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50 trends influencing Europe's food sector by 2035

The FOX project

FOX is a unique collaboration between universities, research institutions, small to medium enterprises, industries and associations, who are extremely grateful for the financial support of seven million Euro from the European Commission's Horizon 2020 Research and Innovation programme. The project lasts for 4,5 years (2019–2023).

The FOX partners

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European Commission

Food processing in a box

Introduction

Europe 2035 – What are we going to eat? Where will we do our grocery shopping? How can we produce food using fewer resources? Who can benefit most from new trends? Which other industries will affect the food industry? What will the food sector look like? These questions are part of the EU Horizon 2020 project FOX, and are at the core of FOX's foresight research component.

FOX – Food processing in a Box – is a project in which more than 25 European partners aim to transform large-scale technologies for the processing of fruits and vegetables, to small, flexible and mobile units in your neighbourhood! FOX is all about health and sustainability. The innovative processing solutions are therefore flexible, resource-efficient, and based on seasonality and demand. It considers the expectations of farmers and small food businesses, looks at the technical and economic feasibility, and takes into account the needs of the food chain and consumers. Consumers will be actively involved in the development of new products and new business options for sustainable consumption. This allows for transparency and trust in the food chain. FOX stimulates short food supply chains; transitioning from a more centralised industry, to local production hubs. So-called food-circles are the European regions in which the FOX technologies will be demonstrated to be integrated into the entire food production chain.

The Competence Center Foresight of the Fraunhofer Institute for Systems and Innovation Research ISI derives and conducts foresight processes for developing future scenarios that outline the framework conditions of the European food innovation system of 2035. As part of this process, scientists and experts have identified and analyzed a variety of trends influencing the food sector. The most compelling 50 are presented as "trends to go" in this brochure. With additional information, the 15 most relevant trends are explained in more detail as "trends à la carte".

50 Trends to Go

1 New nutrition pattern

As scientific and technological advances develop in the field of health and nutrition, more focus has been directed toward the emerging field of nutrigenomics. The science of nutrigenomics involves the application of the human genome to nutrition and personal health to provide individual dietary recommendations. Therefore, consumers may one day have a greater ability to reduce their risk of disease and optimize their health. Nutrition is becoming a life's work. People take services that will help in filtering the offers and choose the right food. There is an asymmetric development: Healthier cooking methods on the one hand, a shift to packaged processed unhealthier food, especially in urban areas, on the other hand.

2 Functional food

The Term "Functional food" is not clearly defined. It is advertised an added health benefit above the food product's traditional nutritional value. Added ingredients are e.g. vitamins, plant sterols, omega-3 fatty acids, and folic acid. Examples include probiotic yoghurts, fruits and vegetables, whole grains, fortified foods, and dietary supplements. The scientific community continues to increase its understanding of the potential for functional foods and their role in maintaining and optimizing health while new food products are developed to include beneficial components. Synonyms are "Nutritional Food", "Designer Food", "Pharma Food", "Healthy Food", or "Wellness Food".

3 Vooking – vegan – gluten free

More and more people stop eating meat for a variety of reasons. Many prefer vegetarian food for health reasons, for sustainability, but also for culinary pleasure. The VOOKING project develops a new kitchen design has a positive influence on the future of nutrition and cooking. In addition, the gluten-free cuisine will be a trend. In this context, more ancient, super-nutritious grains such as quinoa and amaranth will be used instead of wheat flour. The number of people who must avoid gluten for medical reasons is considerably smaller. For the majority of people on gluten-free diets, there is no medical necessity. However, it is still a lifestyle boom, which has to be considered by producers.

4 Increased flexibility of consumption

As an expression of increasingly mobile lifestyles (e.g. out-of-home meals, simultaneous travel and working hours, mixing of working hours and household work), consumers' shopping habits are also becoming more flexible. Shopping routes are optimized to buy more in fewer shopping trips (e.g. one-stop shopping in a large shopping centre, reachability of shopping opportunities or neighbouring networks) or substituted (e.g. online shopping with a delivery service). This flexibilization of consumption promotes full-range retailers, more flexible shop opening hours and new sales channels (mobile offers with instant shopping and no spatial or temporal boundaries, both stationary and online shops).

5 Customization of products

The paradigm of mass customization emerged in the late 1980´s, as the demand for product variety increased. A continued move away from mass production with virtually identical products to increased customization, in which customers demand the product to be manufactured to their exact requirements. Customizing also requires the delivery of products and services within much shorter periods. The main drivers are plural life forms between tradition and modernity; this also relates to globally concurring value systems and the development of hybrid cultures, e.g., changing family orders and life forms as well as the increasing "do it yourself"-movement and economy.

6 Presentation of goods for specific purchasing types

The product range and product offers are increasingly oriented towards consumer profiles. From the customers' point of view, shopping should become simpler, more transparent and more sustainability-oriented. Products that are harmful with regard to sustainability will be sorted out and products that promote sustainability will be promoted. In the future, packaging will also be tailor-made and individualized, which will increase the complexity of logistics. Traceability of products will increase. Because of the digitalization of society, "marketing for one" will offer new opportunities to producers and retailers to personalize advertisement and target consumers directly and more effectively.

7 Products and service bundles

Firms will increasingly bundle goods, services, technology, and financing to achieve competitive advantage. Over the past few years, an explosion in technology-driven delivery options for consumer goods and services has been disrupting traditional distribution methods, e.g. Google (Google Express). As refrigerators, cabinets, packages, and even bodies become connected in a tapestry of networked matter, shopping turns into a wholly automated process that requires no human decision-making. Food orders are determined by our inferred preferences and health needs and are triggered automatically when supplies dwindle. The role of the consumer is more and more passive because the device takes proactive actions.

8 Products for single households

There is a trend, e.g., in Germany and the UK, toward smaller "family units". This change has particular implications for the scale and type of housing demand and may further exacerbate the issue of housing affordability. Emerging trends such as divorce, later parenting, and cohabitation without marriage are changing traditional household and family structures. Single-adult households are often composed of young unemployed individuals or the non-working elderly. Cooking, especially in single households, might be seen as not economic. Convenient food is usually ready to eat without further preparation as, for example, dry or frozen foods.

9 Consumption in upheaval

Digitalization, technological progress in the food manufacturing industry and new business model innovations for the distribution of individualized or personalized products are changing the behavior of consumers. The expansion of consumer opportunities allows more options for individual action by users. Because of the increasing use of mobile devices, situational shopping – of whichever products – is gaining in importance. Here, the place, time and emotions of the user

are decisive for the purchase. In the future, the ratio of different purchasing options such as specialist retailers, weekly markets/farm-gate sales by producers, online trading or convenience stores will change considerably.

10 Peer to peer based consumption decisions

Networks of people around the world advising each other are the dominant factor in democratized consumption and purchasing decisions for products and services. Competing and complementary digital platforms provide access to detailed product information provided in a transparent manner. At the same time, retailers have bridged digital and physical shopping experiences so that virtual shopping now involves a range of personalized high quality interaction to support the consumption decision making.

11 Increased market power of retailers

The world's wealthiest companies include Walmart, Fast Retailing, IKEA, H&M, Tesco, Carrefour and the discount chains Aldi and Lidl. The balance of power has shifted from fast moving consumer goods producers such as Unilever and Nestlé to retailers. Retail is highly localized in Germany, which is why few players can significantly change distribution e.g. drive-in, delivery services and pick-up stations. Current delivery services are being developed in cooperation with retailers, which maintains their power. Through its gatekeeper function between production and consumption, the retail trade has a considerable influence on prices, quality, preferences, assortment, and production conditions.

12 Changing legal framework for retailers

For the retail trade, at the interface between production and consumption, an abundance of regulations is relevant. Supply chains are affected by trade agreements such as TTIP, CETA and Mercosur and other global developments such as Brexit. For the first time, the EU's package of measures on recycling also addresses obsolescence. The Packaging Ordinance is already available in the 7th amendment, among other things for addressing the online trade. Packaging of fresh foods for delivery services is also heavily regulated. The Food Information Ordinance (LMIV) health promotion measures such as a sugar tax, the food traffic light system or other nutritional labelling have been widely discussed.

13 Digitalization of trade

In the Point of Sale of the future, virtual and real worlds are increasingly merging (including automation and networking with Supply-Chain Management, multimedia shopping environments for an individual customer approach, virtual shelves for price comparison). Online trading is also growing strongly because of "Amazonization" in individual segments. When online and offline are combined, the range of purchasing processes is widening from incremental (e.g. smartphones in shops, delivery of products to a store) to disruptive (e.g. automated shopping on the Internet of Things). Digitalization is making data protection and data security more important, but also makes customer data more valuable.

14 Diversification of business models and marketing

The stationary retail trade relies on its strength of the emotional shopping experience and uses strat-

egies such as pop-up stores or viral marketing. Online-Shops also use Pop-up stores occasionally to test their products. Retailers are increasingly addressing their customers via various channels such as Point of Sale, websites and various social media platforms (multi-channel marketing). At the Point of Sale, different senses are addressed to influence the perception, evaluation and behavior of the customer (multi-sensory marketing). The Internet of things opens up new possibilities such as automatic checkout systems, automatic transmission of product status information and orders from home.

15 Blockchain and smart contracts

Companies may be able to automate and decentralize the management of their operational business. Blockchain technology and smart contracts make this possible. Blockchain describes a decentralized database that records transactions and stores them in chained blocks (e.g. Bitcoin). The owner is not an institution, but the network. The transactions are checked and validated by the network itself, which requires an encryption/digital signature. Smart contracts are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. Trust in Blockchain needs to increase and data protection regulations need to be updated for a wider application of Blockchain and smart contracts.

16 Local food circles

A food circle is a new way of conceiving and organizing our agricultural and food systems. It connects the many people involved in food production in an interdependent and holistic way. Practically, a food circle is engaged in promoting the consumption of safe, locally grown food that will encourage sustainable agriculture and helps farmers preserve rural areas. While the concept sounds simple, it means that we must radically change the way we participate in the act of growing and consuming food. In countries around the world, a number of social innovations are emerging in the context of this vision of localized food production and consumption chains.

17 Changing food systems

While population growth increases the demand for agricultural products and stimulates farming activities, urbanization requires food to be easily stored and transported. Thus, food processing has become a key factor in the transformation of food systems. It has brought with it the standardization of agricultural output and, in many cases, the localization of primary production and the consolidation of farmland. Many smallholder farmers have become landless agricultural workers, or have migrated to towns and cities in search of employment, accelerating urbanization.

18 Increased requirement for transparency of supply chain

Many consumers demand more transparency and control along the often complex and opaque supply chains because of increased specialization and division of labor. The product origin plays a greater role in consumer decision-making. Incidents such as the collapse of a textile factory in Sabhar, Bangladesh, in 2013 or Food Fraud (targeted ingredient fraud in food) usually outrage the public in the short term and can lead to long-term loss of consumers. Individual companies are restructuring their supply chains according to new ethical standards. Cross-company standards and cooperation (e.g. f-trace developed by GS1 Germany) to promise to meet the new requirements as cost-effectively as possible.

