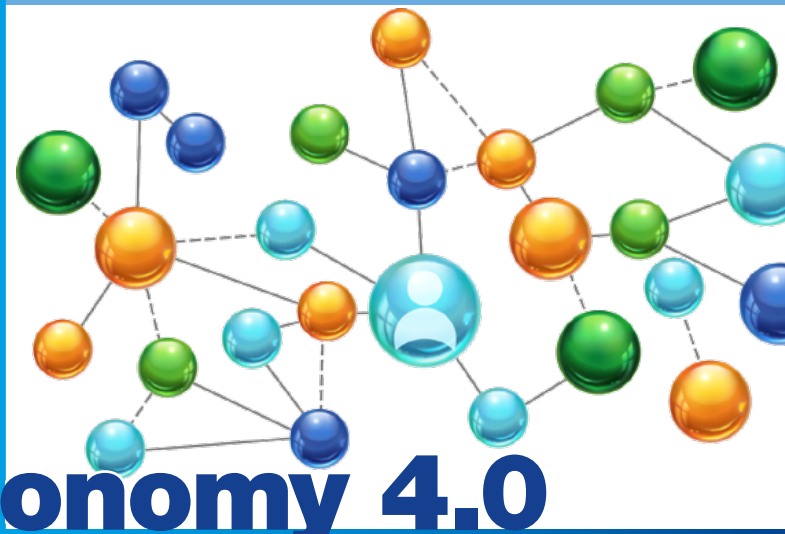

Food economy 4.0

VTT's vision of an era of smart consumer-centric food production

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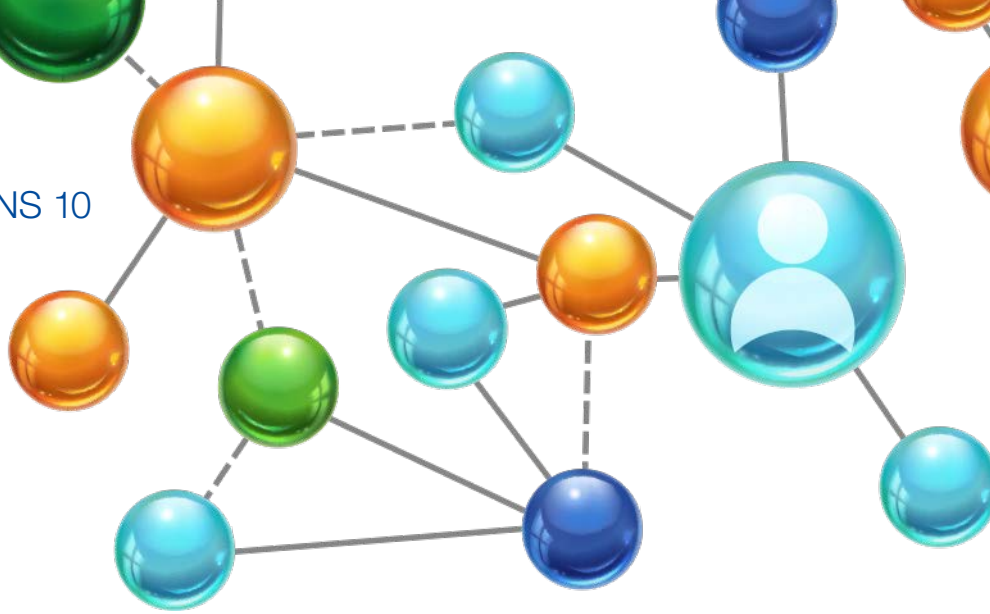
VTT VISIONS 10



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CONTENT

Preface

This roadmap has been created as part of the VTT Technical Research Centre of Finland Ltd's strategy process during 2016. The object was to create change paths for the food production and market, which are going through change, and to identify drivers, technologies, and new solutions based on them in order to develop business connected to the offering of food.

The roadmap is focused on the industrial production and distribution of food, as the development of primary production has already been examined previously; another roadmap on the effect of digitalisation on primary production was completed in 2016 as a joint project of the Natural Resources Institute Finland and VTT.

During the work, VTT experts in different fields were interviewed, and four workshops were arranged, with representatives from companies in the food sector also participating. We would like to offer our heartfelt thanks for the great input of all who participated in the work. Our special thanks go to Principal Scientist Nesli Sözer at VTT and Senior Business Development Specialist Mikko Utriainen for their participation in planning the roadmap process and their ideas. Thanks to Senior Scientist, Adj.Prof. Marjukka Kolehmainen for her input in the initial stages of the project, and to Research Scientist Pia Silventoinen for her great help during the finalisation stage.

We hope that the roadmap acts as a springboard for the development of Finnish food production in the era of the bio and smart economy, and that the Food Economy 4.0 described in this publication provides inspiration for innovation that breaks sectoral borders by developing new food and eating related services.

In Espoo and Tampere, December 2016

Kaisa Poutanen, Emilia Nordlund, Jaakko Paasi, Kaisa Vehmas and Maria Åkerman

1. Towards a new food economy

Eating is one of our basic needs. The first humans sustained themselves by gathering berries and other plants. Humans at some point began to hunt and trade their catch. This can be considered to be the earliest manifestation of a food economy.

When humans learned agriculture, it represented a real revolution in food production. The birth of agriculture can be considered to be the beginning of civilisation, and as agricultural skills developed, the human population began to grow rapidly.

The next revolution in food economy did not occur until the late 19th century, when food production started to become more centralised and developed into a form of industry engaged in mass production. At the same time, the food industry began taking steps towards internationalisation. Indeed, the major players today are global giants.

The mass production of food played a role in making it possible for the global population to multiply in the 20th century. At the same time, the standard of living increased. As the standard of living increased, the selection of food increased, but the share of the cost of living spent on food decreased, and is currently 14% in Europe and 12% in Finland[1].

The financial importance of food production is extremely high; in the EU, its gross value is EUR 1,089 billion and it employs 4.3 million people. In Finland, roughly one in ten employed persons (266,000 persons) work within the food chain, and the food industry is the largest producer

Key figures of food production (2014-2015)

	Finland	EU
Production value	EUR 13.3B	EUR 1,089B
Direct jobs	33,000	4.3 million
Jobs in the entire food chain	266,000	44 million

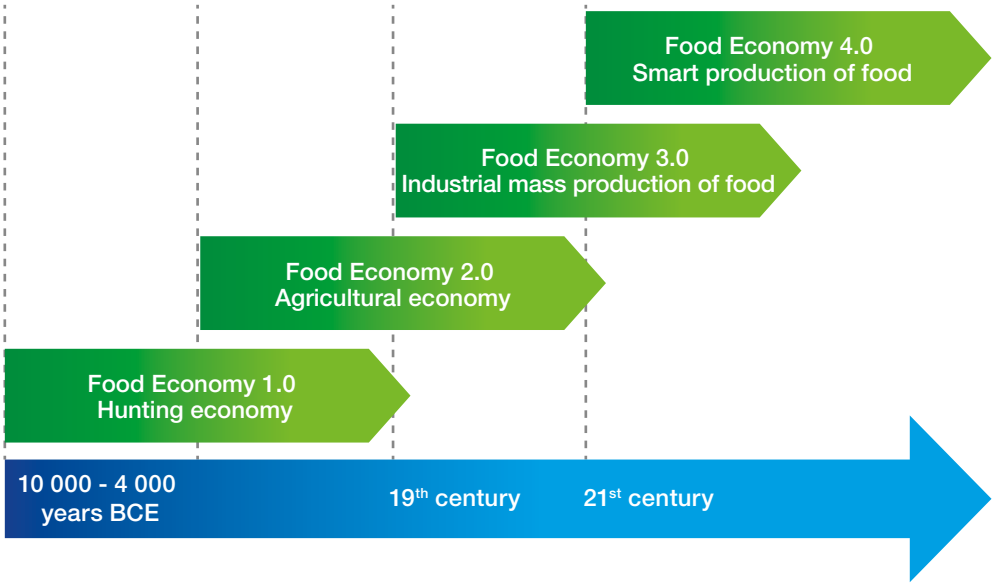

Figure 1. Developmental stages of food production.

of consumer goods. The roughly 500 million consumers in Europe spend around one trillion euros on food and drink every year [1].

Sufficiency of food is a global cause for concern. Still, food is not just a source of energy. As an element of other living habits, eating behaviour is very important for one's health. Living habits are estimated to be linked to around 40% of premature deaths, and 38 million people die from related chronic illnesses each year [2].

'You are what you eat' does not, however, just mean how you feel, but also what are your opportunities: what are your thoughts on environmental protection, the wellbeing of the workforce and production animals, or trade policies – or yourself. We live in times where consumption and living habits become individualised, and food has become an important means of self-actualisation.

The manufacturing industry is transitioning from the era of mass production into the era of smart production, where physical production merges with the opportunities created by digitalisation into cyber-physical systems [3]. Ensuring the sufficiency of food combined with the individual needs of people is doing the same in the food industry.

The increase in vegetarian food, individual selection, consumer-oriented business, online stores, new service models, and new kinds of local production utilising technology are examples of the changes taking place. We are on the cusp of a new revolution in the food economy.

The revolutions described above can be thought of as different evolutionary stages of the food economy. Each of them has, in turn, represented the prevalent way of acting in society (Figure 1). However, as the next stage has risen, the previous one has remained as a parallel way of acting; as a consequence, all these forms of food economy can still be seen.

The roadmap presented in this publication describes change paths towards a new 21st century consumer-centric and sustainable food economy, where new food production and distribution methods will rise alongside traditional value chains. An interdisciplinary group of VTT research scientists and experts from businesses in the food sector have participated in the creation of the roadmap.

2. A centralised food chain that wastes resources

Ensuring food production while utilising natural resources in a sustainable manner is a global challenge. At the same time, it is also an opportunity for new business. The efficiency of food production is affected by the choices of raw materials and production methods, the waste generated during processing and distribution, and the use of resources.

The industrial production of food and the retail sector have become heavily centralised over the last decades. The centralisation of the retail sector has increased the power of purchasing managers in food production (Figure 2). The chain of actors in food production is shaped like an hourglass, as the food production actors and the large consumer base are connected by only a small number of purchasers, wholesalers, and distributors.

As already mentioned, a large part of food production is in the hands of only a few large manufacturers and brand owners as a result of globalisation. In 2015, the combined turnover of the ten internationally largest food companies was USD 455 billion [4]. Totally the large companies have a 50,4% share of the turnover of the food companies [5].

The strong centralisation of the production and distribution of food has raised concerns of and a need for the transparency of the chain. Food is bought from increasingly larger stores; in Finland, for example, 64% of purchases in 2015 were made in super and hypermarkets, while their share was only 39% twenty years ago [6].

Figure 2. The funnel structure is typical to the food chain; the agricultural and vegetable production chain for seven European countries is given as an example. Figure modified from the following source [8].

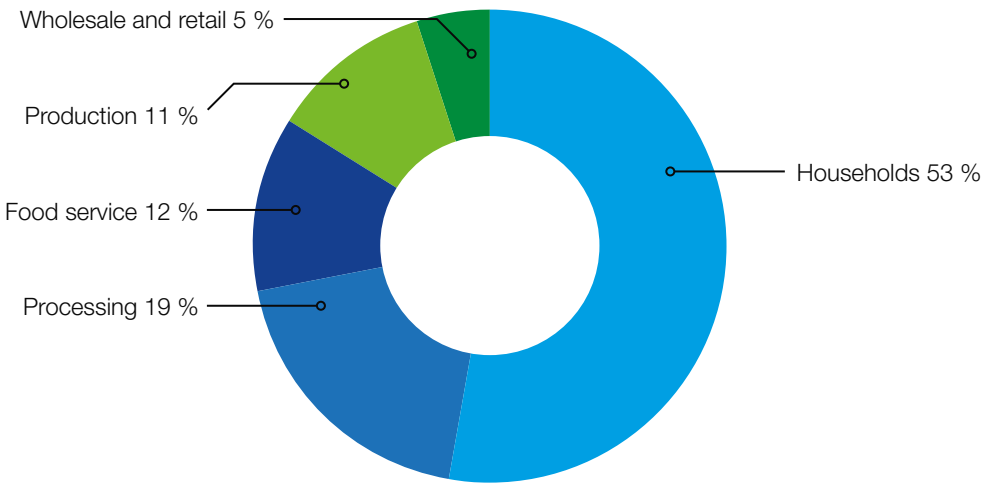

Figure 3. A cake depicting the origins of waste in the EU. Figure modified from the following source [9].

