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Addressing the current and Future skIll needs for sustainability, Digitalisation and the bio-Economy in agricuLture: European skills agenDa and Strategy

D1.8 - Trend and scenario analysis	
Document description	This deliverable will present the scenarios, their hypothesis and justification and their consequences. It will contain an executive summary presenting the main trends, their impact and skill needs.
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1 Introduction

1.1 Structure of the report

WP1, task 1.5 of the FIELDS project aims to create scenarios for EU agriculture, food industry and forestry sectors, based on the analysis of socio-economic trends impacting on these sectors and specified for the dimensions sustainability, digitalisation, bio-economy and business models. Business models reflect the elements of management & entrepreneurship and soft skills that were included as dimensions in Task 1.3 - Country and Focus Group Discussions, and Task 1.4 - Bottom-up Surveys.[1]

The identification of trends is relevant because they can dictate the direction of developments in the sectors analysed in our project. For example, the climate change trend can alter the potential future of agriculture and forestry by pushing it towards more sustainable solutions.

We investigate the potential impact of these trends on agriculture, food industry and forestry from the year 2020 until the year 2030. As the future is inherently uncertain (Durance & Godet, 2010), we construct scenarios. Scenarios reflect different possible futures, thereby supporting public sector or business leaders in policy making (Meissner & Wulf, 2013).

1.2 Policy Framework of trend and scenario analysis

The aims of the Erasmus+ FIELDS project are consistent with main EU policies in the fields of sustainable and circular production.

The European Green Deal, announced by the European Commission in December 2019, followed up on the UN Sustainable Development Goals (SDGs) and COP21 (the UN climate change conference of 2015). It commits the EU to become climate-neutral by 2050 whilst promising to help companies to become world leaders in clean products and green technologies. It aims to boost the efficient use of resources by moving to a clean, circular economy while restoring biodiversity and cutting pollution. The Green Deal encompasses a New Circular Economy Action Plan, a Sustainable Europe Investment Plan, a Biodiversity Strategy for 2030 and, a new Farm to Fork strategy on sustainable food throughout the value chain (EU-Green Deal, 2021).

For the FIELDS project, sustainable food production, biodiversity, and circular economy are key issues. A circular economy is instrumental in delivering on the European Commission’s ambitions to decouple resource

[1] Management & entrepreneurship and soft skills are intangible and difficult to capture in trend analyses. However, business model developments that assume development of these skills have been studied throughout Europe. In this way analysis of business model trends is complementary to the skill needs analysis of T1.3 and T1.4.

use from economic growth. The Green Deal aims to halt, and as much as possible reverse, the pressures we place on our planet's resources, ecosystems, climate, and biodiversity.

The Farm to Fork Strategy aims to enable the transition to a sustainable EU food system that safeguards food security and ensures access to healthy diets sourced from a healthy planet. The strategy sets concrete targets to transform the EU's food system, including a reduction by 50 % of the use of pesticides, a reduction by at least 20 % of the use of fertilizers, a reduction by 50 % in sales of antimicrobials used for farmed animals and aquaculture, and reaching 25 % of agricultural land under organic farming. It also proposes ambitious measures to ensure that the healthy option is the easiest for EU citizens, including improved labelling to better meet consumers' information needs on healthy, sustainable foods (EU-FarmToFork, 2021).

Biodiversity underpins vital environmental, social and economic functions. It is therefore not only placed at the heart of EU environmental policy, but the Commission wants biodiversity criteria to be fully factored into public, corporate and individual decisions at all levels, from farming and fisheries to trade, industry, energy, climate, and economic policy (Oneplanet, 2021).

Coherent with the Green Deal the new (post 2020) Common Agricultural Policy (CAP) aims to foster a sustainable and competitive agricultural sector that can contribute significantly to the European Green Deal, especially with regard to the Farm to Fork, circularity, and biodiversity strategies. Action points of this policy instrument are as follows: - better integration of climate issues as well as environmental issues such as biodiversity protection, natural resource conservation, and soil health and fertility, - access to healthy food for all EU citizens, - promotion of sustainable agriculture (Farm to Fork initiative): reduction of chemical fertilisers, pesticides, and antibiotics, nutrient losses, increase of the organic farming area, - support of digitalisation of agriculture to improve sustainability and competitiveness (EU-CAP, 2020).

1.3 FIELDS project dimensions

The Erasmus+ FIELDS project aims at skill development in Sustainable production, Bio-economy (addressing both sustainable and circular production), Digitalisation (to support sustainable and circular production), and Management and Entrepreneurship skills, including Soft skills. This report will include trends in Business Models, to reflect skill needs developments in Management & Entrepreneurship and Soft Skills. T1.3 (Focus group discussions) and T1.4 (Survey) of the project have paid in-depth attention to these skill needs, this report focuses on the business model behind these needs. Figure 1 depicts the dimensions included in this report.

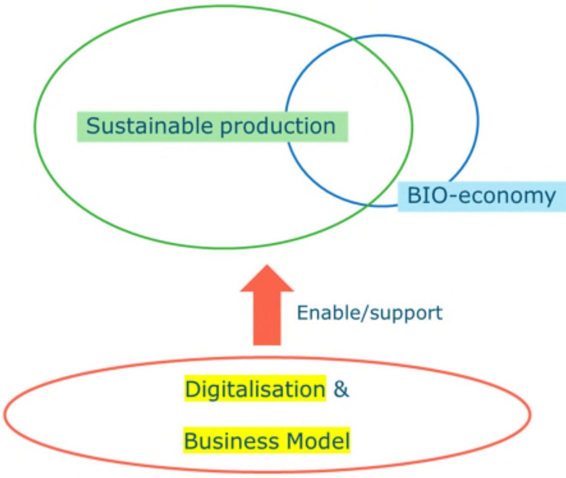

Figure 1 FIELDS dimensions

The four-dimension Sustainability, Bio-economy, Digitalisation and Business Model are strongly interrelated. Bio-economy focuses on sustainable use of (agriculture and forestry) resources. Digitalisation supports and often enables sustainable production, e.g. through more efficient use of resources. A business model reflects the economisation of the use of resources and whether this sustainably takes place, both environmentally as well as economically.

The focal sectors in the FIELDS project are agriculture, food industry and forestry sectors.

This report is structured as follows. In chapter 2, trends in sustainability, bio-economy, digitalisation and business models in EU agriculture, food industry and forestry are identified. The analysis was executed on EU level and country level, for 7 selected countries. Chapter 3 design 3 scenarios for EU agriculture, food industry and forestry and 3 country-level scenarios for the 7 selected countries. For each scenario key skill needs in agriculture, food industry and forestry sectors are identified. These identified skill needs will support the prioritisation of training needs in WP2. Chapter 4 will conclude.

2 Trends in agriculture, food industry and forestry

2.1 Method

This chapter focuses on the understanding of trends affecting European agriculture, food industry and forestry.

The EU level trend analysis has been performed by WUR (Wageningen University and Research Centre), PlantETP (Plants for the Future ETP), FoodDrinkEurope, GAIA-Greece and CEPI (Confederation of European Paper Industries). Seven country-specific trend analyses were performed by: WUR (the Netherlands), Confagricoltura and University of Turin (Italy), ISEKI (Spain), FJ-BLT (Austria), ANIA (France), Association of ProAgria Centres (Finland), ICOS (Ireland). All partners were supported by their country teams. The trend analysis in this report has taken as starting point a recent trend study from the Horizon2020 project Fit4Food2030 (Fit4Food2030.eu), in particular, deliverable 2.1: 'Report on baseline and description of identified trends, drivers and barriers of EU food system' (Wepner *et al.*, 2018). This extensive trend study was conducted through interviews with selected stakeholders across Europe, in-depth desk research and a European survey. Further, trends identified were in-depth discussed with European experts from different areas of the food system, before these were finally selected. Fit4Food2030 identified 60 trends in and beyond the food system in the EU (Wepner *et al.*, 2018). These trends range from megatrends like climate change to more specific trends like the increase in the use of bio-based plastics.

We follow the definition of ''Trend'' from (Fit4Food2030.eu D2.1, page 4): ''A trend is a development or change over a long time, which is likely to affect society or parts of it after a few years. A trend cannot easily be influenced in a mechanic way by individual organisations, players, or nations. It is often a result of specific drivers or can be promoted by strong influencers. It becomes visible only in retrospective.'' Trend studies usually distinguish between megatrends and trends. Megatrends are defined according to OECD (2016), as ''large-scale social, economic, political, environmental or technological changes that are slow to form, but which, once they have taken root, exercise a profound and lasting influence on many if not most human activities, processes and perceptions.'' Trends, contrary to megatrends, focus at smaller, regional, or sectoral scale. Fit4Food2030 identifies 11 megatrends (Table 1) linked to Global socio-economic-technological developments.

Table 1 Megatrends identified by the Horizon2020 project Fit4Food2030

Megatrends identified by the Fit4Food2030 project	
Climate Change Malnutrition Rise of Non-Communicable Diseases Urbanisation Demographic Change Migration.	Scarcity of Natural Resources Rise in Energy Consumption Industry 4.0 – Digitization Big Data Analysis Economic Globalisation

These megatrends have been specified for their impact on agriculture and the food industry in the EU. For this, the Fit4Food2030 project distinguished the following categories: Agricultural production; Food processing; Consumer trends; Market economy, Retail and logistics; Packaging and waste; Policy and other trends. These categories included specific trends. (For an overview of all trends identified in the project Fit4Food2030, see annex 1; and for a detailed description Wepner *et al*., 2018).

Next, trends were, if applicable, specified for the four dimensions of the FIELDS project. This was done jointly with an extensive analysis of the literature and sector and policy documents in the four dimensions of our FIELDS project, for the agriculture, forestry and food industry. These steps led to the identification of main trends relevant to the FIELDS project. Table 2 gives an overview of identified trends in agriculture, forestry and the food industry grouped into the categories Sustainable production, Bio-economy, Digitalisation, and Business models. The next sections 2.3 - 2.6 will present the underlying literature and sector and policy documents that have been analysed.

Table 2 Identified trends in agriculture, forestry and the food industry in Europe

Identified trends in Agriculture, Food industry and Forestry	
Sustainability	**Agriculture:** Integrated pest management, Integrated nutrient management, Agriculture pollution and GHG emissions, Organic farming and extensive production systems, Animal welfare, Scarcity of natural resources (land, nutrients), Pressure on water resources, Biodiversity and conservation of eco-systems, Food waste and loss, **Forestry:** Large scale forest disturbances (droughts, heat waves, etc.), Impact of climate change on tree species and biomass characteristics, Biodiversity challenges, Illegal logging, Fragmentation of ownership, Health and safety challenges **Food Industry:** Technologies to deal with food waste and loss, Circular production, Energy efficiency, Environmental footprint, Smart logistics systems, Clean and ''green'' label, Consumer diets
Bio-economy	**Agriculture:** Biomass production and transformation, Renewable energy, Biobased products, Resource-efficient technologies and reduction of losses, Circularity of production, Biodiversity **Forestry:** Biomass production and transformation, Renewable energy, Biobased products and eco-system services, Increasing demands for wood, Urban green spaces/forests **Food Industry:** Use of food waste, Circular production, Energy efficiency, Biomass transformation, Bio-based products, Bio-based packaging, New proteins

Digitalisation	**Agriculture:** On-farm applications (combined technologies), Integrated FMIS, Big Data analysis and Agriculture 4.0, Traceability of produce, Supply Chain information systems, New customer relationships **Forestry:** In-forest applications (combined technologies), Mechanised harvesting, Timber transport and traceability, Forestry management information systems **Food Industry:** Food processing control, Food supply-chain monitoring, Factory design and industry 4.0, Robotics, Digital twins and augmented reality, 3D Printing/additive manufacturing, New technologies in processing and packaging,
Business Models	**Agriculture:** Changes in farm structure, Multi-functional farms, Urban farming and Indoor cultivation systems, Health and food consciousness of consumers, Traceability, Short food supply chains and Local/regional products, **Forestry:** Economic importance of forests, Urban green spaces, Fragmented ownerships, Lack of forest entrepreneurships, Weak infrastructure and technology **Food industry:** Complex consumer demands and new diets, Interaction with consumers, New logistics and e-commerce, Short food supply chains, Novel foods, New packaging

2.2 Trends in Sustainable production

The term sustainable production is based on Brundtland Report published in 1987 and is based on the broader paradigm of sustainable development: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs“ (Brundtland *et al.*, 1987). Multiple definitions of sustainable agriculture, food industry and forestry can be found in the literature. These reflect different priorities and specific values for stakeholders.

The sustainability discussion in this report is focused on and related to climate change impacts of human activities and the depletion of resources. Indeed, increased intensification and industrialization of agriculture has led to water pollution (Moss, 2008), water scarcity (Fitton *et al.,* 2019), climate change due to greenhouse gas emissions (Fellmann *et al.,* 2018), loss of biodiversity (Hallmann *et al*., 2017) and soil depletion (Lal, 2015). Agriculture is seen as the main driver of biodiversity loss (Geiger et al., 2010; Kremen & Merenlender, 2018). However, the European forest industry is vital to conserve biodiversity, mitigate climate change and contribute to a growing sustainable bio-economy. A majority of challenges in the forestry sector stem from climate change and land-use change, which are the key source of global biodiversity loss. It is important to note that – compared to agriculture/farming - developments in forests are slow; young forests today reach their maturity after decades. The food industry adds to the sustainability challenges because of the inefficient use of resources and its contribution to the production of food waste. In sections 2.2.1-2.2.3 the trends in sustainable production (Table 3) are further specified for agriculture, forestry and the food industry. The following trends will be addressed.