19 Sustainable production and value chains

The value chain consists of all steps included in the production, consumption and disposal/recycling processes of a particular product or service. A typical value chain goes from raw material sourcing to disposal, through suppliers, manufacturers, retailers, consumers, and other actors. In the circular model of the value chain, materials are reused or recycled to minimize waste. In the sustainable value net, there are no longer up- and down streams but a network of interactions and value ex-changes. The concepts of production and consumption become increasingly blurred. Seamless integration of small producers will allow procurers to meet demands for locally sourced food and reduce waste.

20 Convergence of the food and health markets

Increasingly, food should not only satisfy the requirement of being "tasty" and "healthy", but also promote health and beauty. The boundaries between the individual industries and products, from food and pharmaceuticals to cosmetics, become blurred. Drug stores and supermarkets are competing for customers, who put an emphasis on healthy food. Pharmaceutical, food and cosmetics manufacturers are thus penetrating each other's fields. They exert influence on agriculture in order to secure its raw material base and steer it in the right direction. As consumers want reliable information about a products health effects, regulators are putting strict limits on health claims in advertisements.

21 Do-it-yourself as competition to industrial production

More and more people worldwide are starting to produce goods and services themselves – alone or in small communities – instead of buying them. A wide variety of goods such as clothing, software and energy are thus produced directly by private individuals or repaired instead of new purchases. Borders between consumers and producers disappear. Emphasis on individual creativity for identity formation and rediscovery of local crafts traditions, complementary to globalization is an important characteristic. In the food sector, Do-it-yourself does not mean cooking, but rather preserving products for stock. In other words, products that we would otherwise buy in supermarkets, such as preserves, cans and fermented foods.

22 Sharing instead of owning

There exists a growing number of movements, initiatives, entrepreneurs, and new business models that aim to facilitate sustainability in the way we consume, live, and move. One example is the collaborative consumption (sharing, swapping, etc.) revealing a shift in preferences away from ownership of goods to "access" to goods and services and from being passive consumers to becoming co-producers of goods and services (e.g. urban farming, growing your own food). Pooling resources in various ways is becoming integral to urban life and is likely to influence the future of cities. For consumers, collaborative consumption means convenience, innovation, local, virtual currencies community and also green values.

23 Sufficiency society

A constant and still existing assumption in political science and economics is that economic growth leads

to an increase in the prosperity of society. This is justified by the fact that growth enables new jobs, rising income and a social system that secures basic needs. Recent findings show that this relationship has been shaken. The issues of "social responsibility", "quality of life" and "qualitative growth" (counterweight to economic growth) are gaining in importance. Sufficiency research questions which personal, economic social and political conditions stand in the way of an orientation towards moderate consumption and a redefinition of good life and how these obstacles can be overcome.

24 Slow life movement and Downshifting

Downshifting is a social behavior or trend toward a simpler life: It emphasizes an improved balance between leisure and work; the focus is on life goals such as personal fulfilment and building relationships rather than the pursuit of economic success alone. It has the same orientation as the Slow life movement, which aims at reducing life's pace and eliminating nonessentials from your life. Downshifting is by no means a radical turning away from society, as in the case of so-called "dropout". Rather, it means taking cautious, clever partial steps to reduce the workload to an individually acceptable or desired level and to use the resulting freedom for more diversity and meaning in life.

25 Civilization diseases on the rise

Living conditions in industrialized countries are causing an increase in diseases that are only prevalent in these regions. These are generally non-transmissible, but often lead to temporary or early retirement. Examples are cardiovascular diseases, cancer, tooth decay, diabetes mellitus type 2, and eating disorders. Mental illnesses are strongly becoming the most frequent cause of occupational disability. The phenomenon is not limited to the elderly. Many people already fall ill in their young and middle years. Diseases are multifactorial; factors can be environmental toxins, malnutrition, noise, a lack of exercise, changes in working conditions, alcohol and nicotine consumption, etc.

26 Urbanization

While, in general, world population growth is slowing down, in some regions population will continue to expand well beyond 2050 and even into the next century. More people now live in cites than in rural areas, and this discrepancy is projected to increase as population grows. The effects of urbanization include, inter alia, increased resource use, increased vulnerability to natural and other disasters as well as the strengthening of the trend of declining birth rates. Urbanization has been also accompanied by a transition in dietary patterns and has had great impacts on food systems.

27 Competition for land in urban agglomerations

Land intensive economic sectors (e.g. agriculture) compete with the living and working space of other sectors due to increasing urbanization. The sustainable securing of urban food and resource supplies is increasingly becoming a challenge – especially in densely populated cities with limited access to surrounding agricultural areas. Furthermore, intensive farming practices and the massive use of chemicals are putting pressure on natural resources. Against this background, the first pilot projects are working intensively on innovative cultivation methods and technologies (e.g. urban farming and gardening) that will bring food and resource production back to the places where it is consumed.

28 Resource utilization

Global consumption of energy, water, and other strategic resources is drastically increasing. This relates to fossil energies, fresh water, minerals, and metals. Rising energy and resource consumption is being driven by population growth and economic development, particularly in developing countries and emerging economies. Even though fossil resources will continue to play a major role in future energy supply in terms of managing and mitigating the impacts of climate change, other natural resources will be needed to realize and facilitate progress in the creation of renewable energy. Improved energy efficiencies and decentralized power supplies will become more important.

29 Consumption-related resource usage

In the EU, around 88 million tons of food waste are generated annually, 53 percent of the volume is wasted by households. The costs associated with food waste for the EU are estimated to be around 143 billion euros. Two-thirds of the costs are associated with food waste from households. This large share is due to the expenses that accumulate along the supply chain, such as packaging costs. The total amount of packaging waste is ever increasing due to more mobile consumption habits. For land use, materials and water consumption, the food sector has the largest footprint of all demand areas, for CO_2 it is the mobility sector. Hot spots in online trading are mainly CO_2 emissions from returns and multiple trips.

30 Re-use of food

The world wastes more than 1.3 billion tons of food each year. Now South Korea is taking a lead, recycling 95 percent of its food waste. The South Korean government has taken radical action to ensure that the mountain of wasted food is recycled. Dumping food in landfill was banned and the government introduced compulsory food waste recycling using special biodegradable bags. An average four-person family pays $6 a month for the bags, a fee that helps encourage home composting. The bag charges also meet 60 percent of the cost of running the scheme, which has increased the amount of food waste recycled from two percent in 1995 to 95 percent today. The government has approved the use of recycled food waste as fertilizer, although some becomes animal feed.

31 Scandalization of food waste

Reasons for food waste on the part of consumers include increasing numbers of single households, poor shopping planning, misinterpretation of the use-by date and inadequate storage and preparation. The EU aims to halve food waste by 2020 in order to secure the world's food supply, conserve resources (material and financial) and protect the environment. The Federal Ministry of Food and Agriculture launched an initiative against food waste (“Too Good for the Bin”) in 2016. In the mass media, waste due to misinterpretation of the use-by date is the subject of discussion. “Containering”, food shops and food sharing initiatives to pass on still good food are part of the cityscape in many places.

32 Food losses and waste

Globally, around one third of all food produced is lost or wasted in production, post-harvest, processing, retailing or consumer handling. Consumers in industrialized countries throw away around ten times more food than in developing countries. In a world where millions of people are starving, this is a strong indication of the inefficiency of current food systems.

Food losses and waste often lead to economic losses for farmers and other actors in the food value chain, as well as to higher prices for consumers. Both have an impact on food insecurity by making it more difficult for vulnerable groups to access food. Reducing food losses and waste would increase the supply of available food and strengthen global food security.

33 Stricter waste regulations

Each year around 20 percent of food produced in the EU is lost or wasted, causing unacceptable social, environmental and economic harm. EU is committed to solving this problem and putting its food system onto a sustainable path. In the revised EU waste legislation, adopted in May 2018 as part of the Circular Economy Action Plan, specific measures on food waste prevention have been introduced which will provide the EU with new and consistent data on food waste levels. The new waste legislation requires Member States to implement national food waste prevention programs and, importantly to reduce food waste at each stage of the supply chain, monitor and report on food waste levels.

34 New ways of food storage

The goal of any kitchen renovation is to create a functional cooking area making the most of the space you have at your disposal. Whether it is a redesign of your current kitchen or increasing its footprint through expansion within or outside of the home, choosing the right layout is important in meeting your family's needs. The drivers for food storage are among others extreme seasonal climates worldwide, which cause radical changes in traditional agricultural characteristics and might cause food shortages. Most people have probably thrown out food due to spoilage, but regularly doing this is terribly wasteful and expensive. The preservation of the quality of food could be enabled by new food storage techniques.

35 Climate change

The impacts of climate change are expected to be most adverse in low- and middle-income countries, where millions of people depend on agriculture and are vulnerable to food insecurity. With regard to food production, the sharp rise in meat consumption has massive impact on our climate. In 2015, world leaders explicitly acknowledged the need to address the threat of climate change. They negotiated, under the aegis of the United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement on climate change, which recognizes "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse effects of climate change" (UNFCCC, 2015).

36 Hidden environmental impact of consumption

Today's consumption patterns are decisive for future disposal and environmental problems (e.g. material diversity and combinations). Consumption and environmental effects are often spatially decoupled, e.g. in the case of active pharmaceutical ingredients in the drinking water cycle and micro plastics in the oceans. Some effects are also temporally decoupled. The location, distribution, nature and dynamics of such creeping environmental effects are often only known in isolated cases. Individual consumption patterns are closely linked to traffic- and production-related environmental impacts. The consumption patterns of consumers with high income cause by far the greatest environmental impact.

37 Sustainable food for all

With the rising global population, food availability is an important need and an important challenge. A sustainable food system is fundamental in solving many of the global issues, such as climate change, land use, biodiversity and mass migration. Another development that needs to be highlighted in this context is the double burden of famine of obesity: While undernutrition in developing countries is still a huge problem, particularly in Sub-Saharan Africa and South Asia, malnutrition caused by unhealthy diets is becoming an increasingly serious problem today. This development not only applies to high-developed countries but also among the poorest populations.

38 Edible packaging of food

On average, every citizen in the 27 Member States of the European Union generated 164 kilograms of packaging waste in 2008, and the trend seems to be that we will produce a lot more in the future. The packaging we discard is stuff like paper, cardboard, glass, plastics, wood, and metals, and it all ends up in huge landfills or as trash polluting nature. An example: WikiCells is a new technology addressing this growing, global issue in a simple and unique way – namely via commercial food products with edible packaging. The skin is made from vegetal elements such as fruit, nuts, grains, and even chocolate, using only a tiny portion of chitosan (chemical polymer) or alginate (algae extract).