While the average number of products in supermarkets is almost 40,000 [7], and the consumer wants to buy only around 30 of them at one time, the choices may be difficult. This leads to change pressures in consumer communications, store design and distribution methods.

173 kg of waste per capita is generated each year.

Centralised production, long transport distances and storage also cause a lot of spoilage at different stages in the food chain. The annual amount of food spoilage in the EU has been estimated at 88 million tonnes, and the related costs are EUR 143 billion [9]. Slightly more than half of the spoilage takes place in households, and a fifth in processing (Figure 3). This means 173 kg of waste per capita each year.

In 2016, a survey of the food industry's waste and side streams was carried out in Finland. The annual total amount of waste was estimated at around 390,000 tonnes. The largest quantities of waste comprised cell sap, soil, animal by products, sludge, mash and vegetable skins [10].

More economical and efficient use of raw materials in food production is an important step in the transition towards a sustainable bioeconomy. In particular, the utilisation of side streams generated in the food chain as food and other valuable fractions is an essential part of a more sustainable food chain and circular economy.

In addition to cost savings, reducing spoilage is also ecologically important, as food production consumes significant amounts of renewable natural resources. Globally, the current water consumption of agriculture exceeds the supply[11]; agriculture also generates 10% of all greenhouse gas emissions [12,13].

The Earth Overshoot Day, or the day on which humanity is calculated to have used up the renewable natural resources regenerated during the year, comes earlier and earlier each year. In 2016, the worldwide Earth Overshoot Day was in August, and as early as in April in Finland [14].

In 2016, the worldwide Earth Overshoot Day was in August, and as early as in April in Finland.

3. Change drivers and megatrends in the food chain

The operating environment of food production is currently undergoing a transition, which will open new earning possibilities to the actors in the field, and force food production to reinvent itself. The most important megatrends and drivers affecting the change in the food chain are presented in Figure 4.

The drivers constantly reinforced by technological development are globalisation, digitalisation and urbanisation. Drivers related to Earth's carrying capacity and the environmental crisis include climate change and population growth. Malnutrition, lifestyle diseases and the ageing population are globally major challenges. On the other hand, globalisation and digitalisation also act as enablers of change.

Food production is also subject to more specific trends that alter how people feel about the importance of food in their everyday life (Figure 4) [15]. Consumer segmentation and the growth of wellbeing differences increase the demand for individual solutions fostering health and wellbeing. Food choices are also steered by the consumers' need for enjoyment and ease in everyday life.

Instead of mere nutrition, food can be seen in a broader sense as a wellbeing service. Consumers are also increasingly interested in sustainably and ethically produced food. With global drivers, the importance of production reliability and food safety will increase, and their communication in the consumer interface will be emphasised.

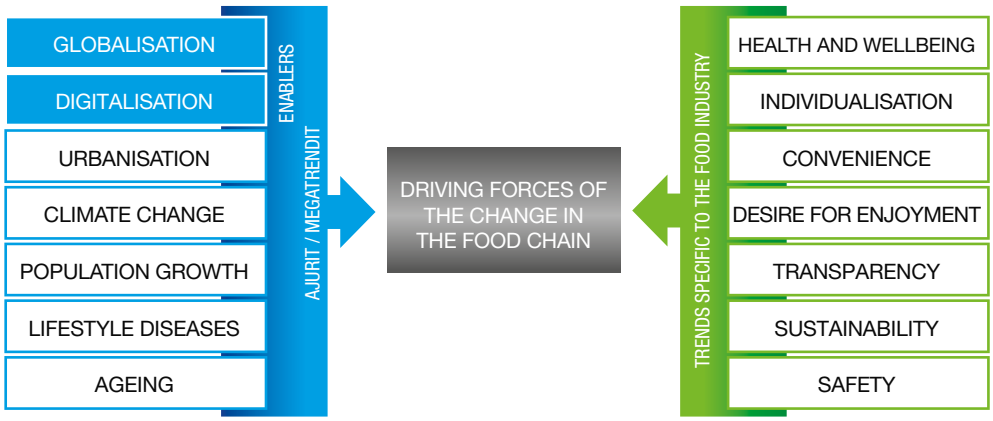

Figure 4. The general megatrends and drivers as well as food-chain-specific trends influence the food chain.

GLOBALISATION

In globalisation, the economies and cultures of different countries become increasingly intertwined with each other through the flows of goods and telecommunications. As a result, economic, cultural, and political influences as well as information spread around the world increasingly easily.

The capacity of international telecommunications has grown 45-fold since 2005.

Today, globalisation's most significant growth factor is considered to be the flow and increase of information. According to estimates, the share of information flow in the annual growth in gross world product is USD 2.8 trillion (2014). According to a recent report, the capacity of international telecommunications has grown 45-fold since 2005. [16]

The share of online shopping is also increasing: today, around 12% of goods worldwide are delivered via an online store. Improved telecommunications and logistics connections have opened the global markets to small actors, too. Up to 86% of technology start-ups involve international cooperation [16].

In the food chain, globalisation is evidenced by conglomerations of companies, which increases the importance of powerful actors as the rule-makers of food production. Multinational food and agricultural companies are currently dominating the global food sector.

500 companies control 70% of the range of food products and, on the other hand, just ten companies with the largest turnover control almost all goods available in the stores [17].

DIGITALISATION

Digitalisation is a strong force propelling change onwards, enabling the roles of both globalisation and the consumer to become larger in the food chain. The industrial Internet is an important part of digital change in both Finland and abroad. By connecting real-world devices and machines with networks, the internet and each other, it enables the development of new kinds of intelligent products and services.

According to one estimate, the value of new business generated through networking will be $15 trillion by 2030, when the existing fixed assets are utilised better, working becomes even more efficient, supply chains and logistics become more efficient, and new consumer services and innovations become more prevalent [18].

Finland is in the best position in the world to benefit from digitalisation.

We no longer talk about the one-time delivery of products and services to the customer; instead, the topic is solutions that are in constant operation and optimised for the customer's real-time environment. All objects and things have a digital identifier that allows the optimisation of their use, properties and added value for the consumers [19].

The new services are based on the effective utilisation of data from different sources. In Europe, for example, the Big Data sector grows 40% annually, seven times faster than the information technology market [20].

Industrial Internet provides an opportunity for the creation of new markets, new competition, and growth alongside, on top of and between the current business models. This requires actors to make strategic and operational choices and extensive cooperation between companies.

Companies can offer their customers services providing added value by integrating different technologies and service platforms and by jointly developing new kinds of services both locally and globally [19]. Digitalisation also enables closer communications with the customers; future services will be developed together with customers to meet their requirements [21].

According to the Digibarometer, Finland is right now in the best position in the world to benefit from digitalisation. Finland is ranked fifth in the utilisation of digitalisation and third in terms of the impacts. In Finland, the most digitalised sector is retail business targeted at the consumer market, while the food industry is in the fifth place. Although Finland is among the top countries in comparisons, the possibilities for digitalisation remain mostly unutilised. [22]

URBANISATION

Urbanisation refers to the phenomenon currently evident around the world where the share of population living in cities of the total population is growing. Urbanisation is primarily caused by the migration of the population from the countryside to growth centres or major cities, usually seeking a higher standard of living.

Today, over half of the world's population live in cities, and this share has been predicted to increase to 66% by 2050. The share of population living in Western cities is already very high, 73% in Europe and up to 82% in North America [23]. In Finland, the level of urbanisation is currently around 84% [24].

Over half of the world's population live in cities, in Finland around 84%.

Urbanisation creates challenges for society with regard to both the growing, dense cities, and to the countryside that is becoming increasingly scarcely populated, particularly in poorer countries. Careful planning of the infrastructure is required so that the functioning of the growing cities can be guaranteed, ghettoization avoided, and the destruction of the surrounding nature prevented.

Urbanisation also challenges modern food production, because huge cultivated areas are required to feed the population of major cities, and the cultivated area can no longer be enlarged to any greater degree. On the other hand, busy lifestyles and modern dietary habits have the effect that healthy snacks and the consideration of health trends are required of the food production sector.

EARTH'S CARRYING CAPACITY: CLIMATE CHANGE AND POPULATION GROWTH

The acute environmental crisis is one of the main drivers in the food chain. Climate change and the limits of nature's carrying capacity, combined with an increasing population, force the development of sustainable food production solutions.

Global warming is largely caused by human actions in energy-consuming and emission-generating sectors. Intensive agriculture, and cattle farming in particular, also has a significant effect on climate change.

In Europe and the United States, agriculture and cattle farming generate around 10% of all greenhouse gas emissions annually, and in the rest of the world, the share is expected to increase far above that in the coming years [12,13].

The increase in emissions is particularly notable in developing countries, where methane emissions from agriculture, for example, are expected to increase by up to 60% compared to the current situation by the year 2030. Today, methane emissions from cattle farming make up 40% of the greenhouse gas emissions from agriculture.

Cattle farming also generates around half of the nitrous oxide emissions of human origin. In order to curb climate change through carbon sinks and to prevent biodiversity loss vast forest areas are protected; on the other hand, this creates pressures for the food sector seeking new arable land and struggling with population growth. Then again, the effects of climate change have repercussions for food production,

when, for example, extreme weather conditions become more common and changes in climate temperatures affect cultivated areas [25].

In 2015, Earth's population was 7.3 billion, and it has been predicted that the population will grow to 9.7 billion by 2050 and further to 11.2 billion by 2100. As a rough estimate, Earth's population will double during this century.

Regionally, population growth is currently fastest in Africa, as according to predictions, over half of the population growth between 2015 and 2050 is caused by population growth there. The growth estimate from 1950 to 2100 is from 2.5 billion to 11 billion [26].

The global need for food will increase 60% by 2050.

More sustainable food production methods are essential also to be able to produce high-quality food for the increasing population in an environmentally friendly manner but in comprehensive volumes. According to predictions, the need for food in 2050 will be 60% more than today's need [27]. However, this is not possible with the current meat production and field cultivation technology.

Firstly, cattle farming currently produces food with a poor efficiency, while being a major contributing factor to climate change [28–30]. In order to have a concrete understanding of the environmental impact of meat production, it has been calculated that the reduction of meat consumption by 50% would have a larger effect than the reduction of food waste [31].

At the same time, estimates indicate that the cultivated area can be increased by only 2% from the current area, which means that merely increasing agriculture and plant production to directly produce human food is not a given. Agriculture also faces the challenge of environmental impacts caused by nutrient leaks, particularly into water systems.

According to an estimate by the Finnish Environment Institute (2015), the share of agriculture of the phosphorus load in water systems is already around 70% and somewhat below 60% of the nitrogen emissions. On the other hand, valuable nutrients are lost throughout the entire food chain: in primary production, refining, consumption and, finally, in municipal waste water [32].

HEALTH AND WELLBEING OF THE POPULATION: LIFESTYLE DISEASES AND AGEING

In today's world, health and wellbeing can be seen as multidimensional challenges, the resolving of which are essentially impacted by differences in living standards and wealth. In some parts of the world, health problems are caused by poverty, and the lack of means causes deficiencies in both health services and nutrient supply. In wealthy countries, however, the

basic requirements for health and wellbeing can be achieved more readily, but poor lifestyles in a plentiful everyday life cause health problems.

As over half of the illnesses in the world can be linked to incorrect – either too high or too low – supply of nutrients, the food sector has a tremendous impact on health and wellbeing. Up to 30% of the world's population suffers from some degree of incorrect nutrition [33].