Table 3 Trends in sustainable production

Agriculture: Integrated pest management, Integrated nutrient management, Agriculture pollution and GHG emissions, Organic farming and extensive production systems, Animal welfare, Scarcity of natural resources (land, nutrients), Pressure on water resources, Biodiversity and conservation of eco-systems, Food waste and loss,
Forestry: Large scale forest disturbances (droughts, heat waves, etc.), Impact of climate change on tree species and biomass characteristics, Biodiversity challenges, Illegal logging, Fragmentation of ownership, Health and safety challenges
Food Industry: Technologies to deal with food waste and loss, Circular production, Energy efficiency, Environmental footprint, Smart logistics systems, Clean and ''green'' label, Consumer diets

2.2.1 Trends in sustainable production in agriculture

Agricultural inputs[2] of pesticides and fertilizers form one of the main challenges for sustainable agricultural production. Pesticides are used to protect crops from pests, diseases and competition from weeds, thus improving crop yield and quality. At the same time, pesticides present a risk to human health and the environment. The push to reduce the use and impact of pesticides (EU commission - Sustainable use of Pesticides Directive 2009/128/EC) in agriculture is driving the development of alternatives with lower environmental impact, as well as the breeding of crop varieties with increased resistance to pests and diseases. Instead of conventional chemical pesticides biopesticides, living creatures, or compounds derived from living things that deter pests can and are increasingly used (NPIC, 2020). They may be derived from animals (e.g. nematodes) (Kumar, 2012). Biopesticides are less "persistent" than some synthetic alternatives. This means that biopesticides typically break down in the environment, leaving no residual activity after a relatively short time (McCoy, 2020).

Similarly, excessive fertiliser application and soil nutrient mismanagement can lead to loss of productivity by hampering soil health. Moreover, the very process of producing synthetic fertilisers has an important environmental impact. Better **soil nutrient management** combined with an efficient use of organic fertilisers (e.g. manure, compost) can help reduce external inputs and restore soil health. Moreover, instead of synthetic fertilizers organic fertilizers can be used which are produced from agricultural waste residues such as livestock manure and spent mushroom compost or municipal solid waste compost (Olfati *et al.*, 2009). Organic fertilizers in comparison with chemical fertilizers have lower nutrient content and are slow-release

[2] To improve readability of the report for every text block in the trend analysis and in the scenario analysis a key word is presented in bold

but they are as effective as chemical fertilizers over longer periods of use (Sharafzadeh & Ordookhani, 2011). Slow-release is often more desirable for crop production and will significantly reduce leaching.

Agricultural production (crops and livestock combined) and the associated land use changes account for ~ 16-27 % of anthropogenic **GHG emissions**. This is in particular due to the release of soil organic carbon. Excluding the impact of livestock farming, other important contributors to GHG emissions are synthetic fertilisers and rice cultivation (13 % and 10 % of agriculture emissions, respectively) (OECD, 2021). Total non-CO_2 greenhouse gas emissions from agriculture are expected to decrease by 1.5 % by 2030, compared to 2008. However, most emissions of non-CO_2 greenhouse gases (i.e. methane and nitrous oxide) in agriculture originate directly or indirectly from animal production – this sector will be directly responsible for 72 % of those emissions in 2030 (EU, 2017).

To cope with these challenges we see a move towards **organic and extensive farming systems**. Organic farming is an agricultural system that uses ecologically-based pest controls and biological fertilisers, derived mostly from animal and plant wastes and nitrogen-fixing cover crops. Moreover, organic production systems are based on agronomic, biological and mechanical methods, such as crop rotation, crop residues, animal manure, off-farm organic waste, and plant protection (Meena, 2014). Additionally, organic farming rules encourage a high standard of animal welfare and require farmers to meet the specific behavioural needs of animals. Organic farming aims to produce food using natural substances and processes. One of the objectives of the EU is to increase the organic farming area in the EU. Between 2005 and 2017 the total organic farmland in the EU almost doubled from 6.5 million ha to 12.6 million ha (7 % of total agricultural area). The EU has set the ambition to have 25 % of farmland under organic farming practices by 2030 (EU-Organic, 2020), whereas currently, only 8.5 % of farmland is under organic production (Eurostat, 2019).

In general extensive production systems use small inputs of labour, fertilisers, and capital, relative to the land area being farmed. Both organic and extensive systems require more land to produce the same amount of food as conventional systems. While organic farming has a lower environmental impact per unit of land, its lower yield means that organic systems often require more land, cause more eutrophication, use less energy, but cause similar greenhouse gas emissions as conventional systems per unit of food (Clark&Tilman, 2017).

An important trend is the increasing attention of society to **animal welfare**. In 1998, Council Directive 98/58/EC on the protection of animals kept for farming purposes, gave general rules for the protection of animals of all species kept for the production of food, wool, skin, fur, or for other farming purposes, including fish, reptiles or amphibians. Legislation has been further developed since that time to progressively improve the welfare status of farmed animals and to set standards for their transport and conditions at the time of stunning and slaughter. Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well-nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress (AVMA, 2020).

However, **scarcity of natural resources** (e.g. land, water, nutrients) and cost-driven agriculture imply intensification of agriculture and production in monocultures and, therefore, a loss of biodiversity in Europe. Land scarcity can occur due to the need for expansion of agricultural land (Fitton *et al.*, 2019). While water scarcity can be caused by increasing demand for animal products (Doreau *et al.*, 2012). **Biodiversity** refers to the variety of life on Earth. Biodiversity conservation is about saving life on Earth in all its forms and keeping natural ecosystems functioning and healthy (Turner et al, 2007). Agriculture is seen as the main driver of biodiversity loss (Geiger *et al.*, 2010; Kremen & Merenlender, 2018). Biodiversity is essential for the natural ecosystem on which agriculture depends. Some key contributions due to biodiversity are water purification, flood and drought control, nutrient cycling and climate regulation. (Bartz *et al.*, 2019). There is a push to ensure that the EU's biodiversity will be on the path to recovery by 2030. Actions include increasing protected areas and restoring degraded ecosystems (EU-Biod, 2020).

Enhancing **irrigation** infrastructure and management will increase irrigation efficiency, thereby reducing water use while maintaining high yield and quality. In many regions, crops are rainfed, which puts yield and quality at the mercy of weather conditions. Harvesting rainwater and water conservation systems can help secure water for periods when rain is lacking. Selection of climate-resilient crops and varieties that are more water-use efficient in regions experiencing increasing periods of drought would reduce the irrigation needs where water scarcity is highest. **Indoor farming** (e.g. vertical farms, hydroponics) requires significantly less water due to a more controlled environment and the possibility for a closed circuit that not only allows the recirculation of water but also eliminates nutrient run-offs.

Finally, an important trend is the increase in **food waste and loss** in the food chain. Food loss consists of the amount of food material produced and ultimately discarded during any stage of the food supply chain (Dou *et al.* 2016) of all the food produced for human consumption that is not eaten by humans. Food waste is considered to be a part of food loss and is understood as food intended for human consumption being discarded or left to spoil as a result of decisions taken by actors along the food supply chain (FAO, 2018). An estimated 1/3 of all food produced globally is lost or goes to waste. Reducing food waste and loss will enable more efficient land use and resource management.

2.2.2 Trends in sustainable production in the forestry sector

An important trend in forestry is a growing frequency of large-scale **forest disturbances**, including extreme droughts, heat waves, extensive insect outbreaks, and more extensive forest fires (Forest Europe, 2020). These natural disturbances, for example, disrupt wood/biomass supply leading to overload of sawmills and/or shortages.

Moreover, climate change supports an accelerated growth rate of certain tree species (Forest Europe, 2020). In line with this development changing growing conditions and new demands from more diversified forest-based products call for an improved understanding of tree genetics. This includes understanding in detail the role genetic factors have on the tree's growth dynamics, resilience to climate change, susceptibility to native and invasive pests and diseases. Also, how the genotype controls biomass characteristics is important for the quality and value of wood products. In this regard, there is a potential to increase harvesting possibilities through the creation of **climate change-resilient and stress-tolerant forests** (e.g. improving seeds/seedlings/plants to increase productivity and resilience) and careful, long-term forest management (Forest platform, 2021).

Global biodiversity is declining because of climate change and land-use change. For the forest sector in Europe, this is not the case as the forest cover and growing stock have increased in the last decades. The number of genetic conservation units has increased about 10 times since 1990. However, continued **biodiversity integration** into sustainable forest management is needed to fill the gaps in geographical representativeness of conserved populations of tree species (Forest Europe, 2020). New science and technological advances relying on modelling, artificial intelligence and big data can provide a good basis to better understand complex socio-ecological systems and address sustainability questions connecting different disciplines. However, lack of data makes it difficult to do timely and detailed monitoring of natural ecosystem change and uses.

An important trend in the forestry sector is that **illegal logging** and related trade are still ongoing in the EU, resulting in lost revenues and other foregone benefits. In environmental terms, illegal logging causes environmental damage, retards sustainable development and is associated with deforestation, climate change and a loss of biodiversity (Forest Europe, 2020a). Another challenge is the **scattered private forest ownership** in Central, South and Eastern Europe (60 % of EU forests are privately owned, with a high proportion of small-size forest holdings (< 10 ha)) (Forest Europe, 2020) leading to difficulties to connect suitable habitats for nature conservation efforts (Forest Platform, 2021).

Fatal accidents among forest labourers have reduced significantly in Europe. However, forestry-working practices will need to be adapted to minimise the impact of still existing high occupational risks. 24 in 1000 workers are subject to a work accident every year. The incidence of fatal accidents in forestry alone is 24.5 per 100,000. The many self-employed foresters have limited access to occupational health & safety resources/training. They also lack resources to invest in new, safer machinery and infrastructure (EU-OSHA, 2021).

2.2.3 Trends in sustainable production in the food industry

The efforts from the food industry to reduce food waste and loss have been an everlasting challenge. Linked to the Bioeconomy, the reuse of waste streams and the optimisation of by-products, such as energy, is one of the main drivers of innovation within the food industry. This development covers the supply chain from the primary producers up to the consumers, including logistics and distribution (FoodDrinkEurope, 2014). In line with these developments, there is a shift from linear processing and consumption of products, to a sustainable economy that is regenerative by design. In other words, **circular production** requires disruptive innovation. It allows reduced fossil fuel use and food waste, enhanced resource use efficiency, and increased recycling to retain as much value as possible across the food supply chain (Lazaro-Mojica *et al.*, 2020).

In this respect, more **efficient energy use** in food systems may be achieved through optimising energy use throughout the entire value chain. This means, for instance, moving towards the use and scaling-up of renewable energy sources in food production, but also redesigning and innovating industrial food processing. The use of Life Cycle Analysis, or more specifically, Product Environmental Footprint (PEF) is a tool that will become widespread within the food industry in the years to come. PEF is an EU-wide multi-criteria assessment of the environmental performance of a good or service throughout its life cycle; it assesses several parameters of the environmental impact such as carbon dioxide emissions, water depletion, waste management, etc. (FoodDrinkEurope, 2017).

Common goals across sector-specific technologies include reducing environmental impact and increasing nutritional quality while maintaining food safety, and the enjoyable experience of consuming food. **Innovations** have been taking place, from cutting-edge technologies (water-beam, laser, ultrasound), fractionation, separation and extraction (dry bio-refineries, membranes, adsorption technologies, electrostatic separation, supercritical CO_2), to structuring (emulgation utilising membranes, microfluidisation, ultrasound), and heating (super-heated steam, microwaves, induction, sous-vide, radio-frequency). Also, non-thermal and mild preservation (electromagnetic energy and pulsed electric fields, high-pressure treatment, reverse osmosis, cold plasma), filling (aseptic filling, clean room tech, super cooling). (Lazaro-Mojica *et al.*, 2020). One of the strategies to minimise **environmental impact** is the search for new products with high productivity/low environmental impact, like the higher use of legumes in the diet, the insertion of marine sources (algae) and the utilization of insects. Other ways might be the fermentation of side-streams or cultivating animal cells in a laboratory (cultured-meat) (ETP Food-For-Life SRIA, 2017).

New **smart logistic systems**, such as the physical internet and smart delivery systems try to implement intelligent, efficient, and less environmentally damaging transport (Mittal Al, 2018). In addition, strategies for the rational use of **packaging** for reduction of environmental impact on production, recycling and waste treatment of packaging are emerging. Some strategies include the use of biodegradable packaging, new recycling methodologies, new design in food packaging, or new business models (Han, 2014).

Concerning consumer communication **Clean and "green" label**, surveys have shown that "Clean or transparent label products" are associated with natural, organic logos, free from artificial ingredients, or "free from allergens, GMOs", ''minimally processed", "short & simple ingredients list", or "transparent packaging". However, consumers around the world have different associations. To the concept of "clean label" the concept of origin and the impact in sustainability from food products are adding up. In any case, this consumer trend is shaping the market and the way foods are reformulated and labeled for better consumer acceptance (Wepner *et al.*, 2019).

Another important trend is related to **consumer diets**. Consumers select specific diets for different reasons. Traditionally this selection was based on nutrition and health, or ethical related factors. However, there is an increasing trend in the perception of sustainability factors in the diet, with a strong drive for reduction of meat consumption (vegetarianism and veganism). The discussion on the environmental impact of the food that we consume is also changing consumer behaviour, and thus affecting the food industry, where the most common environmental issues are related to food processing loss, food wastage and packaging; energy efficiency; transportation of foods; water consumption and waste management (Alsaffar, 2015).

2.3 Trends in the Bio-economy

Bioeconomy can be defined as those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy" (EU-Bioecon, 2020). Bioeconomy aims to ensure food security and increase the innovative use of resources in a competitive society in a manner friendly to the natural environment. For the future, Bioeconomy is expected to transform the current fossil-based economical system into a more sustainable one that takes various dimensions into account such as food security, resource scarcity and climate change. The world will face an increasing demand for food and energy due to an ever-increasing population. Therefore, renewable energy and resource-use-efficient technologies must be fostered which increase productivity in agriculture, forestry and aqua-culture. At the same time, this process must happen within the planetary boundaries and without jeopardizing our ecosystems and biodiversity. Bioeconomy in agriculture also means increasing productivity while reducing losses in the production, storage, transport and processing of foodstuff. However, more focus should be put on end-of-life bio-based products in order to achieve more sustainable bioeconomy but not less secure food products, i.e. circular product design, recycling and cascading.

The Bio-economy trends were identified in Table 4.