39 Food safety

Access to sufficient safe food is a basic requirement for human health. Ensuring food safety and security in a highly globalized world presents increasingly difficult and often under-appreciated challenges for governments, commercial organizations, and individuals. The risks of unsafe food are substantial but can be difficult to quantify. In parallel with the increasing size of the world population, consumer demand for a wider variety of foods is growing, entailing a longer and more complex food chain. There is a need to refocus attention and to reenergize commitments on food safety. Better data and methods are needed to estimate the health impact of foodborne diseases and to guide response and prevention actions.

40 Transboundary pests and diseases

The spread of pests and diseases, which has dramatically increased as a result of globalization, trade and climate change, can have far-reaching economic, social and environmental impacts. In particular, this trend poses a major threat to global food security. Cross-border plant pests and diseases can easily spread to several countries and reach epidemic proportions. Outbreaks and upsurges can cause huge losses to crops and pastures, threatening the livelihoods of vulnerable farmers and the food and nutrition security of millions at a time. Plant pests and diseases are spreading through trade or other human-migrated movements, environmental forces such as weather and wind, and insects or other vector borne pathogens.

41 Conflicts, crises and natural disasters

Conflicts are a major driver of food insecurity and malnutrition. They reduce food availability, disrupt access to food and health care, and undermine social protection systems. Every famine in the modern era has been characterized by conflict. These conflicts are complex by nature. They can be triggered or amplified by climate-related natural disasters and the impact that they have on poverty eradication and

food security. Natural disasters tend to trap vulnerable people, in particular, in a cycle of poverty because they are less resilient and lack coping capacity. It can be assumed that extreme weather events, caused by climate change, will further worsen the situation of these people.

42 Decline of biodiversity

Biodiversity is the diversity of species, of organism communities, and genetic diversity. It influences agricultural systems in many beneficial ways, for example by supporting nutrient cycling, soil formation, regulation of pests, pollination, etc. Therefore, biodiversity has a prominent role in mitigating yield risks in agriculture. On the other hand, economically optimised agriculture contributes significantly to biodiversity loss, e.g. by landuse changes, by monocultures, by replacing traditional plant varieties and animal breeds by high-yielding ones which meet uniform quality criteria and can easily managed by machines. Due to biodiversity losses, adaptation of agriculture to climate change and other changing environmental conditions has become more challenging 60 to 70 percent of global terrestrial biodiversity loss is related to food production.

43 Label accuracy and transparency

Certification helps consumers to make informed decisions. Many of the early products designed to be environmentally responsible, such as electric cars and recycled paper, did not meet the basic expectations of consumers. Rightly or wrongly, these early disappointments have made it tougher to convince today's consumers that green products work as well as those that they are intended to replace or are worth higher prices. In their search for guidance on consumption choices, people trust each other more than any other source of information. At the same time, studies are showing that consumers are less trusting of brands than in the past.

44 Agricultural productivity and innovation

To meet demand, agriculture in 2050 will need to produce almost 50 percent more food, feed and biofuel than in 2012. This estimate by the Food and Agriculture Organization (FAO) takes into account the recent United Nations (UN) forecasts indicating that the world's population would reach 9.73 billion in 2050. In sub-Saharan Africa and South Asia, agricultural production would need to more than double by 2050 to meet increased demand, while in the rest of the world the projected increase would be about one-third above current levels.

45 New forms of food production

Worldwide food production currently consists primarily of traditional agriculture, livestock breeding and marine food production, and is caught between the conflicting demands of various intensive, highly economically oriented forms of production and ecologically shaped food production. The rising world population and its increased demand for protein-rich food creates a higher demand, while climate change forces agricultural practices to adapt to higher temperatures, more extreme weather events and less precipitation. New forms of food production include, for example, vertical farming, urban gardening, aquafarming or the production of artificial meat using microorganisms or tissue engineering.

46 3D printing of food

Many professional chefs are currently exploring the use of 3D printing for food and culinary purposes. While some efforts are being made to commercialize and make 3D printed edibles mainstream, for the moment it seems its true potential might lie in either gastronomic environments, where the professionals can play with and experiment with new 3D printed flavors and textures; or in medical ones, to help persons who have trouble eating.

47 Automated indoor farming

There are a number of reasons to move farming indoors. In areas with high radioactivity – such as those experiencing the aftermath of nuclear disasters – there are fears that traditionally grown produce could contain radioactive fallout. In areas where water resources are lacking, growing vegetables can be challenging. In such cases, factory farming, which is mostly indoors, may be viable and scalable. Some people think that in the long run agriculture could become fully automatized, first in areas with a lack of human workers and extreme conditions and then around the globe. This could have disruptive impacts in areas like food culture, sustainability, social fabric and employment.

48 Precision farming

Precision farming, also known as Satellite Farming, Site Specific Crop Management (SSCM) or Computer-Aided Farming (CAF), relies on the latest information and technologies available – GPS, satellite imagery, control systems, sensors, robots, variable rate technology, telematics, software, etc. – to improve crops in every step of the growth cycle: soil preparation, seeding, and harvesting. The ultimate goal of applied technology in agriculture is to proliferate yields, reduce harvest times, and reduce costs and environmental impact. In the long term, it is foreseeable that the farms of tomorrow may no longer need people to grow crops at all.

49 Remote interaction with people and machines

Being able to interact with other people from a distance as if they were physically present and to control things, machinery and processes has been a guiding ideal for communications technology experts, providers and politicians inhabiting Ministries of Telecommunications. This ideal continues to drive the development of interfaces between people, machines and infrastructures. As interfaces improve, the multiplicity of distant modes of interaction becomes a core feature of socio-technical networks that become more and more independent of place and enable individuals to reach the whole world.

50 Artificial intelligence and machine learning

Artificial intelligence has (self-)learning abilities. However, the term is not clearly defined. Strong artificial intelligence generally refers to the computer-aided reproduction of human intelligence. The goal is an autonomous computer system that can work independently on abstract, non-trivial problems under changing boundary conditions. Weak artificial intelligence refers to the imitation of intelligent behavior by programed algorithms. Machine Learning is a part of artificial intelligence, in which machines develop solutions through algorithms based on patterns in available data. Artificial intelligence has a huge impact on products, production environments and socio-economic systems.

Which trends will influence Europe's food sector by 2035?

Relevance of different trends for the European food sector by 2035
Opinion of the FOX consortium and external experts

Very high relevance High relevance Moderate relevance

Fraunhofer ISI

PRODUCTION

PROCESSING

PACKAGING

LOGISTICS

SALE

CONSUMPTION

Methodology and food value chain

In this project, future scenarios for the European Food Sector 2035 will be developed, beginning with the identification of trends influencing its future development trajectories. For this study, experiences from previous and ongoing projects conducted for national and international industry clients as well as results of public funded projects on national and European level have been analysed and used as input for the trend analysis. In addition, a range of current trend studies with focus on agriculture, food production and nutrition were taken into consideration. From more than 100 trends, the most compelling have been selected as "50 trends to go".

Based on these trends the FOX consortium and external experts identified the 15 trends with highest relevance for Europe's food sector 2035. Fact and figures underlay the trends with current data and assumptions for the future. Implications for the food sector and the relation to the food value chain were identified. The icons at the side show at which step in the value chain this trend will have the highest impact. The food value chain covers all phases of the food lifecycle, from production (livestock farming and crop production including input industries) and processing to packaging and logistics as far as sale and consumption.

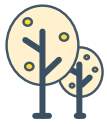
Further foresight activities in this project

The identified trends are indicators for change. They will be used to develop future framework scenarios, describing different possible futures for the food sector in 2035. These scenarios will serve to align other work packages towards future requirements in the food sector. For each of the four FOX food circles, specific regional scenarios will be elaborated in workshops with internal and external experts and relevant stakeholders. The workshops will be held around local food events and conferences to maximise the involvement of local expertise. The foresight process is designed and conducted by the Competence Center Foresight of the Fraunhofer Institute for Systems and Innovation Research ISI.

The aim of the Competence Center is to use foresight activities to strengthen the future viability of its clients and society as a whole. With the help of participatory and discursive formats, it promotes the exploration of alternative developments, initiates learning processes, question thought structures and perceptual filters, and opens up new design possibilities. Its clients develop future competence (futures literacy) and are sensitized for a conscious handling of uncertainties and changes.

1

Production



Processing

Packaging

Logistics

Sale

Consumption

Local food circles – changing food systems

Description

Food circles promote the consumption of safe, regionally grown food that encourages sustainable agriculture practices and helps maintain farmers and rural areas. The circular practice relies on spatial proximity and ideological parity of actors across all production, consumption and waste management activities. A functioning food circle accounts for material, geographical, sociocultural, and political dimensions. Advantages include better traceability and freshness of products, reduced packaging, improved relationships between farmers and consumers, and decreased environmental damage from agriculture and logistics. One disadvantage is that consumers may face constraints in accessibility of food from their local circles, due to climatic and seasonal limitations or higher prices, for example.

Facts and figures

Increasing interest in direct sale from farmer to customers has led to various innovations. Examples of social innovations include: a) community supported agriculture b) food circle buying clubs, c) seasonal food box subscriptions, and d) online farm shops. Additionally, cascades effects create value from material previously considered waste, encouraging novel business models and technologies. Food circles build on the concept of nutrition system localization, which refers to creating and maintaining distinctive food identities. These identities are preserved and protected against external influences. The full automation of production (robotics, automation technology, sensor technology) is made possible and necessary. This process automation leads to a change in the market segment of agricultural machines. The operator models are currently still unclear, as the boundary between producer and consumer is increasingly disappearing.

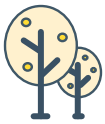
Implications for the food sector

Food Circles shift food production from centralized structures towards decentralized, partially autonomous nutrition systems. This paves the way for bottom up innovations and can decrease market share of big players. Local niches for the delivery of distinct food services can lead to innovations and an efficient customer response.

2

Alternative proteins

Production



Description

Reshaping the food system is crucial to meet the protein needs of estimated 10 billion people by 2050 in an inclusive, sustainable, healthy and nutritious manner, while meeting the Paris Agreement climate-change targets. There are three pathways to meet the increasing needs for protein: Developing alternative-protein products, changes to current production systems and consumer behavior change. In the field of alternative-protein production, there has been a burst of recent innovation involving new purely plant-based alternatives, products based on insects and other novel protein sources, and the application of cutting-edge biotechnology to develop cultured meat.

Facts and figures

Meat poses a special challenge to the future development of the global food system. The per capita consumption of meat in the USA is around 90 kg per year, with an upward trend, in Europe it is around 65 kg per year. In the context of climate change, it would be impossible for a global population of 10 billion people to eat these amounts of meat. It would require too much land and water, and lead to unacceptable greenhouse-gas and other pollutant emissions. In addition, excess meat consumption and current production have significant effects on human health, livelihoods and the economy. More and more companies like "beyond meat" are emerging and commercializing alternative proteins. Most of these companies record extreme growth rates proving the demand and the customer acceptance of these food products.

