STT 81

the future of technology in agriculture

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STT Netherlands Study Centre for Technology Trends

Stichting
Toekomstbeeld
der Techniek

Colophon

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Cover and book design	Ellen Bouma, Alkmaar

STT publication no. 81
Keywords: futures study, technological developments, scenarios, agro- & food, agriculture, food, society, demographic trends, health, behavior, scarcity, energy, innovation, connectivity, visions of the future, multi/interdisciplinary, social innovation

Images: Thinkstock/Getty images and Istock. Pag. 6-7: Ellen Bouma

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The Hague 2016

preface

Today, our world produces sufficient food to nourish all people on the planet, although not everybody has access to it in the same degree. In the world of tomorrow the availability of sufficient food is no longer self-evident. In addition, questions arise about the quality of our food and the influence it has on our physical and mental health. In fact, the growth of the global population has made food security a very prominent issue on the geopolitical agenda. Besides, food is *big business* and the global rise of average income will only aggravate this development. The Netherlands plays a leading role in the international food production chains and related markets, which is partly due to the technological development level of its agro & food sector. The challenges posed by today's and tomorrow's global food supply will continue to push the agro & food sector towards technological innovations, the more so as religious and sociocultural changes are influencing the production of and demand for food. At the same time will new technological developments also generate new questions.

Not everything that is technologically feasible will become reality. This STT foresight study addresses the complexity of the agro & food sector and the interwovenness of the many factors influencing its development. This study gives an overview of developments that may influence the future of the Dutch agro & food sector up to 2050. The focus is on technological developments, which in turn are assessed within the context of social, economic and political developments around the globe.

A futures study is a systematic exploration of possible futures in order to determine which strategies and actions will best prepare us for the various possible futures. Looking (far) ahead allows us to create the conditions for an adequate response to crises. More important, it also enables the timely recognition of potential crises, e.g. in food security or energy supply. Exploring the future is not just a game. By starting to think about alternative futures right now we will be able to recognise opportunities and challenges at an earlier stage, which provides us with valuable extra time to respond and thus avoid crisis.

This report could not have been written without the contributions of more than hundred agricultural and foresight experts. The sector, loosely referred to as the agro & food sector, is in fact a collection of sectors each covering different knowledge domains. The knowledge from all these sectors and domains – from agricultural production to the food industry and from technology to market insight – resulted in this rich foresight study. The willingness of the participants to contribute their unique knowledge and expertise, to listen, to appreciate each other's ideas and to learn to understand each other's language turned this foresight study into an inspiring, multi-disciplinary and multi-sectoral dialogue. We are truly grateful for this, since apart from the book that you are holding in your hands, this dialogue is also a very important result of this foresight study.

I am very pleased to see the results of all this hard work synthesized in this wonderful book that brings the technology survey to life through narrative. This book is not merely the tangible result of an STT futures study. It is also meant to inspire the debate about the future, a strategic conversation by policy-makers, researchers, entrepreneurs, consumers and students. This debate will be crucial to prepare the agro & food sector and society as a whole for the opportunities and challenges the future has in store for us. It is my hope that this book will contribute to this ongoing debate, and will help us to face the future in a creative and self-confident manner.

Margot Weijnen, Chair Steering Group

contents

summary

Artificially grown hamburgers, chocolates from your 3D printer, algae used for fuel, and salt water cucumbers delivered by drones to your doorstep. What are the new technologies – or applications of existing technologies – that may have a radical impact on the Dutch agro & food sector between now and 2050? This is the main question in this futures study by STT. And which non-technological developments will – possibly – also play a role here? Can we outline the future of the agro & food sector in trend scenarios?
This publication does not aim to predict the future. It is a starting point for debate that seeks to inspire the reader to think about the future for himself. Granted, the agro & food sector is a complicated business. But it is high time for a debate. In 2050 earth will be inhabited by 9 billion people. Natural resources will by then have become very scarce.

STT employed various methods for this research: a thorough desk study, interviews with experts, futurologists and creative workshops with groups of stakeholders. The result is the inventory of technological developments (Chapter 2), visions of the future (Chapter 3) and scenarios described in Chapter 4, as well as the non-technological developments that have their impact. This book aims to inspire stakeholders from government, trade & industry and research institutes – policymakers, authorities, entrepreneurs, researchers, students, consumers, futurologists and general readers – to start a strategic debate about the opportunities and the threats. It wants to be an inspiration.

The twenty technological developments that may have a large impact on the future of the Dutch agro and food sector are described in Chapter 2. By technology we mean: the systematic application of (exact) scientific knowledge for practical purposes. This overview is therefore not a complete survey, but the result of desk research and consultation with experts. The experts were not only asked about the potential impact of these technological developments, but also about their desirability and feasibility. These are the technologies discussed:

1. 3D printing
2. 4D printing
3. Smart materials
4. Robotics
5. Autonomous micro-robots
6. Sensor technology
7. Information technology and IT infrastructures
8. Bioinformatics
9. Smart farming
10. Renewable energy
11. Biorefinery and biofuels
12. Gen technology
13. Synthetic biology
14. Protein transition
15. Food design
16. Aquaculture
17. Vertical agriculture
18. Conservation technology
19. Transport technology
20. Weather modification

An example

Weather modification (no. 20) is the conscious manipulation or modification of the environment in order to change the weather. A well-known technology is cloud seeding to increase the chance of rain or snow in order to regulate the local water supply. Today (and in the near future) grape and orange farmers often use a hail gun that shoots grenades containing silver iodide crystals into the clouds. The vapour in the cloud will settle on these crystals, leading to smaller individual ice crystals, so that the hail will do less damage to the crop.

In the distant future we may be heading towards climate engineering, intervening directly in a climate system. The two main technologies to counter global warming are the removal of carbon dioxide and the regulation of sun radiation. The latter technology aims to compensate for global warming by making earth absorb less solar heat. But there are risks. For this technology to succeed it needs to be applied for a long time on a large, international scale, but this might be an irreversible process. Weather modification also has a military application, rendering it less popular with the general public. But what if we manage to harness this technology by 2050? It could mean that we could create the perfect climate for crops, and thus be able to produce more food.

The future visions in Chapter 3 draw conceivable (but totally imaginary) images of the Dutch agro & food sector in 2050. Once again, these visions are not meant to be forecasts. They aim to stimulate a strategic debate between all stakeholders involved.

The agro and food sector is just a tiny part of a global food system. There are many factors in play here, including non-technological ones. Chapter 4 describes some of these factors, according to five categories:

1. Demography
2. Economy
3. Socio-cultural
4. Ecology
5. Geopolitics

Demographic developments are, for example, the growth of the global population and urbanisation; economic developments include the circular economy and the rise of online shopping. These developments – thirty in all – will not necessarily materialise in the way they have been described in Chapter 4.

In order to complete the picture this chapter also addresses six archetypal scenarios (including mindmaps), which is simply another way to look at the potential futures and the uncertainties it will bring. These are the scenarios:

Scenario A: Economic optimism
Market dynamics rule. Global free trade produces economic growth. Technological developments are fast, influencing global food security in a positive way.

Scenario B: Reformed markets
Global free trade produces economic growth. Technological developments are fast. When the market falls short – e.g. in social development and the protection of the environment – government intervenes.

Scenario C: Global sustainable development
Protection of the environment and countering inequality are central. Cooperation to achieve this takes place on a global scale. Our lifestyle changes. Technology is aimed at sustainability.

Scenario D: Regional competition

Regions – (groups of) countries or regions within countries – will take their fate into their own hands, working primarily on their own interests and identity. This may lead to tensions between regions or cultures.

Scenario E: Regional sustainable development

Environmental problems and social inequality are handled by a decentralised government at the regional level. The main ambition is not security for the region (as in scenario D), but sustainability.

Chapter 5. Conclusions and Recommendations, points out yet again the many uncertainties surrounding the future of agro and food. Not only because of the complexity of the sector, but also because of the many potential visions and perspectives concerning the sector. The research methods used in this study reflect this diversity. Specific recommendations include a plea for investments in (researching) new technologies. Additionally, it would not be right to reject certain new technologies beforehand because of ethical or moral objections. The most important question facing us in the future, however, is how society will deal with new technological possibilities. Mankind, or to be more specific, changing social dynamics and our trust in technologies will determine which new technologies will eventually play a part in the future.

1. introduction and procedure

Artificially grown hamburgers, chocolates from your 3D printer, algae used for fuel, and salt water cucumbers delivered by drones to your doorstep. These are just a few visions of the future that come up when we start to think about the potential influence of technological innovation on the future of the agro & food sector.

Nobody can predict the future, but scanning the horizon is possible. Between June 2014 and April 2015 STT worked on this futures study on the Dutch agro & food sector. The main research question was:

Which new technologies – or new applications of existing technologies – may have a radical impact on the agro & food sector between 2015 and 2050?

The timeframe of this study – 35 years ahead – was chosen to allow a broad scope and sufficient distance to think outside of the box, creating room for social imagination and empathy. Although the focus of this futures study is on technological developments, it also includes other developments (social, political, economic, ecological). To assess the potential impact of technological developments social factors and changes need to be included.

Tools and lines of reasoning

To find answers and describe the initial lines of reasoning various methods of exploration were used. The results can be found in this publication: an overview of potentially disruptive technologies and other developments, sketches of future scenarios, and creative visions of the future. These results are the tools that can be used to start a strategic debate on an uncertain future.
To unequivocally answer the main research question in a clear and precise answer is, of course, impossible. The images and recommendations

in this foresight study are meant to fuel the debate. Although we cannot predict the future, it will be both wholesome and necessary to start this debate about our future. It will give us insight into the challenges and opportunities it holds and explores the room for manoeuvre when it comes to preparing ourselves, or to benefit from whatever the future has in store for us.

For this futures study STT could draw on the knowledge and expertise of a large group of stakeholders, experts, students and futurologists. This study into the potential influence of technological developments on the agro & food sector was exploratory, participatory and qualitative in nature. We tried to describe the various possible futures of our society using visions of the future. The descriptions of the technologies, the visions of the future and the scenarios in this publication are not based on the ideas of individual people or organisations; they represent a composition of perceptions of all the participants involved.

This publication is not the end of an exercise, but rather a point of departure: tools delivered by this study and the network created together form a starting point for the debate about the future of the Dutch agro & food sector.

Complexity

The focus of this foresight study is on technological developments. The agro & food sector is, however, not an entity that stands on its own, nor do technological developments take place autonomously, because they always interact with developments in the economy, society and politics. Also, the food systems of the various countries are intertwined in many ways, from the trade in raw materials to final products.

A large part of the economic value of food is added not at the farms but in food processing and in retail. And at the end of the food chain we find the consumer, whose needs and demands also influence the production and supply of food. On the other hand companies in the food chain can exert considerable political and social influence, having their effect on consumer demand. It is therefore a highly complex system and to investigate it's future requires many different factors and a large degree of uncertainty to be taken into account.

Crucial

A study into international literature on the future of agro & food shows that many organisations and publications refer to this current era as a crucial moment in history: the need for action and change in the global food system appears to be greater than ever before. In the decades to come we will have to fill the needs of an ever increasing global population, whereas the supply of crucial resources such as water, energy and land is becoming more scarce. The food system therefore has to become more sustainable and to adapt to a changing climate, and perhaps even to the measures designed to counter further climate change. The challenge posed by hunger is increasing. Actors in the food system need to find a balance between the factors pressuring the global food system and the ever growing (and sometimes conflicting) demands placed on this system.

Uncertainty

If we would look ahead for just 2 to 3 years the data that is currently available would be sufficient. If we want to look further ahead thinking about the performance of the agro & food sector in the complex global food system, the degree of uncertainty increases and a wide range of sectors and disciplines is involved. Technological developments may be influenced by policy-makers, entrepreneurs and researchers, but also by other developments. In turn technological developments influence other developments, e.g. in food and health, but also in society. In this futures study we tried to do justice to the complexity of the subject, without pretending to paint the full picture. People looking for answers and forecasts may not find them in this publication. Those looking for inspiration and images of possible futures will.

Approach

This futures study consisted of various stages:

Stage 1. Study of the literature and expert survey

The first stage included a literature review in search of trends and future scenarios described in (inter)national publications. Previous futures studies, e.g. the STT Horizon Scan 2050, provided an important basis for the overview of technologies. Apart from this, experts from the agro & food sector and the world of foresight studies (futurologists, trendwatchers) were asked to share their vision of important trends and developments that will impact the future of the agro & food sector. A major result of this stage is the overview of technological developments (Chapter 2), of social developments and of the future scenarios (Chapter 4).

Stage 2. Creative workshops

In the next stage various workshops were held in which experts, students, futurologists and creative thinkers reflected on the possible future of the agro & food sector. For the workshops the developments and scenarios were used as a basis. Participants included representatives of trade & industry, the government, knowledge institutes and other stakeholders. The results of these workshops formed the basis of the visions of the future and the interpretation of the scenarios.

Stage 3: Working with visions of the future

The first round of workshops led to eight visions of the future: stories that sketch a possible future, inspiring the reader to think about the future and to enter the debate. A number of these visions of the future can be found in Chapter 3. In a subsequent round of workshops these stories were used to discuss the potential opportunities and challenges offered by them.

Stage 4: Starting the debate

This foresight study started a debate about the future of the Dutch agro & food sector, but that debate is far from finished yet. Stage 4 is all about using the results of this futures study to start a strategic debate. The aim is, after all, to initiate a discussion by the various stakeholders about the future of the Dutch agro & food sector. This in order to identify opportunities and potential threats, and to stimulate reinforcement and innovation wherever this is necessary. STT hopes that this publication will generate this debate, using the results of this futures study to discuss the future of the Dutch agro & food sector with stakeholders from the government, trade & industry and knowledge institutions.

For whom?

This foresight study was written for a broad audience: policy- and decision makers, strategists, entrepreneurs, researchers, students, consumers, futurologists and trendwatchers, and all others who are interested in the future of the Dutch agro & food sector. Policy-makers, strategists, futurologists and trendwatchers may use the overview of the (non-) technological developments, the scenarios and the visions of the future for creative sessions, or as the point of departure for further research or new policy. Entrepreneurs and consumers will, we hope, be triggered by the inspiration offered by this futures study to reflect on the possible implications of the future developments described in this book for their own organisations and day to day living, and to adapt their strategies accordingly.

the experts

More than 200 years ago Thomas Malthus published his pessimistic essay in which he stated that the growth of the population would be hampered by the slow growth in food production. The global population is currently estimated at ca 7 billion people, a growth of ca 600% compared to the era in which Malthus wrote his essay. What he did not foresee was the gigantic impact that technological change would have on agriculture. In his day and age technological change was relatively limited compared to today (and to how our own future may surprise us), meaning that the growth of food production was mainly the result of the growth of the production factors land, water and energy. In the centuries that followed innovations in agriculture were mostly aimed at saving land and raising production at the same time. Think e.g. of the "Green Revolution" in Asia and Latin America initiated by R&D and knowledge institutes. (Trewavas, 2013)

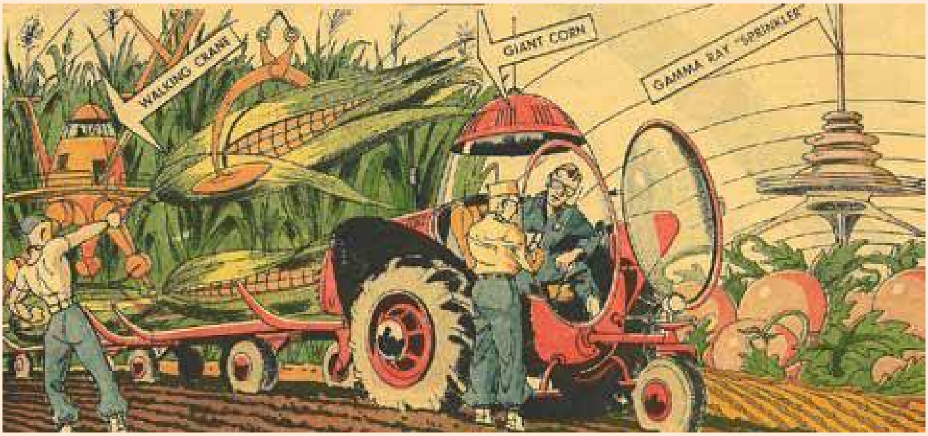
Future farming

Sowing and harvesting will remain the main issue for future farmers, in whatever form. The sowing and harvesting of agricultural products, but also of knowledge, means of production and the data required to achieve this. Circularity and reciprocity will become more explicit in future farming. It will be supported by two pillars propped by connectivity: the connection with technology and design (smart farming) on one side and society on the other (social farming). Future farming will enable the responsible and durable production of sufficient and healthy food for a growing global population with changed demands. Future farmers will also supply biobased raw materials, care and energy. Future farming will require a threefold innovation: technological, social and economic. The Netherlands is the home base of future farming and the living lab for (future) farming in the metropolitan area.

