive, such as time-consuming assembly and secondary machining processes, 3D printing has replaced human labour.

It is important for companies to be recognizable and reliable. They are highly dependent on regional markets, because globalization and world trade have declined sharply in this scenario. Consumers like to remain loyal to a brand, especially if good service (advice, maintenance and repair) is also provided. Companies use revenue models based on usage rather than possession. This also makes a prolonged product life cycle advantageous for producers.

Cascades for biomass

For food cycles, the focus is on urban agriculture and for energy it is on sustainable, local energy networks. The organic 'waste' of households and companies provides a valuable source of raw materials, including phosphate and other nutrients. 'New sanitation' is applied in new residential areas: thanks to vacuum toilets, among other things, the raw materials and energy in our organic waste can be efficiently recovered within the district. There are strict requirements for the use of biomass. A 'cascade' for biomass determines the preferred order of applications. Preservation of soil fertility and the production of food and medicines are located at the top of the cascade, while combustion is at the bottom. In case of large-scale combustion of

– Job offer –

biomass at the end of the cascade, the capture of CO_2 is mandatory. This is stored under the seabed. (Wouters, 2018.)

Sustainability while maintaining comfort

Since the ecological boundaries of the earth were almost reached, people had to change their consumption patterns. They started to consume on a less lavish scale and waste less. In Europe and in the Netherlands, a large part of the prosperity was based on the free movement of people, goods and services. Now that the world economy has broken down into trading blocks and protectionist measures are in place, economic growth has declined. This is accepted, because people consider quality of life and having a sustainable (local) society to be more important than economic growth and material prosperity.

As a result, in combination with the trend toward individualization and the need for customization, there is also a great demand for products and services that reduce our ecological footprint, while still allowing us to live comfortably. The latter was especially important for the large group of baby boomers – who grew up in a consumer society and found it difficult to abandon their luxury in their old age. There is, therefore, a great demand for all kinds of products and services that make a sustainable life comfortable. Think, for example, of smart homes, smart clothing or smart lifestyle coaches. But people do want to stay in control themselves, so devices and computers should not make too many decisions for them.

– Job offer –

Personal privacy advisor

More and more people come to realize that their personal data is precious and must be protected. Our personal privacy advisors help our clients regain and maintain their privacy. Each month, we carry out extensive scans in which we look for data breaches and privacy-sensitive information. Based on these scans, you conduct personal interviews with the clients as an advisor and you counsel them in the area of digital privacy concerning software, media and online accounts, but also offline privacy related to home, mobility and visibility in public spaces.

Community currencies and blockchain

People have a strong connection to their neighbourhood or city in which they live and care for each other. In many cities and districts, in addition to the Euro, payments are made with community coins. These kinds of local currencies strengthen regional economies and social connections and give people a sense of control. Blockchain is used to facilitate peer-to-peer trading and also provides an important basis for local sharing economies, where energy-efficient or expensive devices can be shared. Many local and national governments use blockchain technology for public services, such as payments for healthcare and social security, which means that bureaucracy is greatly reduced compared to thirty years ago. The use of blockchain technology means that no central body or authority is needed to manage the database, which makes it very popular.

Autonomous transport

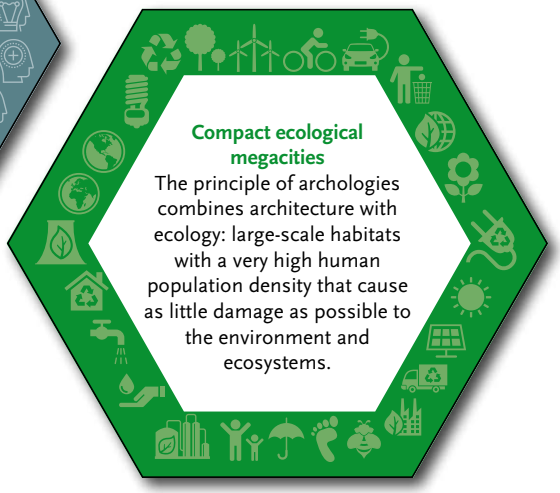
There are fewer transport movements compared to 2020, thanks to the emergence of 3D printing and declining globalization. However, people still want to move around for relaxation, and they consider face-to-face contact to be more valuable than virtual contact. As such, passenger transport continues to be relevant. For the transport of both goods and passengers, developments are aimed at autonomous aircraft, sailing and vehicles. These are relatively economic in use, because, for example, they are better at anticipating and planning more efficient routes than human drivers. An additional advantage is that there are fewer traffic accidents.

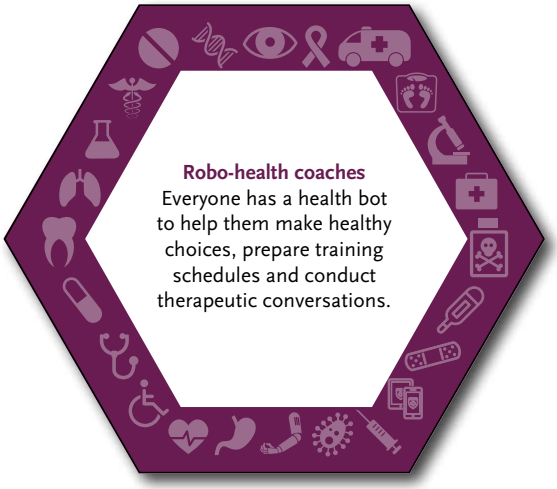
– Job offer –

Taking care of each other

In this scenario, people take care of each other on a regional scale. Because the focus is less on growth, and more on the quality of life, people do not find large income differences acceptable. In this society, a great deal of effort is focused on getting everyone to participate. We also see all sorts of new living arrangements designed to help people care for and share with each other, like kangaroo homes and multi-generation homes.

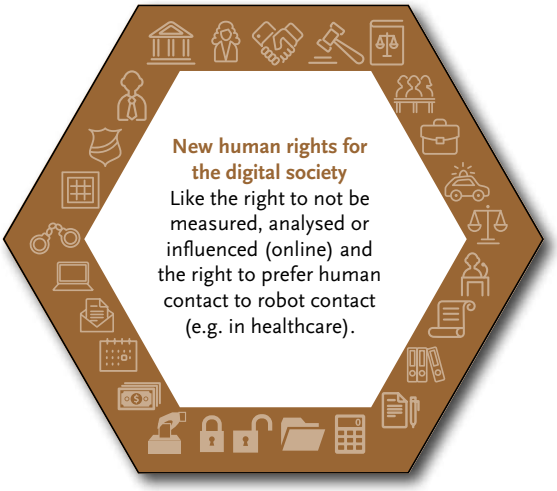

Make exoskeletons mandatory for people in certain occupations
Exoskeletons help people who do heavy physical work to work safer and longer.


Compact ecological megacities
The principle of archologies combines architecture with ecology: large-scale habitats with a very high human population density that cause as little damage as possible to the environment and ecosystems.

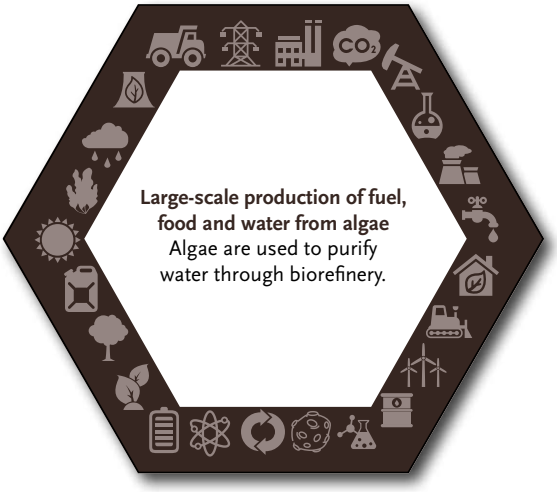

Robo-health coaches
Everyone has a health bot to help them make healthy choices, prepare training schedules and conduct therapeutic conversations.


Control over your personal data
Everyone has a super-secure digital account. Consumers can give organizations (temporary) access and determine who may view or store which personal data.

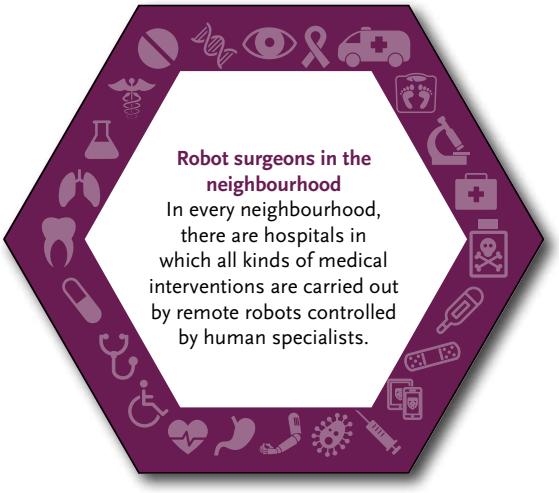
Distilling drinking water from air
With the help of a wind turbine and a cooled underground space, water can be condensed from air and then pumped up again.



New human rights for the digital society
Like the right to not be measured, analysed or influenced (online) and the right to prefer human contact to robot contact (e.g. in healthcare).



Large-scale production of fuel, food and water from algae
Algae are used to purify water through biorefinery.



Robot surgeons in the neighbourhood
In every neighbourhood, there are hospitals in which all kinds of medical interventions are carried out by remote robots controlled by human specialists.

2.2 SCENARIO B: 2050 – BIG GOVERNMENT

Emphasis on communication technology; virtual collaboration – Internationalization and strong international institutions that monitor and regulate – Equitable distribution of wealth leads to a strong state and little individual freedom – Global sustainability, fairness and future generations' interests are paramount

Digital Twins • Internet of Things (IoT) • Nanobots • Mixed reality • Hologram technology • Robotics

A **digital twin** is a digital replica of processes, people, places, systems and devices. They are very realistic models of the current state of the original and the interaction with their environment in the real world. (Rosen, 2015).*

Robotics A robot is a physically embodied, artificially intelligent actor. In other words, a machine that perceives its environment and acts independently on the basis of its observation. (Simon, 2017).

A **micro robo**t is a very small robot that has been built to perform specific tasks. Unlike nanobots, microrobots are usually visible to the human eye. (Techopedia, nd).

The **Internet of Things** (IoT)) is a system of interconnected devices, objects, and animals or people – each with a unique identification number – that can exchange data without the need for human intervention (Rouse, 2018).

Mixed reality (MR) describes the spectrum of reality technologies, of which virtual reality and augmented reality are the most important applications. **Augmented Reality** (AR) simulates artificial objects in their real surroundings – for example explanations at a historical site; **Virtual Reality** (VR) creates completely artificial surroundings.

* Photo Hannover, Germany – April 2018: simulation of car production by robots / digital twins at the Siemens stand at a trade fair in Hanover, Germany.

In this scenario, globalization has generated strong international institutions that focus on global sustainability, fairness and the interests of future generations. Thanks to advanced communication tools, based on technological developments like mixed reality, the Internet of Things and hologram technology, people travel less and less and work together virtually in teams from all over the world. The supranational organizations are strongly committed to monitoring and regulation, and force us to significantly reduce our ecological footprint. In this scenario, the redistribution of wealth has become a central priority, while sustainability and justice are dominant underlying values.

Driving forces

In recent decades, the threat and consequences of climate change, cyberterrorism and bioterrorism, natural disasters, and a global food crisis have dominated the public debate. In addition, rapid technological developments have made us more dependent on countries with access to the raw materials necessary for certain technological applications, like China, Russia and the Republic of Congo. The growing complexity of the infrastructures for energy supply, transport and payment traffic have made us vulnerable to cyberterrorism and extreme weather. People have lost their confidence in the ability of corporations and national governments to solve large-scale cross-border problems. As a result, virtually all administrative power has been transferred to supranational organizations (such as the EU, UN, WEF). A world government is in the making. The supranational institutions have ensured a politically stable climate, and regulate trade and access to raw materials.

A new generation

A new generation has left behind the materialistic and consumer lifestyle that characterized the second half of the 20th century, which has led to an important behavioural and cultural change. Global sustainability is at the top of everyone's agenda. Other important values in this scenario are international justice and a desire to create a better world for future generations. People have given up many personal liberties and luxuries for that better world. Government agencies rigorously check to make sure that everyone makes a sufficient effort to minimize their ecological footprint. The aim is to achieve a global circular economy and close the global resource cycle.

No major new breakthrough technologies have emerged, and ICT continues to be the dominant General Purpose Technology. The focus in investment and innovation is on communication technology. Virtual communication can no longer be distinguished from face-to-face communication, which, together with the increased

– Job offer –

importance of sustainability, has led us to travel less and to work remotely. People work from home in virtual teams from all over the world.

Robots

Robots have become an important element of our daily lives: as early as the first decades of the 21st century, efforts were made to develop social robots in response to staff shortages in education, healthcare, ICT and transport. Slowly but surely, more and more people were also allowing robots into their homes, first mainly for household tasks, later also to take care of their children and the elderly. There was simply no money to have these kinds of tasks carried out by humans. Governments focus so strongly on urgent problems involving climate, food and water scarcity and on closing resource cycles that there are no resources left for social provisions. In many places, robots are a part of everyday life, in the form of the 'humanoid' babysitters and nurses that accompany children and the elderly, or the nanobots swarms

equipped with sensors monitoring public spaces 24/7 and measuring air quality. All kinds of robots are used for information provision, monitoring, surveillance, protection, rescue operations or even law enforcement. Because robots can recognize emotions in people and have the ability to express emotions themselves, the question arises whether robots should be 'free' and should be given the same rights as humans.

Supranational institutions enforce sustainability

Gradually, people have come to realize that self-interest will always stand in the way of the 'greater good'. In other words: people are not intrinsically motivated to consume less, live climate-neutral lives or choose a healthy lifestyle. External nudging is indispensable to get people to change their behaviour and international institutions have had to enforce the desired behavioural change. Because of the need to be efficient with raw materials and resources, it is important to be as self-sufficient as possible. This applies to regions as well as households.

Virtual communication makes physical contact unnecessary

Because the electrification of automobiles has proven to be counterproductive for the environment and for CO_2 emissions, and because of a lack of climate-neutral alternatives, people have started to travel less and less. Over the past decades, there have been considerable investments in (virtual) communication technology, including highly realistic hologram technology or the ability to manage a personal avatar remotely, for instance by storing the avatar in the workplace (an office, shop or factory floor) and activating it by logging in. Because communication now often takes place virtually, it is no longer necessary to cluster economic activities or for people to live close to their work. In the Netherlands, there is a much more even distribution of people and economic activities: people choose in favour of more space and an attractive living environment with relevant facilities in their neighbourhood. The houses are getting bigger, homes and their immediate surroundings are geared towards self-sufficiency and creating the smallest possible ecological footprint. In and around homes, all kinds of smart devices and robots take over as many tasks as possible and make decisions about a sustainable lifestyle for people.

Control and regulation

In this scenario, technological innovation is accepted, although all the consequences of new applications must be thoroughly researched before they are allowed to be widely distributed. There is a strong belief that sustainability and a fair society

can only be realized through intensive control and regulation, which is supported by developments like big data, the Internet of Things, machine learning and robotics. Data and networks are controlled by the supranational authorities. There is strong competition in the globalized market. Companies focus their innovation activities mainly on direct application and incremental innovation. As a result, radically new technologies remain on the shelf. What is in high demand are technological applications involving security safety: nanotechnology has improved monitoring and surveillance by making sensors smaller, more efficient and even invisible. Nanobots are used to deactivate bombs or intervene in dangerous places (after an attack or natural disaster). Nano-structured filters and smart nanomaterials are used to purify water or detect contamination. In agriculture, nano-sensors monitor the growth of crops and detect diseases. As a result, agriculture can be more environmentally friendly and yields have increased

Powerful supranational institutions

In the 20th and 21st centuries, prosperity in the Netherlands was acquired at the expense of other people in the world, and that of future generations. The Netherlands ran out of natural resources and had to import many raw materials, which took a heavy toll on the natural capital of other countries and that of future generations. (CBS, 2018a.) The same was true for most other Western economies. As the 21st century progressed, people became more sensitive to the rights of future generations, and to issues like sustainability and international justice. Strong international institutions were given a great deal of political and economic power, and now regulate access to scarce raw materials. People trust supranational institutions to solve transboundary and cross-generational problems, and maintain political stability. Important instruments that the international institutions have at their disposal are making money available for research and innovations that contribute to solving large-scale problems (the grand challenges and the sustainable development goals), in addition to the ability to enforce strict legislation and regulations.

– Job offer –

CYBORG UPCYCLER: REFURBISHING WARTOOLS TO SUPER CAREGIVERS

We issue discarded cyborgs from the military/defence industry a second life by upcycling them to personal super-caregivers. Many of our customers need continuous care and prefer a human-like presence over a fully automatic house with ambient smart technology. The cyborgs that are nog longer needed by the military can be deployed with minimal adjustments. As an upcycler, you provide the cyborgs with new software and algorithms and process their organic material to give them a friendlier appearance.