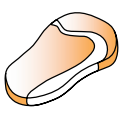
Implications for the food sector

How the food sector will develop is far from clear, but there is a possibility of genuine disruption in the near future. It is foreseeable that the meat and alternative-protein industries will coexist and have the opportunity to complement one other. Both incumbents and new players, and the various stakeholders who are involved throughout the protein supply chains, will gain from a nuanced debate about how to evolve and reshape regional and ultimately global food systems to provide healthy and sustainable diets.

Emission intensities of food types

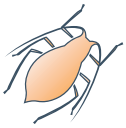
Beef

24 kg CO_2-eq. **per 200 kcal**



Insects

2 kg CO_2-eq. **per 200 kcal**

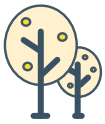


Source: Meat: the Future series, white paper WEF (2019)

Consumption

3

Production



Logistics

Sale

Consumption

Sustainable food for all

Description

A sustainable food system is fundamental in solving many of the present and future global issues, such as climate change, land degradation, loss of biodiversity and mass migration. At its core, sustainable food is characterized by low environmental impact and contributes to global food security and healthy living for present and future generations. Moreover, it is culturally acceptable, economically fair and affordable, nutritionally adequate, safe and healthy, and optimize natural and human resources.

Facts and figures

Besides ecological malformation, sustainable diets attempt to address undernourishment, nutrient deficiencies and obesity. While undernutrition in developing countries is still a huge problem – 842 million people are still suffering from chronic hunger, particularly in Sub-Saharan Africa and South Asia – malnutrition caused by unhealthy diets is becoming an increasingly serious problem today. It is the single largest contributor to disease in the world: Increasing physical inactivity coupled with an increased consumption of meat, sugary drinks and processed foods leads to obesity and lifestyle diseases such as high blood pressure and diabetes. This development especially applies to high-developed countries but also more and more among the poorest populations. One third of the developing world's population suffers micronutrient deficiencies leading to blindness, mental retardation and early death.

Implications for the food sector

The promotion of sustainability in the food sector requires a look at the entire food value chain. Innovative solutions that lead to more sustainability are possible in all areas. To list just a few examples: In the field of production, general purpose technologies like Artificial Intelligence or new forms of production can make a positive contribution to sustainability. In the area of logistics, the promotion of regional and seasonal foods may be helpful in reducing negative environmental impacts of global food transportation. In the area of consumption, awareness campaigns about healthy diets can be useful in combating the global problem of malnutrition.

Ethical practices of consumers

77% of people recognize the Fairtrade mark,

87% of those trust it.

Source: TNS research by the Fairtrade Foundation (2017)

4

Sharing instead of owning

Description

Through the advancement of technology, e.g. digital platforms, social activities such as sharing, donating, neighborhood help and swapping are gaining in reach and diversity. Alongside a growing number of local initiatives, this facilitates a shift in preferences away from ownership toward sharing. The most advanced forms of this shift happen in the mobility (Uber, Lyft, Blablacar) and housing (Airbnb) sector, but the financial (lending club), fashion (Kleiderkreisel) and food (food sharing) sectors have also become part of the sharing economy. Convenience, innovation and green values are appealing to consumers. While the sharing economy can have positive impacts on sustainability by fostering efficient resource use and greater human trust, challenges concerning data protection and current forms of regulations still need to be solved. In recent years, many cities have put in regulations to protect employees in the sharing economy and to increase tax revenue from these services.

Facts and figures

The most relevant sectors for sharing industry are media streaming, shared mobility, hospitality, P2P-finacing and on-demand staffing. Large companies in the sharing economy have exponentially grown in recent years. One key driver for this development are the changing demographics, as women, the growing middle class and the elderly participate more in the economy. In 2017, Airbnb generated $2.6 billion and Uber generated $11.3 billion in revenue although Airbnb unlike Uber is turning a profit. These companies have disrupted their respective sector. Airbnb has led to a decrease in hotel bookings around 8 percent and increased property values by 6–11 percent, while Uber and other drive-sharing companies decrease global car sales by 1 percent.

Implications for the food sector

The phenomenon of emerging new flexible forms of producer-consumer relationships and activities within the food sector, particularly in urban areas and their surroundings, is challenging the traditional models of consumption and ownership. Interaction takes place through flexibility of scope and levels of consumer integration into the food production and distribution process and the common sustainable use and sharing of resources, in specific land, labor, production facilities, money, and knowledge. Furthermore, the sharing economy in the food sector includes shared kitchen spaces, meal sharing, food business incubators and collaborative delivery services. The experience of meeting new people and experiencing local cuisine from residents is a key selling point. A potential problem are safety and regulatory concerns, as the hosts may be subject to the same health standards as a restaurant.

Processing

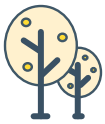
Packaging

Sale

Consumption

5

Production



Precision farming

Description

Precision farming is an umbrella term for new agricultural production and management techniques. It is based on observing, measuring and responding to inter- and intra-field variability in crops. In addition, it can be applied to herd management in livestock farming. The following groups of technology enable precision farming: object identification technology, sensors, robotics and autonomous navigation, global navigation satellite systems and connectivity as well as other information and communication technologies. These technologies are expected to increase the efficiency of agricultural production and hereby proliferate yields, reduce the workforce, agricultural land usage and the use of plant protection products. At the same time, it requires investments into professional training of farmers to be able to handle these new technologies.

Facts and figures

An example of the increased application is precision milking and feeding robots. 90 percent of the new equipment installations in Sweden and Finland and 50 percent in Germany include robotic milking. Precision agriculture is currently more prevalent in developed countries. An example for resource enhanced resource efficiency is fertilizer use. Variable rate N-fertilization reduces N-fertiliser use by 8 percent while increasing production by 4.1 percent. Machine guidance reduces fuel use by 5.4 percent. The majority of farmers perceive the payback time for machine guidance and variable rate N-fertilization to be lower than five years. A new software can facilitate smartphone users to detect in-field stress. With a simple photo taken with the smartphone camera, the application determines weeds, classifies and counts insects, recognizes diseases and more information, and gives recommendations to the user. In 2018, the global market for precision farming was $ 4.07 billion. It is expected to increase toward $ 10.23 billion by 2025. Yield monitoring and field mapping are the two largest application by market share.

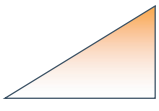
Implications for the food sector

Precision agriculture will optimize the production process, as it allows optimal use of plant protection products, produces less waste and higher yields. Due to the costs associated with the technology and the needed capacity to adapt to the new technology, precision farming might lead to further concentration toward large-scale farming. All-in-one robots will replace human labour in the future, fulfilling all functions from planting, driving tractor, harvesting and weed eating, controlled from a central artificial intelligence.

Global market for precision farming

2018

$ 4 billion



2025

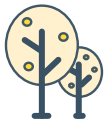
$ 10.2 billion

Source: Precision Farming/Agriculture Market Size, Grand View Research (2019)

6

Food losses and waste

Production



Processing

Logistics

Sale

Consumption

Description

Through the advancement of technology, e.g. digital platforms, social activities such as sharing, Recent years have seen an increase in public awareness about food waste in the developed world. Due to the scandalization of food waste, some countries (e.g. France) have established laws prohibiting retailers from throwing away unsold, edible food, and requiring them to donate it appropriately. As 23.9 percent of the world's population suffer from moderate or severe food insecurity, and 10.8 percent are malnourished, the amount of food waste in the industrialized world signals inefficiency of the global food system. The rising world population makes it necessary to reduce food waste to feed the rising number of people. The global economic cost of food waste is $ 750 billion and primarily disadvantages consumers and farmers. Local initiatives such as food sharing, which collect surplus food, are on the rise.

Facts and figures

Roughly one third of annual global food production, approximately 1.3 billion tons, becomes waste. Annually, industrialized countries waste 670 million tons of food, while developing nations throw away 630 million tons. Overproduction and aesthetic-focused quality standards are the major reason for food waste at retailers with fresh fruit and vegetables having the highest waste rates. It is estimated that up to 2/3 of food waste in industrialized countries is preventable and local initiatives to save food have increased membership in recent years. For example, the platform Food-Sharing grew from 35.000 users in 2014 to 281.747 users in 2019 (www.foodsharing.de).

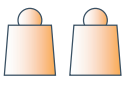
Implications for the food sector

Societal pressure and government regulations to decrease food waste will increase in the future. Improved production and logistic will be developed to reduce food waste. Retailers will offer flexible pricing and discounts for food, which is close to its sell-by date in an effort to reduce food waste. This development could lead to lower prices for consumers and increased access to food for many people around the world.

Per capita food losses and waste in Europe

Consumer

90 kg per year



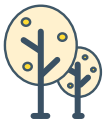
Production to retailing

180 kg per year

Source: Global food losses and food waste, UN Food and Agriculture Organization

7

Production



Processing

Vooking – vegan – gluten free

Description

More and more people stop eating meat for a variety of reasons. Many prefer vegetarian food for health reasons, for the culinary pleasure, but also due to a growing awareness of the sustainability. The Vooking concept developed a new kitchen design having a positive influence on the attitude toward nutrition and cooking. In addition, the gluten-free cuisine is a trend that has gained on relevance, in particular in western countries. In this context, more ancient, super-nutritious grains such as quinoa and amaranth will be used instead of wheat flour. The number of people who must avoid gluten for medical reasons is considerably smaller. For the majority of people on gluten-free diets, there is no medical necessity. However, it is still a lifestyle boom which has to be considered by producers. The vegetarian, vegan or gluten free diet is an important component of a general change in nutrition patterns.

Facts and figures

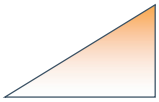
It is assumed that about 1 percent of the population suffers from celiac disease. The global market for gluten-free foods is expected to exceed $ 13 billion by 2025. However, this growing demand is not solely due to the persons with gluten intolerance, but rather to a food trend. The most consumers abstain from gluten without medical necessity, but due to a widespread opinion that gluten is bad for their health. A similar trend is taking place in the area of vegan or vegetarian food, where customers not only for health reasons but mainly for moral and ethical reasons abstain animal products. Also the kitchen of the future is linked with these trends. The word Vooking (Vegetarian Cooking) describes a kitchen, which contains for example more working space for the cutting of vegetables or in addition, a climatic cabinet, in which herbs and plants salads can be cultivated season-independently.

Implications for the food sector

The food sector this provides an opportunity to launch new gluten free or vegan products, for that customers are less price-sensitive. However, there are also difficulties, e.g. the preparation of gluten-free products is a big challenge to the manufacturers with the main challenge of finding suitable alternatives for gluten. Hence, gluten removal results in major problems especially for bakers in terms of quality.