Malnutrition is the largest problem in developing countries, where society's functional structures and food production are not enough to provide the food resources needed by the population. One ninth of the world's population is malnourished, and over half of the world's annual child deaths are linked in some way to a poor nutritional situation [33,34].

At the same time, 38 million people die annually from lifestyle diseases, the majority of whom are in low and middle income level countries. Lifestyle diseases are considered to include cardiovascular diseases, cancer, chronic respiratory diseases, diabetes, and mental disorders. Risk factors expediting these diseases include unhealthy lifestyles, such as poor dietary habits, lack of exercise, smoking and excess consumption of alcohol.

30% of the world's population suffers from some degree of incorrect nutrition.

According to the World Economic Forum, lifestyle diseases can be considered to be one of the greatest threats to wellbeing [2]; furthermore, these diseases cause significant costs to society. In 2010, for example, diabetes caused worldwide costs of almost EUR 470 billion, and according to the predictions, these costs will increase to at least EUR 700 billion by 2030 [35].

In Finland, research has shown that lifestyle changes can help avoid the onset of diabetes in up to 20% of people in risk groups, thus allowing annual cost savings exceeding half a billion euros [2]. Since changes in dietary habits play an important role in preventing lifestyle diseases, the food sector can have a decisive effect on the onset of these diseases through their offerings.

In addition to health challenges related to lifestyle, population ageing – the increase of the

share of elderly people compared to the entire population – is a globally observable phenomenon caused by both decreasing birth rates and constantly increasing life expectancies.

The share of people aged over 60 years of the world population grows by over 3% per year, and it has been predicted that by 2050, the share of people over aged 60 years in the entire world with the exception of Africa will rise to almost 25% of the population. An ageing population creates challenges for societal structures, as health care requires more resources while the share of people who are of working age decreases significantly. According to predictions, in 2050 there will be only two citizens of a working age in the 27 European countries for each citizen over 65 years of age [26].

The challenges posed by ageing must be taken into consideration also in food production, as nutrition has been shown to have a clear effect on the onset of age-related diseases. On the other hand, the food industry must also take into consideration the specific nutritional recommendations for older people, as they differ from the recommendations defined for those of a working age.

As a consequence of the changing age structures and increases in the standard of living, around 75% of all deaths of people aged over 65 years in industrialised countries today are linked to cardiovascular diseases or cancer, while the corresponding share was only 35% as recently as in the beginning of the last century [36].

4. Vision: Food Economy 4.0

In the future food production, raw materials will be utilised more efficiently, and some of them will be new alternatives to the current ones

Consumer activity in food choices will increasingly be empowered by digitalisation, and easiness will be a key factor.

Individual solutions and services reinforce the role of food in demonstrating values and supporting health and vitality.

Food Economy 4.0 is an ecosystem that connects traditional and new actors with end users in new ways.

Biomaterials know-how, modular processes, robotics and digital technologies will create new international business opportunities, but they will also improve the competitiveness of domestic food production.

As mentioned at the beginning of this publication, the fourth revolution in food production is currently under way. The forces of change affecting food production are threefold: 1) Ensuring the sufficiency of Earth's limited resources and food; 2) The increasingly different needs of consumers, though still sharing the need for healthy, easy, safe and pleasurable eating; and 3) The impacts of developing technologies such as telecommunications and ambient intelligence on the living environment and food production, and the distribution and buying of food.

We coined the term Food Economy 4.0 to describe the food system of bio, circular and digital economies, and the elements related to it are visualised in Figure 5. With the help of the industrial Internet, we are moving towards more efficient processes and from mass production towards a more consumer-centric and personalised production of food and its information content. In addition, the retail sector and food services are undergoing a change. Combine these with new raw materials and food production technologies, and we have a foundation for the birth of new ecosystems. Based on the identified change drivers, this roadmap has defined three paths towards a new food economy and its business ecosystems.

Figure 5. Elements of Food Economy 4.0.

5. Three roadmaps to a new food economy

According to the Food Economy 4.0 vision, the food chain is becoming a networked, consumer-centric operating environment. This renovation is propelled by digitalisation, new production and distribution technologies, and new kinds of service business models.

The transition is a great opportunity for creating new business, but it is also a threat to those actors who remain attached to old ways, operating models, and structures, and fail to react to the new competitive environment in time. Utilising the transition to promote more competitive and sustainable food production requires an open-minded change in the modes of thinking and methods of acting.

In order to further the change, we have worked in cooperation with a multidisciplinary team of experts from VTT and representatives from companies in the food sector to identify three change paths promoting the transition:

1. From mass production to personalised solutions
2. From centralised to agile manufacturing and delivery
3. From horizontal to vertical food production.

The visions, enablers of change, and the advancements required for the change have been identified and defined for each change path. The change has also been illustrated by means of concrete stories.

CHANGE PATH 1:
From mass production to personalised solutions

The individualisation of consumers and the resulting segmentation into increasingly small groups with regard to their needs, values and expectations is a significant trend steering the food chain. Consumers increasingly want healthy, safe, easy, local, and responsibly and sustainably produced food [15].

Personal health and wellbeing, in particular, are strong change drivers for the food industry. This challenges the companies to modify their product portfolios towards products with higher nutritional quality and health benefits.

Product development is made challenging by the fact that consumers value different factors in different ways, and increasingly want products that are precisely suited to them, personalised according to their profiles. Although the amount of information is constantly increasing, emotional decisions often guide consumer choices.

While in the traditional food chain, the consumer has been the last link who acquires food from the selection available in a retail store or a restaurant, in Food Economy 4.0 the consumer is at the centre of the food production and able to choose food that supports his or her own wellbeing and ethical values and is individually customised.

In the new food economy, individual solutions also include functions and services making everyday life easier, allowing the consumers to maintain and promote their mental and physical wellbeing through eating and food services.

Based on these views, we have brought up two themes in Change path 1: *"**From mass production to individual solutions**": Food products and services customised according to individual needs increase wellbeing and An intelligent grocery store and home reduce spoilage and make the consumer's everyday life easier* (Figure 6).

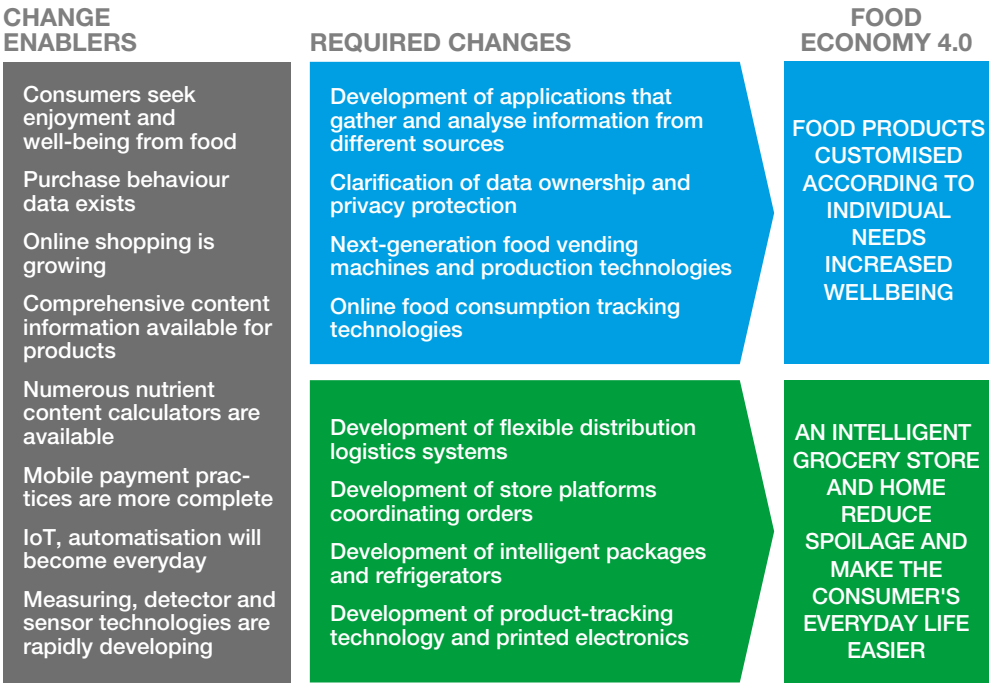

Figure 6. Change path 1: From mass production to personalised solutions.

Food products customised according to individual needs increase wellbeing

As a key enabler of individualised food production, the digital transformation offers both producers and consumers tools for gathering and monitoring information on the consumption habits of individuals, the nutrient contents of foodstuffs, and the lifecycle environmental impacts. This transformation is already under way, and actors in the food sector are currently utilising information on, for example, the purchasing choices of the consumers in their marketing [37,38].

However, the utilisation possibilities in customised food production are more wide-reaching than just for marketing. Sensor and tracking technologies are constantly becoming cheaper and enable more widespread generation of data concerning the production and processing of food. In the future, this data can become an important component of a comprehensive food service.

In addition to data on food, digital services enable consumers to monitor their own behaviour and wellbeing in real time and receive feedback on them. Data collected from different sources (e.g. health data and purchase history) can be linked to a certain user profile in My Data services and thus offer food and services that meet the needs and wishes of that particular person.

Combining food data with wellbeing metrics that monitor the health and energy consumption of individuals creates the possibility for tailor-made meals that constitute comprehensive wellbeing services rather than being mere food. This servitisation development is supported by the fact that today consumers are already used to using, for example, online food energy calculators and devices for measuring daily energy consumption in support for their meal planning.

Furthermore, the use of applications for monitoring the user's activity and encouraging them to exercise has increased strongly; this increases the readiness of the consumers for new monitoring applications. Indeed, in Food Economy 4.0, it is considered that through new mobile measurement and monitoring applications, food and nutrition will be more closely integrated into health and wellbeing services for consumers and into health care.

Snacktracker

I would like to eat healthily and I know what healthy food is like. Despite this, I sometimes find it difficult to eat well. I start using the "Snacktracker" application that can be linked to my activity bracelet. The application recognises and records the times of eating, eating speed, time spent eating, and the location. If I wish, I can add information on the reason for my eating during the meal (hunger, sadness, smell of delicious food). Information on my eating habits are collected in a database. From this database, I can view illustrative summaries of how often I have eaten, at what time of day I usually eat, are there differences between weekdays and weekends, how long are my intervals between meals, do I tend to snack in certain situations, or am I in the habit of eating too quickly. Based on these observations, I am able to better identify and correct problems in my eating habits. Via the activity bracelet, the application connects my eating habits to data on my daily activity. The application highlights possible problems and gives me hints on how to resolve them. If I wish, the application will also guide me in my everyday life, by alerting me to too long intervals between meals or other detected problems.

Meal options are also tailor-made for consumers based on the health data in the health care systems, and applications for wellbeing monitoring are offered to them. This could provide solutions for supporting older people to live at home, for example. In the second model, the consumers hand out My Data they have collected to a personal trainer, including nutrition data.

At the moment, combining nutrition as part of applications such as activity bracelets is not common, but the related research and product development is active. An example of this is an application that monitors dining rhythm currently under development at VTT, its purpose being to guide individuals towards more balanced eating habits (the '**Snacktracker**' story).

Food manufacturing technologies are a critical component in the development of individualised food products and services. Instead of mass production, the production in Food Economy 4.0 is based on technologies and processes enabling widescale customisation. With their help, the agile modification, manufacturing and distribution of products, and food preparation at the point of consumption according to individual needs, will be possible. This meets the consumer's need to have food products and meals delivered fresh, flexibly, and affordably to the desired location.

The consumer's desire for enjoyment and need for easy solutions are, indeed, critical factors when successful, individual food products and services are developed. Products prepared at the point of consumption according to the individual's needs are an example of customisation taking place at the consumer interface. This kind of solution combines an intelligent user interface, robotics and new food ingredients (the '**Personalising food vending machine**' story).