Between 2020 and 2030, environmental degradation, water scarcity and shortages of raw materials and fertile soil led to food shortages and volatile food prices, which created a global demand for Dutch knowledge involving agriculture, food and water management. Because the Netherlands focused on circular businesses in a timely fashion, sectors that were sensitive to the supply of raw materials, or large price fluctuations in raw materials (such as biomass, rare earth metals and plastics) proved to be robust, the country has become a leader in the field of circular enterprise. Strong regulation, more efficient use of raw materials and the fact that people increasingly communicate virtually and travel less have proven to be important success factors when it comes to realizing a circular economy.

International resource-roundabouts

The organization of production processes is all about reducing the use of resources and energy consumption. Initial demand for products drops because products last longer and are reused. Demand for raw materials also falls due to ‘virtualisation’ and declining mobility. Passenger transport has been reduced, but freight transport still takes place.

– Advertisement –

Junior Holocoaches

Because our children are the future, we naturally want the best for them. The best guidance and attention and a safe environment for them to learn and play. Unfortunately, almost no one has the luxury of being able to guide their child every day, and teachers may have different values and ideas. That is why we help you program your own customized holocoach. You choose which psychological, educational and philosophical or religious values the holocoach emphasises in its interaction with your child. The Holocoach is available day and night for your child to talk to or as a playmate. Our Holocoaches come in different forms: ranging from mythical animals to superheroes. Do not hesitate any longer and give your child the best that technology has to offer.

Global production centres and international resource-roundabouts emerge, where large amounts of residual flows come together and are reused. The renewed products are distributed worldwide. This new approach to the production and handling of raw materials is very labour-intensive and gives a boost to employment and the robot industry. In this scenario, we work with a true cost-price system that is as accurate as possible, which is made possible by big data, the IoT and digital twins. A true cost-price system means that the environmental and healthcare-related costs are included in the price of products.

– Job offer –

For our gated community in archology 416 we are looking for a community safe keeper. You are responsible for the quality of life and safety of our community of some 3000 families. You monitor the quality of the locally produced food, the drinking water and the air. You know at any time who is present within the community and for what reason. You use the latest hardware and software in the area of big data, Internet of Things and sensor technology. You ensure that digital and physical infrastructure is always in top condition and you know which nanorobots to use for repairs or emergencies. You are also the point of contact for residents who want to communicate traditionally (with another person).

International institutions and producers continuously look at which location the production costs and ecosystem services are minimized, not only in terms of the financial costs, but also with regard to externalities, such as environmental pollution during production and transport.

Repairing, refurbishing, remanufacturing, repurposing and recycling are interesting economic activities that can earn a lot of money. Another highly profitable activity is urban mining: the large-scale recovery of valuable materials from electrical and electronic equipment. Blockchain technology helps manage production chains and verify a sustainable or ethical origin of products. It is used to determine the origin of certain raw materials. It is also successfully used for resource pricing through a cap

and trade system[3]. The cap and trade system is also an indispensable technology for the introduction of complementary currency systems that stimulate sustainable behaviour, like the SolarCoin system that rewards the production of solar energy (Mul, 2016).

Outcome as a service

The boundaries between technology companies and other types of companies have faded, because manufacturers of machines have spent the past decades working on new business models, for instance using IoT connections and IoT data to offer their products as a service. In almost all sectors, the revenue model has shifted away from selling products towards delivering results, in what is also known as outcome as a service (OaaS), for example an air conditioning company which no longer sells devices but instead sells targets for energy consumption and temperature in buildings using sensors and user analysis via the IoT. Powerful prognosticate, predicative analytics and more advanced algorithms have led to better decision-making, increased customer involvement, and optimized resource management and planning.

Virtual

Companies change into global communication networks in which virtual connections play a central role. People work from home in virtual teams with experts from all over the world. Companies strive to involve the most talented people in their teams. People need to communicate globally to establish their reputation on the international labour market and work with people of different nationalities to be successful.

In addition to the indistinguishable hologram technology and other virtual communication applications, there are other forms of mixed reality that are integrated into all aspects of daily life. After smartphones made augmented reality (AR) accessible to the general public with well-known applications like Layar, Pokémon Go, Aurasma and Google Skymap the way forward was paved for more intensive applications such as AR via glasses and lenses. For virtual reality (VR), there are more applications in the area of communication technology, entertainment and education. AR has a major influence on the interaction between people in their physical environment: all information in the public space is offered customized and AR advertising campaigns and games cause unexpected behaviour in certain places, similar to the flash mobs at the beginning of the 21st century.

3 A regulatory instrument that usually consists of issuing a limited amount of rights of use for a certain product and setting up a market to trade these rights (Erasmus University Rotterdam, 2018).

Large-scale urbanization and digital twins

The supranational institutions focus on big data analytics, artificial intelligence (AI) and digital twins to solve problems related to climate change, natural disasters, healthcare, the availability of water, food, energy and large-scale urbanization. On a global level, smart city concepts have been developed in which the IoT helps prevent traffic congestion – for example by dynamically operating traffic lights and quickly finding people a parking space; by managing waste flows by reporting when waste containers need to be emptied; and by the early detection of flooding. The IoT and advanced artificial intelligence enable many cities to work with digital twins: highly accurate digital replicas that address specific environmental factors, such as local legislation, physiological location characteristics or people (digital personas). These digital twins for cities make it possible to simulate policy plans, for example for environmentally-friendly housing, wireless network antennas, solar panels and traffic flows, and to check for potential problems before these policies are physically implemented. This increases the effectiveness of policy-makers and implementers and adds to the confidence that has been placed in them in this scenario.

Incorrect correlations?

Of course there are also downsides to betting on big data and analysis. Especially in the first two decades in which we made the transition towards data-driven solutions, there were examples where the use of incorrect correlations or incorrect data caused damage, discrimination and violation of privacy. However, the benefits were more important than the drawbacks and people did not want to throw out the baby with the bath water. So the possession of the data was transferred to the international institutions, which now ensure that data analyses are used for the public interest and when there are negative effects on a personal level, that has to be accepted as inevitable.

Less moving space and social control

Many households want to be self-sufficient and reduce their ecological footprint. Technological developments that contribute to making that happen include smart homes, 3D printers and VR holidays. Because global sustainability and justice are considered to be top priorities, people give up part of their autonomy. There are strict rules and guidelines for people to live as healthy and sustainably as possible. The government has taken control and, after decades of experimenting with quality marks, such as ecological, organic, fair trade and FSC, certain products – like sugar, meat, dairy products, detergents and plastic – have now simply been banned or replaced by sustainable and eco-friendly alternatives. In some cities, CO_2 quotas are used for households.

Because realizing the most sustainable approach to consumption involves complex considerations, a large part of people's day-to-day decisions have been handed over to computers and other devices, which take into account health, comfort, and the prosperity and well-being of people elsewhere in the world and of future generations. Wearable technology keeps track of people's ecological footprint, which is then widely available on social media, so peer pressure is a serious concern. The IoT also makes it easier to keep an eye on vulnerable groups, for example by monitoring how much water elderly people drink.

Group interest above self-interest

Because the interests of the collective and the creation of a better world for future generations is more important than people's own interests, people trust that institutions know what is best for everyone in the longer term and will make the right decisions accordingly. Smart data analysis and simulations provide insight into that process. Government priorities are climate change, sustainability and international justice, at the expense of social and economic security.

Completely free education
Nobody has to pay tuition fees, even if they have already completed a higher education or are over 35 years old.

A supercomputer consultant for public administration
When making complex choices the advice of the supercomputer should be obtained. The computer takes economic, social, ecological and ethical aspects into account.

Legislation to make companies work as sustainably as possible
Companies are fined when they do not make the most sustainable choices for now and later.

Mandatory healthy diet
Your health profile determines what you can eat and drink. For example, you have to have a chip scanned before you can buy certain products.

True cost pricing system
The costs of environmental and healthcare-related damage of products and services are included in their price, which helps distribute the negative effects of production and trade more fairly.

Imports of two-child policy
Families can have two children at the most. This puts less pressure on natural raw materials and the social security system.


Insects as the most important source of proteins
Insects as a source of proteins in the daily diet instead of dairy and meat. They reduce the ecological footprint and are very healthy.


A basic income for everyone
An unconditional, guaranteed income for everyone over 18. A simple social system making people work more, do more volunteer work and provide informal care more readily, among other things.


Hologram technology as realistic as face-to-face contact
This communication technology will make us travel less, which saves time and puts less pressure on the environment.


Personalized outdoor advertising with augmented reality
Through augmented reality, people receive customized advertisements on their phone or via lenses or glasses when they are outside. Physical advertising expressions in public spaces, like shop windows, advertising signs or billboards, will disappear


Virtual reality vacations
Through virtual reality, people can experience all kinds of holiday destinations or activities. People will travel less often and less far

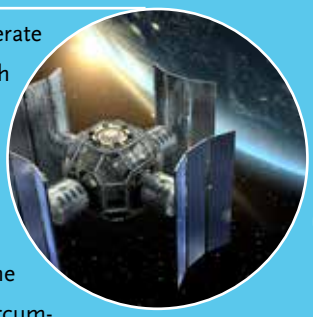

Strong supranational institutions
Strong supranational institutions can create a stable geopolitical situation and stimulate international trade.

2.3 SCENARIO C: 2050 – SURVIVAL OF THE MOST EFFICIENT

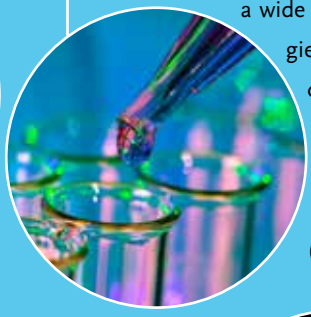
Biotechnology, gene technology and quantum computing are new General Purpose Technologies – Struggle for raw materials: international tensions between largely self-sufficient regions – Scarcity forces high-tech solutions and new applications to enable manipulation of the environment – Techno-optimism, self-sufficiency and safety are paramount

Biotechnology • Gene technology • Metamaterials • Quantum computing • Geo-engineering • 4D printing • bioprinters

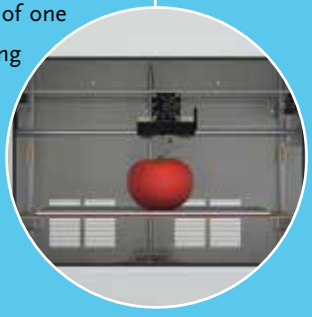
Geo-engineering is the deliberate large-scale manipulation of the earth and the environment. It is seen as a means to reduce global warming through anthropogenic greenhouse gas emissions (Bellamy, 2015). Weather influencing can also have the purpose of preventing harmful circumstances such as drought, hail or hurricanes.



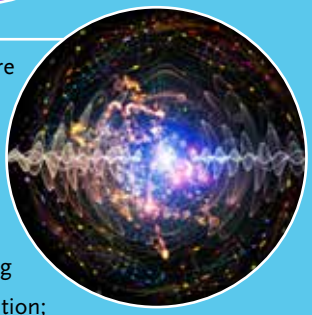
Biotechnology Biotechnology includes a wide range of technologies that use living organisms or parts of them to make a wide range of products (Lorenzo, 2018).



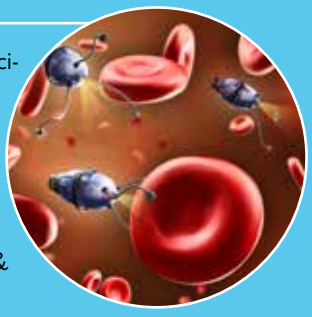
Bioprinters, or 3D bioprinting, refers to the printing of one or more types of living tissue, structures or biomedical implants using 3D printing technologies.



Quantum technology. There are four domains in which the most important (most impactful) applications in the coming ten years can be developed: quantum computers (computing power), quantum communication; quantum simulations; and quantum detection and metrology.



Nanotechnology comprises the science and technology where phenomena that occur at nano-level are used in the design, characterization, production and application of materials, structures, devices and systems (EU, DG Health & Consumer Protection, nd.).



With **4D printing,** programmable objects are made that can change shape and function (programmable matter) after production. 4D-printed objects can adapt to changing environments and can easily be recycled, repaired or adapted for other applications.

The battle for scarce raw materials has led to international tensions and created a world consisting of regional trading blocks. Highly urbanized, self-sufficient regions are committed to high-tech solutions in response to the shortage of raw material. Biotechnology, gene technology and quantum computing are used to develop new materials and ecosystems are being restored, which significantly reduces the pressure on the environment. 4D printers and bioprinters have become available to consumers, allowing them to create dynamic products and design new, sustainable organisms. In this scenario, resource scarcity is the main driving force and all sorts of technological developments are used to close cycles and create alternative materials, crops and dynamic products.

Driving forces

The growing world population and prosperity have led to an increasing demand for rare raw materials, which in turn has generated international tensions, giving rise to more and more conflicts involving territory, access to raw materials and control over trade routes between Western countries and other superpowers, notably China and Russia. The additional emergence of a high-tech economy at the beginning of the 21st century increased global dependence on countries with access to rare earth metals, like China, Russia and the Republic of Congo. This has lead to further geopolitical tensions and, after a number of trade wars between different power blocs, many countries implemented protectionist measures. Most economies are closed and there is little international cooperation. Strong regional trading blocs operate as self-sufficiently as possible. The EU has fallen apart and the Netherlands is now a member of the Northwest European Union. We are constantly looking for alternatives to rare raw materials, which means that investments in biotechnology, gen technology and nanotechnology take flight.

Regions use technology to solve scarcity

Scarcity and the pressure on natural resources are important driving forces in this scenario. In combination with developments in the area of ICT and quantum computing, biotechnological developments make it possible to identify alternatives for raw materials in this fragmented world. Regions, especially metropolitan regions, are largely self-sufficient and form dense markets for labour, goods and services. Congestion and pollution are priorities for the megacities, presenting opportunities for new technological applications. Closing cycles and high-tech solutions for a circular economy are also among the top priorities.

Developments in the areas of nanotechnology and biotechnology, in combination with quantum technology, make it possible to identify alternatives to scarce raw

– Job offer –

materials and earth metals. Experiments are also being carried out with the reversal of pollution and degradation of ecosystems through geo-engineering.

New nature

The programming of artificial intelligence and artificial life has increasingly been approached from a bottom-up perspective since the beginning of the 21st century, in the sense that computers and robots developed themselves according to biological principles. In the 20th century, the focus was on controlling the existing nature through the technical application of principles; in the 21st century, the emphasis is on the creation of new nature. We are able to combine natural and artificial (basic) elements into self-organizing systems and create 'machines' at a molecular level (nanotechnology). Given the challenges of the growing world population, climate change and the depletion of fossil fuels, the focus is in particular on creating applications for food production and development of biofuels. With the help of genetics, new high-yield food crops and organisms that can clean polluted environments are designed. Designing plants that convert sunlight into energy and food in a cheap and environmentally friendly way is a particularly lucrative activity. (Mul, 2016).

Modified crops

For several decades, large multinational companies have been working to gain ownership and exclusive control over biological sources and products. After the many protests of environmental action groups in Europe, due to regulations, these processes have become so expensive that only multinational companies can afford them. Farms are vulnerable to the price fluctuations of the modified and synthetic crops, while existing traditional crops are being displaced. In addition, many of the modified synthetic crops are only profitable for two years, after which a new variant has already been introduced to replace the previous one.

Self-sufficient regions and local production

Companies adjust their products and services as much as possible to the local context, namely the available raw materials, the social capital and the organizational capacity in a given region. Large power blocs focus on their own research and development, which leads to a variety of technological solutions and applications, creating major differences between regions. Self-sufficiency, safety and security are important values in this scenario and technological applications that contribute to these areas are very successful. Innovations focus on increasing efficiency and closing the raw materials cycle, or on creating alternatives for rare raw materials, often through biorefinery and the design of smart metamaterials.

Companies develop large research centres and production facilities to apply the new technologies in products and services. In addition to biotechnology and nano technology, artificial intelligence, machine learning and other technologies have penetrated every sector and every aspect of daily life. Intelligent systems and robots replace most of the physical work. Aircraft, drones, robot taxis, hyperloops and other autonomous, connected means of transport are used to transport people as well as freight. People want the physical world to be as flexible as the virtual world and expect buildings to be just as adaptable as their electronic devices and to be suitable for a variety of purposes, for example as offices during the day and residential units in the night.

Nanotechnology and quantum technology for a cleaner energy system

The interplay between biotechnology, nanotechnology and quantum computing generates radical innovations in this scenario. Quantum computers, which are able to make calculations much faster than traditional computers in a small number of cases involving specific calculation tasks, appear on the market in 2025, with the

– Job offer –

Personal disorganizer

help people get ready for change

It is not only organizations that have to be prepared for disruption and change, people also have to prepare themselves for the work they will do in five years' time. That is often easier said than done, and many people postpone the necessary preparation until it really is no longer possible. To ensure that people do not become stranded in the future, they can call on your services as a personal disorganizer. As a personal disorganizer, you simulate life-changing events (such as separation, illness and loss) and the end of their job (being fired, not being able to find a new job), forcing them to prepare for change.

chemical and logistical industries at the forefront of developing applications and benefiting from this breakthrough. Quantum technology not only led to much more powerful computers, it enabled us to develop medicines more quickly and cheaply; to discover and develop new materials; to accelerate machine learning and data analysis; and to accurately simulate the entire climate system – providing accurate weather forecasts.