Consumption

Global market for vegetable meat is estimated

2019		2025
$ 12.1 billion		$ 27.9 billion

Source: Plant-based Meat Market, Global Forecast to 2025, MarketsAndMarkets (2019)

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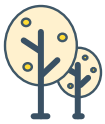
New forms of food production

Production



Description

Worldwide food production consists primarily of traditional agriculture, livestock farming and marine food production. New production forms include urban horticulture and special forms such as vertical farming or aquaponics. Vertical farming can enable viable agriculture and mass production of crop and animal products in multi-storey buildings (so-called farmscrapers) all year round. Fully controlled, sensor-assisted production provides personalized food that can prevent allergies and diseases. Since environmental conditions play no role, the farm can also be located in a large city, but requires sufficient energy and water resources. Aquaponics combine conventional aquaculture (raising aquatic animals) with hydroponics (cultivating plants on water) in a symbiotic environment. A special advantage: Fish excrements act as a natural fertilizer for better plant growth.

Facts and figures

The aquaponics market is expected to have a Compound Annual Growth Rate of 12.8 percent from 2019 to reach $ 1.4 billion by 2025, provoked by growing fish consumption, rising demand for organic fruits and vegetables, improvement in urban farming methods, growing reduction in arable land areas, and changing climate conditions. Urban agriculture is already a broadly applied concept. In Amsterdam in 2011, roughly 95 percent of all ten years old pupils take care of their school garden with vegetables, fruits and herbs. The Netherlands capital amounts 37 allotment parks and about 6500 allotment gardens. In Cuba in 2001, 90 percent of Havana's fresh produce comes from local urban farms and gardens. As smaller urban clusters represent about two thirds of global urban extent, urban food production should also target smaller urban areas and not only large cities.

Implications for the food sector

New forms of food production can be a promising building block in securing future food supply of an increasing world population. Furthermore, they can provide solutions for challenges concerning climate change. The process automation in greenhouse systems leads to a change in the market segment of agricultural machines.

Vertical farming as an answer to future challenges until 2050?

+1.8 billion **populations growth**

−500 m^2 **loss of agricultural land for foodstuff per capita**

Source: Vertical Farming, Think Tank Impuls, Fraunhofer (2015)

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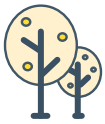
Production



Climate change – natural disasters

Description

There is scientific agreement that releases of carbon dioxide including other greenhouse gases and their accumulation in the atmosphere lead to global warming and hence to a change in global climate. Life in destabilizing climate systems is the main challenge to solve for humanity in the 21st century. As temperatures and sea levels are rising, increased probability of drastic natural disasters already affects basic human needs as settlement and nutrition. The majority of food production systems depend on regional climate conditions and will be affected by changes in global temperature, water scarcity, distribution of crop and livestock diseases, as well as by the occurrence of extreme weather events.

Facts and figures

Climate change increases yield losses caused by natural disasters as e.g. cyclones, droughts or floods. To protect against such large-scale events, insurances and infrastructural installations, as well as the selection of arable crops have to adapt to these new framework conditions. In addition, tropical zones, where poor and agricultural dependent people live, will be most affected. Climate-smart agriculture (CSA) proposes one way of addressing these challenges by a sustainable improvement of productivity, adapting to and mitigation of climate change, as well as reducing greenhouse gas emissions where manageable. Climate change provokes negative impacts on the productivity of global crops, estimated to reach –12 percent for wheat, –15 percent for rice, and –20 percent for maize by the 2080s.

Implications for the food sector

Climate change is driving the food sector as an externality and as an internality: Increasing risks make new management and production systems necessary to ensure food supply. On the other hand, food production is a main cause for climate change. Therefore, new approaches in the food sector are crucial for lowering climate change. Combining adaptation and mitigation is the key challenge.

Consumption

Estimated rise / decline in crop yield between 2011 and 2050 due to climate change

Canada +27%

Mexico +8%

India –5%

Africa –12%

Source: Agricultural commodity markets, UN Food and Agriculture Organization (2018)

10

Blockchain – smart contracts

Production

Processing

Description

The Blockchain is a technology that allows people who do not know each other to organize a network to keep trusted records. Once recorded on a Blockchain a piece of information cannot be changed. The most common application is that of a "distributed ledger" that keeps track of transactions. This solves, among others, the problem of double spending digital money (or other information). Using the Blockchain, digital data can have an owner recognized by everyone in the network. Transactions are recorded and saved in interlinked blocks, owned not by an institution but by the network. This network verifies and validates the transactions itself, encoded with digital signatures. Smart contracts directly control the transfer of digital currencies or assets between parties. Blockchain and smart contracts are changing the entire economic and political system.

Facts and figures

Blockchain is passing an early stage in the innovation life cycle, being yet implemented by early adopters but still facing considerable hesitation in the industries. The global Blockchain market size in 2018 was estimated at $1.2 billion and projected to grow with 80 percent annually to a market size of $23.3 billion in 2023. In 2018, Gartner asked 293 CIO about plans with Blockchains – almost eight out of ten had no actions planned or no interest in Blockchain. However, companies are seeing Blockchain technology as an opportunity to increase traceability in their own business. Especially in finances, Blockchain offers a potential for cost lowering and rationalization while increasing transparency. There is a high likelihood of a significant use of Blockchain in the next 20 years.

Logistics

Implications for the food sector

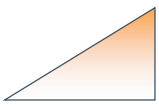
A Blockchain-enabled world without central controlling authorities might happen through decentralized networks, providing a neutral and fair result. By facilitating operationalization, Blockchain can shorten supply chains. Traceability increases mentioning management, logistics and process information. Smart contracts would contribute to food safety. Farming would be more transparent by improving tracking, tracing and documenting. The food chain will be easier to monitor for producers, retailers and customers.

Sale

Consumption

Global Blockchain market size

2018 $ 1.2 billion

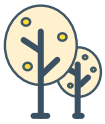


2023 $ 23.3 billion

Source: Blockchain, Global Forecast to 2023, MarketsAndMarkets (2018)

11

Production



Processing

Logistics

Sale

Increased market power of retailers

Description

Large retail stores and discounters have largely replaced the traditional supply structure of small-scale grocery retail. This resulted in a shift of power from consumer goods producers to retailers, as the latter control the main distribution channels. This gatekeeper function allows retailers to exert their influence on prices, quality, assortment, and production conditions. The emergence of e-commerce in the food-sector puts pressure on retailers to maintain their power, as new actors such as Amazon try to establish themselves in the food sector. E-commerce allows for direct delivery to customers without retailers. However, retail stores such as EDEKA and REWE are developing their own delivery services. Moreover, retail stores, including discounters, implement innovations such a "recipe machines" to maintain and increase their market share.

Facts and figures

In 2018 AgeCore, a European association of six retailers, took all products from one major brand out of its shelf due to a dispute over prices and forced the brand to make concessions. The profit margin for retailers is at 2 percent, while Nestlé's is around 18.5 percent. In over 60 percent of German processing companies, the biggest customer makes up over 22 percent of business volume, a threshold the EU considers critical. More companies also report, that retailers are using their market power more aggressively. In 2018, the online food sector grew its revenue by 20 percent to 1.36 billion euros. However, the customer base only grew by 1 percent (28 percent to 29 percent) since 2016. This indicates that online e-commerce in the food sector has reached its current peak, as in Germany Amazon Fresh (4 cities) and REWE (75 cities) have both stopped the expansion of their delivery services into more areas.

Implications for the food sector

The concentration in the food retail sector is at its peak, as anti-trust laws would certainly prohibit more mergers. However, the retailers have just started to exert their power and might try to grow their revenue at the expense of consumers and suppliers. While its rapid expansion has been temporarily stopped, e-commerce for food products will continue to play an important role in food supply. New actors and start-ups emerge and form partnerships with established companies. The delivery of refrigeration-mandatory food presents a unique challenge to retailers and distributers.

Food retailer and supplier imbalances

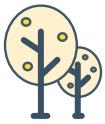
For 60% of German brand manufacturers in the food sector, the biggest customer makes up more than the so-called critical 22% of the business volume.

Source: The power of retailers, DIW Econ Economic Bulletin (2017)

12

Label accuracy and transparency

Production



Description

Labels perform a very important function. They serve as an orientation point for customers at the point of sale. Labels also allows companies to brand their product as for example environmental friendly or healthy. However, with few exceptions (e.g. the EU Bio-label), there are no legal requirements for obtaining a food label. Rather, the majority of labels is issued by business associations, which set their own standards. For consumers, the plurality of labels can be confusing, as they may not understand each label's meaning. The emergence of IOT allows for the development of a digital product memory, which stores all necessary information and provides them to the consumer at purchase.

Packaging

Facts and figures

85 percent of German customers want to be able to retrace their food and 60 percent say, their food purchase is influenced by labels. These percentages are higher for food than for any other product. Labels issued by the government and environmental organizations are in general perceived as more trustworthy than labels by profit-orientated companies, although exception remain (Öko-Test, TÜV). One approach is the Nutri-Score, in which a five-step colour and letter scale provides an overview of the nutritional quality of a product. The Nutri-Score has been introduced nationwide in France since 2018 and in Belgium since 2019. In Germany, it is planned to be applied on a voluntary basis from 2020. Trust in labels is not associated with a willingness to pay more for the same product unless the mechanism behind the label are well understood. In Germany, only 23 percent trust most of the brands they buy and use. Overall brand trust still ranks amongst the highest buying consideration at 81 percent and in 5th place behind quality, convenience, value and ingredients. The global market for intelligent packaging is expected to grow 5.4 percent annually and reach $ 52 billion in 2025.

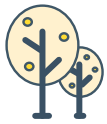
Sale

Implications for the food sector

Governments and retail companies have reacted to consumer demands by either introducing new labels or standardising theirs across retailers (e.g. the "animal welfare label"). The digitalization will allow for greater transparency and traceability of a product. This empowers the consumer to make an informed decision about their purchase. The increased transparency will put pressure on supplier to update their production method and be aware of consumer preferences. This ability to retrace food will also involve question regarding data security and protection of trade secrets.

13

Production



Processing

Consumption

New nutrition patterns

Description

Genetic variation influences individual human health and nutrition (Nutrigenetics), and reversely individual nutrition and health influence the genetic variation (Nutrigenomics). This insights provide individual dietary recommendations. Consumers are able to reduce risk of disease and optimize health with the right, personalized nutrition. Therefore, they try to choose appropriate food for their organism, often by taking services that filter the offers and suggest the right products. The development of new nutrition patterns is asymmetric: It includes the tendency for healthier cooking and using healthier products on one hand, but is also expressed by a shift to packaged processed unhealthier food especially in urban areas on the other hand. Metabolic disorders, e.g. obesity, diabetes or celiac disease are important research fields.

Facts and figures

Influential dimensions lay in the diet's quantity and quality, and in the correspondent's response to the diet regarding the specific genetic profile. Companies design nutrigenetic solutions directly to consumer (DTC), as e.g. AncestryDNA and 23andMe. The DTC genetic testing market is forecast to grow between 15 percent and 20 percent annually through 2023. According to an L.E.K. study, 37 percent of respondents would purchase a personalized nutrition program, suggesting a $ 3.2 billion retail opportunity. The market for nutrigenomics was valued at $ 252.20 million in 2017 and is projected to expand at a CAGR of 16.48 percent to 2025.