Elies Lemkes, General Director ZLTO

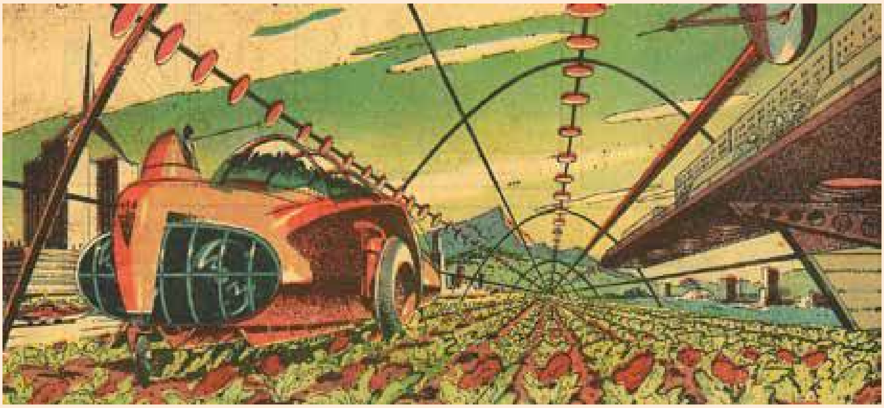
yesterday's future

Reflecting on the future requires creativity and empathy. How did people see the future of the agro & food sector in the past? Between 1958 and 1963 The Chicago Tribune published the weekly cartoon "Closer Than We Think", in which the futurologist Arthur Radebaugh gave his vision of the future.

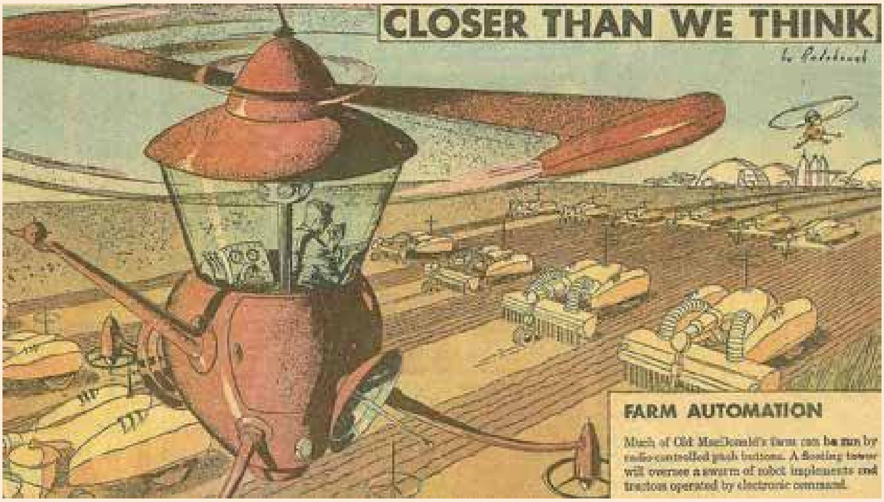


'Colossal Crops' (1962)

'Factory Farm' (1961)



"Fat Plants and Meat-Beats" (1958)



'Farm Automation' (1958)

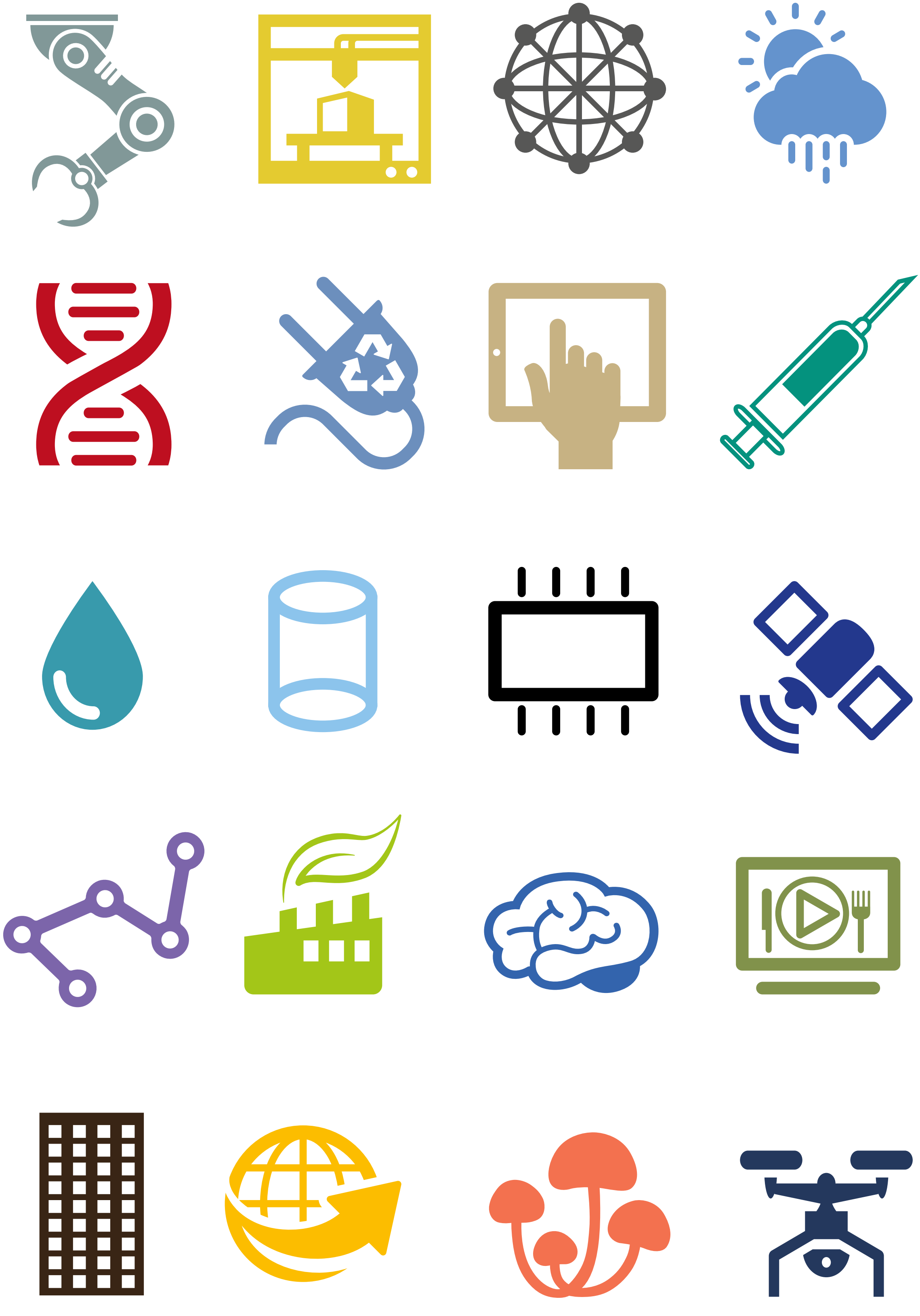
Source: http://paleofuture.gizmodo.com

2. technological developments

This futures study focuses on the technological developments, or to be more specific, the technological developments that may have a major impact on the Dutch agro & food sector. Changes may be found in processes, services, business cases and/or related issues, such as educational requirements, legislation, etc.

In this study we define technology as *the systematic application of (exact) scientific knowledge for practical purposes*. On the basis of this definition it makes sense to refer to the technological developments according to scientific domains. However, in daily practice people often use completely different terms. E.g. in the case of robotics, in which various technologies all come together in a single product. And in the case of information and communication technology a combination of technologies are concerned, but the name refers to the aim of the user. In the case of nanotechnology we are dealing with scale. Whichever names we use, there will always be an overlap between the various developments. Some cross-references have been added to highlight this overlap.

It should be stressed that this overview is not complete, but only a selection of developments that we think will have a large impact. The selection was made on the basis of literature review and ca 30 expert interviews.



2.1 3D printing

Also known as: *additive manufacturing, rapid prototyping*

What is it?

3D printing is a process for the manufacture of 3D objects made on the basis of a (digital) blueprint (a computer file). This generally is an additive process in which the object is build layer by layer by means of a 3D printer. The objects can take (almost) any shape or geometry. The building material for these solid objects consists of a fine powder (a mix of vegetable material, plastics and gypsum).

3D printing today and in the near future

Each week – if not daily – we see new press reports on what the 3D printer can do. 3D printing stands for convenience and the saving of costs. An experiment in the US showed that the printing of household appliances such as showerheads and garlic presses was ten times cheaper than buying. At this moment it takes considerable time to find or manufacture models. Developments in materials and colours, on the other hand, are taking place at a rapid pace. We can already print glass, metal (jewels) and biological tissue such as bones and organs. TNO has been experimenting with food for a number of years now, in 2013 producing chocolate pralines in various shapes and colours. 3D printing offers opportunities for the production of exclusive snacks, but also for more serious applications, e.g. food for people who cannot eat solid food, but do not want to mash every meal. It is possible to vary the consistency, the number of calories and the added vitamins at will. 3D printing also enables the production of moving parts that are ready to use, e.g. tools made to measure. This latter may mean a lot to the maintenance of agricultural tools. Already people are printing parts of robots and drones. By manufacturing prototypes cheaper and faster, it becomes easier to identify design flaws in new products or tools, and adjust them accordingly. For repairing and maintaining tools and machines specific parts can be printed just like that. Another large advantage is the reuse of material (e.g. plastic from discarded milk cartons) as print material. The use of a so-called RecycleBot would allow discarded and cleaned material to be adapted for use in a 3D printer, saving more energy than in conventional recycling.

Overlaps with:

- Food design
- 4D printing
- Sensor technology
- Smart materials
- Conservation technology

3D printing in the distant future

Many cities already have copyshops where people can have 3D models printed, and the expectation is that within ten years each household will have its own 3D printer. At this moment experiments are taking place with conductive materials, allowing the printing of electrical appliances. Printed items with integrated flex and touch sensors already exist, such as a gamepad for gaming computers and a mug that indicates how much liquid is left. Companies will find it easier to deliver customised and personalised products, because manufacturing small amounts of products will become cheaper.

A risk, however, is that people will prefer free downloads – as happened in the music industry – instead of the official products (piracy). The effects of 3D printing on the transport and logistics sector could be immense, if it has to shift from the delivery of end products to the delivery of massive amounts of raw materials for printing at home.

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2.2 4D printing

Also known as: *programmable material*

What is it?

4D printing is the extpansion of 3D printing by adding time as fourth dimension. As in 3D printing a solid 3D object is produced by a printer, but the composition of the building material is such that the printed object can change its shape in the course of time. 4D printing allows the manufacture of objects that consist of a single complete structure that is able to change its shape under specific conditions. Think of in-built pivoting points, pressure points or electronic components which allow a product under the influence of light or changes in temperature to increase in size only in a specific part, and not as a whole.

4D printing today and in the near future

At this moment 4D printing is still at an experimental stage. Already scientists are working on appliances able to assemble themselves, but these are mostly minuscule appliances at the nanoscale (e.g. biochemical sensors), electrical parts or appliances able to transport medicine to the right location in the body. If this technology develops further it may lead to new types of sensors that can be integrated in medical equipment to detect all kind of measurement values.

4D printing in the distant future

What will be the impact of 4D printing once we are able to manufacture programmable objects large enough to detect with the naked eye? Think e.g. of clothing that can adjust the degree of isolation or cooling to the environment, or self-repairing material (see also 2.3). And what happens if we are able to create water and gas pipes that will repair themselves? Scientists are hoping to use 4D printing in the future to create objects that will change their shape under the influence of light, temperature and even sound. Pipelines might in this way be able to transport liquids without the use of pumps. Instruments and tools might change shape as required. 4D printing could be applied to construction, using programmable material that turns itself into a building, including electricity cables and a

Overlaps with:

- 3D printing
- Smart materials
- Sensor technology

water supply system. This could be very useful in environments that are hostile to humans, such as war zones or Mars. Other potential applications include car tires providing optimal grip by adapting their surface to the road and to weather conditions, self-repairing materials for bridges, aircraft, furniture, tools, etc. Materials able to adapt to the weather conditions could be useful in agriculture. If programmable materials break through at a large scale this could mean that raw materials are no longer in limited supply, because all material can be reused and reshaped into what we want it to be. Indefinitely. Extracting less raw materials from the bottom would cause less damage to the environment. The key question, however, is at what scale programmable material will become available and who will have access to it?

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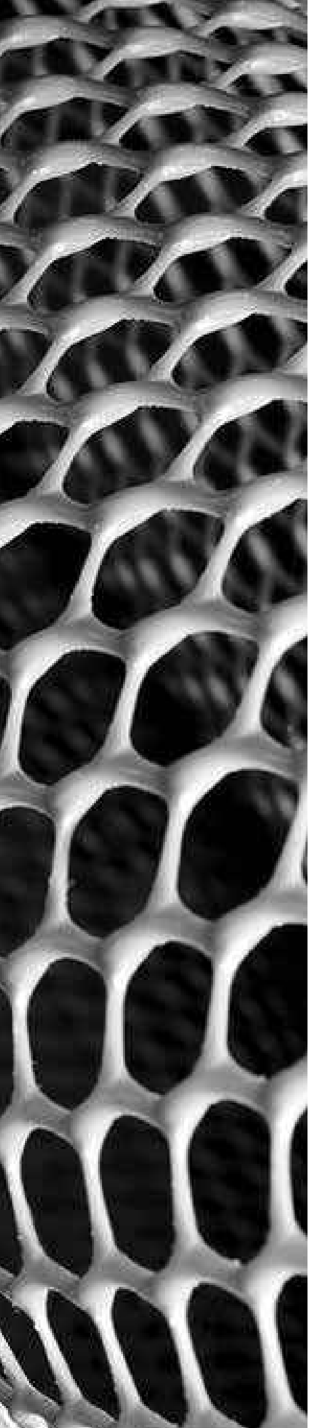

2.3 Smart materials

Also known as: *smart packaging*

What is it?

The term smart materials is used as a collective name for materials that are able to change their shape through external influences, including pressure, temperature, humidity, acidity (pH), and electric and magnetic fields. This is all about desired changes in shape in applied materials, such as the car tires in 2.2 above. Depending on the type of material the process is either reversible or irreversible. Examples include:

- Piezoelectric materials or piezocrystals
- Shape memory metal
- Electric and magnetic-rheological (ER/MR) liquids
- Conductive polymers
- Colour-changing materials
- Light-emitting materials

Smart materials adapt to their environment without human interference, which gives them much added value for products.

Smart materials today and in the near future

Ultra-absorbing materials may be used to clean up hazardous materials such as oil and poison. They may also, by adding e.g. functional performance, have a large impact on packaging. Food can be kept longer or will be quicker to prepare if the packaging material cools or heats by itself (consumer-friendliness). Developers work on packaging for the elderly that will be easier to open and still keeps a product fresh, as well as on sensors indicating in colour how fresh a product really is.

Smart materials in the distant future

There is no limit to the number of applications for smart materials. Just like 4D printing (2.2) this development is still experimental, and it is still not very clear what impact it will have. The food industry has very high expectations of smart materials. In the future product labels may perhaps be able to communicate with the entire food chain, rendering registration and monitoring increasingly accurate and giving

Overlaps with:

- 4D printing
- Conservation technology
- Information technology & IT infrastructures
- Sensor technology

consumers a better insight into what is in their food and where it comes from. Suppliers of fresh produce will be able to monitor transport and check whether the products are both healthy and delivered in a safe manner. This will, of course, require IT networks (2.7). In the future, communication between packaging material and household appliances may be included. Once there will be both smart labels and smart packages, data can be sent throughout the entire distribution chain, meaning that e.g. fridges can place orders at the supermarket as soon as a package indicates it is nearly empty. Packages may even be able to communicate with tv's and be able to order special offers that are advertised. Smart packaging allows suppliers to learn more about their clients and offer them customised products. Smart packaging may even help to make recycling easier and to prevent the waste of food.

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2.4 Robotics

Also known as: *autonomous systems, mechatronics*

What is it?

Robotics is about the theoretical implications and practical applications of automated systems. The role of autonomous, smart systems will increase dramatically in the next decades. Robots can perform fully autonomously or semi-autonomously (with an operator). Robots come in all types and shapes, varying from grip arms and drones (unmanned flying robots for sowing, planting, fertilising, weeding, monitoring, etc.) to microrobots (so small that they can e.g. perform in human blood vessels; see also 2.5) and humanoids (robots mimicking human appearance and behaviour).

Robotics today and in the near future

Robots are often used for comfort and safety or to save costs. In smart farming (2.9) robots perform autonomously; sensors allow them to evaluate a situation and to take decisions. The data from these sensors can be used to compile ever expanding datasets (big data; see also 2.7) to improve their decision-making skills. Robots offer many opportunities for the automation of the agro & food sector, including cultivation and harvesting, automation of food preparation and automation of food logistics. At present robots are used in the Netherlands for shoot production, crop protection, sorting and packaging. Experiments are already underway in plucking (tomato, cucumber, strawberry, etc.), weed control, the harvest of peppers and roses, the packaging of food and the handling of soft products. Most people are familiar with the milking robot, but automatic feeding, cow dung disposal, cleaning of barns, and field fencing have come to be just as common. In the near future breakthroughs are expected in miniaturisation, efficient use of energy, sensor technology and communication. In the past years robots were operating in the background of production processes, but the focus has shifted to the interaction between the user and robots. Replacing human labour with robotics is, however, an important issue in society. Some view robotics as an undesirable development, but it is a fact that the Dutch agro & food sector is always short of skilled personnel. It is also plagued by rising labour costs and – due to the

Overlaps with:

- Data analysis
- Sensor technology
- Smart farming
- Information technology & IT infrastructures
- Autonomous microrobots

use of illegal labourers from abroad – a bad image. The large-scale use of robots could therefore be part of the solution. Robots could also be used for dangerous work and contribute to a much more efficient production process. Yet safety and legal liability issues still need to be solved.