Quantum simulators have helped us understand issues related to chemical reactions, magnetism and superconductivity, which in turn has led to major innovations in the storage, distribution and transport of energy. In combination with nanotechnology, quantum technology has helped make solar energy very cheap and universally available. Based on these insights, applications of nanotechnology – such as

polymer electronics and polymer optics – have allowed us to create a clean energy system, making wind turbines and solar cells more efficient and improving their output. Other applications involving nanotechnology that have contributed to a more sustainable energy system are applications regarding battery recycling, and oil leaks, by converting the oil into a jelly that can then be scooped up.

New materials

By changing the structure on a nano-level, materials obtain new or additional properties. Think of water-repellent or dirt-repellent materials; thermal and chemical sensors in clothing; invisibility cloaks or self-healing materials in which nanoparticles can migrate to seal cracks.

The development of self-cleaning and self-healing materials (clothing, glass, metals) has resulted in much fewer harmful substances being required for maintenance of all kinds of products. Environmental groups are still concerned about the spread of nanoparticles in the living environment – which is difficult to establish. But the benefits of the self-cleaning materials and the sustainable energy generation are such that the environmental groups cannot stop the large-scale deployment of nanomaterials. There are also many applications that help keep ecosystems intact: iron nanoparticles are used to clean chemicals that pollute groundwater, and nanoclusters that act as catalysts are used to produce considerably fewer contaminating by-products in the production of materials like plastics, paints and detergents.

The breakthrough of quantum technology and the accurate weather simulations that became possible as a result have also led to an advance in geo-engineering. In many regions, experiments are now carried out to combat extreme weather conditions and to maximize agricultural yields. However, the use of geo-engineering often has unforeseen negative effects in other regions and the experiments thus lead to further tensions between power blocs.

4D printing and the voxel industry

4D printing has led to fantastic innovations, such as airplane wings that change shape during flight, tires that change shape or traction (summer and winter tires in one), furniture that is stored in a compact package and then assembles itself after purchase, roads that adapt to different levels of load and weather conditions, and self-repairing materials that can be used in aircraft, bridges and tools. The breakthrough of 4D printing has ensured that we handle raw materials much more

– Advertisement –

efficiently. The 4D printing of objects makes it easy to recycle, repair or reconfigure objects, leading to a reduction in demand for what used to be scarce raw materials, which are now being used and reused in a smarter way. Since production takes place 'on demand', fewer stocks are needed.

In agriculture, infrastructure and construction, 4D printing has brought considerable changes because the products and machines that are used adapt to (changing) climatic conditions. There are even entirely printed buildings that can change shape and adapt to changing circumstances. For example, walls that can let through light and air, and temperature and air circulation that automatically adapt to external weather conditions outside and indoor activities. In 4D printing, digital voxels are used in desiging. The models are then 3D-printed by applying physical voxels layer by layer. Physical voxels can include titanium, nanomaterials, integrated circuits, biological materials and micro-robotics. The design and production of the voxels needed for 4D printing constitute an entirely new industry, and countries that have responded to this development in time have benefited economically.

4D printers and bioprinters in your home

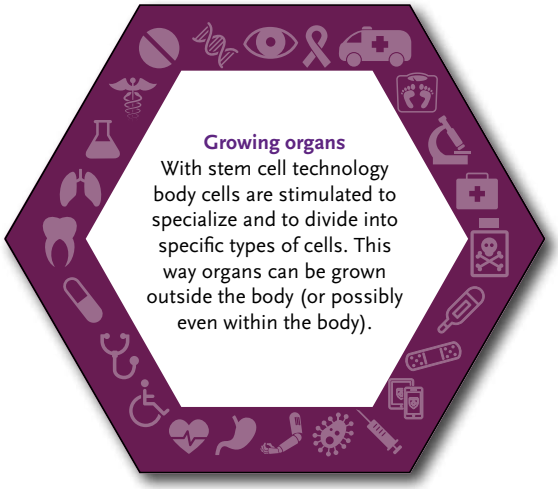
Thanks to breakthroughs in biotechnology and nanotechnology, average life expectancy has increased for those people can afford to benefit from the technical applications. Not only do people live longer, they also stay healthy longer. 4D printers have been available on the consumer market since 2035. Producing static products is seen as waste; dynamic objects that can adapt to people's wishes are preferred. With 4D

printers, consumers only need a certain amount of programmable matter, which they can always transform according to their changing needs, which means it often not necessary to buy new products. In addition to the voxel industry, there is also a huge industry for blueprints to program the programmable matter.

In addition to 4D printers used to print dynamic objects, there are also cheap DNA scanners and bioprinters available that allow consumers to design and print their own plants and animals. Because people with low incomes cannot yet afford, 4D printers and bioprinters there is a major divide between rich and poor. In some regions in Asia and Latin America, since 2045, people are allowed to manipulate their own genetic code and that of their (unborn) children. Because of the unequal access to these expensive technologies and diverse philosophical and religious views on this, a new social dichotomy is emerging between genetically improved people and 'natural' people.


High-tech urban agriculture
Every city has high-tech city farms that provide 80% of all the food needed in that city.


Drones for passenger transport
In places with a lot of congestion, drones for passenger transport provide a solution for people who want to reach their destination quickly and can afford it.

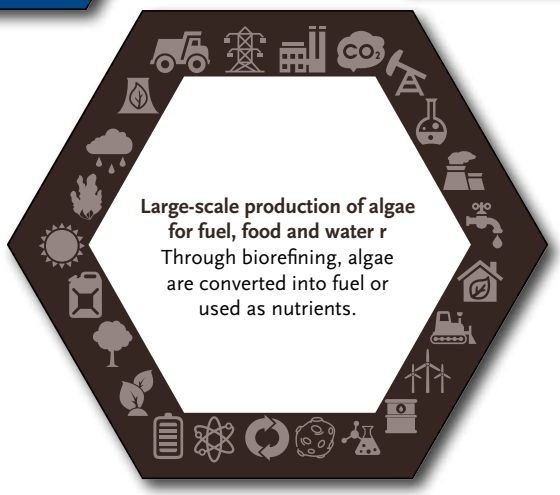

Growing organs
With stem cell technology body cells are stimulated to specialize and to divide into specific types of cells. This way organs can be grown outside the body (or possibly even within the body).


Protection against bioterrorism
Bioterrorism involves the use of micro organisms as biological weapons, like anthrax. They can be more radical than conventional and chemical weapons.

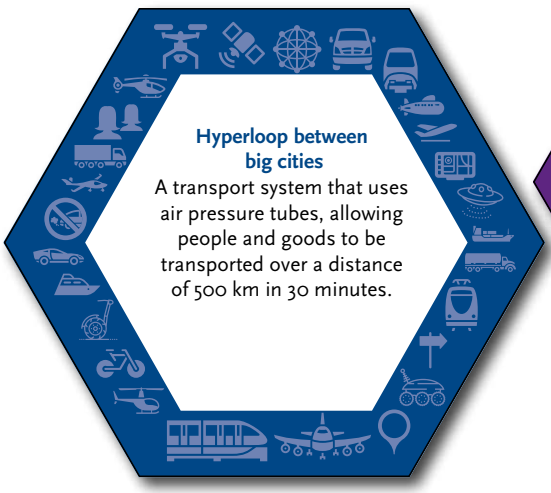

Asteroid mines for rare raw materials
This mining company can excavate gold , platinum, nickel, iron and water from passing asteroids.

Robot mail deliverers
Robots that deliver parcels and letters are resistant to extreme weather conditions and can fly over busy traffic points.

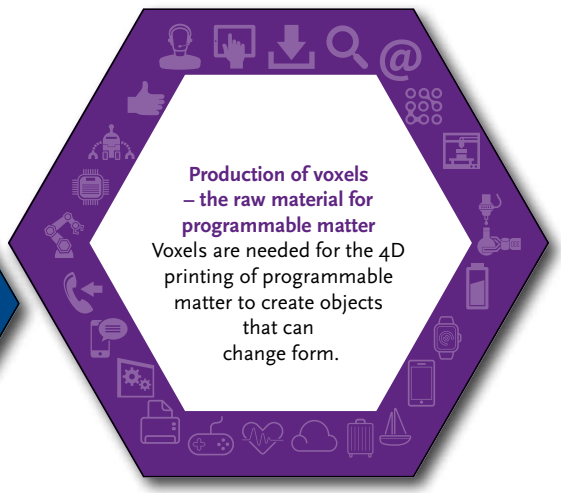
Weather influence
Affect the weather to prevent certain extreme weather conditions and be able to grow more food.



Large-scale production of algae for fuel, food and water r
Through biorefining, algae are converted into fuel or used as nutrients.



Hyperloop between big cities
A transport system that uses air pressure tubes, allowing people and goods to be transported over a distance of 500 km in 30 minutes.



Production of voxels – the raw material for programmable matter
Voxels are needed for the 4D printing of programmable matter to create objects that can change form.

2.4 SCENARIO D: 2050 – I AM TECHNOLOGY

Bio- and neuro-technology as a new General Purpose Technology – Internationalization and multinational companies have a lot of power – Production is highly automated and people choose human enhancement to remain competitive – Techno-optimism, market forces and individualization are important

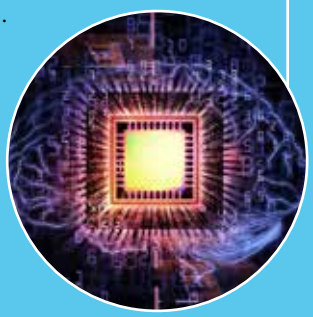
Human enhancement • Brain-machine interfaces • Artificial intelligence • Nanomist • Brainternet

A **brain-machine interface** (BMI) converts brain waves into digital commands that control software or hardware – like a computer or robot arm. The realization of a BMI can be done by invasive technology, such as applying sensors or implanting a chip in the body, or by non-invasive technology, like using a hood with sensors.

Brainternet

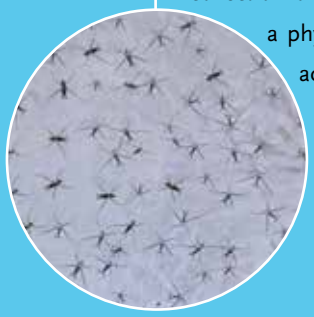
Through brain-machine interfaces the human brain becomes a node for the Internet of Things.

Artificial intelligence is a branch of computer science that aims to create intelligent machines that work and respond as people (Techopedia, 2018).



Human enhancement is the non-medical use of biomedical technologies to improve the human body or its performance beyond the 'natural' limitations (Dijkstra, 2015).

A **nanomist** (also called a utility fog) is a collection of small robots that can replicate a physical structure. In fact, it is an active, polyform material that can change into any form, autonomously or with a simple instruction from a human.



In this scenario, world trade increases and multinational companies control much, if not everything, in this world. Technological developments happen quickly and artificial intelligence (AI) is a pivot in the production chain. Fully automatic companies and new jobs and tasks for people emerge. We see the rise of all kinds of applications in the area of human enhancement: people use bionic prostheses and brain-chips to stay active for as long as possible and to compete with advanced robots and AI systems on the global labour market. Economic growth, individualism and freedom are important values. In this scenario, there is a whole new approach to production and people and machines appear to blend together.

Driving forces

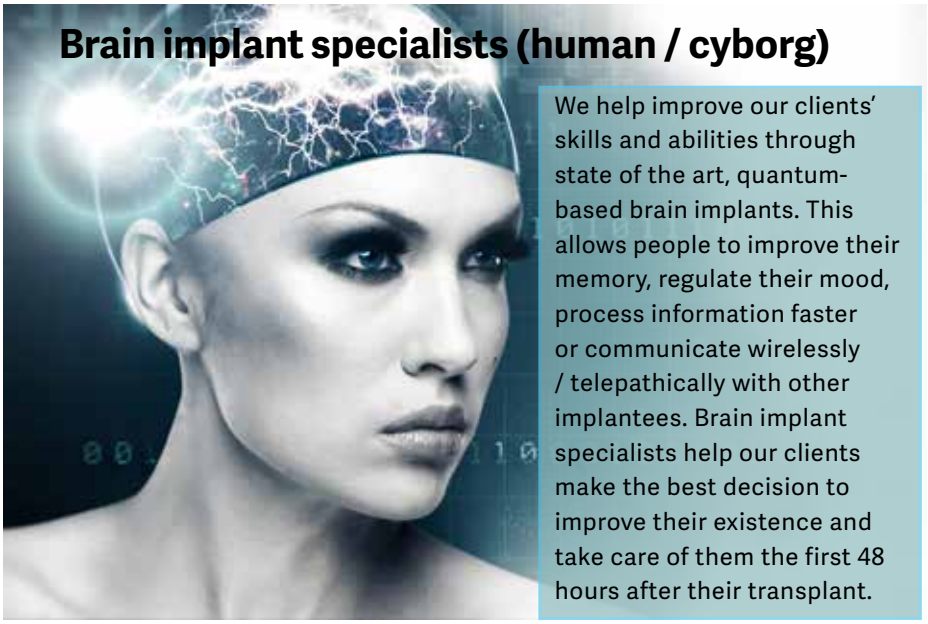
There is a strong internationalization: a stable international environment with free exchange of goods, people and ideas. At a global level, there is a lot of confidence in market forces, as there is in technology and rapid technological developments. There are major breakthroughs in the areas like deep learning, machine learning, artificial intelligence, neuro-technology and biotechnology, which together lead to a flourishing market for applications involving smart expert systems, artificial intelligence and human enhancement.

A multipolar international order has emerged. Emerging economies have put the Western-oriented economic relations under pressure. In addition, there is an increasing number of non-state actors exerting influence on governments, citizens and businesses, including non-profit organizations, religious organizations and multinational companies. (Mega) cities and multinational companies gain more economic and political power, which means that administrative layers at a national level are less important than those at a regional and supra-national level. There is rapid technological development and great confidence in technology. Important breakthroughs take place in areas like deep learning, machine learning, artificial intelligence, gene technology and neuro-technology. To solve international issues like resource scarcity and climate change, we rely on market forces and high-tech solutions.

Autonomous companies

Since deep-learning machines are finally able to 'understand' large amounts of big data, artificial intelligence is a key element in most production processes. AI is no longer a form of 'narrow intelligence' (made for specific tasks), but operates at the level of 'general artificial intelligence'. This means that it can carry out complex and diverse tasks, at which it often performs better than people. As a result, many processes have been fully automated. Currently, the level of 'authentic AI' (superintelligence) is becoming reality. (World Economic Forum, 2017).

– Job offer –



AI technologies can supplement, replace and improve virtually any task carried out by people. Many tasks and jobs that were carried out by people at the beginning of the 21st century have now been automated. But more complex, new skills are also needed to get the best out of AI and other technologies, resulting in a variety of new tasks and jobs. In addition, AI has ensured that work is further divided into tasks that can be performed by people wherever and whenever. The AI systems also know exactly what people are good at and divide the tasks. Instead of people looking for work, work is looking for people (Peters, 2017).

Thanks to the rise of blockchain and smart contracts, production processes as well as general business processes are automated. And, in this scenario, we see the emergence of autonomous companies, where no human labour is required – not even at management level. It is therefore no longer just people who make decisions and conduct transactions among each other, but machines also engage in transactions with people or with each other.

Nanomist

The nanomist has been available on the consumer market since 2048. A nanomist consists of a large number of nanobots grouped into mega swarms of billions of bots, which are centrally controlled and can carry out assignments together. They

– Job offer –

Mind-transfer specialist

Mindsforever is a young start-up that aims to have mind transfers available for the general public in 2057. We have conducted successful tests transferring minds from our customers to clones of themselves and to synthetic organisms, and in the next seven years want to perfect our services, making them affordable to a large part of the population.

Are you an ambitious mind transfer specialist who believes in our mission: To allow everyone to live forever? Respond quickly.

know where the other robots are and can communicate with each other. They are in fact made from an active, polyform material that can change into any form, autonomously or with a simple instruction from people. The use of the nanomist means that we need much fewer raw materials: nanobot swarms can change into all kinds of objects, depending on what is needed.

Space travel

Space travel is a sector that has created many technological spin-off effects. However, it is no longer the playing field of governments and universities, and instead, commercial companies benefit from the economic opportunities of space, like space tourism, asteroid mining and the construction of space habitats. 2045 saw the first

settlements on other planets and, for adventurous people with poor economic prospects on Earth moving to another planet is an attractive idea.

Human improvement

AI has also made it possible to develop digital twins of people that use biometric, medical and environmental information to monitor certain health risks. Especially in healthcare there are many applications for this, and this innovation – together with personalized medicine and preventive healthcare – has drastically increased life expectancy to an average of 110 years. In this scenario, people use wearable technologies and human enhancement to be more efficient, more attractive to employers or feel more beautiful. Prosthetics and bionics are no longer reserved for people with physical disabilities; many people have healthy limbs or organs removed in favour of improved bionic prosthesics. Since a few years, neuroprosthetics have also become popular among more highly educated (and wealthier) people. These are neurotechnical implants – or brain chips – that function as a brain-machine interface to improve our memory and turn the human brain into a kind of supercomputer. Among less highly educated people (and those with lower incomes), nootropic drugs – medicines that improve the thinking process and help improve concentration – are still popular. There is a lot of discussion about negative side effects, such as schizophrenia and paranoia, but manufacturers persist that there is no proof that a causal relationship exists between these conditions and the use of the drugs.