Implications for the food sector

As the importance of food for health is increasingly understood, consumers change their demand. Supply chains can experience sudden fluctuations corresponding publications about the healthiness or defectiveness of foods and beverages. The complexity in operations can further increase when regulatory instruments are implemented. Even so, healthy food is a promising tendency, which responds to a major societal change toward healthiness, sustainability and long life. Knowledge gained by nutrigenomics can improve people's life, by showing how to use nutrition to live in good health or to live longer. Therefore, nutrition is developed matching the correspondent's genes.

Valued global market size for nutrigenomics

2017	2025
$ 252.2 billion	$ 854.6 billion

Source: Nutrigenomics Market Size, Grand View Research (2019)

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Sustainable production and value chains

Description

A value chain consists of all production, consumption, and disposal/recycling processes of particular products and services. Typically, value chain analysis begins at raw material sourcing and finishes with waste management, accounting for activities of suppliers, manufacturers, retailers, consumers, and other actors. Circular value chain models challenge traditional concepts. By eliminating "up- and downstream" conceptualizing, and understanding value creation across the spectrum of interactions and ex-changes of a network. Materials are reused or recycled to minimize waste.

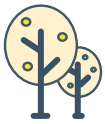
Facts and figures

It is estimated that in Europe alone, between 280 billion euros and 470 billion euros can be saved annual through adoption of more sustainable value chain processes. Reduced material and energy consumption results in lowered emissions and lowered damages compared to those currently associated with resource extraction. Shifting taxation from labour to natural resource usage; or introducing an alternative wealth indicator (not GDP), could incentivize the adoption of more circular practices.

Implications for the food sector

A more sustainable value chain is associated with several challenges to companies including: substantial upfront investments to improve end-of-life design for products, find sustainable sources, monitor supply chains, and find retail collaborators. Consumers also face challenges in adoption of circular practices and many cultures associate ownership of luxury goods with societal status, while concepts like repair and reuse are looked down upon.

Production



Processing

Packaging

Logistics

Sale

Consumption

15

Production

Processing

Packaging

Logistics

Sale

Artificial intelligence and machine learning

Description

Artificial intelligence (AI) is a set of new technologies that perform functions generally associated with human intelligence, such as reasoning and learning. Human skills and capabilities are complemented by automated learning programs, which work in iterative cycles of designing, prototyping, and gathering feedback. Artificial Intelligence in agriculture has exploded over the past years, facilitating "smart farming" with self-learning automatized machines. Machine learning is used throughout the whole growing and harvesting cycle, first when seeding plants in the soil (soil preparation, seeds breeding and water feed measurement) and later when robots pick up the harvest, automatically determining the ripeness with the use of computer vision. Critics express their concerns that learning machines can replace humans as an input in food supply chains while further increasing intensification in agriculture and thereby fuel climate change. Supporters argue, that artificial intelligence can support to fight climate change and improve efficiency in food supply.

Facts and figures

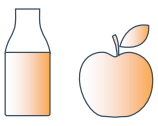
In food industries, neural networks are already used to improve process dynamics with various raw materials and different processing conditions. A new iceberg lettuce harvesting system is able to harvest with a 91 percent accuracy and error rate for false positives of 1.5 percent. Learning systems help also out in additional services and administration. In 2016, 80 percent of asked companies wanted chatbots by 2020, expecting to create salary savings of several billion USD.

Implications for the food sector

In daily service operations as chats, artificial intelligence is already a powerful instrument in supply chain management through logistics, predictive analytics and transparency. Artificial intelligence supports the management of species, field conditions, crop and livestock, and is also a big help in food sorting, quality control and safety compliance, consumer engagement, production, packaging and maintenance. Furthermore, using a combination of digital imaging, spectroscopy and machine learning, food companies can take a picture of food, analyze the unique spectral reflections of the light, and determine nutritional content, fat and protein content and freshness level. With this automated and non-invasive technique, researchers hope to improve the quality and freshness of food available and reduce food waste. Systems that can work with beef, white fish, bananas and avocados are already available.

Compound annual growth rate of AI in food and beverages market

+65.3% from 2019 until 2024



Source: AI in food & Beverages Market, Mordor Intelligence (2018)

Literature

Local Food Circles

Franco, J. C.; Borras Jr., S. M.; Monsalve Suárez, S. (2015): Land and food sovereignty. In: Third World Quarterly 36, pp. 600–617. DOI: 10.1080/01436597.2015.1029225.

Jurgilevic, A.; Birge, T.; Kentala-Lethonen, J.; Korhonen-Kurki, K.; Pietikäinen, J.; Saikku, L.; Schösler, H. (2016): Transition towards Circular Economy in the Food System. In: Sustainability 8 (1), 69. DOI: 10.3390/su8010069.

Lynch, J.; Meter, K.; Robles-Schrader, G.; Goldenberg, M. P.; Bassler, E.; Chusid, S.; Jansen Austin, C. (2015): Exploring Economic and Health Impacts of Local Food Procurement. Illinois Public Health Institute. Available online at https://www.crcworks.org/EHimpacts.pdf.

Martinez, S.; Hand, M.; Da Pra, M.; Pollack, S.; Ralston, K.; Smith, T.; Vogel, S.; Clark, S.; Lohr, L.; Low, S.; Newman, C. (2010): Local Food Systems. Concepts, Impacts, and Issues. U.S. Department of Agriculture, Economic Research Service (ERR, 97).

McMichael, P. (2012): The land grab and corporate food regime restructuring. In: The Journal of Peasant Studies 39 (3-4), pp. 681–701. DOI: 10.1080/03066150.2012.661369

Alternative Proteins

Alexandratos, N.; Bruinsma, J. (2012): World Agriculture Towards 2030/2050. The 2012 Revision. Proof Copy. Edited by Agricultural Development Economics Division. Food and Agriculture Organization of the United Nations (ESA Working Paper No. 12-03). Available online at http://www.fao.org/fileadmin/templates/esa/Global_persepctives/world_ag_2030_50_2012_rev.pdf, checked on 19/09/2019.Barclays (Ed.) (2019): Carving up the alternative meat market. Available online at https://www.investmentbank.barclays.com/our-insights/carving-up-the-alternative-meat-market.html, checked on 10/10/2019.

Bashi, Z.; McCullough, R.; Ong, L.; Ramirez, M. (2019): Alternative proteins: The race for market share is on. Edited by McKinsey & Company. Available online at https://www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on, checked on 10/10/2019.

CB Insights (Ed.) (2019): Our Meatless Future: How The $ 90B Global Meat Market Gets Disrupted. Available online at https://www.cbinsights.com/research/future-of-meat-industrial-farming/, updated on 10/9/2019, checked on 10/10/2019.

Franck, T. (2019): Alternative meat to become $ 140 billion industry in a decade, Barclays predicts. Edited by CNBC LLC. Available online at https://www.cnbc.com/2019/05/23/alternative-meat-to-become-140-billion-industry-barclays-says.html, checked on 10/10/2019.

Godfray, H. C. J. (2019): Meat: the Future series - Alternative Proteins. White Paper. Edited by World Economic Forum. Available online at http://www3.weforum.org/docs/WEF_White_Paper_Alternative_Proteins.pdf, checked on 19/09/2019.

Ministry for Primary Industries; Plant & Food Research (2018): The evolution of plant protein - assessing consumer response. Available online at https://www.mpi.govt.nz/dmsdocument/29141-the-evolution-of-plant-protein-assessing-consumer-response-report, checked on 10/10/2019.

Sustainable Food For All

Baker, L.; Gemmill–Herren, B.; Leippert, F. (2019): Beacons of hope: Accelerating Transformations to Sustainable Food Systems. Edited by Biovision Foundation for Ecological Development and Global Alliance for the Future of Food. Available online at https://foodsystemstransformations.org/wp-content/uploads/2019/08/BeaconsOfHope_Report_082019.pdf, checked on 10/10/2019.

Burlingame, B.; Dernini, S. (2012): Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action.

International Scientific Symposium, Biodiversity and Sustainable Diets United Against Hunger. Edited by Food and Agriculture Organization of the United Nations. United Nations. Rome. Available online at http://www.fao.org/3/i3004e/i3004e.pdf, checked on 19/09/2019.

Burrows, D. (2015): New demand driving sustainable food growth. Edited by Marketing Week. Available online at https://www.marketingweek.com/new-demand-driving-sustainable-food-growth/#navigation, checked on 09/10/2019.

EAT-Lancet Commission (Ed.): The EAT-Lancet Commission Summary Report. Available online at https://eatforum.org/content/uploads/2019/07/EAT-Lancet_Commission_Summary_Report.pdf, checked on 10/10/2019.

Food and Agriculture Organization of the United Nations (Ed.) (2019a): HUNGER-FACTS. Available online at http://www.fao.org/zhc/hunger-facts/en/, checked on 19/09/2019.

Harvey, M. (2018): Sustainable food systems and diets: A review of multi-stakeholder initiatives. Edited by WWF-UK. Available online at https://www.wwf.org.uk/sites/default/files/2018-10/59078%20Sustainable%20food%20systems%20report%20-%20ONLINE.pdf.

Searchinger, T.; Waite, R.; Hanson, C.; Ranganathan, J. (2019): World Resources Report: Creating a Sustainable Food Future. A Menu of Solutions to Feed Nearly 10 Billion People by 2050. World Resources Institue. Available online at https://wrr-food.wri.org/sites/default/files/2019-07/WRR_Food_Full_Report_0.pdf.

Willett, W.; Rockström, J.; Loken, B.; et al. (2019): Food in the Anthropocene. The EAT–Lancet Commission on healthy diets from sustainable food systems. In: The Lancet 393 (10170), pp. 447–492. DOI: 10.1016/S0140-6736(18)31788-4.

Sharing Instead of Owning

Bert, J.; Collie, B.; Gerrits, M.; Xu, G. (2016): Whats ahead for Car-sharing? Boston Consulting Group. Available online at https://www.bcg.com/de-de/publications/2016/automotive-whats-ahead-car-sharing-new-mobility-its-impact-vehicle-sales.aspx, checked on 19/09/2019.

Kessler, S. (2017): The sharing economy for food is the latest thing California may legalize. Edited by www.qz.com. Available online at https://qz.com/909255/, checked on 19/09/2019.

Nieuwland, S.; van Melik, R. (2018): Regulating Airbnb: how cities deal with perceived negative externalities of short-term rentals. In: Current Issues in Tourism, pp. 1–15. DOI: 10.1080/13683500.2018.1504899.

Piorr, A.; Warnke, P.; Beblek, A. (2019): Future | Food | Commons. Future Food Commons. Available online at http://fufoco.net/index.php, checked on 27/09/2019.

Rinne, A. (2019): 4 big trends for the sharing economy. World Economic Forum. Available online at https://www.weforum.org/agenda/2019/01/sharing-economy/, checked on 19/09/2019.