Personalising food vending machine

Today is yet another busy day at work. I will spend the morning in a meeting downtown, and I will have to get back to the office by the afternoon for my next meeting. Looks like I will miss lunch at a restaurant. No worries. There is a new food vending machine at the bus station that will prepare the freshly the foods I choose. While waiting for my bus, I choose a bread with added fibre – baked at site – and a freshly blended smoothie containing protein, evidently popular among other users, as well. Having to skip lunch no longer annoys me at all – after all, I am getting a fresh and healthy lunch for my bus trip. While waiting, I have time to look through the rest of the vending machine's selection. I notice that the options are really healthy and of a high quality, and suitable for a variety of needs. The vending machine also offers several options and meal sizes suitable for small children. Indeed, I intend to test the vending machine's porridge option when we are taking the train to Grandma's with the kids next time.

An automated intelligent grocery store and home reduce spoilage and make the consumer's everyday life easier

In addition to individual customisation and the flexible distribution of food, the consumer's life will be made easier in the future by the automated quality-monitoring of foods. The Internet of Things (IoT) and intelligent packaging will make the consumer's everyday life easier, particularly at the store and at home.

In the future, the consumer will have real-time information on the groceries situation at home, which enables, for example, the automatic updating of shopping lists and, on the other hand, a reduction of spoilage, when the amounts and shelf lives of the foodstuffs are constantly and easily available. This is assisted by the ongoing development of packaging and sensor and imaging technologies.

Sensor and detector technologies are becoming cheaper and the development of intelligent packaging will also lead to an intelligent refrigerator that monitors the quality of products as a part of the consumers' everyday life. The intelligent refrigerator has been talked about for years, already, but technology is now reaching the point where the vision is about to become reality in the near future. When connected online, the refrigerator may even automatically order new milk carton to replace a spoiled one. In addition to spoiling, sensor technology can also indicate when a product is ripe or at its best for eating.

The retail sector and the development of its services play a large role in Food Economy 4.0. The integration of online shopping with the home, and advanced logistics, and distribution to homes via IoT and service platforms will revolutionise food shopping. In addition to this, the services of brick-and-mortar stores will become more individualised, guiding the consumers to easily find products and services matching their own profiles or shopping lists.

In addition to the individualised service of the consumers, when IoT and sensor and imaging technologies are combined with intelligent packaging, it will be possible to also develop retail operations to be more productive, with less generated waste. Digital and intelligent price tags combined with product shelf life information and even real-time monitoring of the freshness of the products using sensor technology will help minimise spoilage in the retail sector, for instance.

VTT has been developing hyperspectral mobile device technology that converts the phone camera into a new kind of optical sensor. With this solution, consumers can in the future use their mobile phones to detect deviations in the quality of food (the '**Spoilage sensor for the home and store**' story).

New food manufacturing technologies will also partially change what products and services the retail sector will offer in the future. The manufacturing of products based on semi-finished products at the store according to the consumer's order is possible with smart manufacturing techniques utilising, for example, robotics. This also enables the reduction of waste, as the products are not finished at the factory, but are instead manufactured according to need from ingredients that have a long shelf life.

Spoilage sensor for the home and store

I have heard that about one third of the food produced in the world is thrown away. To me, this seems like a terrible waste. Fortunately, new technologies have been developed to help both the retail sector and the consumer to reduce the amount of food waste. I have benefited from sensors monitoring the spoilage of food and my new mobile phone camera that is able to detect the freshness of certain products with the help of new imaging technology. In practice, the sensors are small labels attached inside the food package, that are able to observe the product's spoiling process by measuring the gasses evaporating from it. I have utilised the information gathered by the sensor label and my mobile phone camera both at the store and at home. At the store, the product's price is determined by the product's remaining shelf life. As the product's shelf life is running out, the reduced price is automatically updated to the digital price tag on the edge of the shelf with the help of the sensor label. I will be able to get food that is still usable, although near the end of its life cycle, at an affordable price while helping the store reduce the amount of food thrown away. I also use the data collected by the sensor label at home: I read the sensors of the products in my refrigerator to get information on what products I should use up quickly.

CHANGE PATH 2:
From centralised to agile manufacturing and distribution

Long transport distances cause spoilage, which is also increased by storage at wholesalers and retail stores, and by processing in the food industry. According to a study made in the USA, food travels 2,400 kilometres on average from the field to the plate [39].

In a centralised food chain, the producers are in many ways dependent on intermediaries distributing food to the food industry and consumers. The separation of primary production, refining and the end use of food is also typical for a centralised food chain.

In the new Food Economy 4.0, direct online collaboration between the different parties of the food chain and flexible, even mobile production units and new food manufacturing technologies will allow both the producers and consumers to play a more well-rounded role in the value network of food production.

Moving from mass production to mass customisation is an important factor in the transition of the production chain and distribution. This allows increasingly more individual needs of consumers to be met. At the same time, this requires the manufacturing industry to develop agile and modular processes.

In Food Economy 4.0, the consumers' everyday life is made easier not only by the distribution and availability of food, but also the tracking techniques for monitoring the origin and logistics of food, allowing consumers to ensure that the food is safe to eat and has arrived from where it was supposed to according to the communications. As food production takes place at ever bigger distances from the consumer, the importance of consumer trust has been emphasised. For this reason, the food chain's transparency and indication of responsibility will become significant competitive factors.

Cooperation and flexibility between the different parties in the food chain and, on the other hand, the importance of mass customisation and robotics are present in the key themes of Change path 2, "***From centralised to agile manufacturing and distribution***": *Networked actors are stronger than individual parts of the production chain and Automation and new manufacturing technologies bring food manufacturing closer to the consumer* (Figure 7).

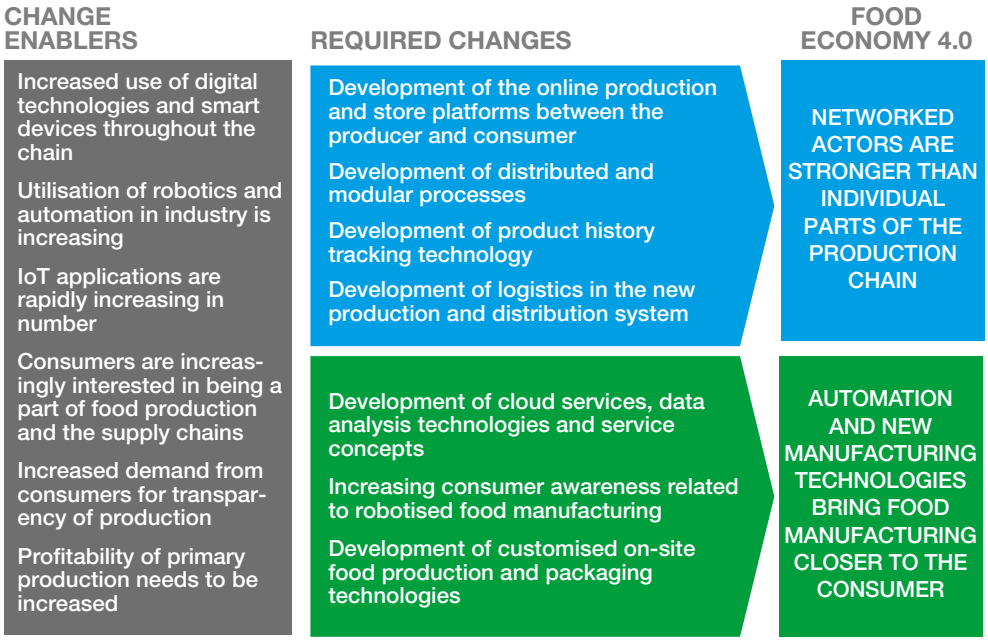

Figure 7. Change path 2: From centralised to agile manufacturing and distribution.

Networked actors are stronger than the individual parts of the production chain

Just as in the manufacturing of individualised foodstuffs, digitalisation is a key change driver for distributed solutions of supply chain, as well. Online platforms offer a cooperation channel and a marketplace for producers who can manufacture batches of differing sizes directly to order to meet the needs of either the end users or the food industry. On online forums, it is also possible to collect for the market precise batches of raw materials or semi-manufactured products from small, scattered producers[40].

Instead of traditional marketplaces, in Food Economy 4.0 the online solutions will create new kinds of marketplace models, where small-scale producers can reach a larger number of consumers. This is seen as particularly useful in the case of speciality products, such as gluten-free and organic products. Interaction also increases the producers' understanding of the consumers' needs, and enables the development of personalised options.

In Food Economy 4.0, the producer is brought closer to consumers with the help of digital communication channels. Interactive networks between consumers, producers and the

Easier traceability and usability of products

I work as a bottler in a craft beer brewery. My company has adopted new intelligent codes that are attached to the bottles along with the label after bottling. Every time before the bottling of a new batch begins, I retrieve information on the beer's raw materials, their possible growing location, and the beer's manufacturing method from the computer. I also mark myself as the bottler of the product in question. Each bottle bears a unique code. Functional inks are used in the printing of the codes: the printed codes change according to, for example, a certain temperature or time that has passed. In addition to manufacturing information, the codes can therefore inform the consumer of when the beer is at a suitable temperature for drinking, and that the best-before date has not yet gone by. The consumer can also receive information on his or her mobile device on how the package must be recycled after use. In addition to the consumer, this new technology will also benefit our other partners, the members of the food network. The store owner, for example, can read the code to ensure the origin and correct transport conditions of the products coming to the store have been followed. The store owner can also use the code to change the pricing of the products, for example when the best-before date is drawing near, without having to attach discount labels on the products. We have gained a lot of benefit

from using this new technology, as it brings us even closer to the other actors in the food network, but also closer to the consumers. We have received a lot of feedback on, for example, our seasonal brews, as the consumers are actively telling us their opinions once seeing the raw materials and the manufacturing method. They also value that we use only Finnish raw materials, and we receive particular praise when they notice that we have acquired the raw materials from a local farmer. I also received a message from my friend yesterday, saying that he was just drinking a beer I had bottled.

manufacturing industry will increase the transparency of food production and play their part in answering concerns about safety and the ethics of production raised by the centralisation of food production.

Already today, the popularity of various food circles connecting producers and consumers is increasing. In the future, communities comprising producers and consumers will play an even larger role in guiding consumer choice. The transparency from the interaction enables a new kind of productisation of immaterial values related to the entire production chain of raw materials, such as solutions related to ecological or ethical production.

Online platforms also promote cooperation between producers who can establish so-called virtual co-operatives, offering flexibility to the producers and enabling improved production reliability. Manufacturing that starts precisely to order reduces spoilage caused by storage and uncertainty in the sales of the products.

In order to work, flexible and distributed production requires the producers to have an active online presence. This requirement is alleviated by the development of sensor and tracking technologies in primary production and the digitalisation of farms [41].

Farms are able to track and analyse the different production phases and, for example, the required amounts of fertiliser and pesticides, increasingly accurately. This promotes the transition of agriculture towards sustainable production methods, where unnecessary nutrient or chemical leaks do not get into the environment.

Intelligent packages and IoT in the distribution chain play a key role in the direction of raw material batches and end products, and in the automation of quality monitoring. Examples of technologies benefiting from raw material tracking, optimisation of the distribution chain, and the ensuring of safe transport conditions include the illustrated solutions utilising printed intelligence currently under development at VTT in the EU-funded TagItSmart project (the '**Easier traceability and usability of products**' story). The technology is based on an ink that changes its colour according to time, temperature, or some other variable, enabling the development of various quality monitoring systems.

In addition to digital solutions, flexible, distributed production also requires the development of modular, partially also mobile production units. With the help of mobile processing units, primary producers and producer networks will be able to increase their production reliability and quality grade, thus increasing the production's profitability and independence of, for example, variations in raw material prices or weather conditions.

Automation and new manufacturing technologies bring food manufacturing closer to the consumer

The cornerstone of agile and partially distributed production is to take the production as close to the end user as possible. In the new food economy, food is prepared for the consumer to order increasingly often, directly at the point of purchase.