Brainternet

The brain-machine interfaces (BMIs) are often implanted as a chip in the human brain and they are a form of human enhancement, which not only increases a person's capabilities, but also makes it possible to control software or hardware remotely. After technologies like artificial intelligence and deep learning have drastically improved the capabilities of machines between 2025 and 2040, it was decided to link these technologies to the human brain via brain chips. The first applications were developed in risk and conflict areas, where carriers of BMIs at a safe distance could intervene in unsafe situations, like handling toxic substances or explosives, or investigating nuclear accidents. However, BMIs soon became available on the consumer market and people who can afford them (having a BMI implanted costs about € 10,000 converted by 2019 rates and an annual € 2000 to keep the system updated) use them for all kinds of purposes: their working environment or home environment can automatically be adjusted to their affective state. The economic benefits of BMIs are enormous: BMIs make a whole range of new products possible, for example in healthcare, the car industry, artificial intelligence and marketing. Like

– Advertisement –

You are considering interplanetary migration?

Use our free simulation first

Are you considering taking the big step and trying your luck on Mars or Venus? Had enough of air pollution, overpopulation, extreme weather conditions, income inequality and political tensions on Earth? We have already successfully guided hundreds of pioneers in their journey to a new planet and we manage your migration from A to Z. We help you with all important choices, based on a personal pioneer profile. From which habitat or space domain fits you to which genetic modifications best suit your journey and new location. Stop dreaming and get started today. Blink three times to be redirected to our free online simulation.

the PC and mobile phone, it is a technology that affects every aspect of our lives. The advanced BMIs help people perform or relax better. BMIs also enable personalized interaction with software through direct neurofeedback, ensuring an optimal learning experience and a fantastic gaming experiences. The first experiments with the so-called 'brain internet' are now underway, with BMIs turning a human brain into a node for the Internet of Things.

Data from your body

The use of prosthetics and bionics in our body and chips in our brain has led to a whole new discussion about privacy. Because the technology is controlled by businesses, all the data acquired in relation to this embedded technology is also the property of the business community. Consumers pay for 'free' services with their data: while users are the collectors of the data, they have no right to make money from the data. Some consumer organizations and ethicists believe that consumers should also be able to use this technology without having to give away their data. But most people do not mind submitting their data in exchange for improved performance and longer life expectancy. The question of opt-in / opt-out systems is an important issue: consumers have the freedom to choose to use new technology, but those who choose not to do become increasingly isolated.

Immortality for sale

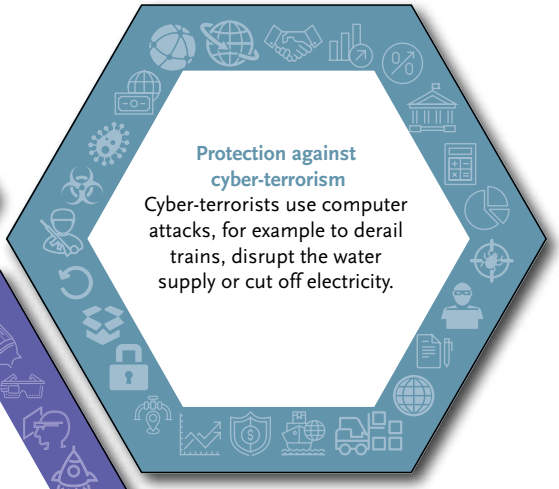
A growing group of people pursue posthumanism: they believe that the next step in the evolution of humanity involves consciousness and they want to upload their consciousness to a cloud and in that way realize virtual immortality. The big tech companies have responded by allowing people to let their consciousness merge with machines that will immortalize them. At the moment, this is only available to billionaires, but expectations are that, within ten years, the price of merging your consciousness with a machine will have dropped from two million dollars to 700,000 dollars.

Strong competition and big differences

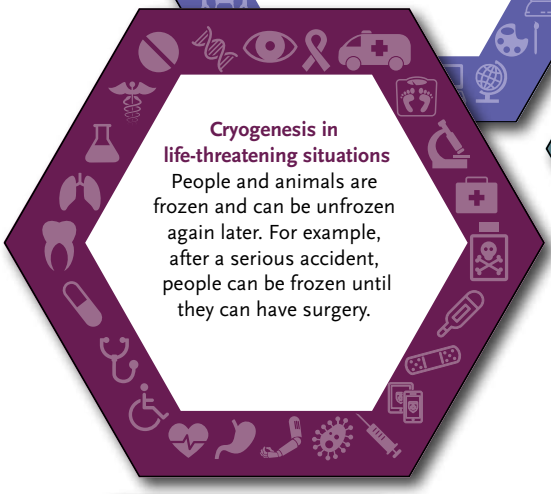
Because of the strong competition at an international level between countries, cities, companies and employees, there is a lot of economic uncertainty. There is little solidarity and little social security. This leads to an increasing demand for services that support people in their careers and important life choices. Many of these services are automated, for example in the area of finance, healthcare, career and relationships. There are huge differences in income levels. Developments in the area of human

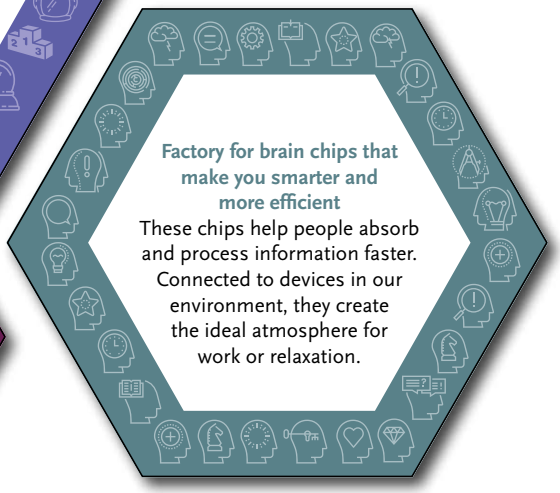
enhancement allow older people to work longer, while people who were previously excluded from the labour market because of physical or mental disabilities can now take part. Because there is a high level of automation in this scenario and even completely autonomous companies, it is necessary for robots and autonomous companies to pay taxes as well on the profits they make.


Legalizing
robot marriage
It is legally permitted
for robots to marry each
other or a human.

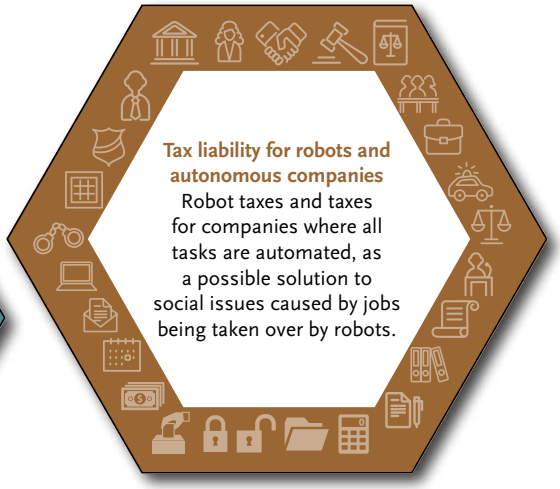

Protection against
cyber-terrorism
Cyber-terrorists use computer
attacks, for example to derail
trains, disrupt the water
supply or cut off electricity.


Space tourism
A company that specializes
in space tourism.


Cryogenesis in
life-threatening situations
People and animals are
frozen and can be unfrozen
again later. For example,
after a serious accident,
people can be frozen until
they can have surgery.


Factory for brain chips that
make you smarter and
more efficient
These chips help people absorb
and process information faster.
Connected to devices in our
environment, they create
the ideal atmosphere for
work or relaxation.


Introducing labour
replacement robots
Legally allow people to have
a robot do their work and
continue to receive salary.


Tax liability for robots and
autonomous companies
Robot taxes and taxes
for companies where all
tasks are automated, as
a possible solution to
social issues caused by jobs
being taken over by robots.

Remove and recover memories
In case of traumatic events, access to memories can be blocked. The blockade can be undone.

Exoskeletons mandatory for people with heavy occupations
These exoskeletons help people who do heavy physical work to work safer and longer.

Subsidies for people who want a (third) robot hand
With a robotic third hand, people are more productive and more efficient. This prosthesis will be available for people who already have two “normal” hands.

Right to vote for robots
Smart robots fulfil all sorts of meaningful social functions and have earned the right to take part in the political process, just as everyone else.

Interplanetary migration
Interplanetary migration reduces the pressure on the Earth’s ecosystem.

A supercomputer consultant for public administration
With complex choices advice from a supercomputer must be obtained. This computer takes economic, social, ecological and ethical aspects into account.

SCENARIO TABLE: THE MOST IMPORTANT FEATURES PER SCENARIO

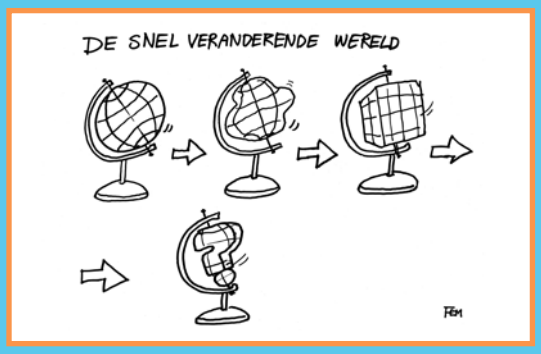
	A: Less is beautiful	B: Big government
Driving forces	• Struggle for raw materials • Dislike of growth-thinking, globalization and multinationals	• Cross-border issues lead to emergence of strong supranational institutions
Technologies typical for this scenario	• Information technology • 3D printing • Big data • Blockchain • Biorefining • Autonomous transport	• Digital Twins • Internet of Things (IoT) • Nanobots • Blockchain • Mixed reality • Hologram technology • Robotics
Scarcity	• Struggle for raw materials leads to self-sufficient regions and less consumption	• Scarcity of raw materials has led to strong international institutions and less individual autonomy
Producing	• Self-sufficiency • Small-scale production • closing resource cycles • 3D printing leads to less global trade • Biomass cascades	• Virtual collaboration leads to spread of economic activities • Global production centres and resource-roundabaouts, trying to reduce costs and environmental degradation as much as possible • Repairing, refurbishing, remanufacturing, repurposing and recycling
Consuming	• Less consumption • Durable but comfortable • People keep control • Community coins	• Outcome as a service • Less mobility and obligatory sustainable behaviour • Institutions monitor people's ecological footprint
(Re) distributing	• Quality over quantity • Solidarity with own group • Mutual caring at neighbourhood and city level	• Striving for sustainability and justice • Sacrifice prosperity here and now for elsewhere and later
Values	• Sustainability, solidarity and quality of life come first	• Common interest above personal interest • Global sustainability, justice and future generations' interests are paramount

	C: Survival of the most efficient	D: I am technology
Driving forces	• Scarcity of raw materials leads to self-sufficiency and investments in high-tech solutions	• Internationalization and strong role for multinationals leads to rapid technological developments
Technologies typical for this scenario	• Biotechnology • Gene technology • Metamaterials • Quantum computing • Geo-engineering • 4D printing • bioprinters	• Human enhancement • Brain-machine interfaces • Artificial intelligence • Nanomist • Brainternet
Scarcity	• Struggle for raw materials leads to self-sufficient regions and high-tech innovations designed to manipulate the environment and resources	• Technology is used as a olution for scarcity • Mining asteroids makes earlier rare raw materials available again • To surpass earth's ecological limitations, investments are made in interplanetary migration
Producing	• Production is location-specific • Create new nature • Modified crops and animals with help of bioprinters • 4D printing and the voxel industry emerge	• Production is almost ompletely automated • Autonomous companies, actions and transactions without intervention of people • To compete with robots and machines people choose human enhancement
Consuming	• Everyone can print dynamic objects • Do your own bioprinting	• Human enhancement to be more efficient or to feel more attractive • BMIs, brain chips and the brainternet • Post-humanism • Submit data to take advantage of technology and not to be excluded
(Re) distributing	• Large differences between regions • In agriculture, DNA patents lead to unequal power distribution	• Big differences between haves and have-nots, knows and know-nots • Access to technology is crucial
Values	• Autarky • Technology as a solution for scarcity	• Freedom and self-realization • Market forces and economic growth

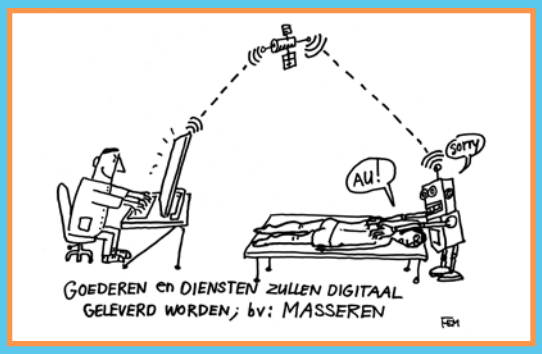
Illustrations made at the creative workshops

Contribution by Fem © Carof-Beeldleveranciers and Carof @ Carof-Beeldleveranciers

Creative workshops were organized in May and June of 2018, where we talked with experts, students and creative entrepreneurs about the future of the economy in relation to technological developments. Illustrators of Beeldleveranciers (a company that supplies visual reports) provided visual reporting. Here are some examples of the results.



The rapidly changing world



Goods and services will be delivered digitally, for example massage

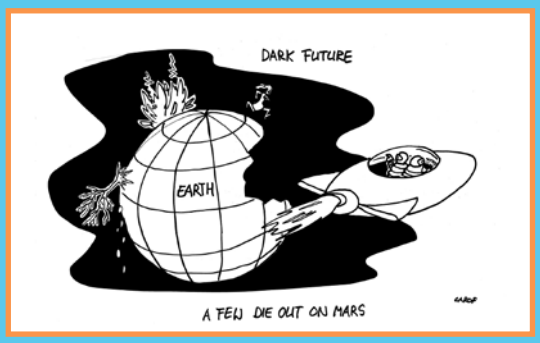
There will be more plastic continents

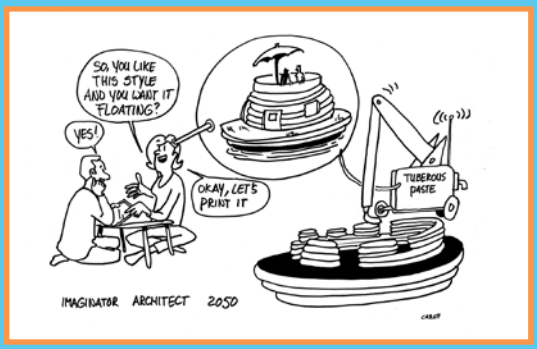
"4D printing.., 5D printing.. make whatever you want"
"Hi, I am your new loving ideal partner "

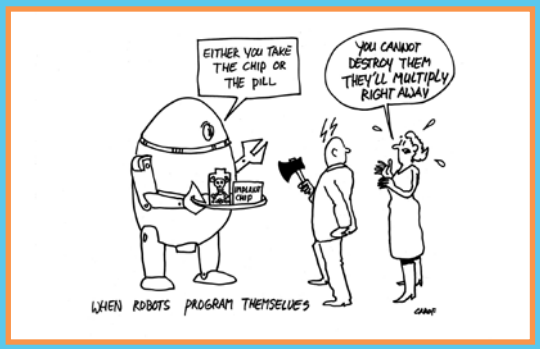
Transport per drone. People loose basic skills.

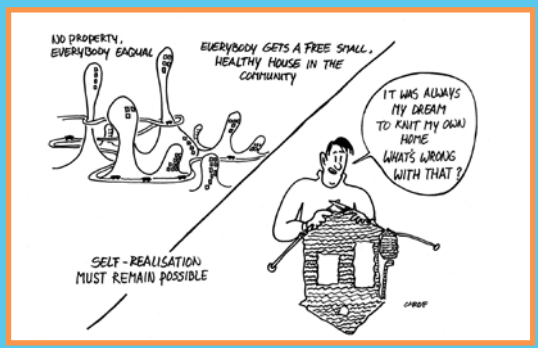
Education for everyone.
"I am allowed too!"

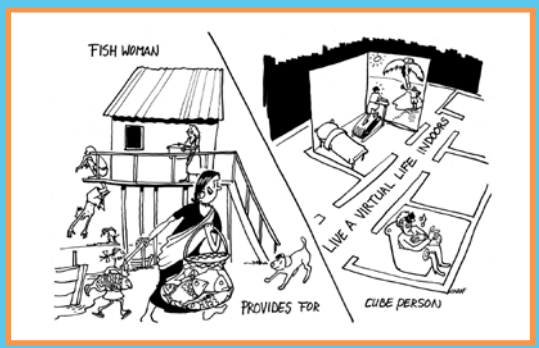
Freedom of religion











The world in 2040

By Maarten van Andel, author of De Groene Illusie

Although we are by no means climate-neutral yet, CO_2 emissions have finally been halved, ten years later than planned. Not so much because of windmills and solar panels, which still make up only a small part of our energy supply, but mainly because we use – and waste – far less energy. The CO_2 tax that was introduced at some point has been abolished again, because it did not help – as people expected in 2020, because earlier attempts at something similar had failed to yield the desired result. CO_2 emissions have been legally limited since 2025, like sulphur dioxide, nitrogen oxides and freons had to be restricted in the 20th century in order to really reduce emissions.