Zervas, G.; Proserpio, D.; Byers, J. W. (2017): The Rise of the Sharing Economy: Estimating the Impact of Airbnb on the Hotel Industry. In: Journal of Marketing Research 54 (5), pp. 687–705. DOI: 10.1509/jmr.15.0204.

Precision Farming

BIOPRO Baden-Württemberg GmbH (Ed.): Digitisation in agriculture – from precision farming to farming 4.0 – Bioeconomy. Available online at https://www.biooekonomie-bw.de/en/articles/dossiers/digitisation-in-agriculture-from-precision-farming-to-farming-40, checked on 10/10/2019.

European Commission (2015): EIP-AGRI Focus Group on Precision Farming: Final report. Available online at https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_focus_group_on_precision_farming_final_report_2015.pdf.

Grand View Research (2019a): Precision Farming/Agriculture Market Size, Share & Trends Analysis Report By Offering (Hardware, Software, Services), By Application (Yield Monitoring, Irrigation Management) And Segment Forecasts, 2019 - 2025 (GVR-1-68038-376-8). Available online at https://www.grandviewresearch.com/industry-analysis/precision-farming-market, checked on 10/09/2019.

Omnia Precision (2019): Connecting Agronomy and Precision Farming. Available online at https://www.omniaprecision.co.uk/, checked on 23/09/2019.

Schrijver, R. (2016): Precision agriculture and the future of farming in Europe. Scientific foresight study: study. Brussels: European Parliament, checked on 19/09/2019.

Soto, I.; Balafoutis, A.; Barnes, A.; Beck, B.; Eory, V.; Fountas, S.; Gómez-Barbero, M.; Sánchez, B.; van der Wal, T.; Vangeyte, J. (2019): The contribution of precision agriculture technologies to farm productivity and the mitigation of greenhouse gas emissions in the EU. Luxembourg: Publications Office of the European Union (EUR, Scientific and technical research series, 29320).

Food Waste and Food Losses

Eyerund, T.; Neligan, A. (2017): Verschwenderische Generationen X und Y. Institut der deutschen Wirtschaft Köln (56.2017). Available online at https://www.iwkoeln.de/fileadmin/publikationen/2017/350865/IW-_Kurzbericht_56_2017_Lebensmittelverschwendung.pdf, checked on 19/09/2019.

Food and Agriculture Organization of the United Nations (2013): FAO Factsheet: Food wastage Footprints. Available online at http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_FOOD-WASTAGE.pdf, checked on 19/09/2019.

Food and Agriculture Organization of the United Nations (2019b): Save Food: Global Initiative on Food Loss and Waste Regulation Key facts on food loss and waste you should know. Available online at http://www.fao.org/save-food/resources/keyfindings/en/, checked on 19/09/2019.

Food and Agriculture Organization of the United Nations (2019c): SDG Indicator 2.1.1 - Prevalence of undernourishment. Available online at http://www.fao.org/sustainable-development-goals/indicators/211/en/, checked on 19/09/2019.

Food and Agriculture Organization of the United Nations (2019d): SDG Indicator 2.1.2 - Severity of food insecurity. Available online at http://www.fao.org/sustainable-development-goals/indicators/212/en/, checked on 19/09/2019.

Lipinski, B.; Hanson, C.; Lomax, J.; Kitinoja, L.; Waite, R.; Searchinger, T. (2013): Reducing Food Loss and Waste. Creating a Sustainable Food Future, Installment Two. World Resources Institue. Available online at https://wriorg.s3.amazonaws.com/s3fs-public/reducing_food_loss_and_waste.pdf.

Menn, C. (2017): Die Foodsharing-Bewegung. Übriggebliebene Lebensmittel sichern und teilen. Bundeszentrum für Ernährung. Available online at https://www.bzfe.de/inhalt/die-foodsharing-bewegung-31533.html, checked on 19/09/2019.

Vooking Vegan Gluten Free

Costello, H. (2019): Global Gluten Free Food Market (by Products, Distribution Channels, Regional Analysis), Mergers & Acquisitions, Key Company Profiles - Forecast to 2025. Orbis Research (519010). Available online at https://www.marketwatch.com/press-release/global-gluten-free-food-market-by-products-distribution-channels-regional-analysis-mergers-and-acquisitions-key-company-profiles-forecast-to-2025-2019-05-31, checked on 19/09/2019.

Jnawali, P.; Kumar, V.; Tanwar, B. (2016): Celiac disease: OVerview and considerations for development of gluten-free foods. In: Food Science and Human Wellness (5 (4)), pp. 169–176, checked on 23/09/2019.

Marangon, F.; Tempesta, T.; Troiano, S.; Vecchiato, D. (2016): Toward a better understanding of market potentials for vegan food. A choice experiment for the analysis of breadsticks preferences. In: Agriculture and Agricultural Science Procedia (8), pp. 158–166, checked on 23/09/2019.

MarketsandMarkets Research Private Ltd (2019): Plant-based Meat Market by Source, Product, Type, Process And Region - Global Forecast to 2025. Available online at https://www.marketsandmarkets.com/Market-Reports/plant-based-meat-market-44922705.html?gclid=Cj0KCQjwzozsBRCNARIsAEM9kBPbomC5V3-E1DQjoO6ESrMLsXtjVr-PWY6v3MWvjVIO2s7ZMMHCpAcaArghEALw_wcB, checked on 19/09/2019.

Santeramo, F. G.; Carlucci, D.; Devitiis, B. de; Seccia, A.; Stasi, A.; Viscecchia, R.; Nardone, G. (2017): Emerging trends in European food, diets and food industr. Munich Personal RePEc Archive.

Available online at https://mpra.ub.uni-muenchen.de/82105/, checked on 23/09/2019.

Schierhorn, C. D. (2018): Why Gluten-Free Is Here to Stay. Edited by Food Technology Magazine. Available online at https://www.ift.org/news-and-publications/food-technology-magazine/issues/2018/august/features/gluten-free-is-here-to-stay, checked on 10/10/2019.

Smithers, R. (2018): Third of Britons have stopped or reduced eating meat - report. Edited by The Guardian. Available online at https://www.theguardian.com/business/2018/nov/01/third-of-britons-have-stopped-or-reduced-meat-eating-vegan-vegetarian-report, checked on 10/10/2019.

van der Meulen, N.; Wiesel, J. (Eds.) (2017): Culinary Turn: Transcript Verlag (Aesthetic Practice of Cookery). Available online at https://www.jstor.org/stable/j.ctv1wxt0c.8.

Worosz, M. R.; Wilson, N. L. W.; WOROSZ, M. R.; WILSON, N. L.W. (2012): A Cautionary Tale of Purity, Labeling and Product Literacy in the Gluten-Free Marke // A Cautionary Tale of Purity, Labeling and Product Literacy in the Gluten-Free Market. In: The Journal of Consumer Affairs 46 (2), pp. 288–318. DOI: 10.1111/j.1745-6606.2012.01230.x.

New Forms of Food Production

Beacham, A. M.; Vickers, L. H.; Monaghan, J. M. (2018): Vertical farming. A summary of approaches to growing skywards. In: The Journal of Horticultural Science and Biotechnology 94 (3), pp. 277–283. DOI: 10.1080/14620316.2019.1574214.

Eigenbrod, C.; Gruda, N. (2015): Urban vegetable for food security in cities. A review. In: Agron. Sustain. Dev. 35 (2), pp. 483–498. DOI: 10.1007/s13593-014-0273-y.

Goddek, S.; Joyce, A.; Kotzen, B. (2019): Aquaponics Food Production Systems. Combined Aquaculture and Hydroponic Production Technologies for the Future. 1st ed. 2019. Available online at https://doi.org/10.1007/978-3-030-15943-6.

IBP, Inc. (2015): Cuba Investment and Business Guide Volume 1 Strategic and Practical Information // Cuba investment and business guide. Strategic and practical information: Intl Business Pubns Usa.

Lange, P. de (2011): Urban Agriculture in Amsterdam. Understand the recent trend in food production activities within the limits of a developed nation's capital. Master Thesis. Available online at https://areeweb.polito.it/didattica/UPWARD/dwd/agricolture/amsterdam.pdf, checked on 26/09/2019.

Martellozzo, F.; Landry, J. S.; Plouffe, D.; Seufert, V.; Rowhani, P.; Ramankutty, N. (2014): Urban agriculture: a global analysis of the space constraint to meet urban vegetable demand. In: Environmental Research Letters 9 (064025), pp. 1–8. DOI: 10.1088/1748-9326/9/6/064025.

Meticulous Market Research Pvt. Ltd. (2019): Global $ 1.4 Bn Aquaponics Markets, 2017-2018 & 2019-2025. Available online at https://www.meticulousresearch.com/product/aquaponics-market-5018/, checked on 26/09/2019.

Climate Change

Aklin, M.; Mildenberger, M. (2018): Prisoners of the Wrong Dilemma: Why Distributive Conflict, Not Collective Action, Characterizes the Politics of Climate Change. In: SSRN Electronic Journal. DOI: 10.2139/ssrn.3281045.

Campbell, B. M.; Vermeuten, S.; Aggarwall, P. K.; Corner-Dolloff, C. A. (2016): Reducing risks to food security from climate change. In: Global Food Security, pp. 1–11, checked on 23/09/2019.

Consultative Group on International Agricultural Research (CGIAR) (6/27/2019): Will climate change make us go hungry by 2050? Available online at https://ccafs.cgiar.org/news/media-centre/press-releases/will-climate-change-make-us-go-hungry-2050#.XYxwfEexVaQ, checked on 26/09/2019.

FAO (2018): Agricultural trade, climate change and food security. Rome: Food and Agriculture Organization of the United Nations (The state of agricultural commodity markets, 2018).

Food and Agriculture Organization of the United Nations (2019e): The state of food security and nutrition in the world. Rome.

Hasegawa, T.; Fujimori, S.; Havlík, P.; et al. (2018): Risk of increased food insecurity under stringent global climate change mitigation policy. In: Nature Clim Change 8, pp. 699–703. DOI: 10.1038/s41558-018-0230-x.

Masson-Delmotte, V.; Zhai, P.; Pörtner, H.-O.; et al. (2018): Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva, Switzerland: IPCC (Special report).

Roe, S.; Streck, C.; Weiner, P.-H.; Obersteiner, M.; Frank, S. (2017): How Improved Land Use Can Contribute to the 1.5°C Goal of the Paris Agreement. Working Paper prepared by Climate Focus and the International Institute for Applied Systems Analysis, checked on 09/10/2019.

Surminski, S.; Bouwer, L. M.; Linnerooth-Bayer, J. (2016): How insurance can support climate resilience. In: Natural Climate Change 6, pp. 333–334. DOI: 10.1038/nclimate2979.