Table 4 Trends in bio-economy

Agriculture: Biomass production and transformation, Renewable energy, Biobased products, Resource-efficient technologies and reduction of losses, Circularity of production, Biodiversity
Forestry: Biomass production and transformation, Renewable energy, Biobased products and eco-system services, Increasing demands for wood, Urban green spaces/forests
Food Industry: Use of food waste, Circular production, Energy efficiency, Biomass transformation, Bio-based products, Bio-based packaging, New proteins

2.3.1 Bio-economy trends in agriculture

Plant biomass is expected to play a key role in the future bioeconomy by replacing fossil fuel derived carbon. Plant biomass can be converted into renewable energy (fuel, power, heat) with the help of integrated biorefineries (Stegman *et al.*, 2020). Plant biomass can be produced at the farm level (e.g. field, glasshouse, indoor), in the sea and bioreactors (e.g. seaweed). Moreover, different technologies for food waste treatment in order to transform human food waste into animal feed (Van Zanten *et al.*, 2019) are currently being developed. Due to the potential for non-food/feed products, biobased products compete with food/feed for finite resources (e.g. water, land, nutrients). Therefore, the bioeconomy needs to be carefully balanced, so as not to threaten food security or the environment (EU-Biob, 2011).

Overall, the production of **renewable energy** is a fast-emerging trend. Renewable energy is collected from renewable resources, including biomass, geothermal, ocean, solar, and wind energy, as well as hydropower (Balcioglu, *et al.*, 2017; Gorjian, 2017). Also, different kinds of livestock manures are increasingly being used as raw materials for biogas production (UNEP, 2009; IFAD, 2012). Production of biogas provides a versatile carrier of renewable energy, as methane can be used for the replacement of fossil fuels in both heat and power generation in an animal farming system (Weiland, 2010).

Another main trend is the development of **biobased products**, such as bio-plastics, biobased packaging, biobased chemicals, etc. Bio-based products are non-food, non-feed agricultural products that are used in a variety of commercial/ industrial applications and are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilized (Singh, *et al*., 2003). These include a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat), that can replace fossil fuel-based products (Stegman *et al.*, 2020). Interesting examples are that researchers have found that plastic can be produced from the chitin present in prawn shells (Faisal *et al.*, 2018) and that spider silk can be used for a myriad of applications such as clinical applications (Salehi *et al.*, 2020).

Resource-efficient technologies are the technologies that use the Earth's limited resources in a sustainable way while minimising impacts on the environment. They allow us to create more with less, to reduce losses and to deliver greater value with less input. The efficient use of plant biomass includes the use of wastes and residues as resource through the use of **integrated biorefineries**, in order to maintain the value of the product, materials and/or resources for as long as possible. Integrated biorefineries are a combination of several biomass conversion technologies that allow for more flexibility and cost reduction, thereby enabling the combined production of high-value products (e.g. fine chemicals), with lower value products (e.g. bioenergy). These technologies can also be used to optimise the cascading use of plant biomass for various purposes (McCormick&Kautto, 2013)

The **circularity** of production is a tool to optimise resource usage and extend the lifespan of products, parts and components by simultaneously minimising water and energy consumption, reducing carbon emissions, plastics and organic waste, among others (Santibanez *et al.*, 2019; Giama *et al.*, 2019) and hence improving farm production systems.

Loss of biodiversity has been occurring for decades, with agriculture, particularly through land-use changes, being responsible for around 80 % of all threatened terrestrial bird and mammal species (OECD, 2021). Potential competition between the production of non-food/feed and food/feed biomass for finite resources such as water, nutrients and especially land, presents a major threat to biodiversity (EU-Biob, 2011).

2.3.2 Bio-economy trends in the forestry sector

Forestry trends relate to market developments and economic efficiency impacting the functioning of the growing **forest bio-economy**. They cover the use of forests for economic activity (wood mobilisation and usage, eco-tourism, non-wood products) as well as trends affecting the economic efficiency of the European forest industry. With respect to economic potential, it is observed a divide between the North on the one hand and the South and East of Europe on the other hand when it comes to infrastructure, the integration of the forest value chain and the use of modern technology.

Forests are an important source of **biomass production**. There are increasing demands on forests for carbon sequestration, for renewable bio-based materials and products, which can substitute non-renewable ones. The interest in fossil-based alternatives such as new innovative products made from renewable raw materials and the interest in sustainable low-carbon, wood-based fibres (e.g. for textile applications) is increasing due to their lower carbon footprint and renewability (EFI, 2020).

Forests are also an important source of **renewable energy**. There is currently a positive trend in wood energy consumption, while the share of wood energy in the total energy consumption increases – with Northern Europe currently having the highest per capita consumption (almost 2 metric tonnes dry wood matter used for energy). Renewable energy can replace non-renewable energy and contribute to climate change mitigation. Wood is one of the major sources of renewable energy (Forest Europe, 2020).

An important trend in forestry is in the area of **bio-based products and ecosystem services**. Europe's forests provide numerous ecosystem services that benefit the public. Besides provisioning of wood and other products, soil protection, water and air purification and climate regulation are crucial forest ecosystem services, to some extent representing the basis for marketed products and services. These could generate financial revenues but this is still not reflected in market transactions. (Forest Europe, 2020).

Another trend is the increasing demand for wood: large-scale **timber construction** is evolving rapidly to allow for multi-storey wooden buildings and hybrid material construction (lowering carbon footprint and storing CO_2). (EFI, 2020).

Urban green spaces/forests provide increasing recreational use. Urban green spaces ensure a significant increase in socioeconomic and cultural benefits, especially for human health, livelihoods, rural development and employment from forests. There is clear scientific evidence that forests as place for recreation and eco-tourism have positive effects on physical and mental health (Forest Europe, 2020; Expert Group on human health and well-being).

2.3.3 Bio-economy trends in the food industry

The shift to **circular production**, which is regenerative by design, requires disruptive innovation. It allows reduced fossil fuel use and food waste, enhanced resource use efficiency, and increased recycling to retain as much value as possible across the food supply chain (Lazaro-Mojica *et al.*, 2020). More efficient energy use in food systems could be achieved through optimising energy use throughout the entire value chain. This means, for instance, moving towards the use and scaling-up of renewable energy sources in food production, but also redesigning and innovating industrial food processing. Moreover, the food industry and the bio-based industry can join technologies to maximise the output of waste streams and by-products for maximum efficacy, crossing sectorial limitations. This can support the development of new processing technologies that provides added value to resources used for production (FoodDrinkEurope, 2014).

EU **biomass utilisation** in 2011 was estimated at around 2 billion tones, of which 21 % was used for food, 44 % for feed, 19 % for processing (sugar, starch, vegetable oils and other foods) and materials, and 12 % for energy production (BBI, 2017). The bio-based industries set out to add value to the current feedstock base by increasing feedstock production and flexibility and making better use of side streams and residues for new innovative products. Agri-based residues include fruits and vegetables, eggshells, cereal bran, olive mill wastewater, red and white grape pomace, milk and dairy, protein by-products, wheat bran, and wastewater from agro-food production processes and food operations (BBI, 2017). Feedstock from the marine and freshwater environments (including marine and freshwater aquaculture, fish processing industry and marine biotechnology biorefineries) can also be utilised as feedstock for the production of materials. Micro- and macroalgae hold enormous potential for extracting high added-value natural biomolecules (such as pigments, lipids and fatty acids, proteins, polysaccharides, phenolics and phytosterols) for use in industries such as cosmetics, pharmaceuticals, polymers, food and feed ingredients and energy. (BBI, 2017).

Moreover, the **bio-based industry** can develop from new sources high added value food and new food ingredients. These may include starch-derived products, sugar-derived sub-products, new additives, new proteins, or high-value nutraceuticals (BBI, 2017). Biotechnology is one of the main tools for applications in the bio-based production. Some of the current challenges are to increase the yield and productivity of biochemical processes, to deal with the sensitivity of biochemical reactions to impurities, to develop synthetic biology to benefit biomass conversion, to develop new bioreactors, to draw on developments in microbiology and metagenomics, systems biology and synthetic biology to benefit biomass conversion. The latest include new microorganisms such as extremophiles and biocatalysts such as extremozymes (BBI, 2017)

An important trend in the food industry is towards **bio-based packaging**. Currently, the main drop-in bio-based products are plastics. Among the major bio-based plastics on the market are bio-based polyethylene (bio-PE) and bio-based polyethylene terephthalate (bio-PET). These are used in large market applications such as packaging, textiles, fibres and composites, where producers can claim a 'green image'. Bio-plastics and other polymer-derived bio-based ingredients provide a greater source for food grade packaging from a non-fossil-based source (BBI, 2017).

A last trend in the bio-economy is the development of **new protein** and protein fractions. The strategy for tackling the protein gap has two aims: on the one hand, sourcing, extracting and purifying high-grade proteins and developing new protein derivative solutions for food and feed applications; and on the other hand, unlocking lower-grade protein streams and refining these for industrial and food/feed applications. Bioactive ingredients, including proteins and protein derivatives, carotenoids, polyphenols and prebiotics, are widely used as additives in the food, feed, flavouring, fragrance, cosmetics, chemicals, textile, nutraceutical and pharmaceutical industries (BBI, 2017).

2.4 Trends in digitalisation

In this report Digitalisation refers to digital tools that collect, store, analyse, and share electronic data along the value chain enabling better decision making, which helps increase the viability of these sectors (EU-Digit, 2019; FAO, 2017). Currently, a lot of research is focused on exploring the potential application, challenges and opportunities of different digital technologies in different sub-sectors (Lokhorst *et al.*, 2019; Kies&Kleinschmit von Lengefeld, 2018; Villa-Henriksen *et al.*, 2020; Wolfert *et al.*, 2017).

The European commission aims to facilitate the development of new technologies and digitization in agriculture, through the CAP. As EU commissioner, Phil Hogan (April 2019) formulated it: *''European agriculture and rural areas have to benefit fully from the ongoing digital transformation of our economies and societies. The Member States recognize the importance and urgency of working together in order to improve the competitiveness of the agriculture sector and the well-being of the citizens living in rural areas.*

Today's commitment of Member States to cooperate on actions that will bring about this transformation is excellent news. The Commission will support and facilitate such actions.'' However, the pace of development throughout Europe differs. Besides technology challenges typical challenges of Digitalisation relate to: data ownership, data privacy and security, data standards, impacts on the environment etc. (Wolfert&Poppe, 2019; Muller *et al.*, 2019)

Table 5 describes the main digital technologies in agriculture, forestry and the food industry, while Table 6 includes major trends.

Table 5 Definition of main digital technologies used in agriculture, forestry and food industry

Digital technologies in agriculture, forestry and food industry	
Internet of Things (IoT)	A network of ''things'' that can independently operate and connect through the internet. Key component is a Wireless Sensor Network (WSN), a network of sensors (RFID tags, solar-powered field sensors, robots, sensors on tractors etc.) connected through cloud technology that can measure practically anything (moisture, soil humidity, plant/tree density, PH value, solar intensity, etc.). (Villa-Henriksen *et al.*, 2020)
Unmanned Aerial Vehicles (UAV/Drones)	A flying machine without a human pilot which can operate either autonomously by an onboard computer or is remotely controlled. A UAV system in agriculture and forestry consists of one or more UAVs, a ground control station that either communicates with the UAV or controls the UAV directly, a flight control system or autopilot, and sensors for data gathering, which can be camera applications or other purposes like spraying. (Tsouros *et al.* 2019; Probst *et al.*, 2018)
Big Data (BD)	In agriculture and forestry, there is the potential of continuous flows of large amounts of data that are collected by different devices such as sensors, robotics, UAVs and satellites, or from other sources such as statistics on prices, demand, weather data. Data come in a variety of constructs: video, text, audio, etc. These large sets of complex data is referred to as BD. Before the data can be analysed, it has to be cleansed, transported and possibly stored for longer-term analysis. (Janssen *et al.*, 2017; Wolfert *et al.*, 2017)
Artificial Intelligence (AI)	AI is a collection of technologies that combine data, algorithms and computing power (EC, 2020). AI tries to mimic human intelligence and learning capability. The ability to learn means that the machine can figure out a solution for a certain problem without being programmed how to solve the problem. AI applications can be used for numerous applications, like identification of crops, ripeness of crops, irrigation management, health status of animals, weed recognition, etc. (Liakos *et al.*, 2018)
Block Chains (BC)	BC technology assures the permanence of records, thereby providing data integrity, and seamless sharing of information between actors in the food

	chains. While providing maximum transparency in transactions, the system maintains privacy of individual actors. Blockchain systems help to prevent fraud, enable traceability of products throughout the food chain and potentially make large amounts of transaction data available for Big Data analysis. An important application of BC is smart contracts, supporting seamless transfer of assets from chain actor to chain actor. (Tripoli & Schmidhuber, 2018; Drescher, 2017).
Management Information Systems (MIS)	Management information systems store, process and exchange farm, forestry or industry operations data into useable information for the decision-maker. Functions include site-specific operations management, inventory management, harvest management, feed and animal health management, etc. (Fountas *et al.*, 2015; Tsiropoulos *et al.*, 2017).

Table 6 Main digitalisation trends in agriculture, forestry and the food industry.

Agriculture: On-farm applications (combined technologies), Integrated FMIS, Big Data analysis and Agriculture 4.0, Traceability of produce, Supply Chain information systems, New customer relationships
Forestry: In-forest applications (combined technologies), Mechanised harvesting, Timber transport and traceability, Forestry management information systems
Food Industry: Food processing control, Food supply-chain monitoring, Factory design and industry 4.0, Robotics, Digital twins and augmented reality, 3D Printing/additive manufacturing, New technologies in processing and packaging

2.4.1 Digitalisation trends in agriculture

The first trend is the **on-farm application** of (a combination of) digital technologies to on-farm processes such as crop selection, crop/weed identification, handling diseases, etc., see Box 1.

- Crop selection. Based on weather and soil data from (IoT) sensors and crop growing data, the crops that perform best on a patch of land can be identified. Based on this list a farmer can make his choices. Or decision making can be supported by an AI application (Gurnule, 2019; Tatapudi & Suresh Varma, 2019).
- Crop/weed identification. Digital technologies make it possible to differentiate (scanning, monitoring) between crops and weeds. Weed identification through UAV (supported by AI, machine vision) enables focused application of pesticides and herbicides (currently farmers apply the same, mostly too high, amounts of pesticides/herbicides for every spot of land). (Tsouros *et al.*, 2019). Also, intra-row weeders based on machine vision can be applied.