Robotics in the distant future

Experiments are carried out with soft robotics, in which robots are no longer solid and static, but soft and able to change their shape. An example of that is an autonomous robot able to perform under extreme conditions such as exposure to fire or water, or a car crash. Work is also being done on robots that are able to perform in places that are (too) dangerous for humans (disaster areas, extreme weather conditions, war zones or space). In 2050 autonomous systems and robots will probably be just as normal as computers today. The present and the next generations will find it quite normal to interact with robots at any time. Systems and platforms are becoming increasingly smart, and the expectation is that this will make it increasingly difficult for people to control the autonomous systems – with a number of systems performing at the same time – and to interpret relevant information. As technological developments progress human labour will become increasingly superfluous and be replaced with intelligent machines. Many futurologists and engineers, such as Ray Kurzweil in his book The singularity is near, expect people to blend in with intelligent machines, a notion that has led to much debate among ethicists and philosophers. At present the focus in robotics is on sensing, mobility (e.g. autonomous transport), manipulation and end-effectors. In the future there will probably be more focus on e.g. navigation and manipulation in unstructured environments, human safety and the safety of animals and crops, and the conditions in which machines will operate (dust, dirt, temperature changes, etc.).

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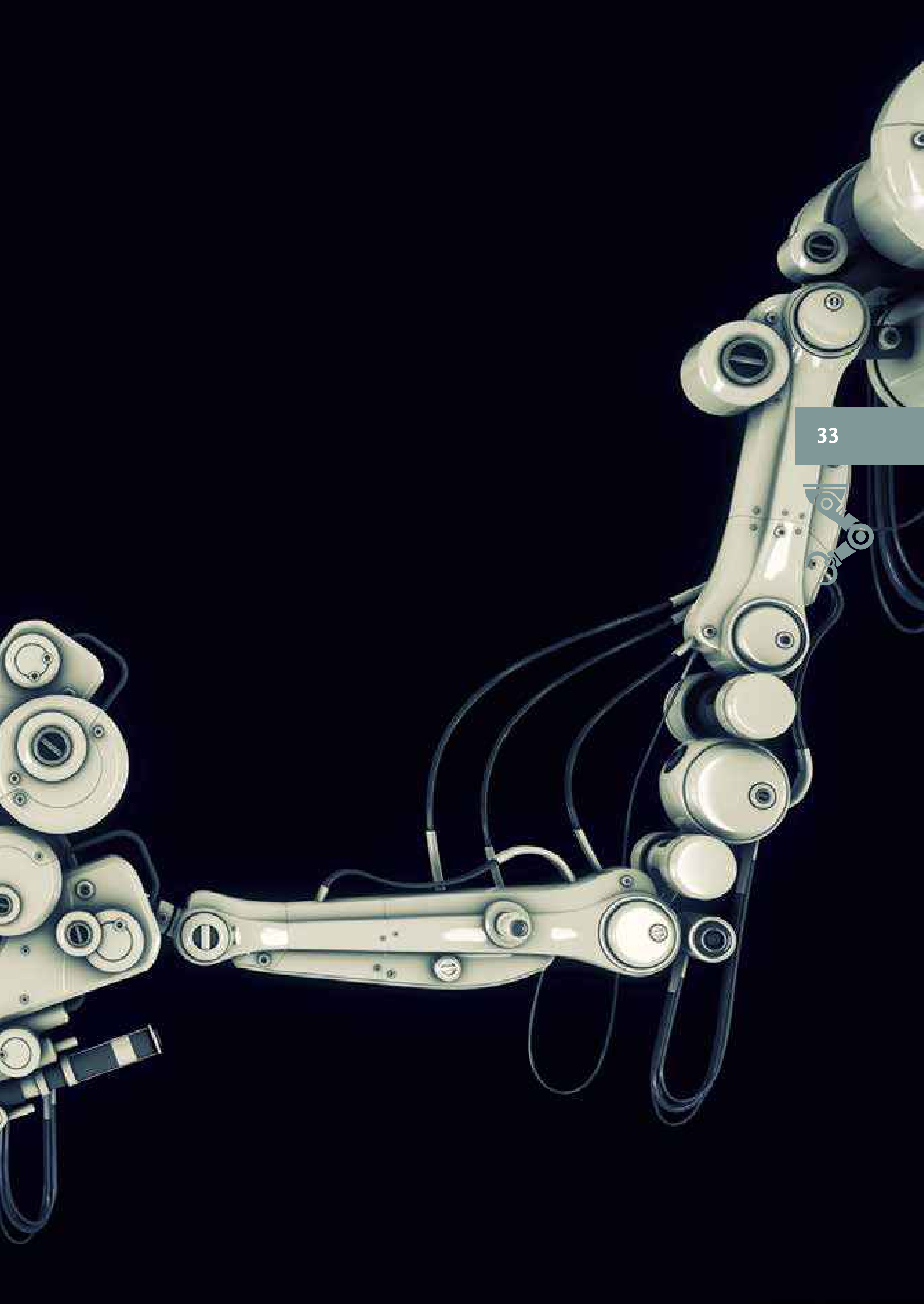

Overlaps with:

- Robotics
- 4D printing
- Smart materials
- Sensor technology

2.5 Autonomous microrobots

What is it?

Autonomous (micro)robots are independent kinetic machines with variable shapes. They are more advanced than conventional robots in the sense that they can change their shape intentionally by rearranging the connectivity of their constituent parts. They may adapt to new conditions and tasks, for instance by changing into a wormlike shape to navigate and carry out repairs in narrow pipelines. Also minidrones are being developed with an steadily increasing operability due to manipulability and low energy costs.

Today and in the near future

Already there are drones so small and light that they do not exceed a weight of 20 grams. It uses 3D camera systems to navigate and avoid obstacles (once the minidrone detects an obstacle it will fly in a semi-circle until the obstacle is no longer in view). This way the drone is able to explore areas without human assistance and without any risk of getting stuck somewhere. A tiny computer inside the drone processes all video data at great speed. Such minidrones can be used to find ripe fruit in greenhouses or to take videos of large events. Autonomous soft robots of silicone rubber, kevlar and glass microtubes will be able to perform under extreme circumstances, such as exposure to water or fire, or a car crash. Another manifestation of a robot is the Kilobot. Kilobots consist of swarms of small robots operated by a kind of infra-red light above the swarm. If an order is given – e.g. to assume a specific shape or to follow the leader – all robots will carry out the order in unison and autonomously. They communicate with each other and pointing with an infrared laser to the ground, they know by the reflection of it where the other robots are.

In the distant future

If the kilobots become even smaller and will be assembled into mega-swarms of billions or trillions of minisupercomputers we get a utility fog. This is, in fact, an active, polyform material that can change into any shape autonomously or through human interaction. One second it is a phone, the next it will be a chair or whatever will be required. In theory entire rooms or even buildings can be built or removed at the blink of an eye. But what will happen if everybody has his own swarm? Will we produce less (and use up less raw materials) if we all have a swarm of robots that can turn into anything? It is difficult to imagine, and the impact is also something that requires careful consideration, but it will completely change our perception of matter and utensils.

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2.6 Sensor technology

Also known as: *food sensors, molecular sensors*

What is it?

Sensors are appliances that can sense e.g. sound, light and weight without direct contact with the object. Sensor technology is also useful for the determination of the composition and/or the quality of food. The agro & food sector uses sensor technology to collect data on the soil, crops and animals through sensors that are integrated in all kinds of agricultural equipment and machines, aircraft and drones (see also 2.4) or even satellites. Sensors provide farmers with real-time information on their crops and livestock, enabling them to respond more effectively, e.g. by taking (corrective) measures. Sensor technology can be used to establish product quality and safety, but e.g. also the origin. Examples of sensor technology in agriculture include aerial photographs, thermal images and near-infrared data (NIR data).

Sensor technology today and in the near future

Sensor technology allows multiple applications, including:

- Smart packaging that is able to tell if a product is still fresh.
- Millimeter wave sensors that enable contact free measurements in the core of a food product. The specific interaction between these waves and water allows manufacturers to optimise drying and freezing processes in the food industry.
- Lab-on-a-chip technology integrating various laboratory functionalities on a single chip of several cm^2. This technology greatly facilitates the diagnosing of sick animals, the detection of specific gases and the determination of the freshness of a product.
- Hyperspectral cameras that are able to detect strange objects, latent defects or food moulds, by inspecting the product surface or analysing and visualising the composition (e.g. liquid, sugar, fat and protein content).
- Optic fibre biosensor to detect (hidden) allergenes, genetically modified organisms and DNA of micro-organisms and viruses.

Overlaps with:

- Smart materials
- Smart farming
- Genetics
- Information technology & IT infrastructures

Sensor technology in the distant future

Sensor technology allows an ever increasing collection of data (see also 2.7) and the expectation is that this technology will contribute to the further optimisation of food processing and quality control. In combination with genetics (2.12) it offers an opportunity for the structural improvement of diagnostics, the combat of animal diseases and the development of more robust animals. In combination with micro- and nanotechnology sensors will be able to select products with a specific composition for specific applications, e.g. milk of individual cows at some point during their lactation, or fruits that do not contain specific allergenes. It also enables real-time observation of livestock (e.g. behaviour). Also here the question is when this technology will see a breakthrough and who will have access to it. For instance, who will own the data collected on a farm: the farmer or the technology supplier?

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2.7 Information technology and IT infrastructures

Also known as: *quantum computing, internet of things, big data, cyberinfrastructure, self-learning systems*

What is it?

The developments in IT advance at a rapid pace, and will continue to do so. The way in which we acquire, store and analyse information has improved considerably. This is matched by the so-called computer processing power. An increasing number of ordinary (electronic) appliances is being connected to the Internet of Things, meaning that our ability to collect, analyse and use an ever increasing amount of information keeps improving.

Quantum computing

In 2000 the best computer processors had a calculation power that equalled that of a spider, and today they are just as good as the brain of a mouse. If the calculation power continues to grow at the present rate (doubling each three years) the computer processors may in 2023 have a calculation power equalling the human brain. In 2045 they will be 100,000 times stronger than the human brain. Once quantum computing becomes reality even these estimates would be surpassed. It is difficult to envisage the impact of quantum computing (perhaps only the quantum computer will be able to do this), but there is no doubt that the impact will be vast.

Self-learning systems

The types of tasks a computer can perform will also change. Self-learning systems are computer systems that learn reasoning and maybe even develop a sense of ethics. The expectation is that the interaction between man and machine will steadily improve as a result of this development. IBM has developed Watson, a self-learning system able to learn from unstructured data. “Supercomputer” Watson became famous when it won the US tv show Jeopardy (2011). At the moment of appearance of the Dutch version of this publication IBM was developing applications for cognitive computing for a number of sectors, including healthcare.

Overlaps with:

- Smart farming
- Sensor technology
- Transport technology

Big data

At present more than 98% of all global information is stored in digital format. Experts foresee that the amount of digitally stored information will be 20,000 times larger in 2045. The collection and analysis of these vast amounts of data is referred to as “big data”. The ever growing amount of data will enable people to predict the spread of diseases much more accurately and tell where natural disasters will strike. In time it may even be possible to predict human behaviour.

Internet of things

The Internet of Things already exists. An ever increasing number of appliances is connected to the internet, including mobile phones, cars and even fridges. It is expected that this number of appliances will increase from 20 billion in 2014 to 40 billion in 2020. If this growth continues this will have become 100 billion by 2045. Decreasing costs and an increased access to these appliances may well help to exceed this estimate. The more we are connected to the internet through various appliances, the bigger and more complex the communication network will be.

Today and in the near future

IT plays an important part in all aspects of our lives. The agro & food sector has already witnessed a strong increase in the number of apps used to e.g. detect failures in machines, to receive instructions for repairs, or to make the right choices in crop selection and harvesting. Simulations and training programmes for the handling of machinery are also widespread. In the years ahead these apps will increasingly be used to analyse the soil and link this data to climatological conditions (rain or not, clouds, etc.). The data will also be linked to global food prices and the prices for e.g. livestock fodder. At this moment the challenges in handling big data are in analysis, storage, privacy, visualisation, information-sharing, and defining the right search question. Big data is a dynamic concept. Today’s “big” may in a few years be “small”. Smart farming already uses large amounts of geodata (weather and soil measurements).

the experts

Our future is rich in data, and data analysts have the future. Who gets to control these datasets? Who will have access to the big data of farmers to advise them whether the potatoes should be sprinkled today or tomorrow? Who will link the data about what we eat and how we move to our chance of a heart attack? Will we receive advice about eating a seaweed roll or an insurance policy?

There is no doubt that Silicon Valley with Google, Apple, UC Davis and Stanford are in pole position. Maybe in due time the gigantic number of Chinese students will boost the performance of China Telecom, Alibaba and the Chinese Academy of Agricultural Science. Is India the outsider we overlook? Could the old continent still play a role through close cooperation between agronomes from Wageningen, doctors from Leiden, IT experts from Eindhoven, biotechnicians from Belgium, Frauenhofer and creative Amsterdam start-ups close to SARA and AMS-IX? This is not something to just hope for. It is something to work at.

Krijn Poppe, Research Manager & Senior Economist LEI Wageningen UR

In the distant future

Our ability to accurately predict events such as natural disasters or spots where climate change will have an imminent, direct effect increases. In several countries the police are working with systems that are able to predict when and where a crime will take place (a US invention called PredPol). According to experts in 2050 many appliances will be connected to the internet, and contain a sensor. There will be a continuous stream of real-time information on e.g. the quality of the drinking water or the damage to buildings and vehicles. The detection and measurement of pollution will also be real-time. Machinery and consumer products can be checked for the status of their components, so that replacement or repair can take place at the earliest possible moment. The data from the sensors and the input by consumers on social networking sites will render the tracking & tracing of products much more accurate. Sceptics are pointing at the effects this will have on privacy, wondering whether it will still be possible to "go off the grid". But the general expectation is that the developments in IT will lead to higher production rates and optimal harvests.

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Overlaps with:

- Smart farming
- Sensor technology
- Information technology & IT infrastructures
- Genetics

2.8 Bioinformatics

What is it?

Bioinformatics aims to enrich biological knowledge and to apply IT expertise to biological data. In short: it is about the storage, analysis and exchange of large amounts of biological data. The present applications of bioinformatics include DNA barcoding, the modelling of patterns of disease outbreaks or individual genomes, and new bio-products. Bioinformatics has the potential to give a large boost to our capability to analyse data and to influence the attributes of plants, animals and human beings. At present, work is underway to improve the exchangeability of all gene and protein sequences. There are large gene databanks in Europe, the US and Japan. The protein databanks in Switzerland and the US have started a collaboration under the name UniProt.

Bioinformatics today and in the near future

The World Food Organisation uses bioinformatics to develop applications that should help against infectious diseases (e.g. bird flu) and to combat outbreaks and the spreading of viruses. The collection and processing of data is aimed at knowledge-building in order to combat the future spreading of diseases. In the Netherlands the Centraal Veterinair Instituut (Wageningen UR) recently used these techniques to determine and analyse the genome sequences in order to be able to determine the infection of various poultry farms by the H5N8 virus. It is also already possible to do local weather forecasts (accurate up to 200 hectares) using millions of daily weather and ground observations. Farmers can use this information to determine when will be the best moment to sprinkle, cultivate or harvest the land. The local weather observations during a number of months can also be used to estimate the yield of a specific piece of land. Livestock may be chipped and connected to the internet (and databanks) to monitor their health and to increase production.

Bioinformatics in the distant future

Once the exchange of information between countries becomes faster and easier, it will become possible to detect disease outbreaks at an early stage and to obtain a picture of the cause(s), which will be both faster and better. The data that was gathered can also be used to do a risk analysis or a prediction of the future. It is expected that the combination of bioinformatics and other technologies will lead to more durable production. The influence on the quality of crops will be improved, production will go up and the resistance of crops against diseases, insects and herbicides will rise.

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2.9 Smart farming

Also known as: *satellite agriculture, location-specific crop management*

What is it?

Smart farming is agriculture in which the crop, animals and soil receive the exact treatment that they need. Other than in traditional agriculture, in smart farming the farmer looks at the need per plant or animal instead of per field or herd. Taking into account the specific conditions of the soil, hours of sunlight and climate will optimise the yield. Effective smart farming is based on data analysis.

Treating the crops and animals as accurately and effectively as possible requires several core elements – such as automatic detection – to determine the variation in soil, crop and animal behaviour. This may be achieved by sensors. GPS is used to map the variation and to give it a georeference. Smart farming also requires so-called decision support systems, decision rules and models that will translate the measured variations into action which – while taking into account the economy and the environment – is tailored accurately to soil, plant or animal. The smart use of these core elements (detection, decision rules, execution, evaluation) requires adapted technology. This technology is mostly dependent on other technologies.