Zhao, C.; Liu, B.; Piao, S.; et al. (2017): Temperature increase reduces global yields of major crops in four independent estimates. In: Proceedings of the National Academy of Sciences of the United States of America 114 (35), pp. 9326–9331. DOI: 10.1073/pnas.1701762114.

Blockchain Smart Contracts

Artificial Lawyer (2018): Hype Killer - Only 1% of Companies are using blockchain, gartner reports. Available online at https://www.artificiallawyer.com/2018/05/04/hype-killer-only-1-of-companies-are-using-blockchain-gartner-reports/, checked on 24/09/2019.

Ganne, E. (2018): Can blockchain revolutionize international trade? Geneva, Switzerland: WTO Publications.

Gartner Inc. (10/2/2017): Gartner Survey of More Than 3,000 CIOs Confirms the Changing Role of the Chief Information Officer. Orlando. Available online at https://www.gartner.com/en/newsroom/press-releases/2017-10-02-gartner-survey-of-more-than-3000-cios-confirms-the-changing-role-of-the-chief-information-officer.

Hays, D.: Smart Contracts. Edited by Crypto Research Report. Available online at https://cryptoresearch.report/crypto-research/smart-contracts/, checked on 10/10/2019.

Kiviat, T. I. (2015): Beyond Bitcoin: Issues in Regulating Blockchain Transactions. In: Duke Law Journal 65, pp. 569–608. Available online at https://scholarship.law.duke.edu/dlj/vol65/iss3/4/, checked on 09/10/2019.

MarketsandMarkets Research Private Ltd (Ed.) (2018): Blockchain Market by Provider, Application (Payments, Exchanges, Smart Contracts, Documentation, Digital Identity, Supply Chain Management, and GRC Management), Organization Size, Industry Vertical, and Region - Global Forecast to 2023. Available online at https://www.marketsandmarkets.com/Market-Reports/blockchain-technology-market-90100890.html?gclid=Cj0KCQjw5rbsBRCFARIsAGEYRwdQZOLMVgeH8eq3UeCt6GHKYT2CRFIq-ACyWxyW-jw0ToLiXiT1D1saAl2rEALw_wcB, checked on 27/09/2019.

Zheng, Z.; Xie, S.; Dai, H.-N.; Chen, X.; Wang, H. (2018): Blockchain challenges and opportunities: a survey. In: Internatinal Journal of Web and Grid Services 14 (4), pp. 352–375. DOI: 10.1504/IJWGS.2018.10016848.

Increased Power Market Retailers

Deloitte (Ed.) (2018): Global Power of Retailing 2018. Transformative change, reinvigorated commerce. Available online at https://www2.deloitte.com/content/dam/Deloitte/at/Documents/about-deloitte/global-powers-of-retailing-2018.pdf, checked on 23/09/2019.

Deutsches Institut für Wirtschaftsforschung (Ed.) (2017): The power of retailers (DIW Econ Economic Bulletin, 3). Available online at https://diw-econ.de/wp-content/uploads/2017/04/Bulletin-No.3-Buying-Power-in-the-German-Retailing-Sector.pdf, checked on 20/09/2019.

Jeffs, C. (2018): E-commerce competition enforcement guide. First edition. London, UK: Global Competition Review, Law Business Research Ltd (GCR Insight).

Label Accuracy and Transparency

Accuray Research (Ed.) (2017): Global Smart Packaging Market Analysis & Trends - Industry Forecast to 2025. Available online at https://www.reportlinker.com/p04653005/Global-Smart-Packaging-Market-Analysis-Trends-Industry-Forecast-to.html, checked on 09/10/2019.

Accuray Research (Ed.) (2019): Smart Packaging Market 2019: Worldwide Overview By Size, Share, Segments, Emerging Technologies, Growth, Leading Players, Application and Regional Trends By Global Forecast 2025. Available online at https://www.marketwatch.com/press-release/smart-packaging-market-2019-worldwide-overview-by-size-share-segments-emerging-technologies-growth-leading-players-application-and-regional-trends-by-global-forecast-2025-2019-08-14, checked on 23/09/2019.

Edelman (Ed.) (2019): Edelman Trust Barometer Special Report: In Brands we trust. Available online at https://www.edelman.com/sites/g/files/aatuss191/files/2019-06/2019_edelman_trust_barometer_special_report_in_brands_we_trust.pdf, checked on 20/09/2019.

John, J. (2019): Global Plastic Jar Packaging Market Will Reach USD 28.3 Billion By 2025: Zion Market Research. Zion Market Research. Available online at https://www.globenewswire.com/news-release/2019/08/29/1908423/0/en/Global-Plastic-Jar-Packaging-Market-Will-Reach-USD-28-3-Billion-By-2025-Zion-Market-Research.html, checked on 26/09/2019.

Reganold, J. P.; Watcher, J. M. (2016): Organic agriculture in the twenty-first century. In: Nature Plants 2 (2), pp. 1–8. DOI: 10.1038/nplants.2015.221.

New Nutrition Patterns

Evans, A. (2019): The Nutrigenetics Opportunity: Poised for Growth. Executive Insights. In: L.E.K. Insights 21 (34), pp. 1–4. Available online at https://www.lek.com/sites/default/files/insights/pdf-attachments/2134_Nutrigenetics_EI.pdf, checked on 26/09/2019.

Fardet, A.; Rock, E. (2014): Towards a new philosophy of preventive nutrition: from a reductionist to holistic paradigm to improve nutritional recommendations. In: Advances in Nutrition 5 (4), pp. 430–446. DOI: 10.3945/an.114.006122.

Grand View Research (Ed.) (2019b): Nutrigenomics Market Size, Share & Trends Analysis Report By Application (Obesity, Cardiovascular Diseases, Cancer Research), By Region (North America, Latin America, Europe, MEA, APAC), And Segment Forecasts, 2019–2025. Available online at https://www.grandviewresearch.com/industry-analysis/nutrigenomics-market, checked on 26/09/2019.

Maclaren, O.; Mackay, L.; Schofield, G.; Zinn, C. (2017): Novel Nutrition Profiling of New Zealanders' Varied Eating Patterns. In: Nutrients 10 (1), pp. 1–13, checked on 23/09/2019.

Selvam, R. (2019): Nutrigenomics - An Interaction of Nutrition, Health and Genomics, a Stepping Stone to Personalized Nutrition. In: International Journal of Science, Environment and Technology 8 (2), pp. 327–330, checked on 23/09/2019.

Technavio (Ed.) (2019): Global Superfoods Market 2019-2023. Available online at https://www.technavio.com/report/global-superfoods-market-industry-analysis, checked on 24/09/2019.

Tonda, E. (2016): Supply chains and Sustainable Consumption and Production. United Nations Environment Program (UNEP). Available online at https://www.cbd.int/business/GP%20meeting%20doc/2016%20Business%20Forum/Speaker%20Presentations/Supply%20Chains%201015-1215/2%20Supply%20chains%20Elisa%20Tonda.pdf, checked on 23/09/2019.

Sustainable Production and Value Chains

Dervojeda, K.; Verzijl, D.; Rouwmaat, E.; Probst, L.; Frideres, L. (2014): Clean Technologies: Circular supply chains. Business Innovation Observatory. Contract No 190/PP/ENT/CIP/12/C/N03C01. European Commission (Enterprise and Industry, Case study 30). Available online at https://ec.europa.eu/docsroom/documents/13396/attachments/3/translations/en/renditions/native, checked on 23/09/2019.

Fessehaie, J.; Morris, M. (2018): Global Value Chains and Sustainable Development Goals: What Role for Trade and Industrial Policies? Edited by International Centre for Trade and Sustainable Devel-

opment. Available online at https://www.ictsd.org/sites/default/files/research/ictsd_gvc_synthesis_report_final_0.pdf.

Genovese, A.; Acquaye, A.; Figueroa, A.; Koh, S. C. L. (2017): Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. In: Omega 66, Part B, pp. 344–357. DOI: 10.1016/j.omega.2015.05.015.

Mol, A. P. J.; Oosterveer, P. (2015): Certification of Markets, Markets of Certificates: Tracing Sustainability in Global Agro-Food Value Chains. In: Sustainability 7 (9), pp. 12258–12278. DOI: 10.3390/su70912258.

Stenmarck, Å.; Jensen, C.; Quested, T.; Moates, G. (2016): Estimates of European food waste levels. European Union. Available online at https://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf, checked on 23/09/2019.

Zucchella, A.; Previtali, P. (2018): Circular business models for sustainable development: A "waste is food" restorative ecosystem. In: Business Strategy and the Environment 28 (2), pp. 274–285. DOI: 10.1002/bse.2216.

Artificial Intelligence and Machine Learning

Arntz, M.; Gregory, T.; Zierahn, U. (2016): The Risk of Automation for Jobs in OECD Countries. A Comparative Analysis (OECD Social, Employment and Migration Working Papers, 189). Available online at https://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7-en, checked on 23/09/2019.

Birrell, S.; Hughes, J.; Cai, J. Y.; Iida, F. (2019): A field-tested robotic harvesting system for iceberg lettuce. In: Journal of Field Robotics, pp. 1–21. DOI: 10.1002/rob.21888.

Business Insider (BI) (2016): 80% of businesses want chatbots by 2020. Available online at https://www.businessinsider.de/80-of-businesses-want-chatbots-by-2020-2016-12?r=US&IR=T, checked on 27/09/2019.

Death, R. G.; Collier, K. J.; Hudson, Maui, Canning, Adam; Niessen, M.; David, B. O.; Catlin, A.; Hamer, M.; Pingram, M. (2017): Does artificial intelligence modelling have anything to offer traditional management of freshwater food resources? ERI Report 107. Environmental Research Institute, University of Waikato. Hamilton, New Zealand.

Ellen Macarthur Foundation (Ed.) (2019): Artificial Intelligene and the Circular Economy. Available online at https://www.ellenmacarthurfoundation.org/publications/artificial-intelligence-and-the-circular-economy, checked on 23/09/2019.

Kondakci, T.; Zhou, W. (2016): Recent Applications of Advanced Control Techniques in Food Industry. In: Food and Bioprocess Technology 10 (3), pp. 522–542. DOI: 10.1007/s11947-016-1831-x.

Liakos, K. G.; Busato, P.; Moshou, D.; Pearson, S.; Bochtis, D. (2018): Machine Learning in Agriculture: A Review. In: Sensors, pp. 1–29. DOI: 10.3390/s18082674.

McCarthy, U.; Uysal, I.; Badia-Melis, R.; Mercier, S.; O'Donnell, C.; Ktenioudaki, A. (2018): Global food security – Issues, challenges and technological solutions. In: Trends in Food Science & Technology 77, pp. 11–20. DOI: 10.1016/j.tifs.2018.05.002.

Mordor Intelligence (Ed.) (2019): Artificial Intelligence (AI) in Food & Beverages Market. Growth, Trends, and Forecast (2019-2024). Available online at https://www.mordorintelligence.com/industry-reports/artificial-intelligence-in-food-and-beverages-market, checked on 23/09/2019.

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