- Disease/nutrient deficiencies. AI technology (e.g. in combination with UAV, Robots, sensors, satellite data) can apply feature selection for the identification of plant diseases and nutrient deficiencies, based on temperature, humidity, soil, etc. data combined with picture and video data. Models for analysis can support pest management and fertilization. (Kale & Sonavane, 2019; Basori *et al.*, 2020)
- Yield prediction. Based on UAV, satellite and sensor data on soil, weather, crop data and crop growth data yields can be predicted, differentiated per plot. Additionally during processing and storage of crop quality can be monitored. (Narra *et al.* 2020; Maktab Dar Oghaz *et al.*, 2019)
- Feed intake monitoring/ precision feeding. Monitoring of feed intake and water supply inhouse can take place through animal identification tags and feed station sensors. Monitoring of grazing time and grazing location of cows or monitoring the (frequency of) use of feeding stations, can be used for several applications, for example as input for (ammonia) emission reduction policies. Precision mineral and medicine supplementation is important, in particular around calving time. Application is through ear tags connected to advanced mineral feeders. (Berckmans, 2017; Groher *et al.*, 2020).
- Animal health and welfare monitoring. Monitoring of health (udder, claw, longevity) and fertility through mounted sensors (temperature, weight, position, animal behaviour, etc), real-time image analysis, or sound analysis. For pigs also for prevention of tail biting. Combined with feed and supplements intake data AI can provide information to the farmer for decision making. (Maroto Molina *et al.*, 2020; Neethirajana *et al.*, 2017; www.IOF2020.EU/trials). Sensors can also support animal monitoring for animal fertility and birth of calves, piglets etc. (Wasaki *et al.*, 2017; Berckmans, 2017)
- Productivity. E.g. in dairy production milk robots can support productivity analysis per animal and analysis of milk components. Milk can be processed and labeled according to groups of animals or even individual animals. For meat production integration of on-farm productivity data with slaughterhouse data for meat quality and disease detection. (Roodenburg, 2017; Wolfert&Poppe, 2019; www.IOF2020.eu/trials)
- Irrigation. Digital technologies can support giving water to the right place, in the right quantity at the right time. WSN makes use of sensors that can measure soil conditions, humidity, temperature, wind, etc., while UAVs are able to map a certain field in order to see where more or less irrigation is needed. AI can optimise water giving, e.g. through smart orchard spray applications. These technologies lead to savings of water up to two-third of conventional irrigation. (Ammad Uddin *et al.*, 2019; Nikolidakis *et al.*, 2015)
- Bio-diversity monitoring. UAV technology enables monitoring of larger spaces of lands on variety and number of plant species (Libran-Embid *et al.*, 2020)

Box 1 On-farm applications of digital technologies

Besides the increasing use of these fields-related applications, there are other trends related to traceability of products, integrated farm management and customer and stakeholder relationships.

IoT devices for cultivation and harvest data combined with blockchain technology may enable **product segmentation** and **traceability** of products (Denolf, 2017; Demestichas, 2020), possibly in collaboration with other chain actors. Blockchain technology is often coined as a technology, which can enable traceability in supply chains (Caro *et al.*, 2018; Casado-Vara *et al.*, 2018; Mistry *et al.*, 2020).

The quality of farm management depends on the availability of high-quality information. A **farm management information system (FMIS)** can provide this information by enabling central collection, processing and storage of data from a wide variety of areas, as well as linking and processing of data to information that is relevant for the execution of on-farm activities. The data collected in an FMIS can be internal as well as external, whereby the latter can encompass the entire value chain, be it on horizontal (inter-company) or on vertical (chain upstream and downstream) level.

Typical functions of farm management information systems are, namely: fields operations management, site-specific management, machine management, inventory management, reporting, quality assurance, performance (e.g. productivity, sustainability-mineral accounting), reporting and integration with slaughterhouse data, health management, feed management and feed intake, performance (e.g. productivity, sustainability dashboards), sales, finance, customer relationships, marketing sales, finance, customer relationships, marketing supported by big data technology and advanced data analytics (Lokhorst *et al.* 2019).

Big data describes data that is primarily characterized by the three dimensions of volume (data volume), velocity (the speed at which the data volumes are generated and transferred) and variety (bandwidth of the data types). If technologies such as precision farming and remote sensing are networked with one another at the data level, one speaks of **Agriculture 4.0**. An FMIS based on agriculture 4.0 provides a comprehensive support function for the farm manager with support of Big Data analysis (Novcovic *et al.*, 2017). Moreover, **Big Data analysis** may facilitate combined analysis of operations data from digital technologies used at the farm as well as financial and customer-related and sales data into information to support management decisions. Fast emerging applications are:

- Design of new product features based on on-farm/business (traceability) data (e.g. quality differentiation; labeling)
- New ways to interact with customers (e.g. internet advertisement/catalogue and sales; advertisement and customer connection through social media)
- Addressing new market segments and channels (e.g. direct sales; connecting to new markets)
- Traceability data exchange (safety, quality, sustainability, provenance data)
- Communication of production data for (supply chain) quality management, planning and marketing purposes
- Support of interaction with stakeholders: government, advisory services, financial institutions, processors, coops, suppliers, data brokers, research organisations, veterinary services, connect to sector best practices databases

2.4.2 Digitalisation trends in the forestry sector

New measurement technologies, remote sensing, land-based smart sensors, detailed production data from machinery, mobile devices, industrial scanning records and standardized interfaces bring opportunities for the collection of detailed and dynamic information in the forestry sector.

The first trend we recognize is the application of (combinations of) digital technologies to **field processes** such as inventory management, fire detection, water management etc., see Box 2.

- Digital forest inventory management (such as trees per hectare, tree heights, and trunk diameters) using drones and laser scanning (lidar) as well as soil sensors, enables harvest planning and maintenance, detection of pests and diseases. Also to achieve precise knowledge of terrain, water flows, for example, to optimize road construction and environmental impact. Satellites and drones also provide early fire detection. (McKinsey&Company, 2018; Kies, Kleinschmit von Lengefeld, 2018).
- Site-specific management enables e.g. fertilization and drainage adapted to site needs. Data can be collected from soil sensors (e.g. assessment of soil nutrient deficiencies). (McKinsey&Company, 2018; Muller *et al.*, 2019)
- Water-management systems enable central control of water infrastructure (e.g. flood gates) based on weather, soil moisture, canal water levels, and analytics. (Muller *et al.*, 2019)
- Controlled environments, e.g. through sensors, enable the selection of plants with the right genetic profile best suited to the site and end-use.
- Fertilisation of young seedlings can be supported, e.g. with the help of drones in remote areas. (McKinsey&Company, 2018)
- UAV technology enables bio-diversity monitoring of larger spaces of lands on variety and number of plant species (Libran-Embid *et al.*, 2020)

Box 2. In-forest digitalisation trends

Next to these in-forest applications there is a trend to fully mechanized (and safe) **harvesting**, supported by on-vehicle sensors. These applications can be integrated with **supply chain planning**, such as automatic loading (Kies, Kleinschmit von Lengefeld, 2018; Muller *et al.*, 2019). However, the uptake of smart technology is slowed down because of insufficient access to broadband for many foresters; only 50 % of EU rural areas have adequate access.

Forestry management information systems and Big Data analysis aim to combine operations data from applied digital technologies as well as financial and customer-related and sales data into information to support management decisions. Optimised decision-making can be supported with advanced analytics. Typical functions of forest management information systems are: forest inventory management, forest safety management, harvest planning and control, timber logistics and transportation integrated with harvest management, route optimisation, quality control and traceability, performance-e-dashboards (e.g. productivity, sustainability-biodiversity), sales, finance, customer relationships, marketing. **Big data technology** and advanced data analytics support forestry businesses in decision-making (Muller et al, 2019).

2.4.3 Digitalisation trends in the food industry

The **connectivity** of machinery, equipment, computers and electronic devices – such as mobiles – through the Internet of , is already in use in industries of other sectors such as automotion. The food industry is lagging in the implementation of this fourth industrial revolution, but some applications that implement IoT, Big Data and AI algorithms, start to arise in food processing control, food quality (e.g. spectral data), food supply-chain monitoring, consumer information gathering (e.g. social media consumer data), or food safety (e.g. predictive modeling) (Misra *et al.*, 2020). Sensors allow for **on-line monitoring** and response, higher efficiency, better quality assurance, food waste prevention and modeling. The application of sensors and biosensors to the food industry is still an evolving science and the measurement of industrial parameters online is still a challenge for some sectors of the food industry (Adley, 2014; Muller *et al.*, 2019).

The trend toward the application of the **industry 4.0** concept starts from the design of factories and its management for higher efficiency, productivity, but also higher environmental sustainability including reduction of waste. Concepts such as paperless factory, standardisation of processes, continuous improvement, workers wellbeing, regulatory compliance, factory footprint, can be implemented from the use of digital tools for its highest efficiency (Demartini *et al.*, 2018)

Specific food industry digital technology trends include robotics, digital twins and 3D printing.

- **Robots** substitute humans in tedious and repetitive jobs, frequently adding precision and speed. Robots essentially have the potential to transform the processes in food processing and handling, palletizing and packaging and food serving. The recent years witnessed a tremendously increased trend of robot deployment in the food sector. (Iqbal *et al.*, 2017).
- **Digital twins** is defined as a virtual replica of the real process operation, which is connected to the real world by sensor data and advanced big data analytical tools. This tool allows digital replicas of complex processes that provide versatility and costs reduction in processing. (Verboven *et al.*, 2020).
- Further, additive manufacturing, within the so-called **3D printing** technology, is opening new dimensions in the food sector, opening the possibilities to foods (shape, texture, structure) that would not be possible with other technologies. Although the transference of the technology to a mass scale is complex, new developments have been already implemented e.g. chocolate. (Dilberoglu *et al.* 2017).

Another food industry trend is the fast rise of new technologies in processing and packaging. The digitalisation of the food sector allows the rise of more complex technologies where digital tools are needed for the control of processes. Some examples of these **new processing technologies** are cold plasma, pressurised fluids, pulsed electric fields, ohmic heating, radiofrequency electric fields, ultrasonics, high hydrostatic pressure, high-pressure homogenization, hyperbaric storage, or negative pressure cavitation extraction. All those allow milder processes (higher preservation of nutrients) and higher efficiency while preserving food safety (Misra *et al.*, 2017).

2.5 Business model trends

A business model describes the architecture of the value creation, deliver, and capture mechanism within a business. Essentially a business model is able to describe the process of how businesses respond and deliver value to customers, and how they convince customers to pay for this value (Teece, 2010). Johnson *et al.* (2018) defines a business model as "*a value proposition for customers and other participants, an arrangement of activities that produce this value, and associated revenue and costs structures".*

As new developments in sustainable production and the bio-economy, and developments in digital technologies offer new opportunities for businesses to structure their relationships with customers and stakeholders and re-structure their company's processes, new business models in agriculture, forestry and food industry sectors are emerging (Bernardi & Azucar, 2020). Current and new business models imply new managerial and entrepreneurial skills as well as soft skills. These can be related to new customer relationships that have to be developed, new relationships with the company's stakeholders such as financial organisations, NGOs, etc., the development of new production systems and the application of new technologies. The main trends in business models are identified in Table 7.

Table 7 Trends in business models

Agriculture: Changes in farm structure, Multi-functional farms, Urban farming and Indoor cultivation systems, Health and food consciousness of consumers, Traceability, Short food supply chains and Local/regional products
Forestry: Economic importance of forests, Urban green spaces, Fragmented ownerships, Lack of forest entrepreneurships, Weak infrastructure and technology
Food industry: Complex consumer demands and new diets, Interaction with consumers, New logistics and e-commerce, Short food supply chains, Novel foods, New packaging

2.5.1 Business model trends in agriculture

Agricultural intensification and specialisation have shaped the **farm structures** across Europe. In the last decades, the total number of farms declined while the average farm size rises. For example between 2005 and 2016, the total number of farms in Europe has declined by 40 % to 10.5 million farms in 2016. This process of scaling has resulted in 3.3 % of the largest farms holding over 50 % of the agricultural land in the EU (Eurostat, 2018). Change in farm structure is influenced by diverse factors. A study by Neuenfeldt *et al.* (2017) identified that an important economic driver of change in farm structure is subsidies and income: 28.8 % of the change in farm structure could be explained by subsidies and income in the EU-12. The **Common Agricultural Policy (CAP)** is the main distributor of these subsidies. Roest *et al.* (2018) argue that the CAP has a severe effect on the change in farm structure because it has a stabilizing effect on farm gate prices. Allowing farmers, or sometimes whole regions to further specialize in, for example, dairy, meat, or arable production. Today, farming in Europe is mainly characterized by family farms. Although the last decade saw strong growth in the share of hired labour in agriculture, still nine out of ten farm employees were either farm owners or a family member (Maucorps *et al.*, 2019).

Future farm structures will include **multifunctional farms** and farms providing both food and social services, as well as vertical farms in or around cities and synthetic food producers (e.g. cell growth). Future farm activities may include **product diversification** (e.g. organic products, Protected Denomination of Origin products) and non-agricultural output diversification (Salvioni *et al.*, 2013). Examples of the latter category include tourist accommodation, the sale of handicrafts, processing farm products (e.g. cheese, olive oil, cider) and wood processing, but also activities like childcare, healthcare etc. (BUEC, 2020). Further, farms may provide essential ecosystem services and contribute to maintaining or even increasing biodiversity. However, this often comes with trade-offs that impact yield (e.g. reduced area of farmed land). However, in order to compensate for the reduction in income, farmers can explore new business models around these services, such as agri- tourism (e.g. on-farm accommodation, catering, and leisure activities). (EU, 2016).

Urban farming/agriculture is defined as production at home or in dedicated plots in urban or peri-urban areas. Urban agriculture includes vegetable and fruit tree cultivation, as well as other specialized crops (e.g., medicinal and ornamentals), small-scale animal rearing (ranging from common, such as bovines and poultry, to local species, such as Guinea pigs), beekeeping, and also aquaculture (Drescher and Iaquinta, 1999; Mougeot 1994; FAO, 2001; Ghosh, 2004). Urban Agriculture (UA) takes many forms, from community gardens to commercial peri-urban farms. To get a clearer focus, UA can be sub-divided into two main segments: professional UA and urban gardening. The main difference between the two is that professional UA has commercial goals (Pölling *et al.*, 2017). High-differentiated added value crop production is the most common farm activity. Differentiation is characterized by creating unique selling propositions with, for example, traditional fruits and vegetables or organic products. Next, urban agriculture shortens the value chain implying direct producer-consumer linkages or direct marketing to restaurants, festivals, parties etc. Urban farming can tap into a niche market where issues like climate change, health and social inclusion are valued (McEldowney, 2017) and can be used as a mechanism that contributes to food security and to meet the nutritional needs of people (FAO, 2007; Mougeot, 2005).