Extensively customised products must be manufactured as cost-effectively as is possible with current mass production. This is impossible with the current production processes; it requires a new kind of combination of automatic production equipment, manufacturing technologies, robotics and Big Data into an intelligent and agile production system that is digitally connected to the final distributor or even the consumer [42].

In addition to the change in the process industry, the development of individualised services is promoted by the development of new raw materials and next-generation food and meal vending machines preparing food to order according to the consumer's wishes. You can already get freshly baked bread from the grocery store, but in the future, the grocery store may change from a store with shelves full of prepared food into a production unit. The ability of the automatic vending machines to produce customised dishes is helped by the ongoing development of service robotics and 3D printing based on additive manufacturing, which has already revolutionised the manufacturing industry's production environment (the '**3D printing of food**' story).

Manufacturing technology combined with an intelligent user interface and connected to both the consumer's and the service provider's direction will, in the future, change the ways in which food production is organised in both the

food industry and in households. As already mentioned in *Change path 1*, in the future it will be possible for consumers to buy food that has been customised according to their wishes and needs from automatic vending machines at their place of work, shopping centres, exercise locations and airports (as described above in the 'Personalising food vending machine' story).

Agile and partially distributed food production, and in this case, also product manufacturing, require support from a functional logistics system. Digitalisation and particularly the providers of service platforms combining and brokering logistics services play key roles in the development of such.

A functional logistics system is an essential part of flexible and partially distributed food production. Raw materials and ingredients must be transported affordably and reliably between producers, and the end products will be delivered fresh directly to your home, place of work or along your route, instead of to a retail store.

Today, the bottleneck of direct business between the producer or manufacturing industry and the consumer is the lack of agile logistics. This is due to the funnel-like structure of the traditional food chain and to logistics being based on the chain model.

In the future, distribution may be based on crowd-sourced home deliveries, food distribution via Uber or some other similar actors, or distributed service points or vending machines working to order. In this development path, too, the creation of digital service platforms and the development of mobile payments are of utmost importance.

A distribution-based logistics system enables the full utilisation of the capacity of the existing transport chains, and the batches from small producers can be transported along those of larger ones, even to more inconvenient locations. At the moment, ColaLife has, for example, transported medicines and food via its own comprehensive delivery chain to distant and inconvenient locations in Africa. The automatisation of the transport system will also change the distribution methods of raw materials in the near future.

3D printing of food

Today, I get to try out our new household appliance, a table-top 3D food printer. Today, a rather diverse selection of different raw materials suitable for a 3D printer is available in online stores. I figured I would start testing the appliance by making custom cookies for my daughter's birthday party. Yesterday, the raw materials required to make the cookies were delivered to my home, everything neatly in a single package. The concept also includes a mobile application that provides me with information on the raw materials and the logistics chain, all the way from the production facility to our home, and plenty of ideas and instructions for printing food. The application illustrated the origins of the different raw materials clearly, and I noticed that the berry pulp, for example, was from my father-in-law's neighbour. I also received a lot of ideas from the achievements of others who had already used their 3D printers, so decidedly splendid possibilities for

both ordinary and red-letter days! The appliance can also be maintained remotely via the application: the service company can connect to the printer, monitor its status, and suggest maintenance and updates at suitable intervals. Yesterday, my daughter and I used the application to draw the cookies we want. Now, it is time to press 'Start'!

CHANGE PATH 3:
From horizontal to vertical food production

As a result of the environmental crisis, current food production must undergo a change. Thus far, meat-eating continues to grow in Finland, but a great transition towards more vegetable-based nutrition can be seen in the future of food production, particularly on the global scale. The development of ecological food production methods is currently largely based on the search for more sustainable vegetarian alternatives for raw materials of animal origin, particularly cattle meat.

Responsibility and legislation are steering food chains to developing environmentally friendly food production and manufacturing processes that still provide sufficient nutrition. At the same time, consumer interest in sustainably and ethically produced foods is also on the increase.

The demand for and usage of vegetable proteins has indeed grown strongly over the last couple of years. Both the retailers S Group and Kesko have stated that the sales of vegetable-based food alternatives, such as the oat-based Pulled Oats and the faba-bean-based Härkis continue to increase. S Group estimates that Härkis has surpassed, for example, chicken meat strips in sales during 2016 [43].

In addition to vegetable alternatives, new food production technologies, insect economy and the biotechnical production of food are rising themes when examining food's raw materials of the future. They enable moving food production from horizontal production technologies requiring a lot of land to vertical, factory-like solutions, where the efficiency of nutrient use in food production is significantly better, particularly compared to meat production.

Another trend that is definitive to the operating environment of the food economy of the future is the growing urbanisation and the increasingly rapid migration of people to urban environments. The development of the technologies and operating models of urban agriculture and food production in the urban environment go hand in hand with urbanisation.

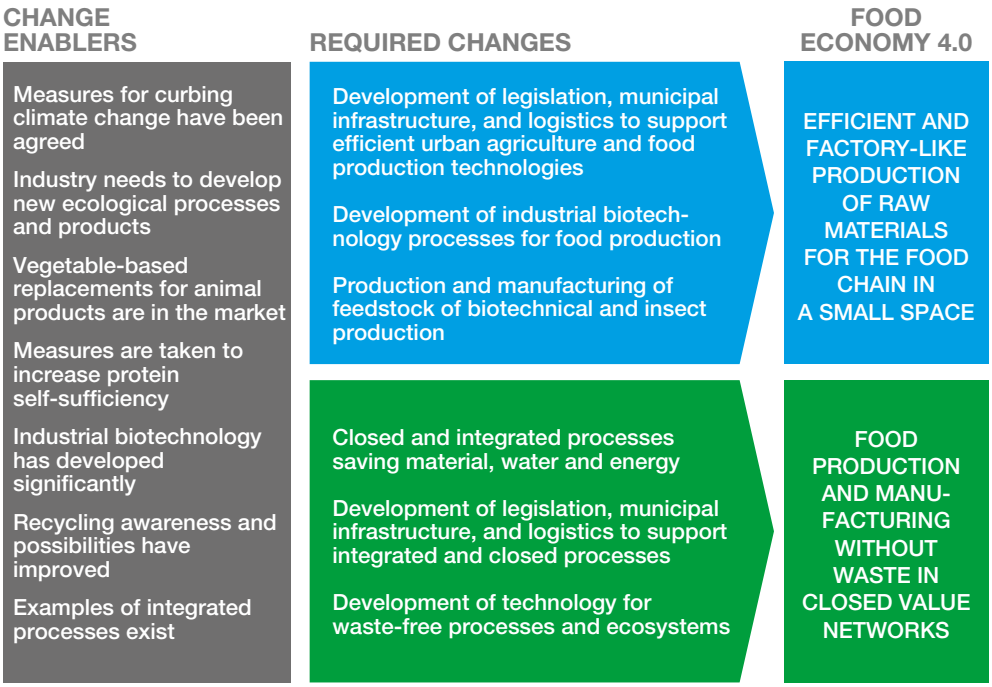

Figure 8. Change path 3: From horizontal to vertical food production.

Insect production and biotechnical food production, for example, can be implemented in an urban environment, too. In the new Food Economy 4.0, food production will take place closer to the urban consumers than before, using production technologies that are not dependent on fields.

The third Change path, "**From horizontal to vertical food production**", emphasises new food production technologies and solutions that are suitable for small spaces and where high efficiency and lack of waste play a key role. Indeed, the themes of this change path are *Efficient and factory-like production of raw materials for the food chain in a small space and Food production and manufacture without waste in closed value networks* (Figure 8).

Efficient production of new food raw materials in a small space

In sparsely populated Finland, urban food production may sound like a futuristic vision. Alternative vertical production technologies are, however, slowly challenging conventional thinking on the primary production of food. In Food Economy 4.0, food production is partially built on new, alternative technologies that enable industrial-scale food production in cities and safe food production around the year without stressing the environment.

The image of farming as a hobby on a balcony or in a park is often connected to urban agriculture. Some of the methods are based on cultivation technologies similar to multilayer cultivation utilising closed water recirculation systems, such as aquaponics and hydroponics. Their purpose is to grow plants using nutrient circulation fed via water or air, with no soil required.

Other production methods of food or food raw materials suitable for a vertical urban environment include the production of food and proteins based in insect farming, and cell cultivations produced in bioreactors that can, in addition to nutrient components, produce additives or minerals utilised in food manufacturing.

Insects offer a sustainable alternative to securing food production and fulfilling the growing need for animal protein [44]. Insect farming is ecological, and insects require only a small space and their nutrition requirements are simple. It has been calculated that insect farming will generate less greenhouse gases and consume less water than the raising of traditional production animals, and is not tied to land area as is the case with larger production animals [45,46]. The feed conversion ratio of a house cricket, for example, is five-fold compared to that of swine [47].

When moving to even simpler organisms, biotechnical food production based on microbes and cell cultivation will, in the future, be seen as an important part of a sustainable Food Economy 4.0. Due to advancements in industrial biotechnology and synthetic biology, the possibilities for the biotechnical production of food and food components in increasing amounts begin to be realistic [48].

Biotechnology has naturally already been utilised in food production, particularly in plant breeding to improve the nutrient and plant disease properties of plants. In addition to primary production, concrete examples of biotechnical food production include the already launched alternative developed for meat protein, the Quorn mycoproteinTM; vitamins, such as carotenoids; and enzymes and yeasts used in the food and beverage industry.

In addition to commercial examples, techniques still in the research phase include the biotechnical production of artificial meat 44 and the harnessing of microalgae for food production 49,50. Solutions for replacing eggs with in vitro technologies are also being sought, and VTT and the Lappeenranta University of Technology are currently researching whether it is possible to produce food out of just air and electricity in a project funded by the Academy of Finland.

The development of substrates for biotechnical food production is critical, when considering the utilisation of industrial biotechnology in the mass production of food. In Food Economy 4.0, nutrient-rich side streams and sustainably produced raw materials are used as feed (substrates) for microbes that produce the desired valuable components from the raw materials. Despite the advancements in biotechnology, a lot more research is still required in order to make it possible or feasible, for example, to industrially produce proteins based on artificial meat or microalgae [49,50].

The food production of the future can also mean entirely new kinds of solutions based on biotechnology used in households. VTT, for example, has been developing for the market a bioreactor for household use that can be used to grow berries or vegetables quickly and effi-ciently. This VTT concept is a device designed for household use that can be used to grow almost any natural berry or plant.

The idea of the concept is based on growing the undifferentiated cells of a plant rather than a whole plant. The final product has been found to contain the same compounds important for health as the naturally grown vegetable or berry, and the nutritional values of a cloudberry cell cultivation are similar or even better than those of the berry itself (story below).

New alternative food production technologies that convert raw materials into food with a high efficiency can, in the future, provide solutions for crisis and famine areas as well. Combined with modular and distributed process solutions, the utilisation of microbes, for example, in protein production can enable nutrition production in places with shortages of food due to natural or other conditions.

Home bioreactor

My Friday at the Hong Kong office has the perfect beginning – I know that I will have a fresh cloudberry smoothie for breakfast, which slightly reduces my longing for Finland, my homeland. You see, today is the day when a new batch of cloudberry cells is finished, allowing me to make a nutrient-rich breakfast for myself. My local colleagues here are even more satisfied than I am with the new fresh smoothie vending machine in the canteen at our workplace, as they can only dream of berries picked from the forest. In addition to a refreshing idea, a cloudberry smoothie is also rich in nutrients, as it contains a lot of protein and fibre that will ensure that I can make it through the morning meetings to the lunch break. My employer has also informed all employees of this new food concept being a part of the company's strategy for sustainable development, and that it acts as an example of how new alternative and ecological food production technologies can really be a part of our everyday life. I can hardly wait for the bilberry cells that will be ready next week.

Food production without waste in closed value networks

The importance of closed-value networks in food production is emphasised when attempting to achieve waste reduction and resource efficiency. Today, a circular economy is emphasised in several business areas, and new technological innovations and solutions play a key role in production and the economy. New operating models, such as smart energy solutions, advanced processes for the minimisation of waste flows, and the further refining of side streams, enabling the realisation of a circular economy in both food production and in other production sectors.