As a result, energy became so scarce, and so expensive, that all processes in society were optimized to consume as little energy as possible. Predictions about an excess of cheap renewable energy turned out to be utopian. Looking back, that makes sense, because if that had been possible, the free market would have settled the matter long before 2025, even without climate targets and legal measures. The utopian ideas about sustainable energy from before 2025 are at any rate regarded as a curious anachronism in 2040.

Circularity is the logical bottom-up result: a very long product life and recycling of materials provide the only way to use as little energy as possible. The current business model is no longer such that products are being bought. Users now pay to use the products, which remain the property of the manufacturer. Manufacturers, after all, cannot do without the raw materials that they have put in their products, so they will do everything they can to get old products back instead of having them thrown away. In addition, it is in his interest to make sure that the product lasts for a very long time.

Production is mainly local for local. Transporting goods over large distances is energy-intensive, making it unaffordable. Whereas in 2020 25% of all energy consumption was related to mobility, by now that is only 10%. On the other hand, ICT, which at 3% was already a bigger energy consumer than global aviation in 2020, has grown to 20%. Microsoft and Google vanished from the market, because they continued to work with an abundance of data. New Chinese and Indian companies offer modern, fast software that uses a fraction of the data, thereby consuming much less energy. In addition, they have developed operating systems, in collaboration with new computer manufacturers from Africa and South America, that can no longer be hacked or infected. HP, Dell, Lenovo and Toshiba have also vanished from the market, because they failed to respond in time to these developments.

Thanks to the efficient software and computer technology, autonomous cars have become very safe, with less than 10% of the number of fatalities in 2020. Although there are still many cars, they weight considerably less and are much more energy-efficient. Electric cars virtually disappeared from the streets, because they saved little CO_2 and the batteries caused a lot of environmental damage. Moreover, extracting lithium was far too energy-intensive. The making of the battery required as much energy as making the rest of the car, as had already been published by German researchers in 2018, and large parliamentary surveys in various European countries in the 2020's revealed that the ineffective policy of electric driving was mainly inspired by the commercial interests of large car manufacturers and electricity companies.

Cars have been programmed to adhere to legal guidelines, so that they never drive too fast, never tailgate and automatically reduce speed when there is a fog. As a result, there are hardly any accidents on the road anymore and consequently much fewer traffic jams. This, in addition to intelligent traffic lights and so-called green waves, have helped make cars much more energy-efficient. No longer having to brake, stop and and pull up again saves a lot of CO_2, and also minimizes the amount of particulates, tire wear and asphalt damage.

Speed checks, with all kinds of electronic systems and police cars, are a thing of the past, the flash units and laser equipment from yesteryear have been relegated to the museum, next to the emergency poles along the motorway we used to call for help when our cars broke down.

Flying is mainly for people, hardly for goods anymore. Planes still fly on kerosene, because that is the most energy-efficient way. Kerosene is the most compact and lightest energy carrier, making it easier to lift. Due to the low weight, the aircraft wings experience relatively little air resistance, which all helps save a lot of energy, compared to other energy carriers like batteries. Cruising speeds have been reduced from 900 to 700 km/h, and flight altitudes have been increased from 10 to 12 km, saving a factor of 2 in fuel consumption and CO_2 emissions. Flying still represents less than 3% of the global energy consumption, like it did in 2020.

Global population has grown to 9 billion, which requires careful nature management and efficient food production. Wood and food are generally regarded as very valuable items that people should not waste from a moral point of view, even if they have a lot of money. Burning biomass (wood, palm oil, biodiesel, bioethanol) to generate energy has been strictly banned since 2025, all the more so because it proved not to save CO_2 at all. Nobody understands that burning wood and food was once considered sustainable in a world where rain forests were disappearing and millions of people went hungry.

Like other products, food is mainly produced for local markets. Kiwis that are actually from New Zealand are priceless. Hoisting pork up and down between the Netherlands and Italy, because otherwise it could not be called Parma ham, is a thing of the past. Most food items are once again seasonal. It is far too expensive to grow strawberries in greenhouses in winter or to import them from faraway countries. Cattle

feed originates only in its own region, and is manured by cattle from the same region. As a result, cattle feed and manure no longer have to be transported over large distances, and the problem of manure surpluses and acidification that existed before 2030, for instance in the south of the Netherlands, has disappeared.

Almost no food is thrown away, and production and supply have once again become demand-driven, which means that, at the end of the day and week, some things may no longer be available. People eat what is still there at that moment, and as a results, much less food goes to waste. The latter also applies to medicines, thanks to a statutory minimum storage period of 5 years. The time when pharmaceutical companies were allowed to use commercially-inspired storage periods of 1-2 years has long gone.

Natural gas has made a comeback. While the Netherlands in the 2020s was the only country in the world to abandon natural gas, after 2030 it came to its senses. Gas extraction in Groningen gradually resumed in 2035, at a rate at which the soil remains stable. Natural gas is still the cleanest and most efficient source of energy for domestic heating and cooking, which is what it is used for. The energy generated with windmills and solar panels is used mostly for lighting, domestic use, ICT and industrial processes.

Since 2030, it is forbidden to store CO_2 in the ground. It was a kind of linear short-term measure that was like sweeping dirt under the carpet, but it also proved to made the soil unstable and even caused earthquakes.

Nuclear energy has been making a steady advance since 2025, the year in which burning biomass to generate energy was banned. It now makes a significant contribution to the CO_2 reduction that is realized. Although thorium has not made a breakthrough, the lessons from Fukushima have made uranium-based nuclear power plants even safer. New insights have also been developed with regard to energy waste: waste that is compact enough to keep in plain sight is much safer than bulky waste that is hidden away. Nuclear waste is therefore regarded as the least risky form of energy waste. It is also no longer put in the ground where it can no longer be seen. On the contrary, it is stored in carefully selected and managed locations above ground. The fact that it is very compact and solid is considered a huge advantage compared to CO_2, because its environmental impact is minimal.

Non-degradable disposable plastic has been banned since 2030, like lead, cadmium and chromium-6 were in the 20th century. Deposit money on packaging proved to be of little help, and covenants with the industry did not help at all. All packaging materials must be naturally degradable within a year. The problem of litter has virtually disappeared, although it will take decades before all the plastic that was dumped in the in the oceans before 2030 will have disappeared.

The average temperature on earth has risen by another degree centigrade, but since 2035 it has been stable, as have sea levels. Apocalyptic predictions about extreme weather and rising sea levels failed to come true. On average, weather

conditions are not more extreme than they were in the 20th century, with a storm surge in 1953 and an icy cold winter in 1963. Arctic flora and fauna has adapted to the reduction in Arctic ice and recovered, as nature tends to do as well after massive forest fires and volcanic eruptions.

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The wallet of the future

How a multiple system of coins and markets can do justice to different value systems in society. A vision of the future.

By Maurits Kreijveld, futurologist and strategic advisor at wisdomofthecrowd.nl

** buzzer makes a loud sound **
"Would you please walk through the gate again, Laura?" The service robot from the Alibaba-to-Go store asks.

Loyalty coins: Ali-Coins

Laura looks at her smartwatch. Strange, usually she can just go through and the payment is settled automatically. Didn't she still have enough funds? She checks her digital wallet, an app on her smartwatch. Indeed, enough Ali-Coins to pay for it. With the Ali-Coins she can pay everything she buys at Alibaba, which is pretty much everything. The payment system has completely ousted the once popular iDEAL, the payment standard with which the Netherlands played a leading role, but which had no bonus system. In fact, in 2035 there are only two major payment systems left: one from Alibaba and one from Amazon. A typical example of the winner takes all, with the two major world players competing globally. After the takeover of Albert Heijn, Alibaba became the largest in the Netherlands. Which of the two systems you use is actually determined by who your parents are. From childhood, you get Ali-Coins with every purchase and every form of data and with important moments in your life that you share with Alibaba. It is a sort of loyalty system like grandmother's grocery stamps or the frequent flyer miles system. By liking products, reviewing and promoting them in vlogs, you can increase your balance.

In terms of discount offers, you really cannot wish for anything better, you get the best price anywhere and Alibaba often already knows what you want to buy before you think of it yourself. Laura regularly receives suggestions as she walks through the city. And for most people, the idea of switching to Amazon, where they would lose all their bonus points and have to start from scratch, just makes no sense. Sometimes, one of the two tries to make customers switch with a big welcome bonus, but most people never switch, as in earlier times, it used to be with banks. Governments have been trying for years to break open this currency system, but without success. Ali-Coins are so popular, especially among young people, that abolishing that system is not a realistic idea. Privacy has finally become a real currency, others say. However, the government regulates the loyalty coin market. For example, certain extra bonus points are

only valid for a short period of time, there is a maximum to the total number of bonus points and they cannot be exchanged for real money.

Worldwide payment money: Euro

Ali-Coins are not the only currency Laura has in her pocket. She also has Euros, the currency in which she receives her salary and with which she can pay anywhere in the world. Exchange rates are updated real-time. A system of central banks worldwide keeps the Euro stable against other currencies, such as the Dollar and the Renminbi – the latter having swallowed up the other Asian currencies. Keeping the exchange rates stable was a major challenge for many years, because it requires large cash flows between the strong and weak economies. Meanwhile, world trade has been decreasing for years, because regions are becoming more and more self-sufficient. As a result, the main currencies have become much less sensitive to financial speculation and competition politics. However, interest rates are still kept artificially low to stimulate business investment and to keep weak economies going.

Laura also has Socio-Coins, which she has earned by getting diplomas at school, doing volunteer work, helping her neighbours and, recently, by shovelling snow. It is a way in which the government rewards its citizens for their efforts. The Socio-Coins are a form of social capital with which citizens can build up a supplementary pension based on their contribution to the community and their reliability. You can lose Socio-Coins for major violations or criminal behaviour and fraud.

The social credit system came over from China, which has had twenty years of experience with it. The system makes sure that people comply with laws and regulations and help each other more. Moreover, the system is completely disconnected from people's economic status. People who are financially poor and have had no job in their lives can still be rich in Socio-Coins and thus have an almost 'free' old age. Sick and weak people are exempt from the Socio-Coins. Fanatic citizens can earn a kind of basic income with their commitment to society, giving them access to sport, care and culture.

Money for later: crowdfunding and Eco-coins

Laura has put the rest of the money she has earned and collected into a 'savings account', the worth of which is guaranteed by her bank, after inflation and taxes. The bank has invested most of it in certificates that finance numerous projects worldwide, including loans to entrepreneurs and farmers, investments in sports clubs and social housing, in development aid and in fair trade products. Occasionally Laura spends some money on special crowdfunding projects that she selects herself. Like deposits in the past, that money cannot be retrieved for a while.

She receives an average interest rate of 5%, much more than the below 0.5% interest rates that were standard rate in the world market for decades. The low rates were not surprising, because they were based were based on a debt economy and kept artificially low by governments to encourage people to investment. Saving accounts now are social markets developed by banks, in which consumers and entrepreneurs invest in each other in exchange for

interests that they consider reasonable. These interest rates are independent from the financial markets, where governments intervene on an ongoing basis and where speculators continually influence the exchange rates of currencies like the Euro. Interest rates in the social marketplace are driven not so much by a desire to optimize returns, but by people awarding and investing in each other.

Her bank has developed a special Eco-coin for the certificates, a Bitcoin-inspired cryptocurrency, which is linked to the global sustainability index. Since governments worldwide are all working to make their economies more sustainable and cleaner, the currency is gradually growing in value, which allows the bank to guarantee its customers a certain value (paid in Euros when they decide to withdraw money), with a small positive interest rate. Most citizens put the money that they do not immediately need into an Eco-coins account.

For now, things look secure for Laura, and she has no financialy worries.

* *The payment has been made* * A voice says in Laura's right ear. Smiling happily, she goes on looking for her bike.

Different currencies, different markets

Perhaps in the future, like Laura, we will have different kinds of money in our 'wallet'. In fact, we are already seeing different variants emerge. The different currencies can be used to do justice to different goals in society. A different 'market' is associated with each currency. After all, society is more than a marketplace where transactions are driven by rationality and selfishness, or, in economic terms, where people try to maximize their own benefits. It is precisely the investment in community spirit and sustainability that can be helped by creating new 'social' markets that elicit and encourage interactions between people, and in which other psychological and social characteristics are addressed. Local coins can support local communities but are less suitable to support world trade. In the course of history, through harmonization, standardization and consolidation, a few large monetary blocs with big strong currencies have emerged. However, it soon became clear that this ideal of a global market and global competition failed to meet the needs of people in their communities.

To a new wisdom of the crowd

The blockchain technology on which the Bitcoin is based has paved the way for countless new financial innovations. Can we, with new possibilities like Bitcoin, be sure that, as a society or a group of citizens, we can realize better markets and, with them, a better society? Could we free ourselves from the unsustainable financial system of 2019, which is based on debt and increases inequality?

Based on previews articles on the future of money, markets and a 'fair' economy on: https://wisdomofthecrowd.nl/startpagina/trends/fair-economy

Dordrecht 2050

By Max Remerie, MxR interim management & consulting

Tomorrow is the day! After three years of saving and thanks to contributions from our grandparents, my friends and I can collect our Tesla Lightyear 3.0, and on my 30th birthday as well! Never thought we could afford this, and boy, are we looking forward to our trip to Portugal! We already have a rental apartment in mind in a crowded neighbourhood in Faro – there seem to be many vacancies in most villages on the coast ... although many migrants have moved into various resorts and hotels.

My grandparents often talked about how they used to fly from Rotterdam or Amsterdam to Southern Europe or Morocco 3-4 times a year for a week. They had friends who flew to America or even Japan with their entire family. Their generation immediately followed the baby boomers and reaped the real fruits of the reconstruction after the Second World War. Everything was possible and the word 'scarcity' was only used when people saw hunger in Africa on TV and were able to buy off their guilt with financial donations.

Although my parents had great memories of their childhood, they also felt guilty about what they left to us and our children. A polluted world, scarcity of raw materials, huge income inequality, cyber-wars and geopolitical tensions – often caused by a loud and narcissistic minority on social media, engaged in personal feuds.

My parents had watched it all and felt powerless and frustrated. They knew something had to be done. With modern technology, a sustainable world and a circular economy had to be possible. Surely, more could be done, apart from building hybrid cars? And why was flying so cheap? While CO_2 emissions were enormous and, around Amsterdam alone, hundreds of thousands or people suffered from more than just noise pollution and filthy air.

New technology had indeed helped, but not as we had expected and hoped for so long. Electricity was still not free and 3D printers created more waste than they re-used. Recycling had a huge impact, as had the use of solar panels on cars and houses. However, the most important change came when people accepted scarcity, something that had taken a generation. No more annual holiday flights, no more eggs for breakfast every morning, no longer a new pair of shoes each month. And we all loved our eggs in the morning, and we did look forward to buying those shoes ... The sharing economy had solved another type of scarcity. In our street, we knew who had a power drill and several cars were shared among each other.

The Netherlands also became more autonomous, less geopolitically dependent on the US and less dependent on China in terms of its products. The basic income had created

financial peace among the population. Yes, the sky was no longer the limit, but hunger no longer existed. Moreover, thanks to the basic income, labour had become cheaper and robotization was limited to physically demanding work and specific medical interventions, which meant that production could also stay in the Netherlands. And, although London may have the headquarters of Unilever, the factories were still located in the Netherlands.

We had been able to take control of Artificial Intelligence – still called a threat to mankind by American social media companies at the World Economic Forum in 2020, –thanks in part to supervision from the International Algorithm Court in The Hague – still the city of law and peace behind the North Sea the dunes. In fact, the development of smart algorithms for ethical purposes by the social mathematical faculty in Maastricht restored the basis of our democracy: legislation was intelligent, monitoring and enforcement efficient and effective thanks to the Internet of Things, and the elections were transparent and without interference from foreign trolls. I woke up to the sound of birds singing on the balcony and felt the sunbeams on my pillow, global warming wasn't so bad after all ...

Enough dreaming about the past and philosophizing about saving the Earth. Going with friends to Portugal in the Tesla Lightyear 3.0, that is really green and fun. Much better than for example the famous Beatles member who had his Toyota Prius Hybrid flown in from Japan on a private jet... And, of course, watching the finals of the Champions League in Faro. Will our team win again?

3. The future of scarcity, production, consumption and redistribution in the scenarios

3. THE FUTURE OF SCARCITY, PRODUCTION, CONSUMPTION AND REDISTRIBUTION IN THE SCENARIOS

As described in the introduction, the following research question has been at the core of this exploration:

What will the future of the economy look like as a result of technological developments?

This research question is divided into five sub-questions:

1. Which technological developments will affect the economy between now and 2050?
2. What will be economically scarce in the future and what will the influence of technological developments be?
3. How will goods and services be produced in the future as a result of technological developments?
4. How do technological developments influence the way in which people consume goods and services in the future?
5. What will the influence of technological developments be on income and wealth distribution?