Indoor urban vertical farming (IUVF) enables the production of food products around or in cities, in a controlled and resource-efficient manner, including low water consumption, no need for pesticide application, optimised nutrient application and closed circuits that avoids run-offs to the external environment, while allowing energy and grey water recycling. (Avgoustaki and Xydis, 2020).

Health and food conscious consumers often take a holistic approach when it comes to food choices such as health history, emotional state, lifestyle habits and animal welfare (Szakály *et al.*, 2011). The demand for healthy and nutritious food is growing. Consumers want increased transparency of food systems, in order to make choices according to their values. Standards of animal welfare play a significant influencing role in the decision of consumers to purchase a product. Moreover, animal welfare such as applied through free-range farming, often is related by the consumer to healthier food. (Grunert, 2018). Food companies increasingly have to be transparent and provide consumers with information about their products and production processes.

Traceability is widely recognised to be the basis of any modern food safety control system integrating both animal health and food hygiene components. Effective traceability systems significantly reduce response times when an animal disease outbreak occurs, by providing more rapid access to relevant and reliable information that helps determine the source and location of implicated products (ITC, 2015).

In the trend of shortening the food supply chain producers and consumers try to limit the intermediate steps in the supply chain. Most of the time products travel only a short distance where producers try to get in direct contact with their end-consumer (Wepner *et al.*, 2018). In this way, farmers create value by developing their own markets where consumers are mostly reached via 'word to mouth' (Milone & Ventura, 2019). This trend of decentralized, independent, community-focused and sustainable business model innovation is also mentioned by other authors, who see this as a clear break away from the dominant paradigm (Bernardi & Azucar, 2020). In such supply chains in many cases, local/regional producers work together to promote local food markets. Through these partnerships, the rural economy is supported, and also cooperation is fostered between local farms, the tourist industry and the food sector (Galli and Brunori, 2013). **Short food supply chains** can be classified into three types: direct sales by individuals (e.g. on-farm or delivered basket schemes), collective direct sales (e.g. gathered on a farm or sold in local outlets) and partnerships (e.g. community supported agriculture).

2.5.2 Business model trends in the forestry sector

The **use of forests for economic activity** (wood mobilisation and usage, eco-tourism, non-wood products) is increasing. There are growing demands on forests, for carbon sequestration, for renewable biobased materials and products which can substitute non-renewable ones (Forest Europe, 2020). These will require more bio-refineries and bio-product mills (SIRA, 2021). However, the continuing depopulation of rural areas, occupational safety and health, pressures of increasing recreation use as well as limited connection infrastructure, volatile wood markets and inefficient use of woody biomass are some of the major obstacles to fulfill socio-economic functions (Forest Europe, 2020).

Urban green spaces/forests provide increasing recreational use and urban green spaces ensure a significant increase in socioeconomic and cultural benefits, especially for human health, livelihoods, rural development and employment from forests. There is clear scientific evidence that forests as place for recreation and eco-tourism have positive effects on physical and mental health (Forest Europe, 2020).

An unprecedented diversity of private individuals and organizations owns the majority of EU forests, often in **small-sized holdings**. This results in differing ownership rights, management objectives and behaviour, and organizational support, which in turn poses challenges on meeting future demand for forest biomass and ecosystem services. Moreover, the relatively low net revenue of forest enterprises poses a risk for forest entrepreneurs, especially in the environment of volatile markets, adverse effects of changing climate, and requirements for more demanding silvicultural systems (Forest Europe, 2020).

This brings about a series of major challenges and obstacles for sustainable forest management, including a **lack of enabling entrepreneurship environment**, lack of support for innovations, contradicting policies (incoherent policies) discouraging forest entrepreneurship, competition for forest resources and their services, and underdeveloped markets for ecosystem services. Collaboration between forest owners, use of traditional/local knowledge, and targeted assistance with planning tools, operational support and knowledge by owner associations and advisory services will be needed (SIRA, 2020).

As described before, there seems to be a divide between the **North** on the one hand and the **South and East of Europe** on the other hand. A weak infrastructure, lack of integration of the value chain and limited digitalisation and mechanisation can, in particular, be seen in South and Eastern Europe, whilst in Northern Europe much more developments towards supply chain integration, the use of side streams and high-tech forestry can be found (Forest Europe, 2020).

2.5.3 Business model trends in the food industry

For **consumers**, in addition to price, taste and appearance, new intangible criteria attributes related to health, sustainability, authenticity, ethics, and emotional and social needs are playing an increasingly greater role. Furthermore, based on sustainability and health promotion, consumers are being pressured to change their food-related behaviours, which are deeply embedded in their social identity and emotional well-being. Moreover, the rise of non-communicable diseases (such as overweight and malnutrition), consumer perceptions on health, ethical and environmental concerns are creating a strong tendency towards new diets and the way food is perceived. This could be perceived as a dietary shift that pressures agri-food business actors to try new strategies to engage consumers and the demand of the society towards new lifestyles, including diets (Lazaro-Mojica *et al.*, 2020).

Therefore, the food industry has to be innovative to satisfy the diversity and complexity of the consumer demand and come up with **new ways to interact with consumers**. Engagement extends the role of consumers beyond passive purchasers of what supply chains provide, into active and self-organising players who shape the food system and develop solutions based on their values and preferences. Some examples are related to labeling information on environmental impact, co-creation of products through consumer insights, or living-labs engaging consumers (Lazaro-Mojica *et al.*, 2020; Wepner *et al.*, 2018). The retail sector or large distributors are innovative to attract consumers. The former "special offers" purchase is starting to be substituted by a consumer experience while shopping, the offer of new products (e.g. organic, special diets, novel foods), new contract-types with the agri-food industry (own branding), food specialties, or different digital experiences to the consumer: E-Commerce, own acquisition through bar-coding, or smart-phone appliances (Nosratabadi S. *et al.*, 2020).

New **smart logistic systems**, such as the physical internet and smart delivery systems try to implement an intelligent, efficient, and less environmentally damaging transportation of products. This implementation assumes new business models that require adaptation to these new ways of deploying logistics (Mittal Al, 2018). For example, the digital revolution is changing the way that E-Commerce operates. New tools are available for consumers, producers, processors and distributors to interact with the final customer. In these operations, the logistics for transport and delivery are changing the way business as usual was performed. On-line consumers are considered mostly millennials and generation X, but the latest Covid19 pandemic has accelerated this transition, widening the range in consumers' age and economical status (Lazaro-Mojica *et al.*, 2020; Wepner *et al.*, 2018).

Short food supply chains create a new consumer-producer relationship, shortening the number of intermediaries in the value chain. Although this trend is usually associated with farm products, small and medium producers and processors also have innovative ways to reach consumers, which provides a different way to develop their business. Small and Medium enterprises often have highly competitive drives that demand innovation in their value proposition. This can be related to health, sustainability, tradition, cultural inheritance, new sensorial experience, or even a new consumption experience. Therefore, new links between small food processors, food service providers and the HoReCa sector are emerging.

Another trend is **novel food**, which has entered the food market in the last two decades. Novel foods are based on a number of recent innovations, such as new isolated food ingredients, microorganisms, or novel animal ingredients like insects, or new production processes. Some of these innovations, such as insect and algae foods, or cultured-meat, require new marketing and business models to enter the market (Wepner *et al.*, 2019)

It is not new that the way that a product communicates to the consumer is about 50 % of the purchasing decision. Nevertheless, **packaging and labeling** is still an innovation drive that goes from the packaging materials and format (Convenience, tradition, innovation, recyclability) to the information it conveys (nutriscore, health claims, environmental claims, recyclability, QR information, etc.). These open new marketing opportunities but also new business models on how products communicate with consumers.

2.6 Regional differences in trends

In this section, some key differences in trends in sustainability, bio-economy, digitalisation and business models at country level are discussed. Moreover, trends in the Agricultural Knowledge and Information System (AKIS) are included in the analyses (Geerling-Eiff, 2019; EU Scar AKIS, 2019). Insight in the AKIS on country level is essential for the development of new education and training tools, as in the implementation these tools have to be embedded in the AKIS of the respective country. As explained before seven country trend studies were performed. The full country reports are included in Annex 3.

Key topics in the different country trend studies are depicted in Table 8. The differences between countries that are presented in the table are also dependent on key country characteristics such as digital infrastructure, level of sustainable production, etc. We will discuss these differences based on Table 8 and by giving one example/indicator reflecting on the development level of the countries included in the study, thereby stressing inter-country differences. In the later development of country-specific road maps for training development, in WP2.4, further indicators can be used to specify the country's strategy.

Table 8 Key topics in country trends in sustainability, bio-economy, digitalisation and business models

	Netherlands	Ireland	Finland	Austria	France	Italy	Spain
Sustainability	-intensive agri-production -nitrogen emission crisis -animal sector under pressure -strong sustainability investments -increase sales of sustainable products -deteriorating biodiversity -policy to extend forest acreage with 10 % to 2030 -food industry follows sustainability trends	-most agriculture devoted to grass land -increase grass-based dairy production -strong reputation and PP policies for sustainable production. -policy to extend forest to 18 % area in 2046 -improving biodiversity	-decreasing meat consumption -low animal imports and low levels of animal diseases and antibiotics use -no soya imports for feed, increasing demand for domestic protein sources -food industry follows trends/ new sustainable products -strong forestry sector	-large organic sector (22 % of all farmers) - increase of corn and soy production -climate pressure on forests (pests) -Donausoja initiative to decrease soy imports -around 16 % of territory is Nature2000 area. -grassland utilisation is policy topic -growing agroforestry	-emission of (livestock) farming poses challenges -water quality poses challenges -increased pesticides use -biodiversity under pressure -higher demands animal welfare -decrease of food waste by industry -31+ % of territory is forest -improving diversity species in forests	-growing pressure on emissions and pesticides use -animal welfare is a growing concern -food industry invests in resource-efficient processing technologies and innovative products -34.7 % of territory is forest -more attention needed for sustainable forest management -pressure on biodiversity	-pressure on sustainable water use -(technology) developments in irrigation -selection of climate-resilient crops -increasing use of renewable energy -pressure on biodiversity -sustainable packaging, water, and use of by-products by food industries -55 % territory is forest (incl. at least 1/3 with <10 % tree cov.) -positive trend for sust. forest management

Bio- economy	-average size (in EU) -public-private collaboration is emerging -trend of renewable energy production in agriculture -trend towards circularity in agriculture and food industry	-strong bio-economy policy -potential to displace fossil fuels with wood fuels (biomass energy) -public and private collaboration and investments	-strong public/private bio-economy policies -high share of bio-economy in economy-16 % -at farms many activities in renewable energy -strong forestry sector contributes to wood and bio-based products	-strong wood-based bio-economy -strong biobased sectors (paper/pulp, wood-based construction, chemical ind.) -fast merging bioenergy sector	-very strong bio-economy sector -growing renewable energy prod. -wood products and wood energy -law on fight against food waste forces large food operators to offer unsold food to aid organisations	-strong agriculture and forestry-based bio-economy -biobased products -food operators are stimulated to offer unsold products for donation - activities include exploitation of renewable energy	-stagnating bio-economy sector. -biorefineries and the production of green energies -food industry: use of waste and by-products and new healthy foods, -optimisation of energy sources -forestry focuses on bioenergy, bio-construction and biorefinery
Digitalisation	-high standard and innovation in precision agriculture and horticulture -public private collaboration in digitalisation efforts	-publ./private investments to speed up developments -national broadband plan -training needed	-investments in improving digital competences - data analytics crushes data from the satellite, weather data, soil moisture properties, etc.	-much innovation and PP investments in precision agriculture -small farm structure holds back developments	-high recent investments for agriculture, so far lagging behind in digitalisation	-government strongly supports agriculture 4.0 developments -food industry follows developments in this area - still training needed on entry-level usage	-tools and models for saving water, actions to reduce energy use, irrigation systems -the food industry and forestry sector at the beginning of digitisation

Business model	-45 % less farms since 2000 -family farms -strong trend towards multifunctional farms -emerging local-to-local food chains	-stable nr of farms -most grass-based agriculture with further move to dairy production	-decreasing number of farms -increasing value chain integration - Farmers increase their skills in the production economy - advising more consultative	-25+ % less farms since 1999 -small farms and coops with specialty products and farm sales -countrywide (machinery) service network	- 50+ % less farms last 30 years -36 % of farms are corporate -trend towards multifunctional farms (e.g. direct sales. Contract work, agritourism, education etc.) -efforts to shorter food chains	-25 % less farms since 2000 -small and medium-size family farms -trend towards multi-functional farming and short food chains -strong food industry -primary prod.in South, industry in Nord	-development of electronic marketplaces -increase of organic farming -traceability -for food industries increased consumer interaction and innovative products
AKIS	-strong and fragmented -PP collaboration -high level of education farmers	-strong and integrated (Teagasc) -advisor network -inhouse services coops	-strong and relatively decentralised -public-private collaboration is strengthened - educated farmers; share knowledge in benchmarking groups	-strong and integrated -strong apprenticeship schemes -need for lifelong learning	-strong and relatively decentralised -rising education farmers -farmer networks.	-middle strong and fragmented -high education farmers -strong agricultural collectives and confederations	-fragmented and middle strong -education levels farmers relatively low -underfunding and slow innovations

For sustainable production, we present the share of organic farming per country as an indicator in Figure 2.