The Sitra publication 'Leading the cycle – Finnish road map to a circular economy 2016–2025' describes concrete actions as well as the industries from which growth and investments are required in order to achieve a profitable circular economy in Finland 51. The purpose of Sitra's roadmap is to raise Finland to be a globally leading country in the circular economy by the year 2025; the focus areas aiming at this objective are a sustainable food system, forest-based loops, technical loops, transport and logistics, and common action.

It is considered to be essential for achieving the circular economy objectives that all stakeholders together commit to applying the focus areas in their own activities, which will also foster the strengthening of the competitiveness of the industry and the creation of new jobs and sustainable growth.

VTT's report on the circular economy proposes solutions for making the material cycle more efficient and minimising the amount of waste[52] which also resonates with the themes emphasised by Food Economy 4.0. The transformation of sales of consumer goods into the offering of services, the reduction of food spoilage due to new procedures in the food chain, the utilisation of digitalisation in developing recycling concepts, the production-enhancing effect of 3D printing, and renewable modes of transport that are less harmful to the environment are concrete enablers of the circular economy concept [52].

The focus areas of an integrated food system in the future food economy are the efficient recirculation of nutrients, water, and energy and wasteless processes that will become possible through the cooperation of different sectors.

These partially closed value networks will create new business opportunities. In Food Economy 4.0, the production units are biofactories that are based on closed raw material cycles instead of processing units generating main and side streams: in addition to foodstuffs, they produce energy, fertilisers, feed, gas, fuels, and industrial raw materials.

Symbiotic cultivation of fish and vegetables based on the aquaponics method is an example of an integrated ecosystem, piloted in Finland by the Sybimar company. Water from the fish farm is recycled and purified through a vertical greenhouse back to the fish. The carbon dioxide emissions from the energy production can be processed through the photosynthesis of plants, and the generated biowaste can be utilised in energy production – what is waste to one, is a nutrient to the other.

Food production close to the consumer also significantly reduces spoilage in the food chain. With vertical cultivation, fresh products can be grown, for example, on the premises of a grocery store, and the packaging sizes of the products can be customised more easily. Urban food production also enables the implementation of a new kind of city block food production, or even a city block circular economy. Further refining of the nutrients in organic waste locally for the needs of food production is an essential component of the latter.

Strides in the right direction have already been taken in the further refining of side streams and recycling, and St1, for example, uses waste dough in the production of bioethanol in South Finland. Neste Oyj's NextBTL diesel uses waste animal fat from slaughterhouses.

The reduction of spoilage in Food Economy 4.0 is heavily based on the maximal utilisation of

the raw material, due to which current production and manufacturing processes must be partially redesigned. Side streams that could be refined into products with added value are generated in the cereal chain, for example.

The bran fraction from mill processes is a good example: bran contains a lot of valuable components that could be returned back into the food chain, but the possibilities of utilising bran are currently limited. The development of agile mill processes could provide a solution to this challenge (the '**Intelligent process**' story). The same analogy also applies to other side streams of the food industry – a larger part of raw materials can be utilised as human food by redesigning the processes.

Intelligent process

Today will be a particularly interesting day at work. We are taking a new process hall into use at our grain mill, containing new equipment for the processing and intelligent storage of raw materials. I will get to test drive the new mill that uses a different milling method than previously. Our research director said that this enables the better utilisation of the different parts of wheat grains in foodstuffs. I heard that this new wheat bran has been used in new products resembling protein smoothies. I will have to check whether it is available in the fresh produce café in our shopping centre. My neighbour told me that her brother, who is a farmer, is also satisfied with our renovated mill. Thanks to the intelligent storage system, he can get a better price for his special product batch, and is able to track the progress of his grain all the way to the consumer, if necessary. Correspondingly, the product manager at our mill said that showing traceability gives my employer a competitive edge. I myself have been missing a local oat product portfolio, so I found myself trying out the new online store of the farmer network and the mill, which also offers the possibility of home delivery for the products, and also allows me to customise the amount of rolled oats to match my needs.

AN ECOSYSTEM OF THREE CHANGE PATHS

The roadmap describes three separate change paths, but in reality, they all interlink into a single ecosystem. This ecosystem is illustrated below with the 'Chicken soup' example (Figures 9 and 10). When a consumer wants chicken soup, the interlinked transfer of raw material flows and information begins at the same time.

The ecosystem's information flows influence the consumer's purchase decision and, on the other hand, the consumer can modify the ecosystem through his or her choices. Correspondingly, the production industry receives information from the consumer interface and can modify its processes in an agile manner to produce and manufacture the raw materials and products needed by the consumer. An agile ecosystem saves raw materials and generates less waste, as the product is only made to order to meet a consumer need.

Information flows

When a consumer wants to order soup in the food economy of the future, he or she has several options for receiving it effortlessly and customised to meet his or her own needs. The consumer's decision is influenced by the social network and its views, and the consumer's own value choices, health information and recommendations, which are constantly available and also form part of the soup manufacturer's service.

The product information and the raw material and manufacturing information are visible to the consumer already at the moment of purchase. Soup manufactured with intelligent and personalising manufacturing technology can be delivered to a specific pick-up point or where the consumer wants to eat it.

The consumer's purchase decision launches the information and raw material flows pertinent to the consumer's choice, and starts the manufacturing process. The consumer is able to monitor the completion and delivery of the product in real time. The food manufacturing combines an intelligent user interface, robotics, Internet of Things, and food technology.

After eating, the consumer receives information on how the product affected his or her physiology and what other consumers have thought about the product in question. The package also has clear recycling instructions.

All this new information is accumulated for the use of the consumer, affecting the next order. In this way, the process is refined through learning in each cycle. At the same time, the producing and manufacturing industries receive information on the purchasing behaviour of the consumers, and can agilely modify its raw material flows and production processes.

Raw material flows

In the food industry, the ingredients and package of the chicken soup are based on the future vision of Change path 3. The raw materials have been produced sustainably and are used efficiently, also taking into consideration the further refining of all raw material flows. As described in Change path 3, bioproduct factories produce both food and packaging materials, as well as feed, fertilisers, and energy for the production

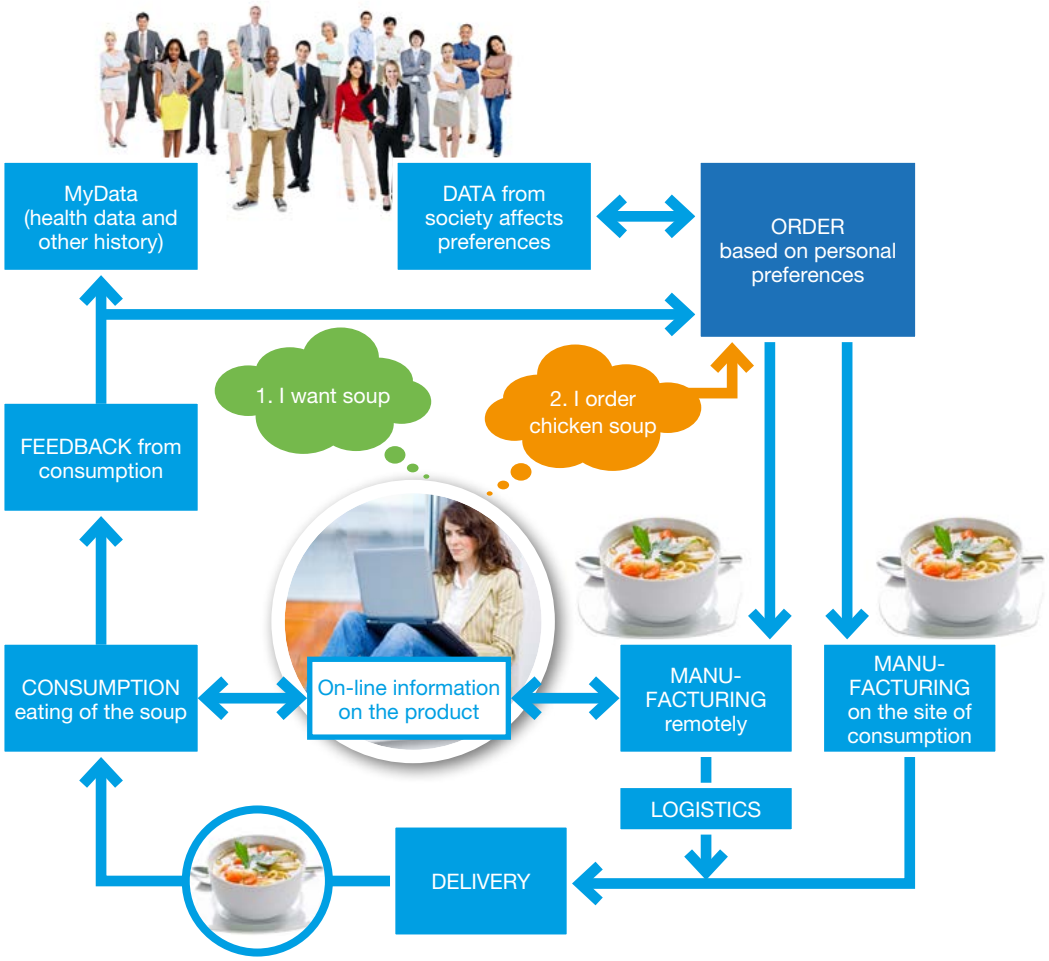

Figure 9. Data flows in the Chicken soup example.

of food and food packaging. In accordance with sustainable food production, the chicken soup contains, in addition to chicken, bits of meat made from insect protein and tomato, all of which are a part of closed raw material cycles.

Part of the feathers produced in the production of chicken meat is used as feed for insects, and part in the manufacturing of the soup package. The waste from insect farming, in turn, is utilised as nutrients in the tomato greenhouse. The insect carapaces also form part of the soup package.

It is also interesting that forest raw materials have been used both as packaging material and in the product itself. Lignocellulose is part of the recyclable, biopolymer-based soup cup, while the natural carbohydrates from trees provide some thickness and also health to the soup in the form of dietary fibres. Wood-based biomass can also be utilised as a raw material of biotechnically manufactured chicken and insect feed.

The purpose is to produce raw materials according to consumption, due to which anticipatory information on consumption is increasingly important also to the production and manufacturing industries. Indeed, it is essential in the 'Chicken soup' ecosystem that the raw material and information flow systems communicate with each other in real time, so that the production and manufacturing of the raw materials can be adjusted in an agile manner.

Figure 10. Raw material flows in the Chicken soup example.

6. Business in the new food economy

CYBER-PHYSICAL FOOD ECONOMY

The smart food production of Food Economy 4.0 will change the business ecosystem of food and its business models in many ways. The transition already ongoing in both the retail sector [53] and the manufacturing industry in general [3] will also affect the production of food and its distribution to consumers.

There will be a radical influx of new systems alongside the currently used food production value chains, their actors and business models; these new systems will challenge the current models and their actors. Naturally, many of the current actors will likely renovate their business models and move into the cyber-physical reality, where the food production and delivery to the consumer will take place while leaning heavily on digitalisation. Production and consumption will then be close to each other also physically, and the production matches the consumption, thus minimising spoilage.

In cyber-physical systems, the value chains are short, and the roles of the actors in the chain differ from current ones [53]. There may no longer be, for example, separate raw material producers, food manufacturers, wholesalers or logistics operators in the previous sense. The corresponding stages would still be recognisable in the ecosystems of Food Economy 4.0, but at the most extreme, they can be completed by one and the same actor, even physically in the same location.

Instead of the traditional supply chain, the ecosystem may emphasise the horizontal cooperation of the actors, with the actors not seeing each other as direct competitors in the same sense as in the previous value chains. Competition in the market will not disappear, but it can change from competition between individual companies to competition between ecosystems [54].