The trend analysis, the scenarios and the serious game are all instruments that have helped generate possible answers to these questions. The most noteworthy observations are summarized in this chapter.

3.1 Scarcity in the future

Will biodiversity, natural resources, raw materials and ecosystem services become scarce?

In recent decades, population growth and increasing economic activities have increased the pressure on biodiversity and ecosystem services. Natural resources and the raw materials that are most important to our way of life are becoming increasingly scarce. In each of the four scenarios, that scarcity is handled differently: in scenarios A and C, scarcity of raw materials leads to international tensions. In scenario B, it results in the creation of strong international institutions that regulate access to resources and ensure a stable political climate. In all scenarios, the scarcity of raw materials is an important driver for change, although the different societies come up with different solutions:

Scenario A contains a society where people take a step back and consume and waste less. A nostalgic longing for earlier times makes people more economical and focused on recycling, re-use, upcycling, etc. In scenario B, there is a sense of urgency to tackle things in a truly different way and, because of little faith in behavioural change (unlike scenario A), a great deal of power is handed to strong supranational institutions, creating a culture characterized by strong regulation and monitoring, even high levels of social control when it comes to sustainability and reducing the ecological footprint. 'Big brother is watching your eco footprint' would be an appropriate subtitle for this scenario. As a result of advanced communication technology and mixed reality applications, people travel much less. At home maintenance level, self-sufficient, closed-loop systems are developed.

Scenarios C and D contain high-tech solutions to deal with the scarcity of raw materials. In scenario C, that scarcity initially leads to a fragmented world economy, after which strong autonomous trading blocs look for all kinds of solutions to deal with the scarcity, which creates a huge boost for developments in areas like nanotechnology, gene technology and quantum computing, with new materials being developed to replace rare materials with artificial, cleaner and more environmentally-unfriendly materials. Ecosystems are being restored through biotechnology and nanotechnology. Thanks to 4D printing, products and materials last much longer (and even become dynamic). DNA printers make it possible to design and produce new organisms that contribute to a sustainable energy system and a highly effective production of food and water. In scenario D, the focus is on developments in the field of space exploration to alleviate pressure on ecosystem services and the environment on

earth: they include the mining of rare earth metals on asteroids and the emergence of interplanetary migration, which may reduce population levels on earth. There is a comment to be made here about the side-effects of these kinds of technological solutions. One that applies to all scenarios. In this scenario, the question is whether scarcity is really solved; instead, people appear to choose to 'use up' the earth and prepare for a life elsewhere in the galaxy, or for a virtual life where people's consciousness is uploaded to 'the cloud'.

3.2 Production in the future

Producing faster, more efficiently and safer?

Almost all the technological developments that have been described appear to promise that the production of goods and the provision of services in the future can be made faster, more efficient, cleaner and safer:

- Faster: for example by automating processes, increased and real-time data extraction and analysis, and because changes can be simulated before they are implemented. Because production also takes place closer to home or in-house (thanks to the development of 3D printers, 4D printers, nano-printers or DNA printers), products are available more quickly than when they have to be ordered and shipped.
- More efficient: the availability of more data and information, combined with the automation of processes, leads to a more efficient and more precise production, with less residual material. Developments in areas like nanotechnology and 3D and 4D printing also make processes more precise, and more efficient as a result. In addition, efficiency can also be increased because more and more tasks are taken over and carried out by robots and machines. Human labour is more expensive and error-prone (De Lange et al., 2017). There is also a need for efficiency from an ecological point of view, because there is a risk of certain raw materials being lost and the effects of environmental pollution and climate change are becoming increasingly visible (and undesirable). Cleaner production processes can be realized by organizing a more circular economy, in which waste and pollution are prevented. Technology enables the use of renewable energy sources, the development of new materials and the smart reuse or disposal of residual streams.
- Safer: the Internet of Things and big data analysis make it possible to prevent unsafe situations or to intervene when they occur. Brain-machine interfaces allow people to control devices remotely, which means they do not have to physically put themselves in dangerous situations. In addition, in the future, hazardous

tasks or tasks in high-risk areas can be carried out by robots. Finally, geo-engineering could be a solution to changing extreme weather conditions, although the exact consequences of the use of these types of techniques are as yet unclear.

The role of distance: producing closer to home or further away?

Because 3D printing, 4D printing and nanotechnology make it possible to customize production and bring production closer to home, production processes and services that were previously outsourced to low-wage countries can again take place in the Netherlands (reshoring). The lower labour costs no longer outweigh the transport costs. This is a trend that is already visible (Broek et al., 2016). In all scenarios, the assumption is that people will produce more at home, or closer to home, using 3D printers, 4D printers and bioprinters. In addition to these technological developments, there are also developments in geopolitics and ecology (climate and raw materials), that make trade and transport more expensive or difficult. Also, the fact that countries want to operate more autonomously can reinforce the reshoring process, as it does in scenarios A and C.

In recent decades, we saw the emergence of a number of multinational companies (such as Google, Facebook, Alibaba) that captured a large global market share in a relatively short time. These companies have more capital than the entire GDP of some countries, and they have so much power on the international stage that it is quite conceivable that, in the future, they will have more say on the world stage than national governments or international institutions have. In scenario D, we assumed that this trend will continue, which ultimately leads us to explore the ecological limits of the earth and prepare ourselves for a life beyond Earth or in virtual reality. In scenario C, multinational companies could still play an important role, but it will be a major challenge to connect to the many different power blocs that have emerged. In this scenario, we have assumed that multinational companies have a lot to say in terms of crops and food production.

For many people, globalization is an alienating and threatening process. They feel that decisions that affect them or that are about products they use are made on the other side of the world. The rising interest in local products and local entrepreneurs is a reaction to this, and it appears to be gaining in popularity (EEAC / RLI, 2016), which is clearly apparent in scenario C, where the world fragments and local communities take matters into their own hands.

Who does the work? And what work?

As a result of developments in areas like artificial intelligence, robotization and big data, not only the so-called blue-collar jobs (physical labour, mainly in factories) can be automated, but white-collar jobs as well. There are already robot versions of accountants, financial advisers, helpdesk employees and personal assistants in our smartphones. In the healthcare and the education sector, organisations experiment with service robots. As such, much of the work that is currently being done by people, will be taken over by robots in the future. With the emergence of blockchain and smart contracts, entire business processes can be automated and it is conceivable that there will be autonomous companies without any human involvement, not even at management or board level. There are also examples of robots and AI systems that write music, make paintings, or write books or movie scripts. It is perfectly conceivable that sectors with a shortage of skilled people or where the work is dangerous are among the first where robots will take over from people on a large scale.

Some experts warn that all work that is being done by people can be taken over by robots in the future. And that robots will be better at it. History has shown, however, that, although technological developments may lead to the disappearance of jobs, new jobs are created and, in the long run, these developments always lead to more employment. However, there are also people who suggest that, if our work is taken over by robots, we will have to work less or not at all and have more time for self-realization. A less happy alternative is that robots and computers may be making more and more decisions, and in the future, people may end up working for robots.

None of the scenarios included in this study assume that people will no longer be working. Scenario D perhaps outlines the picture that includes enhanced and augmented humans: a situation in which people through human brain interfaces and human enhancement, increasingly merge with technology and will in the future be able to upgradetheir own brain to a supercomputer or quantum computer, or with people becoming very strong or fast with the help of high-quality prosthetics. However, although people continue to work in our scenarios, new technology leads to a new approach of working in each scenario. And like the introduction of the PC and of the internet meant that people needed new skills, the same will be the case in the future, which means that, after all, the question is perhaps not so much who is working, but what kind of work do they do?

3.3 Consuming in the future

More or less consumption?

If we compare the material prosperity of a family today with that of a family from the 1960s, we can see that it has significantly improved in material terms: every household has a refrigerator, a freezer, a vacuum cleaner, a dishwasher, there is a huge choice of fresh and healthy food in supermarkets, and in books and clothing. Transport has become cheaper and for students making a world trip is the rule rather than the exception. It is not inconceivable that we will consume even more in the future and develop a taste for even more luxury products. We are, however, increasingly aware of the consequences of climate change, the decline of biodiversity and other negative aspects of our current economic system. In the agri-food sector, there is already increasing interest in local, sustainable products, and Dutch people looking to buy clothes, furniture and toys often visit a thrift store. Scenarios A and B describe a culture and behavioural change in which people adjust their lifestyle drastically and start to live much more economically. This change is not entirely voluntary but is enforced by the effects of climate change. There have been shortages of food and drinkingwater and, due to rising fuel costs, it has become too expensive to ship certain products (for example food) over long distances. Geopolitical conflicts can also lead to a decline in world trade and a lack of certain products, as we see in scenarios A and C. In scenario C, the scarcity provides a major boost to technological developments.

From consuming to 'prosuming' and the emergence of dynamic products

If we look at energy, we already see examples of prosumption: households are not only consumers, they also produce energy themselves, through solar panels or windmills. The rise of 3D and 4D printing means we can download designs in the future and print things ourselves, or we can even design them and then print them ourselves. In this way, we are becoming prosumers instead of consumers in more and more areas. In scenario C, 4D printers and bioprinters are available to consumers. We no longer make static products but use materials that we can keep reprogramming or changing. This would mean that we deal with (raw) materials very efficiently, although a certain quality high-tech basic material will have to be available (if everyone would really have access to this). Living with dynamic rather than static products and materials would be a huge change to our economy and society, in ways that we may not yet be able to imagine.

Which choices do we make ourselves?

On the one hand, people make more and more choices and get more direct control over their lives, through developments like individualization, digitization and globalization. On the other hand, computers and electrical appliances are becoming more independent and more autonomous. The rise of autonomous transport, smart algorithms, service robots, smart homes, the Internet of Things, nanomedicine and wearable technology makes it possible to outsource or automate more and more tasks and choices, although, in all probability, new tasks and choices will arise. With the emergence of autonomous systems and algorithms that influence our lives, the notion of self-determination is currently very prevalent in the social debate.

In scenario B, there is little self-determination compared to the current situation, because, on the one hand, a lot of power has been transferred to supranational institutions which have to solve large-scale problems and thereby determine and regulate more for people. On the other hand, power is transferred to smart devices and robots, because, in this scenario, it is extremely important to reduce the ecological footprint, but determining how best to do that is a very complicated issue. This may result in less choice-related stress and leave people more time for other things. After all, even now some people hire someone else to make certain choices for them, like personal shoppers or interior designers. Some people even let their smartphones choose restaurants, map out routes and determine the temperature in their home. On the other hand, we can feel restricted when we are not completely free to decide for ourselves. In scenario A, people place a high value on self-sufficiency and turn away from the increasing power of supranational institutions and multinational companies. Whether they really have more autonomy is the question, however, since the very close-knit communities that emerge are often characterized by social control, while our freedom of choice is also curtailed because there are fewer resources, goods and means of transportation available. Compared to the other scenarios, scenario C provides the most room for self-determination, with 4D printers and bioprinters increasingly allowing people to design the world around them. Even human DNA is not safe from tinkering. In scenario D, individuality and self-determination may well disappear due to the emergence of the 'brainternet', in which people are connected to the internet and to the billions of connected devices, via their brain giving rise to a kind of 'hive-mind', a kind of collective consciousness in which individuals are less important.

3.4 Redistribution in the future

How much is there to be distributed?

The aging population puts pressure on the social security system in the Netherlands, including the pension and healthcare systems. Digitization and globalization lead to fleeting networks, volatile employment and relationships, and a growing trend of individualization. People increasingly have the control and responsibility over their own lives and well-being. The social gaps (between the highly and less highly educated, rich and poor, people with and without digital skills, etc.) appear to increase continuously. There is less understanding for people who are unable to keep up, which leads to an erosion of social solidarity, lower levels of support, as well as fewer financial resources for social security. As a result of the reduction in social security, pensions, health insurance and healthcare may become scarce and/or more expensive.

The Netherlands has a strong tradition of income redistribution and, compared to most other countries, income inequality is relatively low (CBS, 2017). Technological developments may put pressure on income redistribution. For example, if a lot of work is automated, this generates less income tax, which means there is less for the government to distribute. Also, more people may become unemployed and have to rely on the social security system. Continuing individualisation and emerging sentiments like nationalism and protectionism can also erode solidarity and support for a national social security system. Non-technological developments also play a role: if geopolitical relations change, world trade may decline and the Netherlands may play a less prominent role on the world stage, which again may mean there is less for the government to redistribute. As is the case, for example, in scenario A, in which the starting point is that communities take care of each other. If you are an 'outsider' in that scenario, chances are that you have to rely on yourself.

Technological developments can also generate new economic activities and growing prosperity, resulting in greater tax revenues. Developments in areas like automation, blockchain and big data can do the work that is now being done by people faster and better, leaving more money to redistribute, while the same developments also make it easier to detect and prevent fraud. This not only generates a greater sense of justice and possibly more support for the principles of solidarity and associated regulations, it also leaves more money for the social security recipients. This idea fits in well with scenario D, where a strong government focuses on regulation and monitoring. In that scenario, the focus is on tackling cross-border problems and it is conceivable that technology will be used to organize the social services that are still

available as efficiently as possible. If more decisions are made in the future on the basis of artificial intelligence and big data, one risk is that non-representative data may be misinterpreted, and certain prejudices could be reinforced. As a result, certain groups in society (elderly, ethnic groups) could be excluded, for example from access to credit, mortgages and jobs.

Does access to technology determine your economic opportunities?

In scenarios B and D, increased internationalization leads to greater competition in the labour market. Access to the right technology can play an important role in finding a job. In scenario D, people are linked to tasks via AI systems. One requirement is that people have to be findable. If there is unequal access to technology, that can increase the gap between the haves and have nots, and between people with and without know-how. In the same scenario, developments in human enhancement allow older people to work longer, while people who are now being excluded from the labour market due to physical or mental disabilities, can participate, which means more tax revenues and less social security expenses. Having said that, it is important to note that these technological developments (because of the costs) can also benefit people who are already well off, which may further increase existing inequality. Developments in human enhancement, like we see in scenario D, can even lead to a new evolutionary pressure in society, if certain population groups perform better as a result of human enhancement, to which not everyone has access.

4. Towards the future

4. TOWARDS THE FUTURE

Given the scale of the challenges facing our society, including demographic change, climate change and changing geopolitical relationships, investing in new technologies is crucial in the coming decades. However, having a social debate about the effects of new technologies on society is equally important. In addition to technological innovation, we have to look at social innovation and the acceptance of new technology, while the potential effects on the environment, well-being and our surroundings must also be taken into account. New technological solutions to particular problems or challenges can have new, unforeseen effects. And, ultimately, decisions about the implementation of new technologies will have to be made within the context of potential risks, including the risk of non-use.

The scenarios in this exploration are not meant to overwhelm the reader, but rather to inspire reflection. We will not be able to completely shape the future, but it is also not something that just happens to us. We can certainly make choices to prepare ourselves for the future and help shape it.

The aim of this foresight study is to inform decision-makers, strategists and researchers about the possible impact of technological developments on the Dutch economy. The trend analysis, the scenarios and the serious game have helped generate more insight into this issue and inspire the participants to think about the future. In addition to informing and inspiring, the results of the exploration also help put topics that will be relevant in the future on the political or social agenda, or to discuss the choices and room for manoeuvre we as a society have in the light of the upcoming developments.

In this study, economics is defined as the way we produce, consume, redistribute and deal with scarcity. Despite the emphasis on technological developments, other trends, including demographic, social, ecological and geopolitical developments, are also taken into account. Adopting this broad view is crucial if we want to do justice to the complexity of the subject.

In order to create a picture of the future and to discuss that future, several experts were interviewed and stakeholders were involved in creative work sessions. For this foresight study, a number of instruments were developed that can help organizations initiate their own discussion about the future. Namely:

- The scenarios (4.1)
- A serious game (4.2)
- Provocative questions and statements for a strategic conversation (4.3)

4.1 Using the scenarios

This foresight study looks ahead to 2050. In addition to relevant scientific insights, a healthy dose of imagination is required. To generate broadly supported insights, it is also important for the exploration not to take place in an 'ivory tower', but in a dialogue with stakeholders and experts. The scenarios included in this study provide an instrument to help people discuss and explore the future.

Thinking through the developments in the different future scenarios allows us to think more carefully about the future. Technological and social developments will have different effects in each scenario.

The scenarios are designed to provide a framework we can use to reflect on the possible outcomes and effects of the developments shaping our future. The scenarios offer different perspectives on the future. Companies, organizations and policymakers can respond to these future images that have been outlined in several ways. They can try to influence the future in order to realize or prevent a particular scenario. Or they can choose to explore strategies that help exploit the opportunities of one or more scenarios.

Generally speaking, the aim of working with scenarios is to either develop strategies that can be applied in any situation (robust strategies) or to develop strategies that work well in a specific scenario. A follow-up step could be to work with an early warning system, in which indicators are identified to tell us whether one or more of the developments described in the scenarios will actually become reality. The consequences of the scenarios can vary greatly per target group, but scenario thinking is an approach that will benefit any organization.