Smart farming today and in the near future

Smart farming allows the customised production of specific products for specific clients. Customised production leads to an increase in the diversity of products and production methods. Recent developments in smart farming include ever increasing data exchange between machines, management systems and service providers, development of injection systems, weed burners and specific hoes for the crop rows. The greenhouse industry already uses robots, e.g. in the plant tissue culture, and GNSS (Global Navigation Satellite System), which allows positioning within a plot or crop with an accuracy of a few centimetres.

Overlaps with:

- Sensor technology
- Information technology & IT infrastructures
- Robotics
- Bioinformatics

Smart farming in the distant future

The developments in sensor technology (2.6), IT (2.7) and robotics (2.4) will extend the possibilities in smart farming further. It is expected that we will be able to determine the needs of a crop at any specific location and moment in a way that will be increasingly accurate, and from a distance. The further automation of agricultural activities, such as plowing and harvesting, will also lead to further developments in smart farming. According to experts the expansion of smart farming will result in increased production per crop, and more efficient production systems.

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2.10 Renewable energy

Also known as: *durable energy, sustainable energy, energy transition*

What is it

The importance of renewable energy such as wind and solar energy mainly lies in the production of electrical energy. The transition to this form of energy requires the electrification of a large number of activities that are now based on fossil fuels, such as heating and rapid movements. Biofuels (2.11) may be (part of) the solution if the world runs out of fossil fuels.

Renewable energy today and in the near future

There are various reasons why the agricultural sector should play a role in the production of renewable energy. It has the required space, it produces biomass and thus plays a part in the CO_2 cycle. Also relevant are the eagerness of the sector in additional activities, its image and sustainability, and the EU and national agriculture policies. Economic motivation lies in the generation of jobs and saving of energy costs on farms, although the latter depends on the type of farm. The cost price of renewable energy, however, is much higher than the cost of energy from fossil fuels. Most options in which agriculture can take the lead are therefore based on biomass (2.11). This makes sense. The agricultural sector is one of the few to produce its own biomass. Also, the space that is available at farms allows multiple opportunities for wind and solar energy, PV energy, and durable warmth production. A major obstacle is that the renewable energy produced by e.g. the sun, water or wind is not continuous, so the electricity will have to be stored. That is why the entire world is now looking for battery technology that will provide the required capacity for storage. Apart from this, smart grids may also help to bring about the energy transition. Smart grids are all about technology to manage the electricity network in a smart way through the accurate (and continuous) balancing of demand and supply. This would mean that individual households would not only buy electricity, but also supply surplus home generated energy back to the grid.

Overlaps with:

- Biorefinery and biofuels
- Aquaculture
- Transport technology
- Weather modification

Renewable energy in the distant future

If the future norm for energy entail sustainable sources there may no longer be scarcity of energy, but in fact a surplus. It is conceivable that an increasing number of appliances running on fuels will switch to electricity (electric cars). The breakthrough of specific technologies will, however, depend on the economic return. The agricultural sector can achieve lower costs for renewable energy by using its own resources for (the use of) renewable energy.

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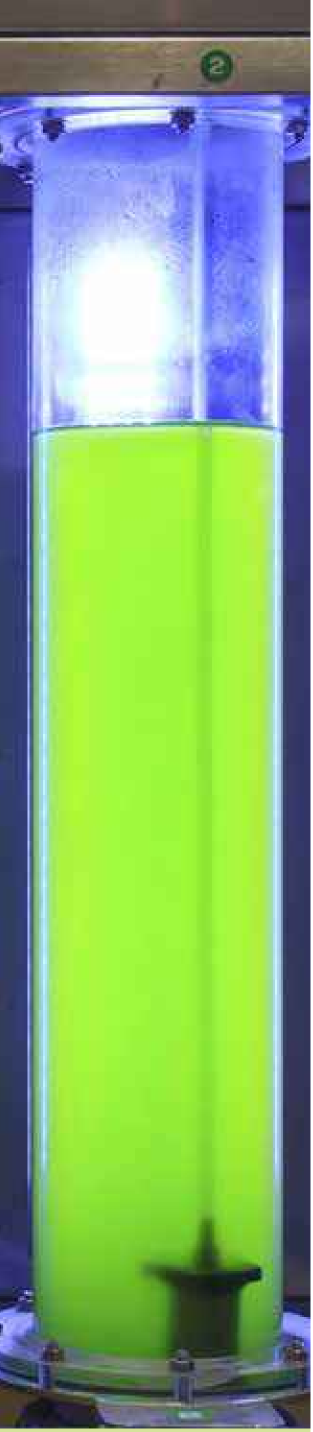

Overlaps with:

- Aquaculture (algae)
- Protein transition
- Energy transition
- Transport technology

2.11 Biorefinery and biofuels

What is it?

The International Energy Agency defines biorefinery as “the sustainable processing of biomass in a spectrum of marketable products and energy”. Biomass is the dry weight of (parts of) organisms. Biorefinery aims to process biomass as efficiently as possible for optimal use of components and minimal waste. In the ideal scenario the full utilisation of the biomass does not require additional agricultural land. It is also possible to exchange the residual flows of biomass between different value chains to achieve optimal use and to avoid competition between food, fodder and fuels. Biofuels is a collective term for fuels made from biomass. It is generally not possible to replace petrol or diesel with biofuel without adapting the engine. The first generation biofuels reduces CO_2 emissions by 50%. The second generation promises a reduction of 90%. This second generation is much more cost-effective, meaning that the yield per hectare biomass is much higher. Other new developments – also known as the third generation to distinguish them from the second generation – include the production of biofuel from algae. In the fourth generation of biofuels the micro-organisms will produce the fuel or chemicals themselves.

Biorefinery and biofuels today and in the near future

Most applications and research in this domain are aimed at biofuels. Biofuels may help reduce the emissions of CO_2, soot and particulate matter in traffic. They also help to reduce the dependence on less stable regions (political, economic or both) that supply many raw materials for fossil fuels. The use of biofuel may also boost Dutch agriculture and processing industry and thus create new jobs. The potential to save costs is in any case very relevant for the agricultural sector. Biofuel has just like fossil fuels the advantage of being a highly compact energy carrier, rendering it highly suitable for heavy transport (trucks, air and sea freight) and long-distance transport. There is, however, a public debate about the production of biofuels from edible biomass, because it is putting pressure on food security. It is hoped that the third and fourth generations will solve this problem. One can also see the rise of bioplastics: plastics made from biomass instead of fossil materials. This development offers opportunities for commercial applications, including biodegradable packaging, paint, medicine and additives (e.g. for food). Experiments are also underway to use biomass for the production of building blocks for construction.

Biorefinery and biofuels in the distant future

An increased demand for biomass could lead to a strong rise in the yield of dung, woods and natural areas. The Netherlands could become leading as the supplier of technology to transform waste water and manure into higher-value products. The production of algae also appears to be promising, because algae can be used to produce fuel, to refine waste water, and as a source for functional food ingredients. An economic system in which biomass (and renewable energy sources such as water, wind and sun) has made the use of fossil materials redundant is often referred to as the biobased economy. In such an economy biomass is used as the raw material for durable food, electricity, heat, transport, materials and chemicals. The global fossil resources are becoming increasingly scarce, which explains why the biobased economy has become popular. The transition from fossil-based to biobased, however, is of a vast magnitude, which raises the question whether this transition will ever happen. From the point of view of technology much is possible but the question is which biomass applications will be the most profitable, and how policy and legislation will deal with it. One should also keep in mind that at present many biomass processing technologies cost more energy than they produce, which has generated much scepticism.

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2.12 Genetics

Also known as: *biotechnology, genetic modification, gentech, genetic technology*

What is it?

Gene technology is grouped under the more general term biotechnology, a collective for all technological applications using biological systems, living organisms or their derivatives. Genetics use DNA modification and a series of increasingly refined technologies to reinforce the possibilities of crops and livestock through selection and breeding. There are various orientations in genetics, depending on the applications.

- DNA sequencing: determining the sequence of the base pairs in the double helix of a DNA molecule using chemical reactions.
- Cloning: making a copy of a DNA fragment, a cell or an entire organism.
- Cisgenesis: direct genetic modification which only uses the genes of the species itself.
- Transgenesis: direct genetic modification which uses the genes of other species.
- The use of marker genes and genetically modified organisms to rapidly crossbreed desirable characteristics through cisgenesis.
- Gen inactivation: direct genetic modification to render a gene of an organism inactive.
- Epigenetics: studies the influence of reversible hereditary changes in the gene function that occur without changes in the DNA sequence in the nucleus. Epigenetics also researches the processes influencing the development of an organism.

The applications of genetics seem limitless. This is a small selection:

- Making crops resistant to threats and hazards such as herbicides, insects, viruses, drought, salt and cold.
- Increasing the desired production per crop. Adding C4 gene complexes to C3 crops may become very important in this respect, as will be the development of agricultural systems of crops able to generate an important part of their own fertilisation through nitrogen fixation.

Overlaps with:

- Synthetic biology
- Biorefinery and biofuels
- Protein transition
- Food design
- Bioinformatics

- Improving food quality by enhancing the nutritional value or the quality of taste, smell, colour and appearance.
- Improving the suitability of plants and plant remains for new generation biofuels.
- Steering at changes in the period of harvest of crops, or in the manner of reproduction: changing crops based on vegetative reproduction (such as the potato) to generatively reproducing crops.
- Stimulating micro-organisms to the production of desired substances (specific proteins, fuels, etc.).
- Epigenetics is currently also used in the research to combat depression and addictions by changing genes. Epigenetics gives us more insight into the way in which food influences the disease progression in human beings and animals. Ultimately it will be possible to tailor food to optimally match the health status of human beings and animals.

Genetics today and in the near future

The DNA of most plants has been mapped, enabling us to accelerate the process of rendering plants more resistant against diseases. By mapping an ever increasing number of types of genomes it will become possible to produce customised populations of individual animals and plants for specific applications. Some examples: cows producing milk that contains a high content of unsaturated fatty acids and potatoes containing a specific type of potato starch or with a resistance against a specific disease. This will allow more sustainable production: the inherent resistance of plants against specific diseases also means we will need less herbicides. Work is also underway on the production of crops in areas that were previously deemed unsuitable for these crops. Genetics could contribute to the creation of a biobased economy (2.11).

Genetics in the distant future

The impact genetics will have in the future is uncertain, also because society is not embracing this technology due to ethical issues. In Europe very strict legislation hampers research, whereas the policy of the US and Asian countries is much looser. Also, manufacturers are increasingly closing doors on gene technological developments through patents and licences. There is a battle going on about the intellectual property rights of (modified) plant material. The outcome will determine who will be leading in gene technology in the future.

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2.13 Synthetic biology

What is it?

Synthetic biology is a technological-scientific development that applies technical design principles at the biological molecular level, e.g. redesigning a living system so that it will do something new such as producing a specific substance. Even more ambitious are the ongoing attempts to create new living systems from non-living material. Synthetic biology overlaps with other disciplines, e.g. genetics. The difference is that the ultimate ambition of this discipline is much greater, viz. the design of living organisms that will meet the needs and desires of humankind. Some people view biotechnology as the successor to genetics. The products include medicine produced by artificial bacteria and genetically modified algae producing clean energy.

Synthetic biology today and in the near future

Biotechnology already makes itself felt in our food supply. Take cheese. Originally cheese was made from rennet (chymosin) from the rennet stomach of weaning calves, but from 1990 onwards this is done through biotechnological processes. Researchers take the rennet-producing genes from the stomach of the calf, and build them into bacteria, fungi or yeasts which then produce rennet through fermentation, killing the genetically modified micro-organism. The rennet is separated and added to the milk, meaning that the cheese will not contain any genetically modified material. Recent examples of synthetic biology include the experiments with the genetic modification of organisms and the research on human fetal stem cells. Apart from expanding our knowledge on the way cells operate, the synthetic biologists also aspire to develop cheaper medicine or to solve the climate issue. DSM recently modified the Penicillium notatum in such a way that it is now able to produce an antibiotic from the cefalosporine group. Work is also underway on the modification of bacteria into a chemical plant that will produce cheap malaria medicine. Popular design methods include abstraction and modular design, known from older techniques such as electrical engineering.

Overlaps with:

- Genetics
- Bioinformatics
- Biorefinery and biofuels

Synthetic biology in the distant future

Researchers hope that through synthetic biology organisms will need less raw materials and no longer any herbicides. They will use less space and less energy, thus contributing to more sustainable farming. Synthetic biology may help to produce ingredients in a way that is more environmentally friendly and also cheaper. The shift from soil-based production of rare ingredients – such as specific spices and medicinal substances – to synthetic biology-based production may have a large impact on production chains and create economic shifts between regions. In San Francisco crowdfunded biohackers are experimenting with the production of animal free milk and vegan cheese.

In 2014 Waag Society's Open Wetlab started the first BioHack Academy in the world: a course to build your own BioFactory that will enable you to start working on your own fuel, food, fibres, medicine, fragrance, fungi and other types of products. Does this mean we are looking at a possible future in which every household designs and produces its own products through synthetic biotechnology? But there are also reasons for caution. The manipulation of existing bacteria or viruses may lead to the creation of new pathogens. Synthetic biology may also be used to create biological weapons. Then there are the aspects of intellectual property and ethics. Can you file a patent on a new organism? Is it done to create artificial life? Intellectual property is seen as prerequisite to the commercial exploitation of new knowledge. There are also voices saying we should head for an open source model, in which we can share knowledge and techniques as much as possible. The advocates of the latter model fear that large companies could monopolise knowledge, thus reinforcing global inequality. According to them open source will actually accelerate innovations in synthetic biology.

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2.14 Protein transition

Also known as: *artificial meat, meat replacements*

What is it?

The protein transition is about the shift to a society in which the protein consumption will rely less on eating meat from animals (chicken, pig, cow) and more on plants and alternatives such as salt water organisms and insects. Seaweed is a primary protein source and it does not require proteins to grow. The advantage of insects above traditional animals is that they convert vegetable food up to five times more efficiently. They are also a good source for fats (omega-3), vitamins, minerals and fibres. The protein transition may contribute to a decrease in the emission of greenhouse gases, due to the fact that we will be eating less animal proteins (the production of animal proteins requires a large amount of raw materials). Food scarcity would also decrease. Then there are people who support the protein transition for ethical reasons, including animal welfare.

Protein transition today and in the near future

The protein transition may be closer than we think. Supermarkets already sell insect burgers and the business of the vegetarian 'butcher' and 'snack bar' is booming, offering products that look like meat, but are actually made from the proteins of mushrooms, soya or dairy products. Many snacks such as chicken nuggets and croquettes already contain a mix of meat and 'alternative proteins'. There are also interesting things happening in the production of artificial meat, meat that is based on cell or tissue cultures. The production of artificial meat is simply the increase in separate cells, using muscle cells but also fetal stem cells able to multiply under the right conditions. The result is a soup of muscle cells. These are then separated from the starting product, becoming a meaty mass. In 2013 the world saw the presentation of the very first artificial burger in the world, costing 250,000 euros. The challenges of 'growing' meat reside in the technology to process stem cells. How do you get them to become a muscle cell? Following this the mass will still need structure and the right taste, the taste of meat.

Overlaps with:

- 3D printing
- Genetics
- Synthetic biology
- Aquaculture
- Renewable energy

Protein transition in the distant future

Once artificial meat and other alternatives for meat become affordable – or even cheaper than traditional meat products – and the consumer adopts the product we could be witnessing a massive trend reversal, both in our diet and in food production. Cheaper energy (2.10) may help artificial meat to become cheaper. The question remains, however, whether the alternative protein sources will lead to a full protein transition or just add to our diet, which will still be based on meat consumption.

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2.15 Food design

Also known as: *functional foods, nutraceuticals, personalised food, food technology, designer food*

What is it?

Food design is the development of food in labs, to which specific components are added (or extracted) to improve the taste, structure or the degree in which the food promotes health (in the latter case we speak of functional food). The adding or extraction of components should not affect the (eating) experience. The taste, structure (does it feel agreeable in your mouth) and appearance are all-important. In its simplest form food design is the addition of water to fat products, in which the tiny drops of water are encapsulated by the fat. This leaves the taste experience (practically) unchanged, although the percentage of fat is much lower. Examples include:

- Products with less fat, sugar or salt without affecting the taste, structure and (eating) experience
- Products with a different structure, e.g. less grainy or easier to chew
- Personalised products for quick(er) recovery
- Products with a specific esthetic attraction, e.g. smell, shape and colour, so that food becomes a different (eating) experience

In 2013, STT published Aspirine op je brood (Aspirin on your Sandwich), the result of the futures study on nutrition and medication, in which more examples of food design have been given.

Food design today and in the near future

Food design is already here to stay. There are even education courses in food design, and food design events have become very popular. From the point of view of technology practically anything goes. It is relatively easy to customise food for individual persons in line with the phase of life they are in. The question is when and in which way food design will impact our lives on a large scale. In due time 3D printing may enable households to design their own food, and print it.