The traditional roles are also shaken up by the consumer's role in the new food economy, where the consumer can also simultaneously act as the producer of the food (prosumer = producer + consumer). In the prosumer model, the actual producer and the consumer carry out the production phase together, with the consumer participating in the production via a digital connection.

EXAMPLES

We have worked together with food industry companies and the retail sector and envisioned what kinds of business opportunities the new Food Economy 4.0 offers, and what kinds of business models could make it possible to succeed in it. With regard to business models, we have concentrated on four key areas at a general level: 1) Offering (what?), 2) Target market and customers (to whom?), 3) Required competence (how and with whom?), 4) Revenue generation model (how to make money?).

The first example of a new kind of a business opportunity is a combination of two business models: **My Food and Food ATM**, Table 1. My Food is a digital service of a new era that guides and steers the consumer in his or her food choices, taking into consideration the

Table 1: Business model example related to personalised solutions.

MY FOOD + FOOD ATM		
REQUIRED COMPETENCE My Food: One database containing all data The data follows the consumer and is relayed to the producer of the meal. Food ATM: a next-generation vending machine that prepares a meal/snack from the ingredients in the machine, located in places with large customer flows.	**OFFERING** My Food: Data for personalised precision food • taste preferences, predictability for the needs of the day, own health taken into consideration • avoidance of 'wrong' choices. Food ATM: personalised meal/snack prepared by the machine utilising My Food data.	**TARGET MARKET/CUSTOMERS** People who are going somewhere and do not wish to stop to eat, but who still want a healthy meal/snack that is precisely suitable for them Optimisers aware of their well-being, such as those on a certain diet
REVENUE GENERATION MODEL Exclusive product sales: the product (meal/snack) cannot be purchased elsewhere than from Food ATM machines with the help of My Food. My Food is subject to a monthly or annual fee		

consumer's personal preferences, health goals, current health, etc. At the same time, My Food is a digital platform where food producers create digital user interfaces to food production services.

Food ATM is one concept of this kind of a food production service. Food ATM is an automatic food or snack vending machine that prepares a meal or a snack for the consumer according to the recommendations of My Food. The manufacturing itself can be done by 3D printing or using some more traditional method of combining ingredients.

The second example is called **Fresh production at the store**, Table 2. The key idea of this business model is to grow fresh produce such as herbs, sprouts, salad, and mushrooms on-site at the store using new indoor cultivation and water recirculation techniques. The farmer would operate at the store under the shop-in-shop principle. From the consumer's perspective, the value would be created by the freshness and ecological nature of the products, as transport costs would be eliminated and spoilage reduced.

The third example of a business opportunity is titled **Ingredient factory 4.0**, Table 3. This is a new kind of production of an ingredient or nutrient mass for a food product in a factory environment utilising forest-based raw materials. With the help of additional ingredients, the finished mass can be used to manufacture many different kinds of foods, such as an energy side dish akin to potatoes, or protein nutrition akin to minced meat.

Ingredient factory 4.0 is a vision of food production of the future based on biotechnology, and the utilisation of a circular economy in the food economy. The technology for realising this vision is not yet complete, but development is rapidly advancing in this direction. This subject also offers plenty of opportunities for export, such as support for emergency aid to various crisis areas.

EXPORT IN THE NEW FOOD ECONOMY

The new business models can open doors for the export of food economy products and services with completely different volumes than today. Digital services such as the My Food platform do not recognise physical national borders in the same way as the export and import of physical products. The country-specific legislation, taxation,

Table 2: Business model example related to agile production and distribution.

FRESH PRODUCTION AT THE STORE		
REQUIRED COMPETENCE Producer has indoor cultivation know-how (aquaponics – hydroponics) Collaboration models of the farmer and the store	**OFFERING** Fresh vegetables such as salads, herbs, mushrooms, etc., cultivated indoors at the store The farmer provides the service under the shop-in-shop principle.	**TARGET MARKET/ CUSTOMERS** Aware consumers who value freshness, local food, and ecological considerations
REVENUE GENERATION MODEL Fresh sales from the producer directly to the consumer Rental revenue for the store		

etc., must naturally be taken into consideration in digital business as well, but data is easy and quick to transfer from one place to another.

Radically different new business models will support entry into new markets. The Food ATM concept, for example, is not dependent on whether the wholesalers and retail distributors of the target country include the product on their lists and how they commit to keeping the product on display. The Food ATM concept has its own distribution and marketing channels.

Food ATM is, in fact, an example of a concept that intrinsically has a greater potential for success in the great metropolitan areas abroad than in Finnish growth centres. In order to have business success, the machine requires active use (in other words, a lot of transactions per hour), which is more likely in London, Shanghai or Tokyo than in Espoo.

The following keywords can be linked to Food Economy 4.0: innovative products, digitalisation, safety, health, sustainability. These are by no means alien terms to today's manufacturing industry in Finland. However, in Finnish industry, they are overshadowed by a term that guides the operations of companies with a heavy hand: cost-effectiveness.

In the current situation, cost-effectiveness is a key requirement, but in the future, it will not be enough to conquer the market. Of course, price will be very important in the food economy of the future, too, but in it, the consumer makes purchase decisions largely based on the customer value provided by the product or service. The customer value can emphasise health, safety, ecological values, etc.

The markets are undergoing a great transition, where Food Economy 4.0 will progress at a rapid pace. This transition has also been recognised outside Finland. Transition is always a great opportunity for companies that wish to seize it and reinvent their business operations. Companies that introduce innovative products and services with new kinds of business models utilising digitalisation.

Seizing the opportunity requires courage and risk-taking ability from the companies. The business opportunities arising from the transition cannot be seized by concentrating on finding cost savings in current processes and making small improvements in current products.

Table 3: Business model example related to vertical food production.

INGREDIENT FACTORY 4.0		
REQUIRED COMPETENCE Production technology of ingredient mass: substrate and biotechnical implementation Processes, equipment, and recipes for refining the mass into various food products	**OFFERING** Protein-rich ingredient mass fit for human consumption Food products manufactured from the mass	**TARGET MARKET/ CUSTOMERS** Urban people/communities with a critical attitude towards the current production with an ecological mindset Emergency aid, crisis areas
REVENUE GENERATION MODEL Sales of ingredient mass to refiners Sales of finished products to consumers		

7. Research strategies supporting the new food economy

Several research strategies and reports are being and have been prepared in Finland and Europe, steering the change of the food economy and marking the path towards the new Food Economy 4.0.

During 2016, VTT has further focused its research and innovation strategy, the goals of which are a clean planet, a good life, and sustainable growth [55]. VTT has chosen the following focus areas, the so-called 'lighthouses': Climate Action, Resource Sufficiency, Good life, Safe and Secure and Industrial Renewal. Almost all of these include elements that support the opportunities shown by the Food Economy 4.0 roadmap.

In 2016, the Ministry of Agriculture and Forestry has prepared a Food Policy Report [56] that is currently being finalised after being circulated for opinions. In accordance with the implementation plan of the Government Programme, it considers the domestic food production's competitiveness,

responsibility, market-and-consumer-orientation and sufficiency from the perspective of supply security.

The vision of the Food Policy Report is that 'In 2030, Finnish consumers are eating domestic, tasty, healthy and safe food produced sustainably and ethically. Consumers have the ability and opportunity to make conscious choices, and their demands are met by a transparent, competent, flexible, and internationally competitive and profitable food system. Food industry growth and development are supported by well-coordinated high-level research, development and innovation work'. This is well aligned with the objectives of Food Economy 4.0.

The national food research strategy prepared under the Finnish Food and Drink Industries' Federation (ETL), 'Sustainable and profitable production and consumer welfare lay the foundations for the success of the Finnish food chain' [57], has the following key objectives: supporting the business and competitiveness of all parties in the food chain and promoting the establishment of new value chains and new business where the food chain intersects with other industries. These objectives remain remarkably topical, although the strategy is already more than five years old.

ETL's waste and side stream report [9], completed in 2016, also presents recommendations for the utilisation of side streams as part of a circular economy. The recent documents, Finnish road map to a circular economy 2016–2025 [51] published by Sitra and VTT's Circular economy policy brief [52], also describe strategies and measures for achieving the goals of a circular economy in Finland.

At the European level, the European Technology Platform ETP Food for Life has prepared a new research and innovation agenda [58] in 2016. In its vision, it too emphasises the partnership of the consumer and the industry and the principles of sustainability, dynamicity, flexibility and transparency of the food system of the future. The strategy emphasises combining social and natural sciences with technological development, thus aligning itself with the principles presented in this roadmap.

The European Institute of Innovation & Technology (EIT) is expanding its operations to food by establishing the Food KIC in 2016. From Finland, VTT, University of Helsinki and Valio participate in the EIT Food consortium that is about to begin its operations [59]. EIT Food's vision is to put Europe at the centre of a global revolution in food innovation and production, and its value in society. EIT Food will engage consumers in the change process, improve nutrition and make the food system more resource-efficient, secure, transparent and trusted. These objectives align well with those of Food Economy 4.0.

8. Where do we go from here?

Food Economy 4.0 offers a lot of opportunities for creating new business. VTT proposes that Finland should choose the development of new business models enabled by sustainable food production and digitalisation as one application area of bioeconomy, and resource a separate technology programme related to the subject.

BRAVELY ACROSS THE BORDERS

The widescale success of companies requires cooperation across traditional sectoral borders between companies, research institutes and the ministries (Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment, Ministry of Social Affairs and Health) in order to establish favourable groundwork for the innovation and development of exports. The foundation of the application of new technologies is the utilisation of Finnish raw materials on the way towards food service innovations. They also offer the opportunity for technology exports.

By investing in the development of new food production methods, Finland will also have the opportunity of exporting its know-how to countries that are already running out of arable land and have a growing demand for urban food production. The new food production methods will also benefit crisis areas, where the most important thing is to produce nutrients efficiently from existing natural raw materials.

We propose the establishment of a collaboration forum that would plan the contents of the development paths required by the roadmaps, as well as plan impact assessments, and implementation projects. In addition to food production companies, actors in the supply chain and representatives of the technology industry should be invited to the forum. This kind of workshopping was found to be necessary already during the roadmap work.

An important goal of the forum would be to assess the future cyber-physical reality, where food is produced and delivered to the consumer utilising digitalisation. The evaluation and brainstorming of the development possibilities of the Internet of Things (IoT), Big Data and smart devices, among other things, from the perspective of the food economy will create new growth. The integration of food and health technologies is also a growth platform of the future.

The forum should develop forms of cooperation in such a manner that competition factors will not prevent the increase of a national level of pre-competition know-how. The use of new technologies will likely lead to new business models that offer natural development targets for interested actors.

NEW DEVELOPMENT ENVIRONMENTS ARE NEEDED

Finland must find its own focus area where we can differentiate ourselves from international competitors. Our development prospects in the utilisation of digital services have been estimated to be extremely good.

We propose the construction of a real-world consumer research environment in Finland; a testbed where new product and service ideas can be tested under real purchasing situations

of consumers. These could include, for example, food produced and customised for the consumer at the time of consumption or purchase, intelligent vending machines and product concepts based on new raw materials. It could also be used to develop new services that make purchasing easier and create new experiences – together with the customers.

There is a special competence centre in Finland called SMACC (Smart Machines and Manufacturing Competence Centre) offering unique services in the field of machinery and manufacturing. SMACC is formed by VTT Technical Research Centre of Finland and Tampere University of Technology (www.smacc.fi). We propose that it will be utilised systematically in the future in the development of new food economy concepts and production methods.

REQUIRED DEVELOPMENT STEPS

The technological development in both the digital and raw materials environments has taken significant strides over the last years. Some clear development views have been picked for the three change paths described in the roadmap, for which breakthroughs still need to be found in the future through research and development (Figure 11). These development actions are described below in more detail.