4.2 Playing the serious game

Another way to get started with the insights from this exploration is to play the serious game. To enter into a dialogue with various organizations, a cooperative board game was developed for this study, in collaboration with game designer Inez Groen. The board game facilitates the discussion about the complex and uncertain future by outlining possible developments and letting players select strategies and possible investments. Much of the game's focus is on technological developments, but – as in

the rest of the exploration – social issues are also covered. In the period September 2018 - February 2019, the game was played in about fifteen different organizations and two game sessions were organized, in which more than twenty participants from different organizations played the game, yielding important perspectives for this exploration. The players interacted with complex subject matter in an interactive way and gained both insight and inspiration.

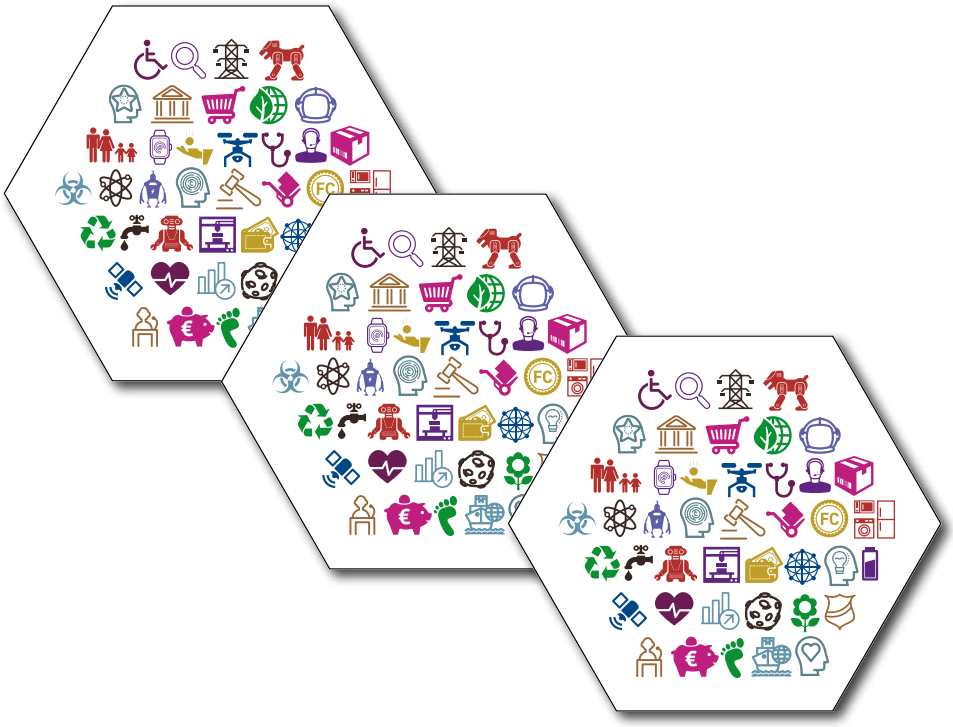
In the serious game, participants are invited to organize a fictional society, to which end they can buy and use 'building blocks' in the form of cardboard tiles (like the board game Catan), with the tiles together making up the ingredients of the fictional society. In all, more than 60 building blocks were designed, based on the trends and the scenarios. Examples of these building blocks are provided at the end of the scenario descriptions.

Everytime the game was played with different teams of three to five people. A session lasted between two and four hours, and the teams played with different goals, to test to what extent the goal for your society influences your choice for a certain building tile (or technology). These goals varied per organization. Examples of goals are:

- *Generate as much wealth as possible for your society.*
- *Realize a circular economy.*
- *Create a CO_2-neutral energy system.*
- *Create a business climate that is as competitive as possible.*
- *Create as many jobs as possible.*
- *Become the most innovative company in your sector.*

Each team also played in a different scenario, with the scenarios included in the sessions determining the price of the building blocks. As such, players have to consider multiple aspects: a goal that they pursue for their society, building blocks they can purchase to achieve that goal and a scenario involving external conditions (international developments) that affect the price of the tiles. Each team played at least two rounds of the game, which means they encountered two different scenarios. After each round there was a short reflection round in which they discussed, among other things, which choices were difficult and easy, how different goals and scenarios lead to different choices, etc.

Like this publication, the serious game can be bought or downloaded for free from our website www.stt.nl. It is our hope that the game helps organizations discuss the future and prepare for change.



Building blocks for the future

Chapter two contains several examples of the building blocks that are used in the game (at the end of each scenario story). At this point, we want to share some observations we gathered during the game sessions:

The following building blocks were selected the most often (ten times or more):

- Large-scale production of algae for fuel, water and food
- Smart sustainable homes
- Replacement of primary, non-renewable raw materials
- High-tech urban agriculture provides 80% of the food supply
- Retraining: employees learn to work with robots
- Free green energy
- A basic income for everyone

While the following building blocks were chosen the least (only 1 time):

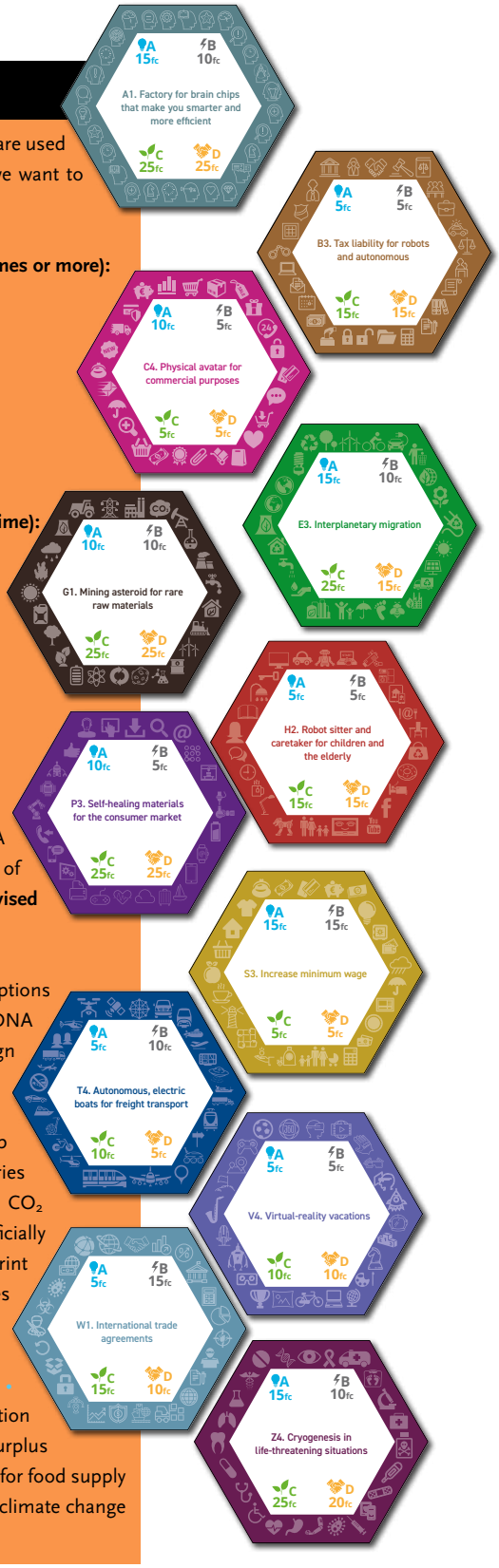
- Retirement age to 85 years
- Subsidies for people who want a (third) robot hand
- Zero gravity soccer tournament

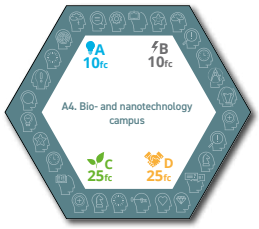
And the following building blocks were not chosen at all:

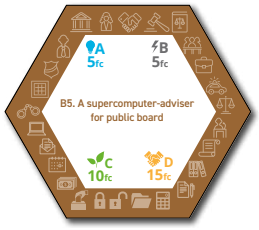
- Electoral rights for robots
- Legalizing the robot marriage
- Robot employment agency for artistic robots
- Participation in the robo-lympics

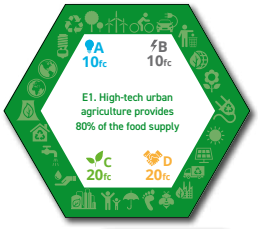
Building blocks were added by the participants in each session. A number of these building blocks are included in the final version of the game. **Below, an overview is provided of the building blocks devised by the participants:**

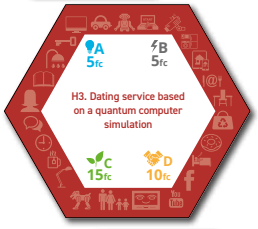
Freedom of establishment becomes a human right (or: no more options to prevent migration) • Cars are banned in the city • Full scale DNA analysis incl. risk analysis for € 50 per person • Circular design knowledge centre (Peter v.d. Berg) • No more pension, but always employable • Cold fusion (Jos Voeten) • Telekinesis (plastic soup) (Jos Voeten) • Reduced VAT on local products • Local deep democracy for local issues: create involvement • Circular batteries for sustainable renewable electricity (Peter / Ruth) • Affordable CO_2 conversion into multi-usable raw material • Mining at sea • Artificially cultivated meat (Happy Grinch) • To learn our ecological footprint and reduce carbon emissions, we introduce in vitro meat factories to supply each person in Amsterdam with clean-produced meat • Printer makes robots who help you in your individualism • Virtual reality after life • Electricity generating bikes • Bicycle highways • Export ban for (imported) raw materials • Completely free legislation on nanotechnology • Climate-neutral aircraft • Melted seawater surplus becomes stored vertically in gas / oil fields • All gardens and roofs for food supply • With Crispr-Cas accelerated adaptation of plants and animals to climate change • International market authority for rare commodities.

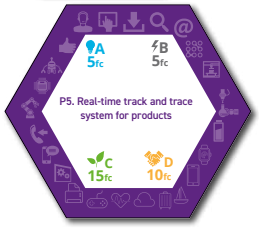












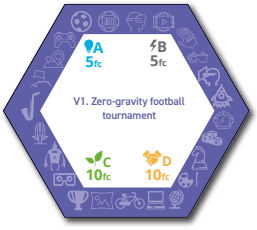
Observations of the author during the game sessions:

The future is subjective and can be interpreted in different ways, as became clear in the discussions during the game sessions:

- According to most participants, scenario B is the one that is closest to the world in which we now live (2019), while the other participants argue that scenario D is.
- Generally speaking, scenario A is considered very desirable, but also very unrealistic, and it is also the scenario in which many organizations question their own right to exist.
- Scenario C is at least as popular, but it is also dismissed, as being 'too science fiction'.
- Both the remarks 'this is too far away, too extreme for 2050', and 'this is not extreme enough for 2050' were heard a lot in the game sessions, with respect to all four scenarios.
- Many groups considered scenario C to be the most plausible, but also a very undesirable scenario for 2050.
- Many organizations asked themselves in at least one scenario: will we still exist then? This indicates that the scenarios help people to question their fundamental assumptions, which is a good thing, in view of the uncertain future.

In the discussion about the choices that participants made in relation to their objectives:

- Groups that aimed for goals that related to human values, like safety, comfort or customer satisfaction, are less interested in technology. These groups were also 'robophobic', in the sense that they believe that building blocks to do with robotisation or automation always detract from those values.
- Groups that aimed for sustainability-related objectives or a climate-neutral society often selected tiles where certain things became mandatory or punishable (with fines). It would appear that the general belief is that it is better to manage people's behaviour than it is to focus on technological possibilities. Furthermore, it seemed that a choice had to be made between more 'social' objectives now and 'greener' objectives for the future.
- The 'enhancement' of people was interpreted as something that is beneficial to companies and employers, the aim being to increase turnover or efficiency, but certainly not as something that contributes to sustainability, safety or solidarity.



4.3 Get started: a strategic conversation

Based on the trend analysis and the scenarios, we have formulated a number of provocative statements and 'what if' questions below that help organizations engage in a dialogue or brainstorm about the future:

What does it mean for my company if ...	**dairy and meat** **drinking water** **phosphate** **steel** **silicon** **iron ore** **air traffic** **self-determination** **free time** **transport** **retirement** **privacy**	are no longer available?

What if...

- The European Union falls apart?
- We will no longer produce static but dynamic products?
- People no longer pay for ownership, but for access?
- Only 30% of the raw materials used in the Netherlands are primary raw materials?
- The aging population leads to larger gaps in society (between generations)?
- There is a brain-drain and young talent is moving away from the Netherlands en masse?
- Robots are just as good at doing people's work as people, for example in healthcare and in education?
- My employer forces me to work together with a robot?
- My employer is replaced by a robot?
- We can manufacture random objects from air molecules (nanofabric)?
- People and machines will attend joint education in the future?

Statements for discussion:

- The Netherlands is too small, as a country, to stop or accelerate certain technological developments.
- I know exactly which activities I will automate over the next five years.
- As an employer, I can ask my employees to have a brain chip impanted so that they work more efficiently and I can have their work environment adapted to their affective state.
- My organization will be successful, both in a globalized world and in a fragmented world.
- Given the current state of affairs in healthcare, it is better for a robot to take care of my elderly parents than for them to have to go to a nursing home.
- Some problems are so extensive and cross-border that only a strong global government can solve them.
- The jobs that we now train our students for, no longer exist ten years from now.
- My staff will be able to work well with robots and supercomputers.
- I know exactly what it means for my company when 3D printing reduces global trade by 70%.
- To reduce our ecological footprint, our actions must be monitored in real-time.
- There must be control over the degree of influence that AI systems can exert on our real world via virtual reality.
- Decisions made by people are more transparent than decisions made by robots and AI systems.
- If companies can function fully autonomously, they still have to pay taxes.
- It is possible to organize our business process in such a way that we no longer generate any waste.
- Every teacher in the Netherlands should have a robotic assistant, so that they can concentrate on the educational tasks.
- I know exactly which tasks I do and do not want to leave to a robot or machine, at home and at work.

It is our hope that the tools that were created for this foresight study (the trend analysis, the scenarios and the serious game) will be used by organizations to start a conversation about the future. STT can help by providing presentations or workshops. For more information, contact project manager Silke den Hartog - de Wilde (denhartog@stt.nl)

Appendices

Appendix 1. Sounding board Group STT foresight study The future of economy

J.M. van Alten, KIVI, Coordinator science, applied science and academic themes

M. van Andel, Fontys University of Applied Sciences, Director Applied Natural Sciences

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P.A. van der Duin, STT, Director

Th.N.M. Föllings, OostNL, Manager Business Development

Th. Grosfeld, VNO-NCW, Manager of economics, innovation, taxation and corporate law

A.M. Herrebout, T-Mobile Netherlands BV, Sr. Strategy Manager

N. Kruijsen, Ministry of Economic Affairs and Climate (EZK), policy officer

M. Middeldorp, Rabobank Research, Chief Economist

M.E. Remerie, MxR Interim management & consulting, digital accessibility advisor

V.C.M. Timmerhuis, Social and Economic Council (SER), Alg. Secretary / General Director

S.E. den Uijl, Social Insurance Bank (SVB), Strategist

G.J. van 't Veen, World Start-up Factory, Director

E. Vogels, Ministry of Social Affairs & Employment (SZW), Deputy Head of SKO of the Directorate of the System and Public Insurances

D.B. van de Waal, Netherlands Institute for Ecology (NIOO-KNAW), Senior Researcher

Appendix 2. Workshop participants

Participants workshops foresight study the future of economics

J.M. van Alten, Royal Institute of Engineers - KIVI E. Augé, Erasmus University
P. Biever Evides, Water company
G.J.W. de Boeck, Rabobank Nederland
B. Boon, Achmea
F.H. van Duijne, Future Motions
K. Le Glaunec, Erasmus University
I. Green, Games & Learning
E. Haijtink, Department of Waterways and Public Works
E. Hueting, Fontys Colleges
K. Koolstra, Ministry of Social Security and Employment
M.W. Kreijveld, Wisdom of the Crowd, future consultancy J. Looman, SinceToday
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C. Reijmerink, ROC Mondrian
A. van der Velden, Brainport Development NV
R. Verschuur, Advisory Council for Science, Technology & Innovation, AWTI
M. van Vliet, Amsterdam Economic Board

Appendix 3. Trend analysis

The first phase of this exploration included the inventory and study of the most important trends and developments that will affect the Dutch economy between now and 2050, based on desk research (in which important national and international foresight studies have been analysed) and expert interviews. Although extra attention has been paid to technological developments, developments in areas like demography, sociology, ecology, geopolitics and the financial sector were also included.

The main findings of the trend analysis are summarized in the digital publication *Looking ahead to 2050*, which can be downloaded at https://stt.nl/stt/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf.

This trend analysis indirectly answers the first sub-question of this exploration:

Which technological developments will affect the Dutch economy between now and 2050?

In the trend overview that was made for this exploration, eighteen technological developments are described. A guiding principle for this was the position of the trends at the Gartner Hypecycle (Panetta, 2018) and the experts' assessment in the interview round that was conducted. Of these eighteen trends, there are a number that are already very visible (like 3D printing, robotization, digital twins and biotechnology), and a number of trends which are expected to become better known in time (geo-engineering, human enhancement and brain machine interfaces).