Overlaps with:

- 3D printing
- 4D printing
- Genetics
- Synthetic biology

Food design in the distant future

It appears that in the upcoming decades people will want to have more control over the composition of their food. Will tomorrow's cooking be just the design of units of nutrients (cubes, gel or powder), including the taste we will fancy at that moment, and then have it printed (2.1)? Eating what we really like and still getting all the nutrients we need? Is this how we can solve health problems and scarcity?

the experts

A pretty and attractive 3D print is just the beginning

New technologies such as 3D printing will enable the design of a range of pretty and attractive foodstuffs. To meet the requirements of consumers, this food will also have to be healthy, safe, sustainable and affordable, apart from smelling nicely and having the right taste. It will have to fit within our present and future diet and eating habits, and also contribute to the many social functions food and meals can have in our cultures. In short, even if a pretty and attractive 3D print is a major leap forward, it is just the beginning.

Joop van Raaij, food expert at RIVM and Wageningen University

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2.16 Aquaculture

What is it?

Aquaculture is the cultivation of aquatic organisms such as fish, molluscs (e.g. mussels), crustaceans (e.g. shrimp, crabs and lobsters) and seaweeds (e.g. algae). The animal and vegetable organisms are kept in ponds and basins for commercial trade. Aquaculture includes the cultivation of organisms at sea. There are various forms of aquaculture:

- Mariculture or aquaculture at sea: the growing of aquatic organisms, of which the end products are being grown at sea
- Aquaculture at the coast in brackish water such as estuaries, bays, lagoons and fjords
- Aquaculture in fresh water, e.g. reservoirs, lakes, canals and groundwater
- Integrated cultivation: the symbiotic cultivation of aquatic organisms. In aquaponics the cultivation of plants (hydroculture) and fish takes place in a recirculation environment. The plants feed on the animal waste products, using these for nutrients and to purify the water
- Algae cultivation: depending on the species algae can be cultivated in fresh, brackish, saline or super salty water. Algae are cultivated for multiple applications, e.g. high-quality products, raw material for food products, biofuel, and purification of smoke gases and waste water

The Dutch aquaculture mainly focuses on the cultivation of shellfish and fish.

Aquaculture today and in the near future

In the food-producing sector aquaculture shows the fastest growth worldwide, due to the rising demand and its role in replacing commercial fishing. The aquaculture sector shows an increased interest in the reuse of residual flows, such as the remains of processed fish products, offal and shells of mussels and oysters. It can also benefit from the residual flows from other agro sectors, e.g. as input for fish fodder, or by making use of the residual heat from factories etc. for the cultivation systems. From a technological point of view

Overlaps with:

- Biorefinery and biofuels
- Synthetic biology
- Genetics
- Protein transition
- Sensor technology
- Renewable energy

the Netherlands is leading in recirculation systems or closed fish systems. These systems are based on the purification and circulation of the water, meaning that they are energy-efficient and hardly produce any waste. One recent development is the rise of city aquaculture. Advanced water purification systems can enable people to keep fish in a water tank the size of a jacuzzi without resort to chemicals. The salination of the coastal environment can actually be used to experiment with the cultivation of vegetables with saline water (Zilt Proefbedrijf Texel). In 2014 a Dutch potato cultivated with saline water won the prestigious Asaid Grand Challenge Award.

Aquaculture in the distant future

It is generally believed that the global demand for food will boost the cultivation of shellfish and fish. In order to maintain food security the interest in sustainable fishing will increase. For the aquaculture research the challenge will be to create a successful link between economic and social sustainability and ecological sustainability. Intensifying aquaculture will also mean that a focus will be placed on (bio)technological aspects. Closed cultivation systems will become more important, which will also be better for the environment. Agricultural areas across the world are dealing with salination. Applications of aquaculture aimed at the cultivation with saline water may prove to be the solution.

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2.17 Vertical agriculture

Also known as: *arcology, city agriculture, environment agriculture, controlled or building-integrated agriculture*

What is it?

Vertical agriculture is agriculture in city highrises, so-called vertical farms. The vertical refers to the fact that the plants are often cultivated behind the glass of skyscrapers, but also to the vertical scaffolding allowing rows of plants to grow on top of each other. Vertical farms increase the food supply in densely populated cities, while limiting the footprint made by conventional agriculture. Apart from vegetables and fruits vertical farming could be used to rear fish and chickens. LED lamps mimick the sunlight in a fully controlled environment. Computers ensure that each plant tray receives an equal amount of light and water. Vertical farmers often manage a number of vertical farms, because apps and computers enable remote control. If there is a problem – e.g. a broken down water pump – they receive a message on their smartphone.

Vertical agriculture today and in the near future

Vertical farms have been built recently in Singapore and in the state of Pennsylvania (US). Although the term vertical agriculture receives much media coverage in the Netherlands only few projects have been realised. Until quite recently it was often difficult to adapt offices to a vertical farm because there was too little sunlight for plants to grow. Technology is now advanced enough to grow plants without natural sunlight. The advantages of vertical agriculture include: no loss of harvest as a result of the weather, pests or animals, more yield per m^2, production takes place near the client or market, no negative impact on biodiversity or damage to the soil, less emission of CO_2, minimal use of water through recycling and considerably lower use of fossil fuels (no tractors, plowing, transport).

Vertical agriculture in the distant future

In 2050 80 percent of the global population – by then 9 billion people – will live in the city. Vertical agriculture will allow production much closer to the consumer, thus cutting transport cost. Highly advanced vertical farm designs may be found in arcology, a series of architectural

Overlaps with:

- Information technology & IT infrastructures
- Smart farming
- Sensor technology
- Aquaculture

design principles by Paolo Soleri. These are aimed at gigantic habitats with extreme population densities including housing, industry and agriculture, and are designed to do as little damage to the environment as possible, while being economically self-sufficient. Vertical agriculture can contribute to the growth of food production with less transport. Vertical farming is also highly suitable for households or communities.

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2.18 Conservation technology

Also known as: *food preservation, preservation technology*

What is it?

Conservation technology contributes to the extended preservability of (the freshness of) food. It protects foodstuffs against contamination by e.g. bacteria or fungi, or chemical and physical processes. Examples include:

- Pasteurisation through high pressure to inactivate decay organisms, pathogenes and various enzymes and to keep the product fresh for over a month if cooled
- Pulsed electric fields to inactivate pathogenes and decay organisms in fluids
- Pasteurisation through microwave processing to keep meals fresh longer, while maintaining a high organoleptic quality
- Cold plasma method using inert gases to disinfect the surface of packaging or foodstuffs, allowing the inactivation of micro-organisms on the surface at temperatures of less than 40 °C
- Application of relevant genes against decay after harvest

These technologies could become alternatives for conventional thermal pasteurisation or sterilisation processes. The lower thermal load of the new technologies will often result in a product that looks and tastes fresher than the product treated traditionally. There is less deviation in taste (no aftertaste of cooking), less thermal damage to valuable nutrients (e.g. vitamins) and the texture is much better.

Conservation technology today and in the near future

The new conservation technologies are generally presented as more sustainable methods to conserve, with less harm to the environment. Extending the preservability of a product can offer a huge contribution to discouraging waste. The figures show that each year Dutch consumers throw away food to the value of € 2.5 billion, more than € 150 per person or 50 kilos. Producers, brokers, distributors, the hospitality sector and supermarkets waste another € 2.5 billion of food. Improved conservation technologies will save money and energy and reduce the emission of CO_2 of transport and waste disposal.

Overlaps with:

- 3D printing
- 4D printing
- Smart materials
- Genetics
- Sensor technology
- Transport technology

Conservation technology in the distant future

Apart from the further reduction of waste it is conceivable that a wider and perhaps more healthy range of food products will become available if conservation technologies are enhanced. If the trend of quick and easy dinners persists and the demand for small portions – one person meals – will continue to grow, improved conservation technologies may be able to contribute to a healthier diet in this respect. The rise of the 3D printer and food printing (2.1) is strongly intertwined with conservation technologies, because these technologies will be crucial for the preparation and preservability of the contents of cartridges for food printing. If small-scale production increases the demand for small-scale technologies to keep the food at home preserved will also increase. Adoption by consumers, dieticians and health care institutions may become an obstacle. For many people it will be hard to believe that products can be kept fresh so much longer than they are used to.

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2.19 Transport technology

What is it?

New materials, manufacturing techniques and progress in IT will probably lead to new possibilities for automated transport and changes in the speed and efficiency of transport.

Transport technology today and in the near future

The transport of products takes time and money. During the past decades technological innovations have made transport faster and cheaper. The improved ability to keep products fresh longer has also allowed long-distance transport, leading to a highly diverse supply of products throughout the year. But the question is whether we will still be able to do this in view of the rising costs of fuel and the increased pressure by politicians to reduce CO_2 emissions. And can it be done with the same means we have available today? New transport technologies and new forms of energy and fuels (2.10 And 2.11) may have the effect that CO_2 emissions no longer stand in the way of an increase in transport. More efficient engines and new fuels may make transport more efficient and presumably more cost-effective. Increased automation and new developments in IT (2.7) may help us to manage transport more efficiently and at greater speed. It is expected that these will help to avoid traffic jams and dangerous situations. Entire routes can be optimised automatically, taking into account both traffic and weather forecasts, potentially resulting in less risk of loss and damage in the transport of raw materials and e.g. perishable goods. The expectation is also that technology will improve stock management by measuring and monitoring consumption. This may actually render it unnecessary to keep large amounts of precious stock for a longer period.

Transport technology in the distant future

Experts think that autonomous transport will become big in the upcoming decades. It may play an important part in the delivery of bulk goods and smaller loads. In the US Amazon is already experimenting with drones for the delivery of goods at home, making just in time delivery even more accurate. New materials will probably

Overlaps with:

- Smart materials
- Renewable energy
- Biorefinery and biofuels
- Information technology & IT infrastructures
- 3D and 4D printing
- Robotics
- Weather modification
- Conservation technology

also improve vehicle performance, potentially reducing the required amount of energy, costs and delivery time.
In 2013, STT published the futures study Het vervoer van morgen begint vandaag (The transportation of tomorrow starts today) in which more examples of future transportation are given.

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2.20 Weather modification

Also known as: *weather control, climate engineering, geo-engineering*

What is it?

Weather modification or weather control is the conscious manipulation or modification of the environment in order to change the weather. The most common form of weather modification is cloud seeding to improve the chance of rain or snow, thus regulating the local water supply. Weather modification may also be used to avoid damaging weather conditions such as hail or hurricanes.

Weather modification today and in the near future

The most concrete example of weather modification is probably the hail gun that is used to prevent hail formation in showers. It fires grenades containing silver iodide crystals into the clouds. The water drops inside the cloud and will stick to the crystals. This way they are distributed, meaning that the individual ice crystals will be less big and cause less damage. The method is used in grape and orange cultivation. In fruit cultivation and viticulture the damage caused by frost is sometimes avoided by creating strong smoke development above the area, thus reducing the amount of heat radiation emitted by the soil. The local manipulation of the weather started in the 20th century. Climate engineering takes this concept even further. Climate engineering is the collective term for a number of technologies enabling the purposeful interference with the climate system. The most important technologies used to counter climate change and global warning are CO_2 disposal and the regulation of sunlight. CO_2 disposal is aimed at the greenhouse gases in the atmosphere. Sunlight regulation aims to compensate the effects of greenhouse gases by reducing the heat absorption by the soil.

Overlaps with:

- Sensor technology
- Bioinformatics
- Information technology & IT infrastructures
- Renewable energy
- Smart farming

Weather modification today and in the distant future

The manipulation of the climate is controversial, given the risks involved in large-scale interference with the climate system. In the 2013 report Klimaatengineering, hype of wanhoop (Climate Engineering: Hype or Despair) the Rathenau Institute stated that “there is no clear answer to the desirability of these techniques. It is, however, certain that the intervention should be on a large scale, international and long-term for it to have an effect. But in view of the large scale the consequences have to be clear in advance. Otherwise irreversible processes may occur.” The general public is not very keen on weather manipulation as a military weapon, meaning that there is insufficient support for this technology. If man is able to influence the weather at will in 35 years time the impact may be gigantic. Weather conditions could then be adapted in such a way as to allow the increased production of food. Depending on the scale of weather modification it will be possible to create the ideal climate for specific crops.

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the experts

The Dutch agro & food sector is leading in the world. This contributes greatly to employment, the Gross Domestic Product and landscape management. In the upcoming decades there will be an increased focus on innovation and sustainability, offering our country a wealth of opportunities to take a leading role. This requires strong trade & industry, high-quality knowledge institutes and an empathic government. The development of high-quality knowledge will, however, only take place if we keep producing. It is therefore vital that the primary sector – and also the suppliers and processors of our products – will be able to keep developing themselves.

Leo den Hartog, Director R&D Nutreco

The future of our food requires large investments in knowledge as well as financial investments. This applies to all technologies described in this book. That makes the future of our food more or less a matter of power. And it raises relevant questions. Who is going to do it? Who may be controlling the markets? Because food is such a close ally to us, these are political questions. We are talking about our own bodies and the environment in which we grow and keep our own food. It often also has to do with the way in which we earn a living. If this futures study tells us anything it is that much will change in the years ahead. Time is a factor and developments are quick. This is relevant at the national level, but also for businesses and local governments in the region. We will have to state our position, and that is what makes this survey so important.

Hans Peter Benschop,
Director Trendbureau Overijssel

3. visions of the future

A futures study calls for creativity and empathy. In the workshops stakeholders, experts and futurologists worked together to create a view of the future based on the technology survey, social developments and the archetypal scenarios (Chapter 4). The resulting images each show a possible future, highlighting a different aspect of the agro & food sector in 2050. These images have also formed the input for the stories about the future, of which four are found in this chapter. These stories are by no means predictions of the future, but rather aim to stimulate the debate (a strategic conversation). They were selected because they created – and will create – dissent. In other words, some people may or may not agree with (some of) the statements and ideas put forward in these stories. Some will see them as desirable or realistic, and others may not. These are stories to feed the debate.

3.1 – Made to Measure

Keywords: local, personalised food, food design, sensor technology, robotics, information technology & IT infrastructures, smart materials, 3D printing

Mare is just putting the last of the remaining mess in a drawer, when her smart-C tells her that Nigel and Pip are 100 metres from the front door.
"Jamie, get the bubbles from the fridge, will you?"
"Bubbles?" asks Jamie.
"Champagne," says Mare.
"Ok, champagne coming up."
Jamie disappears into the kitchen. Mare opens the door.
"Hi, welcome to my new home!"

Jamie is back with the champagne and watches the hugging and kissing from a distance. Not his thing. Neither is champagne, by the way. He does not even understand why people drink it at all. It has absolutely no nutritional value. Worse still, it is bad for your brain, your liver and what not.

The snacks that come with the drinks only make things worse. Although they have – very responsibly – been ordered at a local farm where animal welfare is a priority, this does not make them healthier. They contain too much fat and hardly any fibres. The micronutrients are also not exactly what Mare needs. If it had been up to Jamie they would have had a nice vegetable cocktail with different snacks. In the basement of the apartment building where Mare has come to live people are growing all sorts of exotic vegetables and fruits. It does not get more local and healthy than that.

Mare's health is not that good at the moment. Her biomarkers are far from ideal. Not that she feels ill, but considering the values from the past three months, the chance that she will have some problem with her intestines in the next six to eight weeks is more than 90 percent. This probability is based on the data of millions of people who all keep a tab on their values online. Although these values do not provide any insight into how and why an illness arises, the information is still very useful. You know what's in store for you and which measures can be taken to prevent trouble. In Mare's case this is simple: one extra hour of sleep every day will reduce her risk with 15 percent, a 45 minute walk will be good for an extra 25 percent, and more fibres will reduce it by another 30 percent.

Jamie has told Mare about these unfavourable figures and the measures she can take, but Mare laconically says they are just statistics. The last time Jamie brought it up Mare had replied with an irritated voice that statistics can also be nonsense. Her conclusion was simple: she just wants to enjoy life and not think about her health all day long. At the end of her speech she quipped at him that he would never understand the joy of eating designer food, which is more or less like wearing Jimmy Choo shoes. Indeed, Jamie does not understand.

Jamie then went online to find out more about human behaviour, finding that trying to force healthy choices on someone else usually backfires. Something to do with neuropsychology. So he relented and now trendy cheese and meat snacks from the latest Farmel collection are served at the party. Fortunately, however, Mare had asked him to prepare dinner so that he was able to add some elements to compensate the harmful effects of the snacks, without any difference in taste. Long live the foodprinter and nanotech!

Now that all people have been served with champagne, an animated conversation starts. That is, between Nigel and Mare. Pip is very quiet, tensely watching Jamie all the time.
"What is it, Pip?" Mare finally asks.
"Oh nothing," Pip tries to avoid conversation, but Nigel explains: "Pip was hacked last week and someone has read her biomarkers and then used her robobutler to serve her with food she is allergic to. She has been very ill for two days after that."
"Oh wow, how dreadful!" Mare is visibly shaken. "Do you know how this could happen?"
Sadly Pip shakes her head. "I haven't got a clue. It may have come from anywhere. Before I became ill I never cared about where I logged in to check my values. And I do remember that I have given my data in return for a discount or free product a few times."