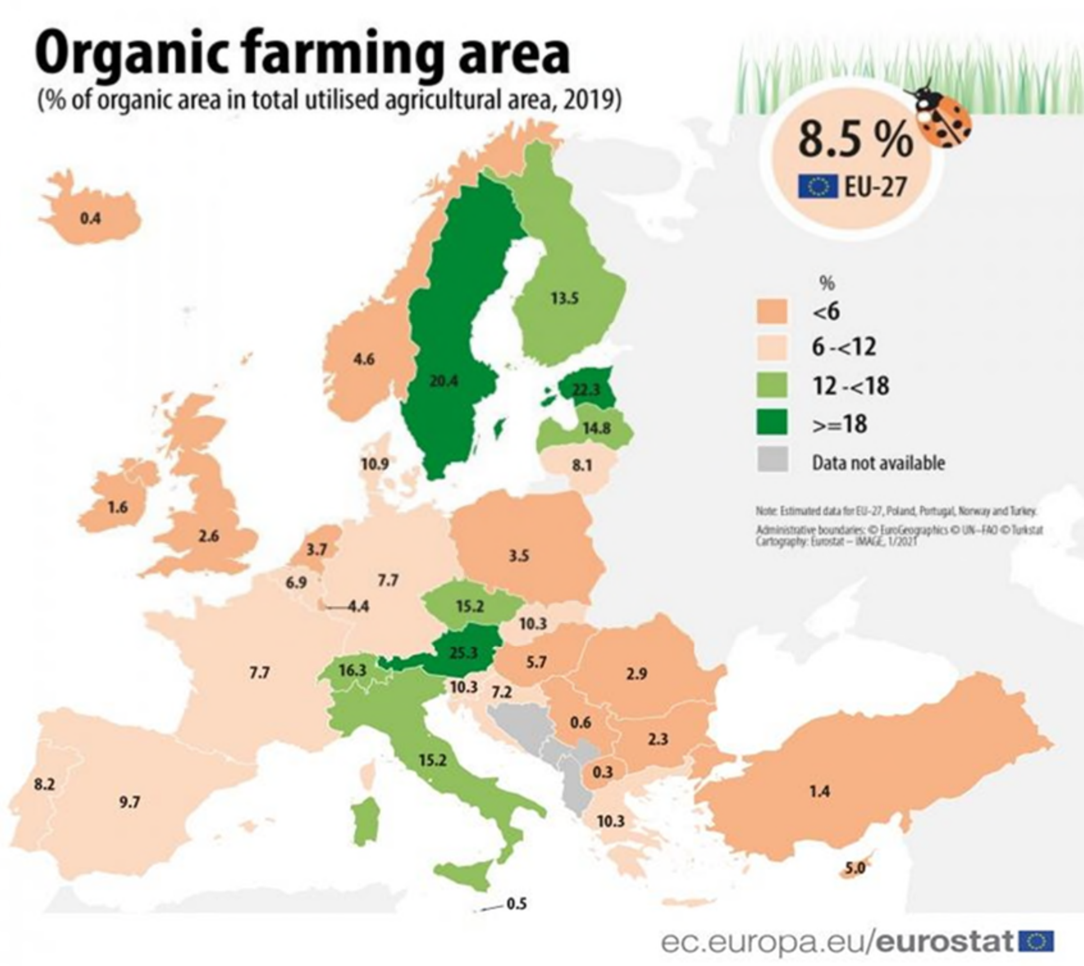

Figure 2 Share of organic farming per country in Europe (Eurostat, 2019)

The figure clearly shows a leading position for Austria, followed by Italy and Finland, and thereafter Spain and France. The Netherlands and Ireland present a relatively low share of organic farming in agriculture. However, Figure 2 depicts only one indicator for sustainable production. As Table 8 shows, agriculture in Ireland, for example, is largely based on (sustainable) grass-based cattle farming, while Italy and France, like many of the other countries, struggle with agricultural emissions and the use of pesticides. Spain encounters severe water and irrigation-related issues, while Austria has forestry challenges (pests) related to climate change.

The second indicator selected addresses the bio-based sector (Figure 3). Table 8 shows that all countries are in a process of development of biobased industries, except for Spain where the sector is lagging. Austria, Finland, France, Italy and Spain are competent in wood-based products, constructions with wood (e.g. Austria) and in the use of wood biomass for renewable energy production. Biobased products and energy production from agriculture are also fast developing in most countries, in particular in Italy, France, The Netherlands. The attempts to reduce food waste are best illustrated by the French Law against food waste, which forbids the disposal of food waste, by the larger food operators.

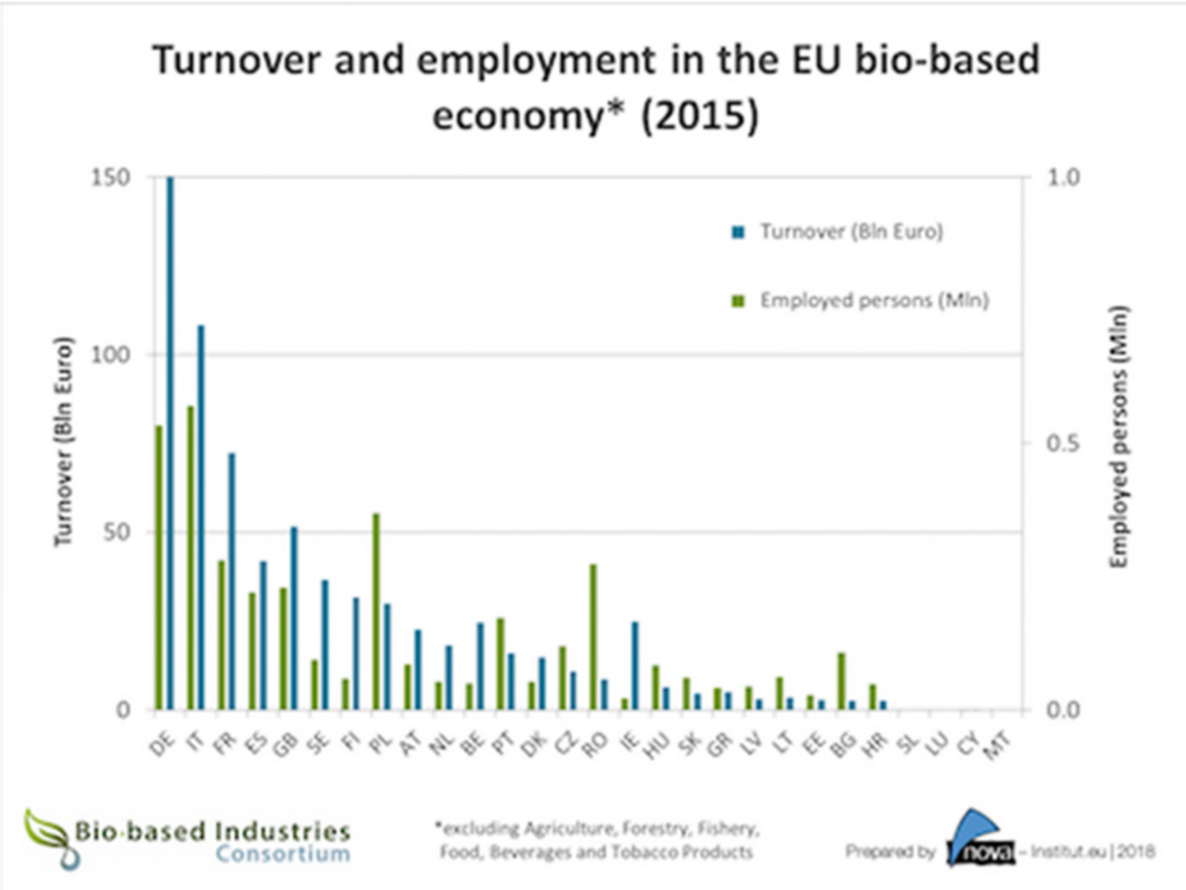

Figure 3 Turnover and employment in the EU biobased sector (Bio-based, 2015**)**

On digitalisation, the status and trend in the use of digital technologies in agriculture, forestry and the food industry are investigated. Figure 4 depicts broadband coverage throughout Europe. Although all selected countries invest highly in digitalisation and public private collaboration, also stimulated by the EU Commission, the current broadband coverage can be a constraint for digitalisation in several regions in Europe. For the selected countries this, in particular, holds for France and Spain (see Figure 4). The Dutch agricultural sector (e.g. dairy, horticulture) already has a strong history in digital technologies, related to its intensive farming systems. But also Austria, Italy and Finland are innovative in this area, although the structure of the agricultural sector in, for example, Austria with its many small farms, constraints the application of digital technologies.

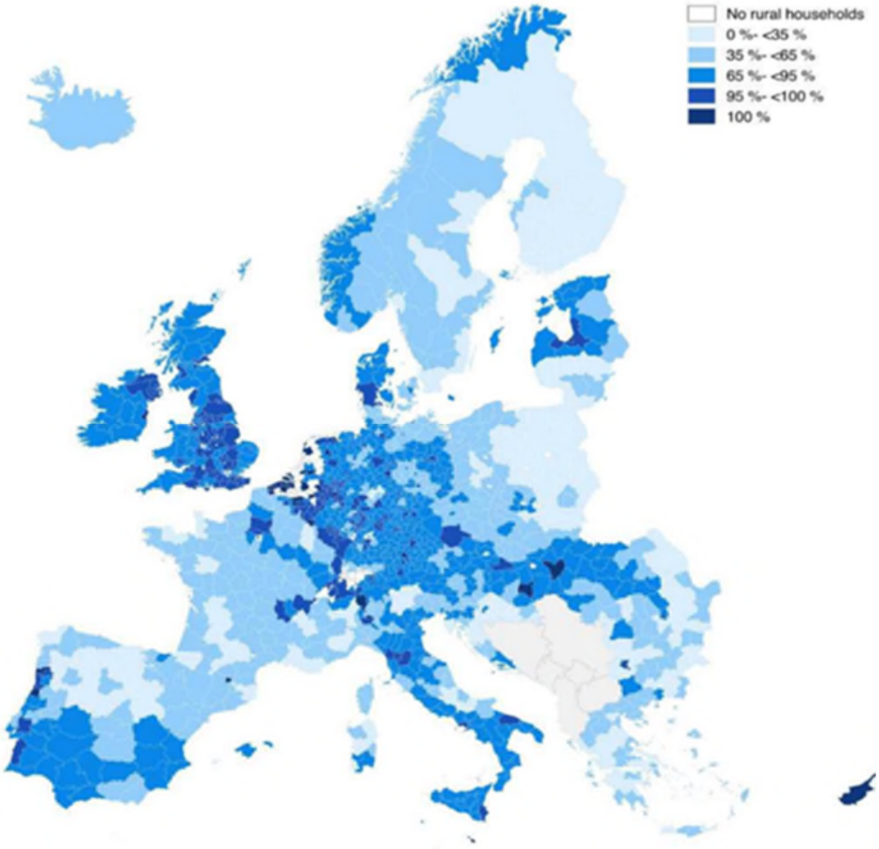

Figure 4 Rural broadband coverage in Europe, 2019 (DESI, 2020)

Figure 5 shows the average family farm size in Europe. The number of farms in the selected countries is decreasing fast, except for Ireland where the number of farms is relatively stable (Table 8). At the same time, the size of the remaining, most family, farms increase. Farmers become more entrepreneurs and multifunctional farming is growing fast, in particular in countries such as The Netherlands, Austria, France and Italy. Moreover, local-to-local chains are emerging in several countries like Austria, France, Italy and The Netherlands.

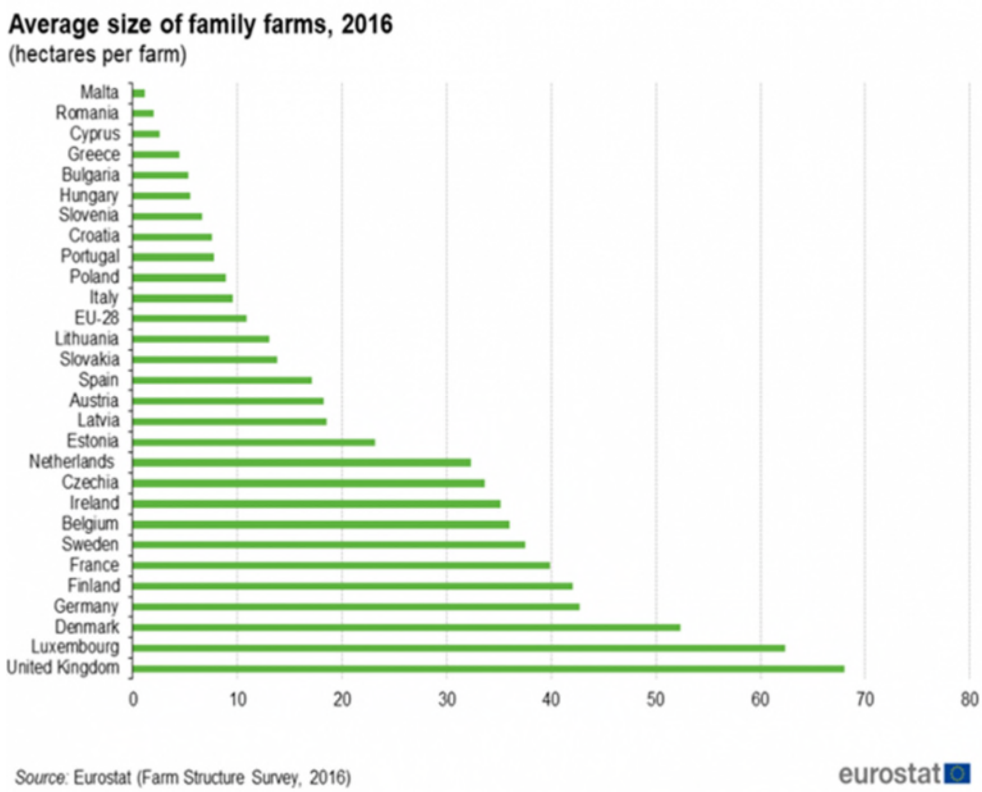

Figure 5 Average size of family farms, 2016 (Eurostat, 2016)

Figure 6 shows differences in the AKIS of European countries. The AKIS of most of the selected countries is considered strong, except for Italy and Spain. The structure of the AKIS is, however, quite different. Ireland and Austria have integrated and strong AKIS, while other countries like The Netherlands, Finland and France also have strong, but more fragmented AKIS.