Thinking about the possible implications of the trends presented in this overview provides a diverse picture of the future of the Dutch economy. The trends being described can develop further in different directions, showing that there is no direct and clear path from the present to the future. For example, developments like globalization and robotization could lead to fewer jobs, but they could just as well lead to more global trade, more prosperity, new types of jobs and thus more employment. The decline of the Dutch population means a decline in the workforce and growing expenditure with regard to social security and healthcare. But it also brings us the so-called silver economy, with a growing group of wealthy older people with a lot of free time and a lot of money to spend on relaxation and health.

As such, the future of the Dutch economy is not singular, but plural. This confirms the usefulness and necessity of working with future scenarios as a follow-up step in this research. The trend research was the first step in exploring the future of the economy and provided an important basis for the scenarios and the serious game that came afterwards.

The trends

This is a summary of the publication that is available online at:
https://stt.nl/stt/wp-content/uploads/2019/04/Trendanalyses-ENGELS.pdf

1. Developments in the field of demography and the labour market

The world's population is growing, and cities are becoming bigger. Cities are also becoming more complex and vulnerable to the consequences of climate change. There will be a great need for solutions to these challenges in the coming decades.

The Netherlands has an aging population, which is one of the reasons that its labour force is shrinking. In the long term, there will be a labour shortage in IT and healthcare, and in the technical professions in the Netherlands. Highly educated migrants can prevent or help solve shortages.

Flexibilization of work gives people more control over their working hours and makes it easier to combine multiple tasks (e.g. care, work and education). In combination with working remotely (time and place independent work), flexibilisation can lead to an increase in labour participation, one of the drawbacks being that the blurring of boundaries between work and private life increases the chance of stress.

The Dutch economy is characterized by job polarization: growth at the top and bottom of the labour market, and a shrinking middle segment, with the income polarization to match. This can lead to social inequality and dissatisfaction among people who are worse off than others.

2. Developments in the field of geopolitics and governance

The Dutch economy is becoming more and more interconnected with those of other countries. Dutch products are exported to more and more countries, across greater distances, and they are changing and internationalizing production chains.

A multipolar international order is on the rise. New, emerging economies are putting pressure on Western-oriented economic relations. In addition, there are more and more non-state actors who exert influence on governments, people and businesses, like non-profit organizations, religious organizations and multinational companies.

Rapid technological developments increase our dependence on countries with access to the necessary raw materials for certain technological applications, like China, Russia and the Republic of Congo.

In part as a result of globalization, the recent economic crisis and (reports of) terrorist attacks in Europe, many Dutch people, especially the less highly educated and the elderly, feel that their economic and physical security is under pressure. Which leads to the emergence of nationalist sentiments, and puts pressure on the support for economic principles of solidarity, like a tax system that is used for income distribution. This further reinforces the feeling of economic insecurity among certain population groups.

3. Developments in the areas of ecology and climate

Demand for ecosystem services (the ability to provide goods, regulate processes and provide services) has been increasing faster than supply in the Netherlands for the last 25 years, and will remain doing so in the future, which means that a scarcity of ecosystem services is to be expected.

Because of climate change, there is more and more extreme weather in the Netherlands and sea levels are rising faster and faster, putting critical infrastructure and facilities, for example, for drinking water, energy and traffic, at risk. Almost 60% of the Netherlands could be flooded. Especially the big cities, where many of the economic activities are concentrated, face the risk of flooding.

The energy transition that the Netherlands has started on the one hand could lead to a reduction in energy consumption. On the other hand, the transition to a renewable energy-based energy system can lead to a situation where energy is practically free and people end up using more energy.

The current Dutch climate policy can lead to a so-called sustainability gap. In particular wealthier households benefit from climate policies (like subsidies for realizing a natural gas-free home), while poorer households have to spend a much larger percentage of their income on this type of mandatory measures. This leads to organisations demanding 'energy justice'. (ECN et al., 2017).

4. Socio-cultural developments

People have more resources to fill in their lives and living environment or to change them to their liking, which means that non-cognitive skills, like planning, self-discipline and collaboration, are becoming increasingly important.

People increasingly live and organize their lives in fleeting connections and (virtual) networks, as a result of which they have to make difficult choices on their own. Having greater control over their lives means people also depend more and more on themselves.

At the moment, Dutch prosperity is created at the expense of that of other people in the world and also of future generations. The Netherlands uses natural resources and imports a relatively large amount of raw materials. As a result, it places a major burden on the natural capital of other countries and that of future generations. We also use up our human capital, which is determined by the number of hours people work, as well as their health and education level (Gerwen et al., 2018).

Although ecological limits place restrictions on our consumption patterns, in combination with individualization and the need for customization, there is also a huge demand for products and services that reduce energy consumption while maintaining our comfort, like smart homes, smart clothes or lifestyle coaches.

5. Financial and economic developments

Developments like cash payments and the rise of FinTech are changing the way the financial sector is organized and which players have an important role. More and more ICT companies focus on financial services.

Community currencies reinforce regional economies and social connections and give people a greater sense of control in a highly internationalized world that is subject to constant change.

The ongoing development of community coins and virtual currencies (crypto currencies) leads to a more diverse payment system.

There is growing interest among (inter-)national governments in true cost economics, where environmental and social costs are included in the price of products. True cost economics is in line with the ideas of sustainability and a circular economy.

1. Robotics

What is it?

A robot is a physically embodied, artificially intelligent actor. In other words, a machine that perceives its environment and acts independently on the basis of that observation (Simon, 2017).

Did you know?

The hardware needed for robots is becoming cheaper. Although their mechanical 'bodies' are still static, the introduction of 3D printing and rapid prototyping can lead to mechanical reconfiguration and adjustments of a robot that is in use. The software needed for robots is also becoming more advanced. Social robots can perform non-physical tasks, using technologies like speech recognition, facial recognition and emotion recognition. Social robots are currently used to help children who are ill and elderly people with dementia, or as companion robots.

2. Artificial intelligence

What is it?

Artificial intelligence (AI) is a branch of information technology that strives for the creation of intelligent machines that work and respond as people (Techopedia, 2018).

Did you know?

AI technologies can supplement, replace and improve virtually all tasks performed by people. Many tasks and jobs will be automated. However more and more complex, new skills are also needed to get the best out of AI and other technologies, creating new tasks and jobs. Pessimists fear that, if A.I. machines become smarter than people, they will make all the decisions for us, from relatively 'small' decisions, like choosing a restaurant, to 'big' decisions such as driving cars or managing nuclear power plants.

3. 3D printing

What is it?

3D printing is a production technique in which a 3D model is created by applying material layer by layer on the basis of a digital design.

Did you know?

3D printing helps lighten the pressure on ecosystems because, in many cases, it is more efficient: it produces less residual material than existing production methods, uses less energy and requires less transport than traditional production processes, because production takes place more locally. 3D printing can speed up production processes, because objects can be made in smaller numbers, without the need to set up a machine or to make a mould. For parts of production processes that are labour-intensive, like time-consuming assembly and secondary machining processes, 3D printing will replace human labour.

4. 4D printing

What is it?

4D printing is used to create programmable objects that can change shape and function (programmable matter) after production. 4D-printed objects can adapt to changing environments and can be easily recycled, repaired or adapted to other applications.

Did you know?

Examples of applications of 4D printing: aircraft wings that change shape during flight, car tires that change shape or traction (summer and winter tires in one), furniture that is packaged compactly and assembles itself, roads that adapt to different loads and weather conditions, and self-repairing materials that can be used in aircraft, bridges and tools.

5. Big data

What is it?

Big data is a collection of large amounts of data, generated by people and sensors, that becomes available online – often in real-time.

Did you know?

The possibilities to obtain useful information by analysing large amounts of data are increasing. And through applications in the areas of artificial intelligence and machine learning, more and more tasks can be performed on the basis of data analysis. In the future, more decisions will be based on big data, for example decisions involving employment contracts, credit, insurance, healthcare and access to services. Non-representative data can strengthen existing prejudices and lead to the exclusion of vulnerable groups, like certain ethnic groups, women, disabled people, elderly people and the poor.

6. Blockchain

What is it?

A blockchain is a long chain of virtual blocks that is regularly supplemented with a new block, in which the most recent changes to the database are included as a list of transactions (SURF, 2017). A blockchain protocol creates consensus in a network by verifying each transaction against previous transactions. The block-chain technology makes it possible to conduct safe transactions without having to trust the sender and recipient (Ortt & Dees, 2018).

Did you know?

The most well-known application of blockchain is that of digital currencies like Bitcoin. However, block chains can also be used, for example, for voting or showing that a document existed at a certain time. Blockchain and smart (self-executing) contracts can lead to companies that function without human intervention, the English term for which is Decentralized Autonomous Organizations (DOAs).

7. Internet of Things

What is it?

The Internet of Things (IoT) is a system of interconnected devices, objects, animals or people, each with a unique identification number, which can exchange data, without the need for human intervention (Rouse, 2018).

Did you know?

In so-called smart-city concepts, the IoT helps, among other things, to prevent traffic congestion, for example by dynamically driving traffic lights, finding people a parking space, managing waste flows by reporting when a waste container needs to be emptied, and as an early warning system for flooding. Another application is wearable, or portable, technology in the form of very small sensors. For example, contact lenses that function as personal assistants or fitness trackers in your running shoes or clothing that provide real-time information about your performance. The potential scale of the IoT is huge: in the future, one trillion devices can be connected. Currently, around 7.5 billion people around the world have an Internet connection.

8. Quantum technology

What is it?

There are four domains in which the most important (most impactful) applications of quantum technology will be developed over the next ten years: quantum computers (computing power), quantum communication, quantum simulations, and quantum detection and metrology.

Did you know?

Optimists believe that quantum technology will make it possible in the coming decades: To accurately simulate the entire weather system – providing accurate weather forecasts; to realize a completely secure Internet that cannot be hacked; to develop medicines faster and more cheaply; to discover and develop new materials; to accelerate machine learning and data analysis; to generate materials that make solar energy very cheap and available everywhere.

9. Mixed reality

What is it?

Mixed reality (MR) describes the spectrum of reality technologies, of which virtual reality and augmented reality are the most important applications. Augmented Reality (AR) simulates artificial objects in the real environment - for example an explanation of a historical object, while Virtual Reality (VR) creates a completely artificial environment.

Did you know?

The Mixed-Reality market is expected to growth tremendously. For VR, there are many opportunities in areas like entertainment and education. The influence of AR could be far more radical because of the intrusive way AR experiences can affect the interaction between people and their physical environment (think, for example, of the game Pokemon GO, which, in 2016, directed tens of thousands of people to the Dutch seaside resort of Kijkduin).

10. Autonomous vehicles

What is it?

An autonomous vehicle is a vehicle that, after a destination has been entered, can take part in normal traffic on its own (i.e. without a driver).

Did you know?

Autonomous vehicles are more efficient because they are able to plan more efficient routes than human drivers. As such, autonomous vehicles, and vessels, would cause fewer traffic accidents, most of which are caused by human error. On the other hand, autonomous transport can lead to an increase in traffic movements and reduce the use of public transport, making it no longer profitable. That would also bring about more congestion and environmental pollution.

11. Small satellites

What is it?

A satellite is an artificial object that has intentionally been put into orbit around the earth through human action. Typically, a satellite is called a 'small satellite' if it weighs less than 500 kg (Fascinetti, 2016).

Did you know?

The interest in geospatial information is increasing among a wide audience and, due to the low weight of small satellites, it costs much less to bring them into space. It is expected that small satellites will become available to the general public at some point, just like drones, which is why it is also called the democratization of space. Because more and more satellites are launched, it is possible that some runways (orbits) become overcrowded, increasing the risk of collisions. Some people also wonder whether it would be desirable for 'laymen' to have access to satellites. For example, American scientists warn for amateurs who use satellites for spying (consciously or otherwise) or for a scenario in which cheap CubeSat networks are hacked and used for hostile purposes.

12. Digital twins

What is it?

Digital twins are digital replicas of processes, people, places, systems and devices. They are very realistic models of the current state of the original and the interaction with their environment in the real world (Rosen, 2015).

Did you know?

Thanks to the Internet of Things and artificial intelligence, more and more digital twins can be connected to each other, resulting in highly accurate digital replicas that include specific environmental factors, like local legislation, physiological location characteristics or people (digital personas). In the future, it will be possible to develop digital twins of people, for which there are many applications, in particular in healthcare, where biometrical, medical and environmental information can then be used to identify certain health risks.

13. Biotechnology

What is it?

Biotechnology encompasses a wide range of technologies that use (parts of) living organisms to make different products (Lorenzo, 2018).

Did you know?

There is a democratization of bio-technology: more and more private individuals with private laboratories, hacker spaces and start-ups work with biotechnology, usually funded by alternative financing mechanisms like Crowdsourcing. On the one hand, this process of democratization offers people more freedom to innovate, while on the other hand, there is less regulation, supervision and transparency. The risks of biotechnology are closely related to its advantages: the technology that can produce medicines, chemicals and 'clean' fuels, but it can also be used to develop bacteria or viruses that are harmful to people and the environment.

14. Nanotechnology

What is it?

Nanotechnology encompasses science and technology where phenomena that take place at nano-level are used in the design, characterization, production and application of materials, structures, devices and systems (EU - DG Health & Consumer Protection, nd).

Did you know?

An important characteristic of nanotechnology research is the common ground with other sciences, such as biology, materials sciences, cognitive sciences, chemistry and engineering, which has led to the emergence of, for example, nano-medicine, nanofabrication, nano-electronics, etc. Materials obtain new or extra properties by changing their structure at a nano-level, for example water- or dirt-repellent materials, thermal and chemical sensing systems in clothing, invisible or self-repairing materials in which nanoparticles can migrate to seal cracks.

15. Micro-robots

What is it?

A micro-robot is a very small robot that is built to perform specific tasks. Usually, they are slightly larger than nanobots. Micro-robots are usually visible, while some nanobots are not immediately visible to the human eye (Techopedia, nd).

Did you know?

Kilobots are small robots that together form a centrally controlled swarm that can jointly carry out an assignment. They know where the other robots are and can communicate with each other. When the kilobots become even smaller – i.e. nanobots - and are grouped into mega-swarms of millions or billions, that is called a utility fog. In fact, it is an active, polyform material that can change into any form, autonomously or with a simple instruction from a person. Futurist John Storrs Hall thinks that, in the distant future, we will all have our own utility fog (Glynn, 2006).

16. Human enhancement

What is it?

Human enhancement is the non-medical use of biomedical technologies to improve the human body or its performance beyond its 'natural' limitations (Dijkstra, 2015).

Did you know?

Improving a person's skills improves their quality of life, for instance helping older people to stay active and independent for longer, providing construction workers, athletes and soldiers with additional strength and endurance. It can also extend a person's lifespan by adding decades. Ultimately, human consciousness can merge with machines, which could even make us immortal. Human enhancement also leads to practical and ethical questions, such as to what extent do we (irreversibly) depend on new technologies? To what extent does it create a new evolutionary selection pressure in society, because certain population groups perform better as a result of human enhancement, to which not everyone has access? And if technology is embedded in the human body, who owns the data?

17. Brain-machine interfaces

What is it?

A brain-machine interface (BMI) is a device that converts brain waves into digital commands with which external software or hardware – like a computer or robot arm – can be controlled. The realization of a BMI may be associated with invasive technology, like embedding sensors or implanting a chip in the body, or with non-invasive technology, like using a cap or hood with sensors.

Did you know?

At the moment BMIs are often used to provide support to people with motor or sensory impairments, but they are also interesting for 'healthy' users. BMIs can improve the functioning of the human brain, allowing us to collect consume, memorize and process information better. There are people who believe that, if artificial intelligence and deep learning can drastically improve the capabilities of machines, that will also be possible for the human brain. There have been experiments at a South African university to create a so-called 'brain internet' through BMIs, with the human brain turning in to a hub for the Internet of Things.

18. Geo-engineering

What is it?

Geo-engineering is the conscious large-scale manipulation of the Earth and the environment. It is seen as a way to reduce global warming through anthropogenic greenhouse gas emissions (Bellamy, 2015). It can also be aimed at preventing harmful weather conditions, like droughts, hail storms or hurricanes.

Did you know?

Two well-known categories of geo-engineering technologies designed to counter the greenhouse effect are technologies to remove carbon dioxide from the atmosphere (Carbon Dioxide Remo-trap - CDR) and technologies to reflect some of the sunlight away from the earth, causing the global temperature to drop (Solar Radiation Management - SRM). One of the main challenges in geo-engineering is that costs and benefits vary greatly at different locations, so what is favourable for some countries and regions may be detrimental to other countries and regions.

Appendix 4. About the Netherlands Study Centre for Technology Trends

The Netherlands Study Centre for Technology Trends (STT) was established in 1968 by the Royal Institute of Engineers (KIVI). STT is an independent foundation that is financed by contributions from government and industry. STT conducts broad cross-domain and interdisciplinary foresight studies at the intersection of technology and society. The General Board of STT consists of top people from government, the business community, the research community and civil society organizations. The Board provides input to the STT program, is involved in explorations and is an important think tank in which the board members talk about future technological developments and innovation. In addition, the STT Academy develops a number of activities, such as the co-financing of special chairs, methodology development, and the management of the Network for Foresight Studies and Young STT, the latter consisting of young high potentials from the participating organizations.

Information about STT, and its activities and products can be found on www.stt.nl

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