Now it is Mare's turn to fall silent. This is exactly what she has done so often with her own values. She looks at Jamie and then at the unhealthy snacks on the table. Why had Jamie ordered these trendy snacks at her bidding without saying something about her health? Wasn't he programmed to always suggest a healthy alternative if people made a choice that was not healthy? Mare is beginning to feel uncomfortable.

3.2 – Farmhouse Control Room

Keywords: smart farming, robotics, information technology & IT infrastructures, sensor technology, bioinformatics, transport technology, conservation technology

"From this control room we can see all our fields," Harm Harmsen senior proudly tells his brother Dirk. "Our wheat in Germany, our potatoes in Friesland and our cows here in Gelderland. All data is available through the cloud 24/7 and anywhere, so we can always see what's happening on our smartwatch, smartphone or smart spectacles." In daily life Harmsen senior is a surgeon, but when the robots started doing part of his work in the operating room he suddenly had more time on his hands to devote to his hobby, farming. Not just some work on his vegetable patch, no, from his control room in the attic he manages several fields with crops.

In 2050 there are only few farms left that remind us of the farms from around the turn of the century. Fertiliser and water are scarce and human labour is expensive. Farms in the Netherlands now need much more land than before to remain profitable. So farmers searched abroad where there was more land, using sensors, robots, machine telematics, appliances measuring the biometry of their livestock real-time, GPS tracking and (self-learning) IT systems for the remote control of their business. Technology saves costs. Infrared-sensitive tractors can actually see which plants need fertiliser and drones map which part of the land needs water, and how much. Sensors monitor plant health and tell the owner if a fence is broken.

These days farmers are data analysts rather than people in overalls getting dirty. Many farms did not survive the transition to large IT-controlled enterprises, and were subsequently acquired by IT specialists. But there are also farmers such as Harmsen, managing his farm from home while still working as a surgeon.

"The good thing is that Harm junior can try out the new software he is developing with his fellow students in Agro Informatics. Look, it not only controls the sorting robots, but it also analyses and predicts consumer behaviour. Up till now these were always separate systems, and extremely expensive to purchase. But nowadays already in the sorting process the robots make the right distinction between pretty tomatoes and less pretty ones, while the computer checks where we will get the best prices this week. All these yuppies buying at the Rotterdam Marqt don't mind paying three times the real price for a nice-looking potato. The average customer will buy at the Superfoods Outletstore, because they don't care if a potato has a little dent or a different colour. This way we have less waste and still make more money!"

"And don't forget pa," junior adds, "in this way healthy food is also affordable for the lower incomes." "Yes, of course, that is a nice side effect, we like to help our fellow human beings," says Harm senior.

3.3 – Philanthropess

Keyword: protein transition

"Grandma, can I interview you for school?" Aisha looks at her grandmother with questioning eyes.
"Of course love, fire away. What do you want to talk about?"
"We are doing a project on food. Food today, food in the future and food from the old days."
"Ah well, you have come to the right person, I love food!"
"What did you use to eat?"
"In the old days? Actually it was not that different from today. But wait, there is a difference. I used to eat much more meat, and I mean real meat. Ham, steaks, chicken. Meat practically every day. Sometimes even a few times a day."
Aisha thinks of the animals at the children's farm where she likes to play, and says: "Yuck, animal meat!" And after a quick thought: "But grandma, were you that rich?"
Grandma smiles: "No dear, I have never been rich. But real meat was not as expensive as it is today. When I was your age there was no artificial meat, and for meat replacements you had to go to special shops, which they called reform shops. When I was pregnant with your mum I did consider for a short while to stop eating meat. At the time there were all sorts of rumours that meat was very bad for your health. People tampered a lot with meat in those days."
"Tampered?"
"Meat producers were not following regulations and added all sorts of things to it that were harmful."
Aisha frowns. "Then why didn't you stop eating meat?"
Grandma falls silent, seemingly embarrassed. "I did try for a while, but I liked meat too much. Only when meat was becoming too expensive, I started to buy meat replacements."
"But you would still prefer real meat?"
"Not anymore. I actually like a lot of these meat replacements and they are healthier as well. It is also a comforting thought not to be responsible for all these cows and pigs being bred in small pens."
"But aren't all these insects in meat replacements also bred practically on top of each other?"
"True, but I don't think the insects mind. They live the same way in the wild."
Aisha nods understandingly. It's just that she still doesn't understand why grandma didn't start eating insects much earlier. "You could buy insects in the old days as well, so why did you not start eating them earlier?"
Grandma smiles again. "To be honest the thought alone abhorred me, and not just me. For a long time insects were seen as second-rate food in the Netherlands. Perfect for feeding fish or cattle, but unfit for human consumption. That all changed with a rich philanthropist."
"A philanwhat?"

“Philanthropist, someone doing good things for other people.”
“So what did the good-thing-man do?”
“Not a man, a woman.”
“So a philanthropess.”
Grandma is amused. “Indeed, a philanthropess. Do you still want to know how she got us to eat insects?”
Aisha nods. She is dying to hear what happened.
“It was actually quite simple. She invested heaps of money in movies and games in which the stars ate food made of insects as if they did this every day of the week. If there were jetset parties, she made sure there were also insects on the menu. Pretty soon everybody who wanted to be somebody started eating insects as well. Within a very short time half of all the meat was replaced by products made from insects. It also helped that meat was becoming increasingly expensive, of course, although I am convinced that this woman played a decisive role here.”
“And if you think of the future, what do you think will be next?”
Grandma wrinkles her forehead. “Oh my, that is a big question dear, a really tough one. What do you think?”

3.4 – Where Did Civilisation Go?

Keywords: climate change, food scarcity, geopolitical relationships

"Isabella, no! Isabella, please open your eyes! Isabella!" Apu is holding the limp body of his wife in his arms. From the corner of his eyes he sees three boys jumping across his roof garden fence and disappear in the crowd. It's no use chasing them or notifying the police. He thinks he knows them; they are gang members. In this part of Amsterdam the streetgangs rule. Besides, Isabella needs him now. He pushes her body against his in despair. To think that they fled all the way from India to build a better life here, in safety. To escape from crimes and terrorism that disrupted their daily life. And here he is now, ten years later, his wife beaten unconscious for some lettuce.

No use moving on again either. It is difficult everywhere. Since 2025 there is no safe place anywhere. The frustrating part is that everybody saw it coming and nobody could or wanted to stop it. At the beginning of the 21st century the population growth was totally underestimated. Experts and world leaders seemed totally surprised when the mark hit 9 billion in 2030. Now it's 2050 and there are 11 billion people on the planet. All institutions have broken down.

Climate change has ruined much of the fertile soil. Technology did in the end not deliver as promised and countless plant and animal diseases did much to undermine the confidence in the authorities. Nation states are feeble entities nowadays and the UN, EU, WHO and WTO lost their influence ages ago. Multinationals rule these days, but many regions have only themselves to look for help due to insufficient legislation. Gated communities have become the norm. Since there is no global policy to protect the environment people everywhere are competing for water, energy, land and food.

For some time Europe was a safe haven thanks to its superior technology. The Netherlands was leading in the desalination of water, being one of the few remaining nations where the food was safe. Many migrants from Southern Europe – followed by people from all over the world – came to the Netherlands to find a place in one of the local gated communities, where there was still hope because they had water and vertical farms.

But the tsunami of migrants such as Apu and Isabella created disastrous scarcity. The Netherlands was unable to handle the inflow of migrants. Shortages and civil unrest ensued. And now your very own neighbours are stealing your food. Where did civilisation go?

the headlines in 2050

Healthiest tomato ever replaces full diet

EU countries order tracking & tracing for individual products

False predictions food production caused by hackers

Insects and seaweed now make up 60% of daily Dutch protein intake

Foodprinting at home: farmers just for luxury food

90% of airmiles flown on dung

New toilets recycle human waste to clean water and fuel

Largest seedbank in the world privatised

Drones delivering harvest to your doorstep

First cucumber harvest on Mars is a fact

Ritual meals to combat depression

CLA negotiations with robots are stuck

Last supermarket to become a museum

Biohackers and multinational join forces

4. uncertainty and complexity

4.1 Social developments

As described earlier, the agro & food sector is part of a complex system that transcends borders and disciplines. The potential impact of the technologies described in Chapter 2 is plagued by a large degree of uncertainty and complexity. That is why this chapter describes social – non-technological – developments that may influence the future of the Dutch agro & food sector. Again it should be stressed that these are not forecasts but only possibilities. Some developments are already more clearly visible than others, and in some cases it is still difficult to assess the impact on the agro & food sector. The diversity of possibilities is reflected by the scenarios describing a possible future world. These scenarios (and the visions presented in Chapter 3) are in fact extreme visions that do not predict the future; they are there to help you establish your own opinion. More scenarios and visions are of course possible. The developments and images sketched in this chapter are mend to help you to shape your ideas....

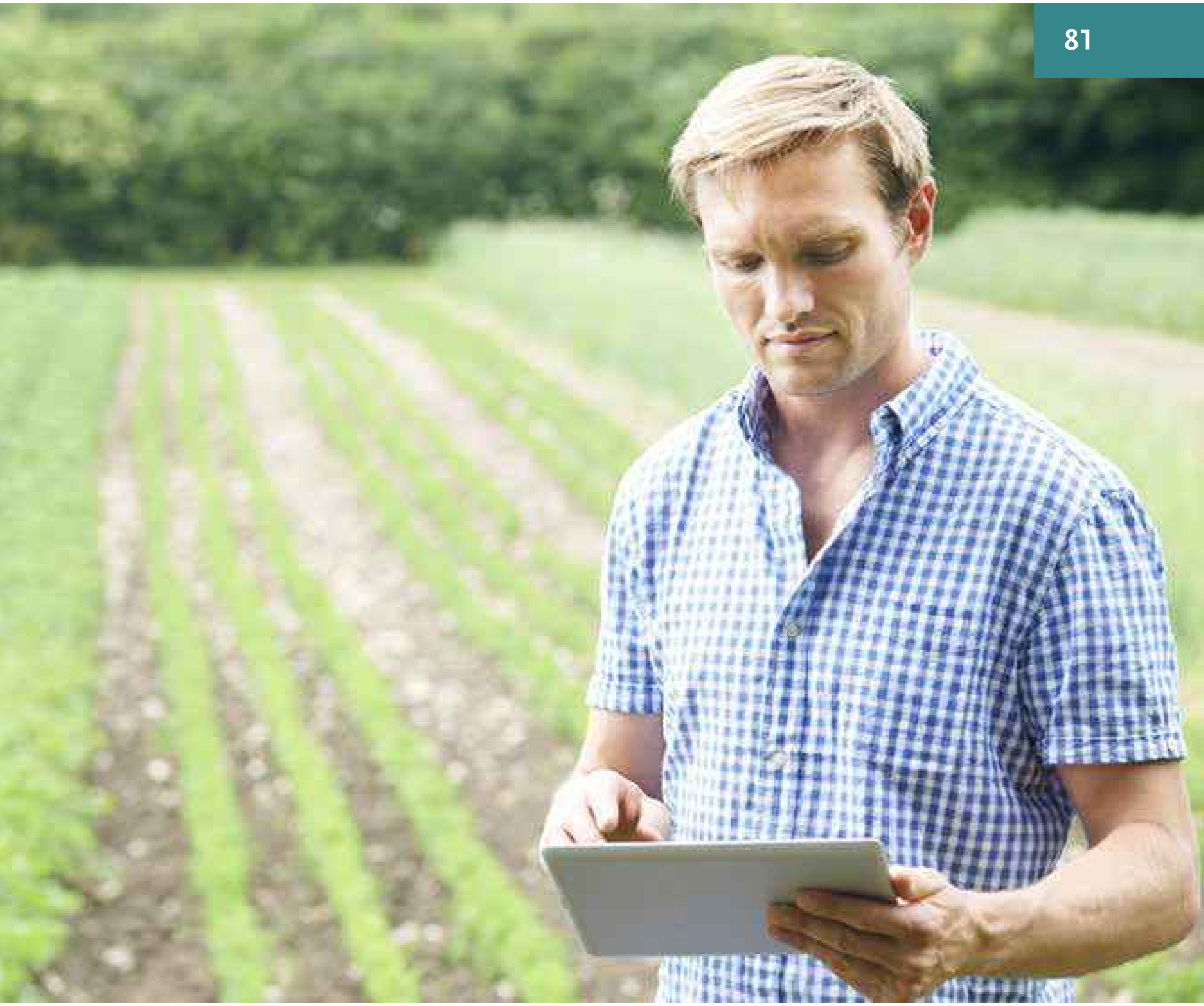
The social developments have been distributed across five categories:

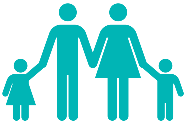
1. Demograpic developments
2. Economic developments
3. Sociocultural developments
4. Ecologic developments
5. Geopolitical developments

All of these developments will be discussed below.

For more information on these developments, see:

- Rijksbrede trendverkenning (in Dutch), Strategieberaad Rijksbreed, 2013
- Welvaart en Leefomgeving (in Dutch), PBL 2014
- Trends en autonome ontwikkelingen binnen en buiten de agri- en natuursector (in Dutch), LEI 2014
- STT Horizonscan 2050, STT 2014





Demographic developments

1. Population growth
2. Urbanisation
3. Depopulation
4. Shrinking labour force
5. Working less

Economic developments

6. Shift in political-economic centre of gravity
7. Internationalisation of trade
8. Changes in income growth and distribution
9. Volatile food prices
10. New forms of financing
11. Circular economy
12. Uncertain economic dynamics
13. Prosumers
14. Online shopping
15. The sharing economy
16. The knowledge economy

Sociocultural developments

17. More focus on production conditions
18. Increased importance of sustainability
19. Changing consumption patterns
20. Increased need for information and transparency
21. Link between health and food
22. Self-organisation and self-sufficiency

Ecological developments

23. The effects of climate change
24. Availability and distribution of raw materials
25. Ecological footprint

Geopolitical developments

26. The role of the EU
27. Distribution of power
28. Concentration of power

Demographic developments

1. Population growth

In the upcoming decades better healthcare, more education and a higher standard of living will lead to an increased population growth. The UN and OESO estimate that the global population will reach 8 billion in 2030 and 9 billion in 2050. It is expected that the growth will mostly take place in developing countries. In the developed countries the population will almost stay the same. In 2050 more than 60 percent of the global population will live in Africa and Asia. Life expectancy will have risen in 2050 to 83 in the developed countries and 72 in the developing countries. One fifth of the global population will be older than 60 by then; in Europe this will be one third [Terluin, Fontein et al. 2014]. The growth of the global population and the expected growth in income will increase the demand for food, agricultural land, water, energy and other (raw) materials.

2. Urbanisation

If the migration to cities continues on a global scale more people will be living in cities than ever before. It is believed that in 2050 80 percent of all people will be living in cities [Min. Binnenlandse Zaken en Koninkrijksrelaties, 2013]. Urbanisation influences diet and spending patterns of consumers. Cities offer opportunities for e.g. large supermarket chains and multinationals. Cities attract investments. Consumers in the city love comfort and saving time; that is why they eat more processed food [IAASTD, 2009]. The increased liberalisation of trade and the decrease in transport costs will boost the size and diversity of the food supply in cities. In order to feed the ever expanding cities, agriculture will shift to metropolitan agriculture: a system that combines agriculture and food production with living, making use of smart connections between parties, values, energy and the flow of raw materials. The producer of agricultural goods will co-own a supermarket and supply fresh products. The chain becomes shorter, and in combination with advanced agro knowledge this will lead to less transport (*planet*) and higher yields (*profit*) [IAASTD, 2009].

3. Depopulation

Most publications predict that the trend of urbanisation will continue, but there are also experts believing that the West will see depopulation. Virtual movements and meetings will become increasingly accepted and perhaps even replace physical movements and meetings. The developments in autonomous transport will make travel time less important in the selection of a residence [Scheerder et al., 2014]. If nearness and distance become less important, why live close to work or in a city? If urbanisation does not continue – or even decreases – and people live less close to each other, this may facilitate the implementation of a circular system (see 11): Circular economy).

4. Shrinking labour force

The Dutch labour force is both aging and shrinking. At present economic growth is slow and productivity has gone down, whereas the spending by the government – especially in healthcare – keeps rising. In the long term the Netherlands will experience a shortfall in sectors such as IT, care and technical occupations [PBL, 2013]. The massive aging may become a time bomb under the financial system of healthcare, pensions and taxes and disrupt social dynamics. We may see new social relationships between young people (working) and older generations (not working). A LEI publication from 2010 shows that c. 2,000 medium-sized and large companies led by directors aged 50 and older did not have a candidate to succeed him or her (yet) [LEI, 2010].

5. Working less

In spite of the shrinking labour force there are experts who believe that digitalisation and automation (robotics) will compensate for the shortfall in manpower, and that human labour will be outsourced to low-wage countries. The working week will become shorter: if robots and computers can take an increasing amount of work out of our hands we may be looking at a 20 hour working week, and have more time for personal development, culture and experiences [NTV, 2008; Scheerder et al., 2014].