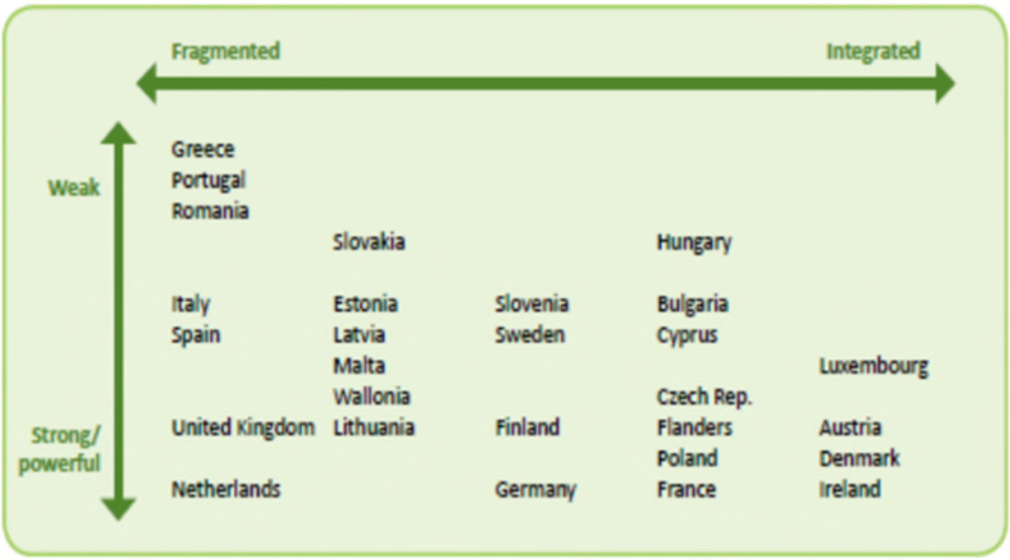

Figure 6 Diversity of European AKISs in 2014 (EU SKAR AKIS 2019)

In chapter 3 scenarios are developed, based on the trends identified in this chapter. Just like in the trend study, scenarios are developed at EU level as well as at selected country level.

3 Scenarios for agriculture, food industry and forestry

3.1 Introduction and method

In this section we develop 3 scenarios, describing possible futures - timeline 2030 - for the EU agriculture, food industry and forestry sectors.

Our starting point is the trend analysis of the previous chapter, performed by a broad group of partners from the FIELDS project. The EU level analysis was performed by WUR (Wageningen University and Research Centre), Plant ETP (Plants for the Future ETP), FoodDrinkEurope, GAIA (GAIA-EPICHEIREIN) and CEPI (Confederation of European Paper Industries).

Further, 7 country-specific trends analysis were performed by WUR (the Netherlands), Confagricoltura and University of Turin (Italy), ISEKI (Spain), FJ-BLT (Austria), ANIA (France), ProAgria (Finland), ICOS (Ireland) and their country teams.

Scenarios describe possible futures based on an internally consistent set of assumptions about key trends and their interrelationships. The scenarios should be plausible, meaningful, consistent across trends and regions, and relevant for multiple stakeholders. Scenarios should reflect maximum internal and minimum external cohesion. Scenarios do not predict but explore possible future pathways. Our scenarios aim to capture uncertainties in major socio-economic, technological, political and environmental trends in European agriculture, food industry and forestry sectors. For this, we lean on the trend analyses on European and country level. The scenarios may be used to inform integrated assessment of agriculture, food industry and forestry sectors, stimulate and guide research and public debate and facilitate policy making, enabling adaptation as well as transformation, on both European as well as on national level.

For the scenario analysis, we build largely on a number of scenario development exercises by EU researchers in the past decade. Important studies include the scenarios used in the framework of IPCC AR5, called Shared Social economic Pathways (SSP) (O'Neil *et al.*, 2014, 2017), recent Horizon2020 projects building on these scenarios, like the SureFarm project, the TransMango project (Vervoort *et al.*, 2016), EC Food Safety and Nutrition scenarios (Mylona *et al.*, 2016), Agrimonde-Terra (Land use and Food security) scenarios (Mora, 2016), and a recent academic study integrating results of various scenario studies based on the SSPs (Mitter *et al.*, 2020). Further, we include an AKIS-SCAR scenario analysis (Poppe *et al.*, 2016), as this study includes possible development pathways of the European knowledge and information system. This is relevant as our scenario analysis, indeed the FIELDS project should give input to this system.

This scenario study includes a description of 3 scenarios on EU level as well as 3 for 7 selected EU countries: Italy, Austria, Ireland, Netherlands, Spain, France, Finland. The 3 scenarios on EU level developed in this report take as a starting point the scenarios identified by Mitter *et al.* (2020) to be enriched by the other scenario studies mentioned above, also including the AKIS SCAR analysis.

The scenarios are developed in the form of narratives of (3) possible futures. These narratives will capture uncertainties regarding generic Global trends and, more specifically, the trends in European agriculture, food industry and forestry sectors. Thereby, we include trends in sustainable production, the bio-economy, digitalisation and business models. The aim is to cover a wide range of uncertainties indicated by trends identified in the previous section. The narratives will connect different trends into an integrated exploration of possible futures.

Following Mitter *et al.* (2020) we take the ''Shared Socio-economic Pathways'' (SSPs, O'Neil et al, 2017, 2014) as a starting point. The SSPs capture climate mitigation uncertainties in 5 possible pathways/scenarios. Several studies mentioned above base their approach on these SSPs and have translated these into scenarios for European agri- and food systems, thereby including trends that are typical for European food and agriculture. Our aim is to develop socio-economic narratives of alternative future pathways for the European agriculture, food industry and forestry sectors.

Although the SSPs on which several scenario studies mentioned built have taken climate change as starting point, the trends or drivers taken into account in these studies extend environmental issues by including generic Global economic, political, social and technological developments: ''... the SSPs can also be useful in other contexts relating more broadly to sustainable development. This is due to the fact that socio-economic challenges are closely linked to different degrees of socio-economic development and sustainability...'' (O'Neil *et al.*, 2017).

Section 3.2 presents key scenario studies from the literature and policy reports. Section 3.3 presents the 3 EU-level scenarios. Section 3.4 presents the results of the country-level scenario analyses and identifies trend-related skill needs per scenario.

3.2 Key scenario studies

In this section, we describe two key scenario studies that are the starting point of our scenario analysis. Other studies that have given valuable input to our analysis can be found in Annex 2 of this report (Horizon2020 SureFarm project; Horizon2020 Transmango project; Agrimonde-Terra Foresight study; EC-JRC foresight study).

3.2.1 IPCC AR5, Shared Social Economic Pathways (SSP)

O'Neil *et al.* (2014) propose a conceptual framework for the development of Shared Socioeconomic Pathways, a set of alternative pathways of future societal development, including aspects such as demographic, economic, technological, social, governance and environmental factors. SSPs include both qualitative descriptions of trends as well as quantification of key variables to be included in assessment and impact models (O'Neil *et al.*, 2017). We focus in this section on the qualitative descriptions, through narratives, of these future pathways, or scenarios.

Figure 7 shows the SSP study outcomes of specific combinations of socio-economic challenges for adaptation to climate change and socio-economic challenges for mitigation of climate change (O'Neil *et al.*, 2017)

Figure 7 Shared Social-Economic pathways (O'Neil et al., 2017)

Scenarios are characterised by O'Neil *et al.* (2017) as follows in Box 3:

Storyline elements: 1. Demographics, 2. Human development, 3. Economy and lifestyle, 4. Policies and institutions, 5. Technology, 6. Environment and natural resources.

SSP1: Sustainability - Taking the green road. A move towards sustainable and inclusive development. Emphasis on human well-being instead of economic growth. Management of the Global commons improves facilitated by increasing collaboration on different levels. This includes stronger public-private collaboration and collaboration with civil society. High investments in education and health, reduction of Global inequality and decrease of population growth. Also high investments in environmental technology, renewable energy and resource efficiency.

SSP2: Middle of the road. Development and income growth proceed unevenly. Global and national institutions make slow progress in achieving sustainable development goals. Technological development proceeds without fundamental breakthroughs. Although intensity of resource and energy use declines, the environment endures increasing pressures. Education investments are not high enough to slow down population growth in low-income countries. Continuing societal stratification, income inequality and limited social cohesion put challenges on reducing vulnerability to societal and environmental challenges.

SSP3: Regional rivalry - a rocky road. Regional rivalries reduce support for international institutions, thus weakening progress towards sustainable development goals, negatively affecting population growth, human health, and environmental protection. Policies become oriented towards national and regional security issues, including protectionism, particularly in agricultural and energy resource markets. Investments in education and technology development decline. For many countries access to safe water, sanitation and health care is jeopardised.

SSP4: Inequality – a road divided. Unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both within and across countries. Economic growth is moderate in high- and middle-income countries while low-income countries lag. Access to water, sanitation and health care is pour in these countries. Technology development is high in the industrialised part of the world. Investments in both fossil fuels as well as in low-carbon energy sources. Environmental policies focus on local issues in high- and middle-income countries.

SSP5: Fossil-fuelled development – taking the highway. Accelerated globalisation and rapid development of developing countries. Rapid technological progress and development of human capital. Integration of Global markets, removing of institutional barriers to participation of disadvantaged groups. High investments in health, education and institutions. Exploitation of fossil fuel resources and the adoption of resource and energy-intensive lifestyles across the globe. Rapid economic growth and believe in effective management of ecological systems.

Box 3 Shared Social-Economic pathways (Derived from O'Neil *et al.*, 2017)

3.2.2 The Eur-Agri-SSPs

Mitter *et al.* (2020) develop 5 scenarios for European agriculture in an extensive European study with participants from multiple EU projects and research institutes across Europe. The study elaborates on the SSP scenarios, where specific elements related to the European food and agriculture sector are added. Storyline elements taken into account include: 1. Population and urbanisation, including elements such as population size, pace of urbanisation, age structure, conflicts, 2. Economy, including elements such as economic model, international trade and global markets, domestic demand patterns, employment, 3. Policies and institutions, with elements such as political stability, international trade agreements, environmental standards, 4. Technology, with elements such as technology uptake, technology acceptance by consumers, 5. Environment and natural resources, with elements such as resource use efficiency, resource depletion.

The resulting scenarios (''Eur-Agri-SSPs'') are presented in Box 4:

Agriculture on sustainable pathways: This scenario is characterised by high social and environmental awareness, public-private collaboration, pro-environmental policies towards farmers, technology development towards resource use efficiency and low emissions, shift towards plant-based diets and decreasing demand for livestock-based products, increase of short food chains.

Agriculture on established pathways: This scenario is characterised by slow but steady social, environmental and technological progress. Limited progress in further environmental standards and policy instruments, multiple public support schemes for farmers, depletion of natural resources increases, agriculture and food systems remain dependent on fossil energy sources, resource-efficient technology development at moderate space, demand for locally produced food increases slowly while per capita meat demand remains high.

Agriculture on separated pathways: This scenario is characterised by decreasing environmental awareness, reduced public payments for environmental services and slow technological progress, less efficient collaboration between national and European entities, emergence of national agricultural policies and relaxed environmental standards, technology development and diffusion suffer from declining public and private investments and collaboration.

Agriculture on unequal pathways: This scenario is characterised by increasing social disparities between and within rural and urban areas leading to social segregation, a business-oriented wealthy upper-class, agricultural policies increasingly support economic growth and technology development, large industrialized farms benefit most, Globally connected agricultural markets, environmental standards decrease except for selected, scenic, hot spot regions, overuse of natural resources.

Agriculture on high-tech pathways: This scenario is characterised by growing faith in technology, material-intensive lifestyles and trade liberalisation, decreasing environmental awareness and reduced payments for environmental services, private investments in technology and education boost economic growth which remains dependent on fossil energy sources, increasing interest for bio-based products, drastically reduced public payments for agriculture and food, low environmental standards and over-exploitation of natural resources.

Box 4 EUR-Agri scenarios (derived from Mitter *et al.*, 2020)

3.2.3 SCAR-AKIS scenarios

In 2015 the SCAR strategic working group on Agricultural Knowledge and Innovation Systems (AKIS) carried out a foresight study on AKIS developments towards 2030 (Poppe *et al.*, 2016). Three scenarios were developed, based on 60 drivers covering various dimensions: including economic, political, technology/knowledge/innovation, and knowledge organisation and actors.

Scenario 1 High Tech:

Socio-economic trends: technology development is industry driven (multinationals), application of advanced technology in agriculture and forestry, strong EU governance, existence of a rich society with inequality, bio-economy flourishes.

AKIS structure: international, specialised technological orientation, large private R&D, IPR important;

AKIS is centralised and privatised, minor role for governments

Scenario 2 Self Organisation:

Socio-economic trends: new business models, diversification of agriculture and forestry, regions and cities rule,

AKIS structure: a regional, generic orientation of food and non-food, diverse business models, mix of public-private and regional finances;

AKIS is decentralised, dynamic regional agri-food policies, differentiated landscape of subsidies and instruments, role EU is to connect dots

Scenario 3 Collapse:

Socio-economic: climate change, increasing migration, political tensions, falling apart of EU

AKIS structure: individualistic, local, holistic orientation, food is a basic priority, small private R&D, rising community thinking,

AKIS is fragmented but influential, agri-food societal challenge 1, basic skills, farming oriented. Much attention to higher and basic level education

Box 5 SCAR-AKIS scenarios (derived from Poppe *et al.*, 2016)

The position of the agricultural knowledge and innovation system within the different scenarios to be developed is of key importance for the development of an integrated training philosophy in the EU and the development of new programs that must be accessible for education organisation throughout Europe.

3.3 Selection of three EU level scenarios

According to the FIELDS project description we develop 3 scenarios on EU level and 3 scenarios on country level (for 7 selected countries).

For the scenario development within this FIELDS task we build on the scenarios developed by Mitter *et al.* (2020) and the AKIS SCAR scenarios (Poppe *et al.*, 2016), supplemented by the other scenario studies (Annex 2). Mitter *et al.* (2020) take many of the insights of the other scenario studies into account. As in other scenario studies, we include a scenario 'on established pathways', this is a scenario assuming developments according to historical patterns, without big changes to be expected in policies and economic, social and technology development. The two other scenarios include two pathways with alternative and distinct developments covering the dimensions of the trend study: sustainability, bio-economy, digitalisation and business models. For this, we initially follow Mitter *et al.* (2020) scenarios Sustainable Pathways and High-Tech Pathways. Sustainability covers the sustainability dimension in our project and, partly, the bio-economy dimension (e.g. circular production). High Tech covers the digitalisation dimension and, partly, the bio-economy dimension (e.g. renewable energy and biobased products). The three scenarios provide a solid basis and starting point for the specification of sustainability, bio-economy, digitalisation and business model trends in agriculture, the food industry and forestry sector. The scenario Agriculture on Separate Pathways of Mitter *et al.* (2020) reflects diversity in agriculture, forestry and bio-economy sectors across Europe and limited collaboration between institutions on EU level. These elements are included in our 2nd scenario (Agriculture, Food Industry and Forestry on established pathways), as these are elements recognizable in current European development. The scenario Agriculture on Unequal Pathways of Mitter *et al.* (2020) reflects policies supporting economic growth and technology development, where large industrialized farms benefit most and globally connected agricultural markets. This element can also be included in our 2nd scenario (Agriculture, Food industry and Forestry on Established pathways), as inequalities are characteristic for current developments in the European agriculture, food and forestry system.