	The present	2-5 years	5-10 years
From mass production to individual solutions	Printed electronics as part of the packages Store platforms coordinating online orders Coffee vending machines, salad bars, personalisation as a physical service My Data services	Product tracking technology Store platforms coordinating orders and flexible distribution Integration of intelligent packages and refrigerators Package as a digital content medium	Next-generation personalising manufacturing technologies Online food consumption tracking technologies Automatic nutrition trackers
From centralised to agile manufacturing and distribution	Local distributors and producers offer products directly to consumers or large retailers Development of raw material and product history tracking technologies Store bakeries	Cooperation in order to reduce logistics and resource costs Agile production and store platforms New intelligent and flexible packaging technologies	Functional logistics of distributed and modular processes Distribution of production, distribution and consumption infrastructures Robotised food manufacturing and distribution
From horizontal to vertical food production	New plant ingredients and development of foods based on them Further refining of side streams	New plant species and insect economy Usage technologies for new raw materials Closed nutrient and material cycles	Food production not dependent on fields, biotechnical and vertical technologies Substrate development Waste-free ingredient and food processes

Figure 11. Timeline of sustainable food production and manufacturing from the perspective of research and development.

Individualised food production requires consumer-centric design

Individualised and consumer-centric production and the servitisation of production enabled by digitalisation is also a topic of much discussion in sectors other than the food production sector. The transition to a service ideology is not simple, however; it requires a fundamental change in how the concept of food production is understood.

In the development of digital services, it must be taken into consideration that consumers like to take a new application into use if they find that it provides added value, if the service is easy to use, and if they can trust the service and its provider. Consumer acceptance is vital for the success of new technology. Indeed, it is essential for the success of individualised food production to involve the consumers in the development work right from the beginning of the innovation process.

The consumer-centric design also applies to new food raw materials and production technologies. The views and experiences of consumers related to new alternative food production methods must be studied. Communicating the new methods and raw materials is an important part of this process.

Individualised foods and meals require the development and integration of measuring, packaging, and manufacturing technologies

In addition to nutrition monitoring and sensor technologies producing valuable data for the consumer in the future as part of wellbeing and meaningful life, development steps are still required regarding the actual food manufacturing technologies, too. The ecosystem of individualised food manufacturing requires cross-sector cooperation between the industries. With regard to this, it would be important to establish interdisciplinary programmes supported by the different ministries to accelerate the cooperation.

Information sharing and privacy protection practices require clear rules

Information on foodstuffs and consumer behaviour is already available in vast quantities from different actors. Indeed, the bottleneck in the development of customised food production will be the practices of combining and analysing information. In the future, demand for applications gathering and interpreting information will increase. On the other hand, digital solutions can also make reporting more efficient, reduce the need for monitoring, and automate food safety.

The practices of information ownership, exchange and privacy protection also need to be made clearer. A clear resolution of the information ownership question (MyData, for example) and even clear principles at the national level would advance digitalisation. One possibility could be that someone handing over “MyData” would benefit from it (receive compensation). Data for compensation would obligate the service provider and make the system more market-based.

The new food economy requires service providers to bring the network together, and a new logistics system

Individualised food production is to a large extent based on a more direct interaction between the producer and the consumer, which enables customised services and transparency of production. It is typical in business that the actors located in network nodes have an advantage in the markets. In a digitalised food chain, instead of wholesalers, these nodes may be providers of digital services who gather and bring together distributed producers and consumers, and analyse data for the needs of flexible food production. These actors come very likely from outside the current food sector.

Logistics and arranging distribution play a key role in the food economy of the future. In order for the partially distributed and modular production and manufacturing processes to be profitable, they need the support of a logistics chain that is able to agilely adapt to the needs of the ecosystem and, in particular, the consumers. There is a clear need for investment in the development of logistics also with regard to research.

Municipal infrastructure must be developed to support new alternative food production technologies and manufacturing processes

The densely built urban environment is an important market of Food Economy 4.0 and also an arena of development. Alternative food production technologies, such as insect economy and microbial processes, are based on a factory-like space suitable even for an urban environment, but this requires the construction of new infrastructure. Bioproduct factories and closed nutrient, energy and water cycles also require a new kind of infrastructure from the municipalities as well. In order to be able to test new kinds of processes and infrastructure at a near-industrial scale and in a real environment, it is important to build test environments suitable for the purpose.

Ingredient and food technologies must be developed as the raw material base changes

The use of new raw materials, such as side streams, insects, wood-based materials, microbial and plant cells requires the modification of the functionality of the ingredients and also the

management of new kinds of food matrices in order to customise the sensory quality. Bioprocess methods and the mastery of food physics play a key role here.

It is also important to take into consideration the needs for legislative changes with regard to new food raw materials. Insects, for example, cannot currently be used for human consumption. The regulations and laws related to novel food legislation and hygiene requirements must, indeed, be taken into consideration early enough and take the necessary measures effectively in order to be able to take the new alternative solutions into industrial production.

Development of value chains supporting the elimination of waste requires the creation of new networks

As ETL's waste and side stream report from 2016 states, the promotion of the circular economy requires a common platform where the information on the generated side streams and their utilisation needs are meet. The utilisation of Motiva's Industrial Symbioses model, for example, could be one alternative 60. In addition to the analysis of the side and waste streams, the financial impacts of the usage scenarios should be assessed.

Food Economy 4.0 requires investment in new business models

The transition at hand opens new opportunities for companies that wish to reinvent their business by launching innovative products and services using new kinds of business models utilising digitalisation. Furthermore, the cyber-physical systems of Food Economy 4.0 offer business opportunities for entirely new kinds of actors in the ecosystem of food production. These include the providers of different service platforms and actors concentrating on data management and digital services.

Food Economy 4.0 is emphatically international in nature. What has already happened in the field of speciality stores, for example, will also happen in the food business to some extent. Now is the right time for Finnish actors to prepare for a new era of food economy. The business models of the new food economy have an opportunity to enter the international markets in completely different volumes than today, since the markets are undergoing a transition almost everywhere.

Business success in the new food economy requires companies to have good preparedness and know-how to utilise the possibilities created by digitalisation. Only a few Finnish food economy actors currently have sufficient capabilities for this: in other words, the ability to utilise information technology and the data and information it produces in the creation of new business models. We must invest in this on a wide front.

IN CONCLUSION

This roadmap work has shown that we are already on the path of change. National and international strategies point in the same direction. The winners will now be those who act fastest and those who provide the best service to consumers in the new digital environment. Finland could be a trailblazer as a combiner of technology and food industries and as an applier and tester of new technologies.

APPENDIX: COMPOSITION OF THE ROADMAP

The preparation of the Food Economy 4.0 roadmap began in the spring of 2016 as part of VTT's strategy process and continues VTT's long-term work in identifying new growth paths for food production.

To build a foundation for the roadmap, experts in VTT's different research areas were interviewed. Trends affecting the change of the food chain and the key competence areas contributing to the change were identified in workshops and group discussions with experts; views were also gathered internally by means of a survey.

After this, the working group compiling the roadmap created preliminary definitions for three change paths that were assessed and refined further by experts from VTT's different research areas at a workshop arranged on September 1st, 2016. This workshop specified the change paths, the technologies and competencies enabling them, and the required development steps in more detail. The workshop also envisioned possible solutions in the new food economy, based on which a third workshop arranged on October 5th, 2016 started building business models of the future in cooperation with food sector actors.

Following these workshops, the working group reviewed the created materials jointly, and used these materials together with reference literature to draw up proposals for the final vision and change paths, and recommendations promoting the new food economy. The created roadmap proposal was presented to food sector actors in a workshop arranged on December 1st, 2016, and it was edited into itsfinal form based on the discussions had during the workshop.

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Kuusisto Olli
Lantto Raija
Peltola Johannes
Pennanen Kyösti
Pursula Pekka
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Toivonen Petri, Kesko Oyj
Vanhanen Arja, Metsä Board Oyj
Vehmas Kaisa, VTT Oy
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Vuorinen Kari, Plantui Oy
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Vehmas Kaisa, VTT Oy
Åkerman Maria, VTT Oy

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Title	**Food economy 4.0** **VTT's vision towards intelligent, consumer-centric food production**
Authors	Kaisa Poutanen, Emilia Nordlund, Jaakko Paasi, Kaisa Vehmas, Maria Åkerman
Abstract	VTT has envisioned change paths towards a new era of smart 21st century food production, where physical production merges with the utilisation of digitalisation into a new food economy. Food Economy 4.0 is a sustainable consumer-centric ecosystem that connects traditional and new food economy actors with end users in new ways. In the Food Economy 4.0 vision, the consumer's activity increases, empowered by digitalisation. Raw materials are utilised more efficiently than today, and some of the raw materials are produced using new production methods. Personalised solutions and services reinforce the role of food in demonstrating values and supporting health and vitality. During the work, three change paths to a new food economy were established in cooperation with VTT's multi-sector team of experts and representatives from companies in the food sector: 1) From mass production to personalised solutions, 2) From centralisation to agile manufacturing and delivery, 3) From horizontal to vertical food production. The visions, enablers of change, and the required advancements have been identified and defined for the change paths. Food Economy 4.0 contains a lot of opportunities for creating new business. The wide scale success of companies requires cooperation across traditional sectoral borders and from both companies and government ministries in order to build a favourable foundation for the innovation and development of exports.
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Nimike	**Elintarviketalous 4.0** **VTT:n visio älykkään, kuluttajakeskeisen ruokatuotannon aikakauteen**
Tekijät	Kaisa Poutanen, Emilia Nordlund, Jaakko Paasi, Kaisa Vehmas, Maria Åkerman
Tiivistelmä	VTT on visioinut muutospolkuja uuteen 2000-luvun älykkään ruokatuotannon aikakauteen, jossa fyysinen tuotanto sulautuu digitaalisuuden hyödyntämisen kanssa uudeksi elintarviketaloudeksi. Elintarviketalous 4.0 on kuluttajakeskeinen kestävän kehityksen ekosysteemi, joka uusin tavoin yhdistää perinteisiä ja uusia elintarviketalouden toimijoita loppukäyttäjiin. Elintarviketalous 4.0 visiossa kuluttajan aktiivisuus ruokavalinnoissa kasvaa digitaalisuuden voimaannuttamana. Raaka-aineet hyödynnetään nykyistä tehokkaammin, ja osa raaka-aineista tuotetaan uusien tuotantotapojen avulla. Yksilölliset ratkaisut ja palvelut vahvistavat ruuan roolia arvojen osoittamisessa sekä terveyden ja elinvoimaisuuden tukemisessa. Työssä rakennettiin kolme muutospolkua uuteen elintarviketalouteen yhdessä VTT:n monialaisen asiantuntijaryhmän sekä elintarvikealan yritysten edustajien kanssa: 1) Massatuotannosta yksilöllisiin ratkaisuihin, 2) Keskittyneestä ketterään valmistukseen ja jakeluun, 3) Horisontaalisesta vertikaaliseen ruuantuotantoon. Muutospolkujen osalta on tunnistettu ja määritelty tulevaisuuskuvat sekä muutoksen mahdollistajat ja tarvittavat kehitysaskeleet. Elintarviketalous 4.0:ssa on paljon mahdollisuuksia uuden liiketoiminnan synnyttämiselle. Yritysten laajamittainen menestyminen edellyttää perinteiset toimialarajat ylittävää yhteistyötä niin yritysten kuin ministeriöiden kesken, jotta luodaan suotuisat puitteet innovoida ja kehittää vientiä.
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Food economy 4.0

VTT's vision of an era of smart consumer-centric food production

How will there be enough food for everyone? How can food be produced while fostering the Earth and its atmosphere? How and from where will we buy our food? How will information technology affect the management of food information?

Internationalisation, urbanisation, and ageing are transforming the consumers and the living environment. In the future, food must be produced with increasingly smaller investments for 'diginative', aware and demanding consumers. Food must support staying healthy. What is the new Food Economy 4.0 that answers these challenges?

The roadmap work described in this publication identified three change paths towards Food Economy 4.0, where physical production merges with the utilisation of digitalisation. The result is a sustainable, consumer-centric ecosystem that also includes entirely new business models.

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