Economic developments

6. Shift in political-economic centre of gravity

A global shift of power appears to be taking place in which the economic and political centre of gravity moves from the countries bordering the North Atlantic Ocean to those of the Pacific and the Indian Ocean, as well as South America. The new geopolitical relationships will weaken the economic, political and military power of the EU. The rising powers are demanding a place at the main platform of international politics. This was corroborated on 14 April 2011, when the BRICS countries (Brazil, Russia, India, China and South Africa) came to an agreement about a reshuffle of the UN Security Council. This shift of power will also bring about a shift in the value systems dominating the world. Capitalism appears to be popular, but the free market is under pressure. The Chinese model (state capitalism) is becoming more attractive to countries in South America and Africa. Western countries are also meddling with the free market by protectionist tendencies. The technological developments will lead to both opportunities and threats. On the one hand there is the risk of dangerous technology falling into the wrong hands (e.g. nuclear weapons) and new threats such as cyberwar. On the other hand technological developments will also provide access to new knowledge and new opportunities to counter threats. The same applies to (potential) scarcity of raw materials. It offers opportunities because it necessitates creative solutions, which will be good for multilateral collaboration. But if countries decide that *they* should obtain as many raw materials as possible this will lead to fierce competition [Min. Binnenlandse Zaken en Koninkrijksrelaties, 2013].

7. Internationalisation of trade

The internationalisation of trade increases and the demand for exotic products grows. An ever growing number of retailers offer a very wide range of products from all over the world, all year long [IAASTD, 2009]. The internationalisation leads to competition for Dutch products, but also to opportunities for export.

8. Changes in income growth and distribution

There is a rise of a new middle class in developing countries, but there appears to be also a wider gap between lower and higher incomes, worldwide but also within countries and regions. The higher average income in developing countries and rising economies will – in combination with urbanisation – lead to an increased demand for more expensive products such as fresh fruit and vegetables, dairy products and meat [IAASTD, 2009].

9. Volatile food prices

In the next decades internationalisation, population growth and trade policy will according to experts lead to an increasing volatility of world market prices. A growing population may result in a possible shortage of food and the matching rise of food prices. On the other hand, in various parts of the world there is economic growth and increased production in the agro & food sector, potentially leading to more competition, and including the corresponding fall of food prices [IAASTD, 2009].

10. New forms of financing

The financial crisis has made it much more difficult for entrepreneurs – also in the agro & food sector – to get a loan [Terluin, Fontein et al., 2014]. This has led to new initiatives in alternative financing, including financing through lease, renting, land banks or landscape funds, crowdfunding, sponsoring and subsidies [Stichting Dienst Landbouwkundig Onderzoek (DLO), 2010].

11. Circular economy

The circular economy is "an economic system that aims at the maximum reuse of raw materials and products, while minimising value destruction" [MVO Nederland, 2014]. The main characteristic of a circular economy is that raw materials and natural resources are not exhausted, but reused in an efficient way by companies, thus turning the production chain into a cycle. The model of the circular economy consists of two cycles: the first is a cycle of organic/biological material, in which the residual material flows back to nature after use, where it serves to support biological processes. In the second closed cycle anorganic/technical products are used again in the same or a different production process, but with as little loss of quality as possible. It is essential that the design, manufacture and use of the products is such that they are easy to refurbish, repair or dismantle at the end of their economic lifecycle [Rabobank, 2014]. There is a strong relationship between the rise of the circular concept and the biobased economy (see 2.11).

12. Uncertain economic dynamics

The financial crisis that started in 2007 made an end to a period of relatively stable economic growth with a low inflation from the mid-eighties onwards. Europe did not get a chance to recuperate, because the economic crisis turned into a debt crisis. The uncertainty about the survival of the eurozone is still keeping the economic prospects hostage. The measures taken by the Netherlands and other countries to sort out their government finances also do much to put pressure on economic growth. Apart from this the recovery of Dutch economic growth strongly depends on developments within the EU. The Netherlands is vulnerable to and dependent on developments abroad, which is due to the interwovenness of financial systems and the fact that Europe is by far our most important trade partner. The question is to what degree the present developments will have an impact on the Dutch growth potential in the long term. In the next decades the challenge will be to render our financial systems more resistant against shocks and increasing uncertainty [Min. Binnenlandse Zaken en Koninkrijksrelaties, 2013].

13. Prosumers

The term prosumer is used to denote consumers who contribute to the manufacturing process of the products they consume. Examples include Lego customers supplying new designs and households generating their own energy, even supplying it to the energy grid [Scheerder et al., 2014]. In the agro & food sector we see increased interest in producing food at home with new technologies such as 3D printing (see 2.1), vertical agriculture (see 2.17) and aquaculture (see 2.16).

14. Online shopping

Online shopping has been on the rise for some years now and the share of online shopping increases each year. In 2013 10.3 million people in the Netherlands between 12 and 75 bought something on the internet [CBS, 2014], whereas retailers experienced a drop in sales. Brokers and distributors also feel the pressure, because consumers want to be able to buy from the manufacturer directly, although online middlemen, such as the website thuisbezorgd.nl, now has a large share of the market. If consumers can buy a product from the manufacturer directly this may mean that manufacturers will see their market grow, as well as their profits, because there are no longer any middlemen.

15. The sharing economy

The sharing economy refers to the rise of sharing services and property. In this concept access to a product is more important than owning it [Scheerder et al., 2014]. Examples include new initiatives such as Greenwheels and 'neighbourhood cars', in which people lend their cars to others or subscribe to a system in which they rent a car only when they need it. People could also share tools with people from their neighbourhood, or cook extra and sell these meals at cost price only.

16 .The knowledge economy

Sectoral shifts have changed the nature of the Dutch economy. The service industry has become much more important. Business and financial services have shown a considerable growth in recent years. The economy is developing into a knowledge economy, in which the manufacture of goods and the supply of services lean on the highly developed cognitive and social skills of the labour force. The growth of the service industry and the knowledge economy are related. They are fed by two processes: the global labour distribution and the technological developments enabling it. The development into a knowledge economy and technological developments require a dynamic labour market, in where changes and shifts in the required competencies will be increasingly quicker. Technological innovations have the potential to radically change the character of a profession. Some occupations may disappear forever, and new ones will appear. The knowledge and service economy calls for different skills. Basic and professional skills will remain important, especially for young people entering the labour market. The importance of generic competencies will also increase (learning to learn, interpretation and analysis, organisation of knowledge processes). Advanced skills such as customer focus, the ability to collaborate and perseverance will be essential as well. Education will have to pay more attention to the rapidly changing conditions [Min. Binnenlandse Zaken en Koninkrijksrelaties, 2013].

Sociocultural developments

17. More focus on production conditions

The Netherlands and other European countries appear to show an increased interest in the production conditions in the agro and food sector, including animal welfare, dung management, the environment, water and crop diversity (biodiversity). Consumers place more value on the provenance of food. They may be prepared to pay more for a product in the future if the quality mark indicates that the authenticity and safety are guaranteed [IAASTD, 2009]. The experience is also becoming more important. Some consumer groups want to identify themselves with a product and the company supplying it.

18. Increased importance of sustainability

Consumers show an increased interest in sustainability. In the public debate the focus has shifted from primary companies to entire production chains. The certification of sustainability becomes more important, e.g. products mentioning their ecological footprint. This may lead to more conscious buying and an increased demand for local products. The trend of corporate social responsibility is closely connected with sustainability, by linking the three Ps of profit, people and planet [Terluin, Fontein et al. 2014].

19. Changing consumption patterns

If the urbanisation continues it is possible that people will take increasingly less time to buy or prepare food. This could lead to a growing demand for convenience products (ready-to-eat meals, etc.) and more money being made in food processing, albeit not by the primary supplyers [IAASTD, 2009]. There are also experts believing that higher food prices and more focus on comfort will boost a demand for food in the shape of pills, shakes and powders with the same nutritional value as real food, but much easier to take with you and eaten within seconds [The Newyorker, 2014].

20. Increased need for information and transparency

The population of the Netherlands is losing its trust in the existing institutions [Min. Binnenlandse Zaken en Koninkrijksrelaties, 2013]. Food scandals and the way these are treated in the media may undermine the consumers trust in food. The result may be an increased focus on food safety (including provenance, transparency about ingredients and method of preparation). This growing need for information also extends to other products. There is also the fear of an increased risk of diseases spreading due to the growing population density and international travel, potentially leading to more use of antibiotics for livestock and herbicides for crops [IAASTD, 2009; Terluin, Fontein et al. 2014].

21. Link between health and food

The insight into the effects of individual food components and ingredients on our health is growing. At the same time society shows more interest in health, healthy living and healthy food. Some experts believe that the rise of luxury diseases such as obesitas may lead to a whole new view on food and that people will no longer eat what they want, but will take into account the curative and preventive nature of food and the effects on their health [STT, *Aspirine op je brood*, 2013] (Aspirin on your sandwich), in which more can be read about how in future the combination of nutrition and medication might look.

22. Self-organisation and self-sufficiency

Citizens are increasingly able and willing to organise themselves instead of depending on institutions and arrangements, aided by social media. Civilian collectives working on durable energy and urban farming show that it is not always necessary to turn to the government for help. There are scenarios describing how nations, cities and regions may eventually strive to become autonomous and self-sufficient, including food supply [CPB, 2012].

Ecological developments

23. The effects of climate change

According to the International Panel on Climate Change (IPCC) global warming will also lead to a rising sea level, more extreme weather and loss of biodiversity. In 2050 c. 70 percent of the global population will live in areas where water will be scarce. The climate issue and the cost of energy have the potential to boost local production and distribution. Our flora and fauna – and their relationship with the ecosystems, duration of the growth season, pollination and semination – will suffer from climate change. The scenarios predict that the climate will be wetter, or dryer. Incidental shortages of water will occur more often. The fresh water supply will sometimes be available in abundance, and sometimes it will fall short. Salination will stimulate the cultivation of salt-loving crops in specific locations [LEI,2014].

24. Availability and distribution of raw materials

The growth of the global population as well as the economy will boost the demand for food, agricultural land, water, energy and other raw materials, meaning that they will remain costly. It is estimated that the global use of energy will rise with 80 percent till 2050, and that this will mostly be energy from fossil fuels (85 percent). The emission of CO_2 will be 70 percent higher, and the average temperature may rise as much as 2-4 degrees Celsius [Terluin, Fontein et al. 2014]. The question remains how we can use energy and water more efficiently in the agro & food production, leading to higher productivity [IAASTD, 2009].

25. Ecological footprint

The ecological footprint tells us how much biologically productive soil and water surface is used by a specific population to maintain its consumption level and process its waste. It is also possible to calculate the ecological footprint per product. Large retail chains are already mentioning this on the packaging. There is a growing interest in regional products, potentially resulting in less products being transported, or at least over smaller distances.

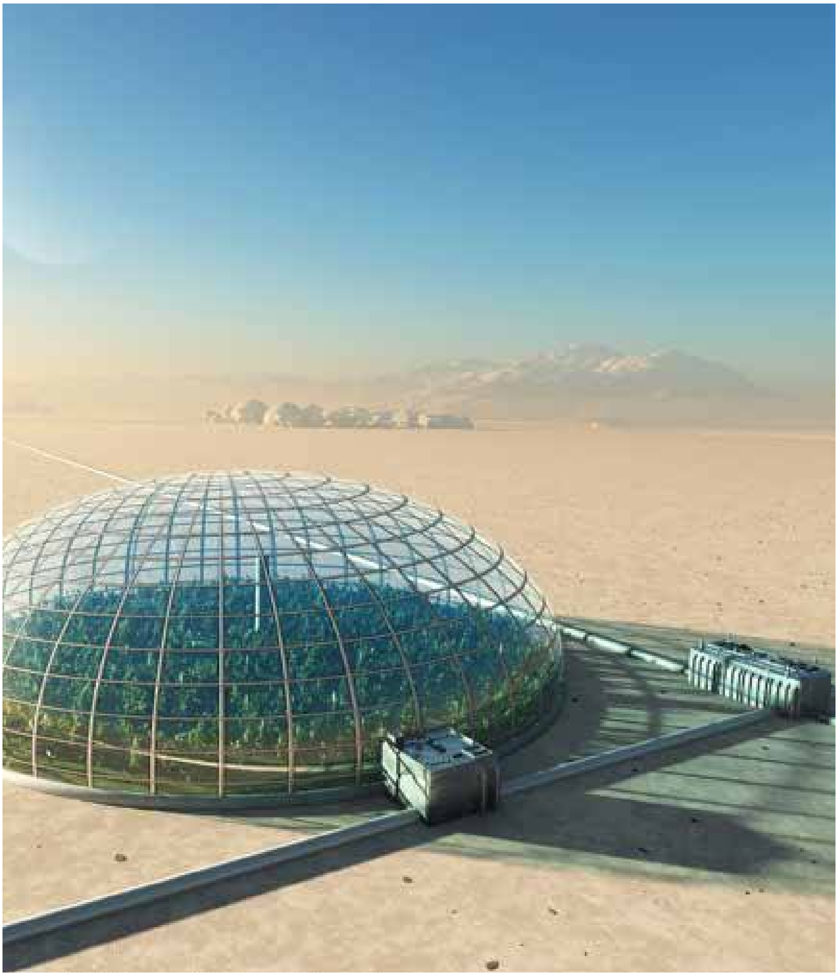
Geopolitical developments

26. The role of the EU

The question is whether we are heading towards a world in which Europe will become bigger (political union) or will be smaller (end of the euro). In a bigger Europe, what will be the role of the European Central Bank and the new institutions established to deal with the debt crisis? Already the euro and the measures leading up to a stable Economic and Monetary Union are creating tensions in and between member states. The further integration needed to create economic stability is increasingly often stumbling over the political boundaries within the member states. More often Europe is becoming the subject of a socioculturally defined polarisation and 'identity politics'. But what will be the consequences of a smaller Europe for the Netherlands? The economic and (geo)political position of the Netherlands in the world depends in part on developments in Europe. The Netherlands still leads in agriculture and horticulture, but keeping this position will require collaboration with the member states of the EU. Then there is the subsidiarity. Which policy domains will be developed as a European project in the years to come and which will be (again) part of the national policy [Min. Binnenlandse Zaken en Koninkrijksrelaties, 2013]?

27. Distribution of power

Visions of power being distributed abound in the existing surveys of the future. Many experts think that national governments will lose their voice. But in that case, who will rise to the surface? Some believe that megacities and city regions will become the new power blocks, such as the axis London-Tokyo-New York. Other potential candidates are the multinationals, the NGOs, the crowd or intelligent computers and robots. Still other experts say that power will lie with supranational organisations (such as the EU and the UN). It is impossible to say where things will go, but a new distribution of power will have an impact on the future policies on the food system at the international, the national and the regional level [Scheerder et al., 2014].



28. Concentration of power

Upscaling is the new buzzword, also in the agro and food sector. Small business are eaten by large ones to achieve advantages through sheer scale or to be able to control more than one link in the chain. It seems that increasing power is residing with less stakeholders in the chain. There are e.g. the few seed producers who are more or less controlling their part of the chain. The debate in the Netherlands is mostly about the power of retailers over the primary producers.

4.2 Scenarios of the future

Exactly how the technological and social developments described in this book will manifest themselves is unknown. Scenarios of the future may therefore help to initiate a structured debate on our future. They are not predictions, but simply sketch an image of possible futures. They aim to help people reflect on the future, taking into account the uncertainties involved.

Our study of the literature showed that there are many parties thinking about the future of the agro & food sector, both in and outside the Netherlands. Since there is little use in reinventing the wheel, it is important to include their findings in this publication. This chapter contains a summary of our findings as well as descriptions of six archetypal scenarios mentioned often in this literature. These are mentioned in the article '*A Review of Global Food Security Scenario and Assessment Studies: Results, Gaps and Research Priorities*' by Wageningen University (2012). These archetypal scenarios can also be found in the agro & food scenarios studied in this project.

These are the archetypal scenarios:

Scenario archetype / Drivers	Economic Optimism	Reformed Markets	Global sustain-able devel-opment	Regional competi-tion	Regional sustain-able devel-opment	Business-as-usual
Main objective	Economic growth	Various goals	Global sustain-ability	Security	Local sus-tainability	Not defined
Economic develop-ment	Very rapid	Rapid	Ranging from slow to rapid	Slow	Ranging from mid to rapid	Medium (globalisa-tion
Population growth	Low	Low	Low	High	Medium	Medium
Technology develop-ment	Rapid	Rapid	Ranging from mid to rapid	Slow	Ranging from slow to rapid	Medium
Trade	Globalisa-tion	Globalisa-tion	Globalisa-tion	Trade barriers	Trade arriers	Weak glo-balisation
Policies and institutions	Policies create open mar-ket	Policies reduce market failures	Strong global govern-ance	Strong national govern-ments	Local steer-ing: local actors	Mixed
Food security outcomes	Positive	Very posi-tive	Very positive	Very negative	?	Slightly positive

Figure 1. Archetypal scenarios from 'A Review of Global Food Security Scenario and Assessment Studies: Results, Gaps and Research Priorities' by Wageningen University (2012).

The scenarios are extreme images. The point is not whether they will become reality or not: for each scenario one may find arguments and pointers indicating whether they will materialise or not. There are pros and cons to be found for all scenarios. These scenarios are meant as mental exercises: what if this future becomes reality? What would this mean for …?

What strikes immediately is that Trend Scenario Business-as-usual is the least elaborated in the scenario studies, leaving the question whether all authors are discussing the same trend scenario. And do we agree on what are the most important and influential developments? What does it mean if the present developments will continue? In the discussion below the decision was made not to elaborate the scenario Business as usual, because it is not extreme enough and does not present an image of long-term changes.

Whether, how and when technologies will make a breakthrough or present opportunities for the Dutch agro & food sector strongly depends on the world – and society – in which we will be living in 2050. Scenarios will help us to take into account the various uncertain factors such as economic growth, faith in technology, the degree of international

cooperation and (the focus on) environmental issues.
By thinking about the developments in the various scenarios of the future we are able to sketch a more nuanced image of the future. The technological and social developments will be different in each scenario. In some scenarios they may even not play any part at all. The workshops and survey have produced *mindmaps* showing the interpretations of the scenarios that were either mentioned most often or were very striking.

This is a creative mental exercise without end. We do not intend to be lured into the trap of making predictions. We are dealing with snapshots and interpretations, not scientific research. If in ten years our insight has increased the mind maps will look very different. We only want to start a debate.

The examples mentioned in the box 'Some of the challenges for the Dutch agro & food sector in this scenario' are the results of the workshops and the study of the literature and aim to illustrate the debate sparked by the scenarios.

Scenario A. Economic optimism

Main characteristics:

- Main target: economic growth
- Very rapid economic growth
- Slow population growth
- Rapid technological development
- Worldwide trade/globalisation/free trade
- Policy and legislation create open markets

In this scenario ***market dynamics*** *play a central role. There is* ***free, global trade****. The* ***economy*** *is booming. People rely on technology, witnessing* ***rapid technological developments****.*

In this scenario people place their trust in technological development and the mechanisms of the market. New technologies see fast breakthroughs, meeting little resistance. Technological innovation will mainly take place in the private sector. The market mechanisms stand at the core, carrying the risk of economic and social inequality. Although there is free trade, the differences in income will determine the global access to technology. People have faith that technology will – in combination with the market mechanisms – be able to solve issues in the environment as well as social and economic inequality, in this case having a positive impact on global food security. As long as they show return on investment technological applications will continue to break through.

Some of the challenges for the Dutch agro & food sector in this scenario:

- *Which technologies will offer an economic advantage?*
- *What should we be selling: technology or the knowledge on technology?*
- *In view of the technological optimism many of the developments mentioned in Chapter 2 will play an important part, and there will be new technological developments we cannot even imagine.*

Mindmap scenario A

Economic optimism

Economic growth outweighs the interests of future generations

Hardly any **government regulation**; risk of monopolies

Business rules, especially **multinational business**

Weather modification in your own garden

Transport increases over longer distances

Bioinformatics owned by multinationals

Circular agriculture on economic grounds

Large interregional differences in income and **access to technology**

Ecosystems are artificially **regulated**

Urbanisation continues, **vertical farming** is crucial

Everbody and everthing always and everywhere connected through **Internet of Things**

Designing and printing your **own** food

3D and 4D printers in every household

Scenario B. Reformed markets

Main characteristics:

- Several simultaneous targets
- Rapid economic growth
- Slow population growth
- Rapid technological development
- Worldwide trade/globalisation/free trade
- Policy and legislation limit market failure

*As in scenario A this scenario sees **global free trade, rapid economic growth** and **rapid technological development**. The market mechanism is, however, managed through **policy** in areas **where the market fails,** e.g. social development, the combat of poverty and protection of the environment.*

This scenario also features great faith in market mechanisms and technological development, although the governments will correct market failure to protect the environment and correct economic and social inequality. The measures include financial and political boosts aimed at technologies that will help to solve specific issues (green technologies) or offer access to new technologies (development aid, knowledge transfer). These measures will – to a greater extent than in the previous scenario – have a positive impact on global food security. In this scenario the promise of food security, sustainability and equality will be decisive for the breakthrough of a specific technology or determine which application technology can(not) be used.

Some of the challenges for the Dutch agro & food sector in this scenario:

- *Which technologies will show a return on investment and also contribute to a better world?*
- *In which institutions (and at which levels) should the Netherlands be heard (vote, lobby)?*

Mindmap scenario B

Protection of biodiversity

Most important function of nature and landscape is food production

Strong EU

Protein and energy transitions continue

3D printing to limit transport

New exploitable stocks of fossil fuels

Reformed markets

Government checks and corrects the market

Society of networks

Worries about privacy and data security

Technology for food security and sustainability

conflicts about property of data

Designing and printing your own food

Scenario C. Global sustainable development

Main characteristics:

- Main target is global sustainability
- Rapid and slow economic growth equally possible
- Slow population growth
- Rapid and slow technological development equally possible
- Worlwide trade/globalisation/free trade
- Strong global governance

This scenario focuses on ***protection of the environment*** *and the* ***combat of inequality.*** *These targets are achieved through* ***global cooperation,*** *a* ***change in lifestyle*** *and* ***efficient technology aimed at sustainability.***

Sustainability, equality and justice are at the core of this scenario. Technology contributing to these targets will be adopted. In this scenario people will therefore be mainly looking for and investing in technologies contributing to a better world. There is global governance by strong international institutions and legislation.

Which technological developments or applications will suit this scenario?

Some of the challenges for the Dutch agro & food sector in this scenario:

- *Controversial technologies (ethical aspects) will break through less easily.*
- *Bureaucracy will slow down many changes and technological breakthroughs.*

Mindmap scenario C

Global sustainable development

- Technologies should specifically contribute to **sustainability**
- Plastics replaced by **bioplastics**
- Public interest comes first: **now and in the future**
- **Protein and energy transitions** accelerate
- Most energy comes from **biorefinery** and **biofuels**
- **Gene technology** only for crops and only to counter food shortages
- **Nature** has **rights**
- Food design mainly aimed at **health**
- **Automation** should not lead to **job losses**
- **Protection** of **consumer privacy**
- **Weather modification** to counter climate change
- **Smart materials** for more **safety** and **production efficiency**
- **Circular agriculture** is the norm
- Reduction of **ecological footprint**
- Power resides with **supranational organisations**

Scenario D. Regional competition

Main characteristics:

- Main target: security
- Slow economic growth
- Rapid population growth
- Slow technological development
- Trade barriers
- Strong national governments

*In this scenario the regions will **take over**. They will concentrate on their **own direct interests** and **regional identity**, which will cause interregional or intercultural **tension**. Regions include groups of countries, countries or regions within countries.*

Security is paramount and trust in technology is low in this scenario. The local food supply will e.g. be based on the sense of national or local independence and the environment will be in second place. In this scenario technologies that have not proved themselves or technologies promising fast and large-scale change will not be adopted. The regional fragmentation makes it impossible to exploit the advantages of scale (e.g. international or global).

Some of the challenges for the Dutch agro & food sector in this scenario:

- *At which scale do we want to operate? Western Europe or Netherlands-Germany?*
- *What will regional fragmentation do to our export?*
- *Technologies contributing to the sense of security and autonomy will have a better chance to succeed.*
- *Technologies have to work at the regional level, be recognisable and suit regional identity.*

Mindmap scenario D

Regions take care of themselves

Protectionism and mistrust

Transport and mobility decrease due to costs

Technology mainly aimes at monitoring and security

People monitor not only products but also each other

Government not trusted but laden with responsibility

Few technological breakthroughs

Food has to be healthy

Much power with cities and local governments

Government prescribes food design for health

Rise of the prosumer

Scarcity necessitates new conservation technologies

Drones and microrobots for surveillance and security

Sustainable energy for autonomy

IT developments hampered by privacy issues and cyber attacks

Scenario E. Regional sustainable development

Main characteristics:

- Main target: regional sustainability
- Medium to slow economic growth
- Medium growth population
- Rapid and slow technological development equally possible
- Trade barriers
- Local management, local actors

In this scenario ***solutions*** *are sought at the* ***regional level*** *for problems with the* ***environment*** *and* ***social inequality****. The key is a drastic* ***change of lifestyle*** *and* ***decentralisation of government****.*

Although as in the previous scenario the focus is on the own region, the drive in this scenario is not security but sustainability. Decisions arise from idealism rather than fear. This scenario is also about small scales, so that the advantage of large (international) scale is excluded.

Some of the challenges for the Dutch agro & food sector in this scenario:

- *At which scale do we want to operate? Western Europe or Netherlands-Germany?*
- *What will regional fragmentation do to our export?*
- *Technologies contributing to sustainability and regional autonomy or to the environment without exploiting it will fit well with this scenario.*

Mindmap scenario E

Self-organisation and **self-sufficiency** at the regional level

The ambition is **sustainability**

Bartering is the **norm**

While **robots** do the work, humans go for the **higher aim'**

We do things **together**

Rise of **sharing economy**

Regional sustainable development

Sustainability and **animal welfare**

Depopulation, with people living in **close-knit, self-sufficient communities**

Circular economy is the norm

Less **transport**

People **themselves** decide which information to share

Rather crowdfunding than a bank loan

Large interregional differences in **income** and **access to technology**

5. conclusions and recommendations

This futures study is based on multiple sources and studies. The STT Horizon Scan 2050 (technologies) and the STT survey on future food also provided valuable input. A large group of experts participated to supply input or to reflect on intermediate results (technology survey, social developments, visions of the future). The different backgrounds of these experts do justice to the diversity of stakeholders in the sector as well as to the various desires, interests and visions of the future.

This futures study focuses on the potential impact of technological developments on the (Dutch) agro & food sector in the long term, transcending domain boundaries and disciplines, and thus offering a view on uncertainties and room for strategic decisions. Uncertainties may lead to opportunities. By working with various methods of futures studies we have tried to do justice to the many uncertainties that are intrinsic to the future of a complex domain such as agro & food. Despite the focus on technological developments this futures study – by reflecting on the scenarios and by looking at developments in a context of non-technological trends – offers a wide view of the future of the agro & food sector as well as the food sector in general.

The discussion of technological developments is not limited to the question whether a technology will break through or not, or will play a role in the future. It seems preferable to sketch the possible perspectives of *how* the technology may be applied or play a role in the future. Clear answers to these questions are not possible, but the sketch of various perspectives of the future does in any case do justice to the complexity and uncertainty involved. It is of course possible to devise more images of the future apart from the archetypal scenarios and the visions of the future described in this futures study.

The response to the visions of the future in this study were not univocal, showing that there are many visions and opinions when it comes to the future of the agro & food sector. Visions of the future do not have to become reality, but serve to make people think. Are we future-ready and what do we do if a specific development becomes reality?

Strikingly so, many images of the future may become reality way before 2050, if we start from just the technological possibilities. However, if we also take into account the social, political and contextual developments 2050 suddenly seems far away, rendering it uncertain whether the technological developments in the upcoming decades will really have the large impact they promise to have. Something to think about on our way to a vision of the future. Reflecting on the future without restrictions helps us to understand how we can translate this – together with stakeholders from the government, trade & industry, academia and organisations from society – into action and opportunities for innovation. The wide range of participants in this research will help to create support for change.

Thinking about the distant future allows us to go out of the box and to create room for social creativity and empathy. The technology survey, the social developments, the archetypal scenarios and the visions of the future in this study aim to boost the debate on the Dutch agro & food sector, especially in the domains where technological developments may have an impact. Taken together, these instruments form an important inspiration for further study, policy studies, innovation and a public debate.

A next step of this futures study could be to translate the perspectives on the future, together with stakeholders – government, industry, science and organisations in society – into actions and innovation possibilities. Especially through the multitude of participating stakeholders a basis for change is being created.

5.1 Back to today

Apart from sketching possible futures this futures study also tells us what we can do *now* to be better prepared for the future. To be able to

adopt change and to grasp the opportunities that will occur.
As stated earlier the focus of this long-term futures study was on the potential impact of technological developments on the (Dutch) agro & food sector, leading to the following insights and recommendations:

- In the agro & food sector, many new technologies and innovations are about to be applied. There is much to be expected from crossovers with other technologies and sectors.
- The scale of the challenges to the food system is such that investments in (and research of) new technologies will be vital in the upcoming decades.
- Debate about the social integration of new technologies is also essential. Besides technological innovation, social innovation and acceptance of new technologies have to be taken into account, as well as possible consequences for the environment and our health.
- The effects of new technologies on human and environmental safety should be tested and applied on a small scale as part of a process of open and transparent decision-making, before we take the next step.
- The (technological) solution for a problem or challenge may generate new and unforeseen challenges. The sector will have to consider the rebound effects.
- Decisions about the adoption of new technologies should be taken in the context of potential risks, including the potential risk of *not* applying the new technology.
- The uncertainty about the impact of new technologies on the Dutch agro & food sector, the environment and society will never disappear. But society, policy makers, scientists and the agro & food sector should make decisions fast. A strategic debate is vital.
- It is unrealistic to suppose that a single new technology will solve all the issues facing us. The sector will have to shop in multiple domains of science and technology, and start an interactive debate with creative thinkers, legal experts and human factors specialists to do justice to the role of social innovation.
- The sector should not lose sight of the dark side (risks) of new technologies. Big data promises much, but also interferes with privacy. Good communication will be essential, because food quality alone is not enough. The welfare of animals and plants may become the dominant factor.

- The Netherlands is in a position to export agro & food technology. Our manufacturing industry and the sector are leading. The sector will therefore have to evaluate the opportunities and threats. Further research could e.g. do a SWOT for each technology. What do we have and what do we require?
- If technological developments become reality, how should the sector deal with this? This study focuses on the long term, but each scenario requires action in the short term.
- Food will be important, but natural resources and emissions will be too. It is not just the demand that will increase. So will the diversification of the demand. The role of technology will be crucial, but social acceptance will determine whether it will break through or not. The sector will need a strategy. The parties able to deal with change best will be the ones to survive.
- Circularity will be the norm. The Netherlands should become a Living Lab and start crossovers between sectors that have always been strong, such as agriculture and hightech, IT and human factors. Focus and write that masterplan. It is time to make choices.

The main question for the future is how society will deal with the new technological possibilities. Mankind – or more specific, the changing social relationships – will determine which technologies will surface and whether we want to trust them.

5.2 The next step

This publication is a snapshot, a starting point. The future will keep unfolding, requiring us to reflect on it and enter the debate. This publication allows us to generate more visions of the future, by thinking about them further or by using them the way they are now, while discussing them with the various target audiences. Each individual technology described in this book could easily be the subject of a new futures study, meaning that this publication is actually just a first sketch of a possible future, leaving us with numerous questions we will have to answer while thinking about the future. It is hoped that the debate on the basis of the instruments supplied by this book will continue, and that it will serve as input for long-term risk analyses and innovation issues as well as inspire to new research, policy studies, innovation and a public debate.

Appendix 1 – Participants

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Appendix 3 –
Recent STT publications

STT 83 Een oceaan vol mogelijkheden. Toekomstbeelden van de oceaan
Redactie: Stéphanie IJff, 2 Marie-Pauline van Voorst, 2016 (also available in English)

STT 82 Beter?! Technologie in de zorg
Redactie: Ellen Willemse, 2015 (ISBN 978 94 913 97 110)

STT 81 Van autonome robots tot zilte aardappels. Toekomstverkenning naar de invloed van technologische ontwikkelingenop de agri- & foodsector tot 2050
Redactie: Silke de Wilde, 2015 (ISBN: 978 94 913 9709 7)

STT 80 Horizonscan 2050, Anders kijken naar de toekomst
Jacintha Scheerder, Rene Hoogerwerf, Silke de Wilde , 2014
(ISBN 978 94 91397 07 3)

STT 79 Aspirine op je brood. Voeding en geneesmiddelen in de toekomst
Ellen Willemse, 2013 (ISBN 978 94 91397 05 9)

STT 78 Het vervoer van morgen begint vandaag. (Ver)voer tot nadenken en doen
Marie-Pauline van Voorst tot Voorst en Rene Hoogerwerf, 2013
(ISBN 978 94 91397 06 6)

STT 77 Samen Slimmer. Hoe de 'wisdom of crowds' onze samenleving zal veranderen
Redactie: Maurits Kreijveld (2012) (ISBN 978 94913970 2 8)

STT 76 Serious Gaming (serie van 3 publicaties).
Vergezichten op de mogelijkheden.
Play On: Serious Gaming voor de nieuwe generatie senioren.
Serious Games, Playful Business: Toekomstbeelden van de spelende organisatie.
Jacco van Uden, 2011 (ISBN 978 90 809613 0 2)

STT 75 Futures of Technology in Africa
Jasper Grosskurth, 2010 (ISBN 978 90 809613 7 1)

STT 74 Bargaining Norms – Arguing Standards
Edited by Judith Schueler, Andreas Fickers, Anique Hommels, 2008
(ISBN 978 90 809613 4 0)

STT 73 Brain Visions. How the Brain Sciences. Could Change the Way We Eat, Learn, Communicate and Judge
Edited by Ira van Keulen, 2008 (ISBN 978 90 809613 6 4)

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