The three scenarios are developed into the FIELDS scenarios by adding storyline elements from the areas Sustainability[3], Bio-economy, Digitalisation and Business models. These are derived from the European trend analysis (chapter 2 of this report). The FIELDS scenario storylines/narratives cover agriculture, food industry and forestry sectors, as well as the structure of the European AKIS.[4]

3.3.1 Scenario 1: Agriculture, Food Industry and Forestry on sustainable pathways

Sustainability:

This scenario is characterised by high **social and environmental awareness** and sustainable food consumption, where consumers show increasing interest in sustainable production of food, food ethics (e.g. animal welfare, fair trade), food culture and health related food characteristics. Diets are balanced and high in plant-based products, including fresh fruit and vegetables, and alternative proteins (and lower in animal proteins and high calory-dense poor nutrient food products). Standards of animal welfare play a significant influencing role in the decision of consumers to purchase a product. Also, consumers believe that free-range food is healthier. Consumers favour local and seasonal products and also produce a portion of their own foods, e.g. in gardens and on rooftops. To cover production costs and compensate farmers consumers are willing to pay higher prices for their food and the share of food in the household budget has increased considerably.

Environmental legislation is strict and business strategies are increasingly pro-environmental. Retail and food industry increase sustainable sourcing (including seasonal) of fruits and vegetables, including local and traditional products and 'ugly'' vegetables and fruits not complying with traditional retail standards on size, form, or colour. Production of European protein crops has increased strongly. Technology development is focused on local and sustainable food production, mitigation of resource scarcity, climate change and renewable energy sources, waste reduction and circular food chains.

Cropping systems have diversified, incorporating production techniques with less external input (fertilisers, biocides and pesticides), while crop and livestock production are jointly incorporated in circular production

[3] As explained in the introduction of this report Sustainability here refers to environmental sustainability. The business model dimensions pays attention to key economic and business related aspects. The social dimension is not included in this study.

[4] We draw from the trend studies in chapter 2. References to specific literature and reports can, therefore, be found in chapter 2

systems where mineral cycles (nitrogen and phosphorus) are optimised. Agro-ecological, climate-smart, production includes techniques such as reduced soil tillage and enhanced soil and water management, permanent soil cover (cover crops), integrated pest management, more diversified and longer crop rotations that incorporate diverse grain crops, climate-resilient crops, protein crops, and vegetable crops and mosaic crop planting. In farming in general biopesticides and organic fertilizers are used. Management of pastures is improved through diversification of grasses and other plants. These practices limit pest development, improve soil quality, increase water availability, intensify soil microbial activity, safeguard soil nutrient cycles and stimulate organic carbon storage. In general biodiversity in agricultural production systems has increased strongly since 2020.

Animal feed is sourced from regional crops and trade in organic fertiliser between livestock and crop farms is organised at small and medium scales. While animal feed production and animal farming decreases, production of specialty crops and fruits becomes more important. Moreover, organic household waste is used as feed component in local livestock farms and as fertilizer. Improvement of manure management has resulted in limited nitrous oxide emissions from livestock agriculture. In general, GHG emissions have decreased considerably by practices in feed production (local and partly based on legumes), precision feeding, smart use of manure and the use of ruminants that emit less methane during digestion.

In food industries, **sourcing strategies** for new sustainable resources, in particular, new proteins (such as insects and, algae) or new processes (e.g. fermentation) have been developed. Smart logistics services have been implemented to minimize environmental impact throughout the supply chain. Moreover, the use of life cycle analysis to optimize the ecological footprint is common among all food industries. Most products, with local sources, have clean and ''green'' labels. Sustainability has become a key component in quality and safety assurance systems through a key set of indicators. Sustainable packaging (e.g. biodegradable, new recycling methodologies) is common among food industries.

New **food processing technologies** focus on reducing environmental impact and increasing nutritional quality and the efficient use of side-streams. Food products are often co-created with consumers and food labels are attuned to environmental and social values.

Agro-forestry systems become more common which simultaneously provides energy, building material and other material for wood-based applications and foodstuffs. Moreover, trees, including fruit trees, provide shaded areas and habitat for pollinators in crop fields and pastures. These allow for a wider distribution of crops across landscapes by incorporating both perennial and annual crops. Degraded land not suitable for agriculture has been reforested, while planting of trees in urban as well as agriculture areas has increased vastly.

Forests are producers of wood, places for tourism and recreation and also represent an important source of biomass for energy production and air purification, next to their function to store carbon. In forestry, further understanding of tree genetics has increased the creation of climate change resilient and stress-tolerant forests and careful, **long term forest management**. Forest cover and growing stock have increased largely and the 2020 gaps in geographical representativeness of conserved populations of tree species have been filled. In general biodiversity in agriculture and forestry has improved considerably compared to 2020.

Bio-economy:

Energy markets have been moved away from fossil fuels. The efficiency of energy use throughout the food chain is a key strategic aim of businesses and policy makers, driven by investments in energy innovation and savings, and fast-developing electrification of transportation means. There is a reorientation towards non-biological renewables (wind, solar, hydroelectric) but still a considerable reliance on bioenergy for electricity generation. Farms are energy autonomous up to high degrees, depending on their farm activities on bio-energy, wind and water.

Throughout the food supply chain the amount of **food waste** and losses have been reduced enormously and new technologies have been put in place to optimize the use of remaining streams. Re-use of food waste (vegetables, fruits, eggshells, etc.) for the feed industry as well as for biorefinery applications, using specialty crops and other biomass to produce energy (e.g. manure for biogas), chemicals, etc. are common. Fertilisation is, for a large part, based on manure and recycled minerals from wastewater, such as phosphate and potassium.

Packaging and storage conditions have been improved to reduce waste, where the application of single-use plastics in packaging has been aborted and replaced by bio-based plastics and fibre-based materials, which are renewable and recyclable. Flexible food packaging and re-usable or recyclable containers have further increased the circularity of packaging materials.

The **biobased** chemical, pharmaceutical and rubber/plastics sectors have become an important part of the economy. Traditional biobased sectors such as textiles, decrease further in importance in the EU (mainly because of imports from cost-competitive regions). Moreover, fossil-based chemicals are being replaced to a large extent by biobased chemicals.

The food industry, by implementing new processing technologies, has moved strongly into **circular production** with minimization of food losses and waste and optimal use of by-products, such as energy, and underutilized side-streams, and circular product design. Renewable energy sources are prominent in the food industries. The developments also imply redesigning and innovation of food processing in food industries.

Forests have a key role for carbon storage, carbon sequestration, and ensuring a substitution of fossil-based raw materials for renewable bio-based materials and innovative renewable products, for rural livelihoods and for recreation. Wood energy consumption makes up a relevant share of total energy consumption. The interest in sustainable low-carbon, wood-based fibres (e.g. for textile applications) has increased strongly due to their lower carbon footprint and renewability. Also, large-scale timber construction has evolved rapidly to allow for multi-store wooden buildings and hybrid material construction (lowering carbon footprint and storing CO_2). Urban green spaces ensure a significant increase in socioeconomic and cultural benefits, especially for human health, livelihoods, rural development and employment from forests.

Digitalisation:

Flexible technologies, smart farming, precision farming and information technology enabled supply chain wide information exchange have highly stimulated sustainable production and spurred the growth of short chains and **innovative relationships** between consumers and food industries and farmers. Social media are intensively used to exchange information within and between the different stakeholders of the food system.

At farm level, Internet of Things (IoT) applications including sensors (in-field, on tractors, etc.), drones and artificial intelligence applications execute most (small scale) **farm operations** (crop selection, weed identification, disease identification, irrigation, harvesting, animal health management, milking operations, etc.), guided by farmer operators. Big data analysis supports optimisation of farm operations and block chain technology is used to ensure traceability of products and prevent fraud in the food chain. **Precision agriculture** and animal husbandry results in high yields, improvements in crop selection and ecological intensification as well as better animal health and better feed utilisation. Online **direct sales** from farmers to consumers have become important for many farmers. A challenge for many short chains is reliable provision of food safety information to consumers. Broadband access is available throughout rural (incl. forests) Europe.

In the food industry, digitalisation has spurred development towards circular production. **Industry 4.0** with technologies such as IoT, AI, Robotics promotes next to optimisation of by-products and waste streams, the paperless factory, standardisation of processes, workers wellbeing, minimization of factory footprint, etc.

In forestry digital technology is hard on its way to be integrated in **forest management**: forest inventory management, biodiversity monitoring and fire detection through drones and mobile devices, site-specific treatment and water control based on sensor data, but also planning and logistics systems for harvest and delivery planning. Big data is used for long-term forest management while blockchain technology ensures traceability of wood supplies throughout the wood supply chain.

<u>Business models:</u>

Markets are decentralised and **dominated by SMEs**, including small-scale (livestock, fruits) farms and urban agriculture (roof agriculture, urban farming) focusing on production in short chains for close-by markets. Direct relationships between these companies and consumers are important. **Health and food-conscious consumers** take control over their diets for (holistic) health and wellness benefits. Collaborative farmer-consumer organisations have emerged where consumers are directly involved in farm activities and source their products directly at the farm-gate. Also, urban-rural relationships are strengthened.

Local innovative entrepreneurship is supported through **policy measures**. Moreover, small family farms are supported through government regulation to integrate into collaborative organisational forms such as collective land holdings, agricultural cooperatives, and producer associations. These organisations focus on agro-ecological intensification and production of high-quality food products, for contract-based sales to food industries, or direct sales to consumers. Products are produced complying with stringent **safety, quality and environmental standards**, which are enforced through multiple certification systems. Indoor urban vertical farming (IUVF) in controlled water and resource-efficient environments, has become a relevant food source for urban populations.

The food industry consists of a **mix of large companies and SMEs** and collaborates closely with the farming sector to comply with stringent environmental and social demands. Food industries focus on a diversity of foods to contribute to healthy diets. Food processing by-products are optimized for maximum output. Food industries connect directly with consumers through social media, for marketing purposes but also by engaging consumers in living labs and co-creation of innovative sustainable products. Moreover, innovative packaging and labeling enforce consumer communication.

SMEs of **artisanal or cultural tradition** often sell directly to consumers, via direct sales or internet sales, also supported by social media. Moreover, these enterprises easily connect to food services and the HoReCa sector.

Markets for **ecosystem services** by forestry businesses have increased. Besides provisioning of wood and non-wood forest other products, soil protection, water and air purification and climate regulation are crucial forest ecosystem services. Moreover, tourism and recreation services are mainly provided by small and medium-size forest businesses. A coherent EU sustainability policy for forests has been established.

AKIS:

The European AKIS is characterised by a **diversity of business models**. Research and development themes focus on sustainable production, bio-economy and social and environmental awareness raising of stakeholders of the food system. Most training activities are small-scale and organised on-location in combination with online group meetings for in-depth knowledge transfer. Research & development has a bottom-up approach in collaboration with farmers and other actors in the food chain including research organisations, NGOs, financial organisations, etc. Financing is mixed public-private and steered on regional level. AKIS is decentralised and reflects dynamic regional agri-food policies. The EU provides connections between the different AKIS, by organising exchange of knowledge and experiences and by stimulating discussion on future growth paths.

3.3.2 Scenario 2: Agriculture, Food Industry and Forestry on established pathways

Sustainability:

Most consumers live in urban environments with busy lifestyles. Inequalities between lower and higher socio-economic groups have increased. In their buying behaviour, **cost, taste and convenience** remain leading food attributes for most consumers. These consumers have moved towards easily accessible food through out-of-home eating, snacking, and consumption of ready-made meals. Fresh produce is more difficult to access. Food is often of moderate quality and with negative health effects. Although sustainable produced food products become more important, for example, seasonal and local products, for cost-efficiency reasons most food products are sourced globally. However, there is a smaller share of consumers that aim for more healthy diets, at home and in out-of-home eating. Therefore, a market for high-quality and traditional products remains.

There is little progress in implementing further **environmental standards and policy instruments**. The use of synthetic fertilizers and pesticides has decreased moderately due to EU and national environmental policies. However, environmental pressures because of the intensive livestock and crop production systems are high. The use of **pesticides and synthetic fertilizers** is only slightly below 2020 levels. The increase in the use of biopesticides and organic fertilizers is moderate. Organic production, being unable to meet increasing yield demands, only covers a small share of European agricultural land and focuses on niche markets. Biodiversity in EU agriculture has further declined. Ecosystem strategies are lacking on EU level and fragmented over countries.

Although **consumption of meat** and other animal products remains high, imports of feed stuffs decrease as both European feed production and the use of by-products and waste streams for animal nutrition increase. Intensive livestock production and the accompanying air and water pollution in North-Western Europe remains, although there is a tendency towards concentration of livestock production in central and Eastern Europe. Animal welfare demands from consumers force livestock farmers to invest in animal-friendly facilities, so as to maintain/increase their reputation through social media.

In **southern countries** droughts and soil desertification impact rain-fed agriculture, thereby increasing the need for irrigation systems and increasing the pressure on water reserves. Moreover, these developments lead to a shift to cultivating crops that originated from other more deserted regions. In general, the increased pressure on natural resources has increased agricultural commodity prices.

The innovation level of agriculture, food industry and forestry differ across regions in Europe. Technology development is **focused on mass food production**, increasing productivity, energy efficiency and reducing cost, aiming at sanitation and preservation of products in primary production and transport. Best practices in water and energy efficiency are used by most farms. In the food chain technologies and procedures to maintain the cold chain and systems to monitor the product flow (temperature, microbiological activity, etc.) throughout the food supply chain are most important. Supply chain food safety and quality monitoring systems and traceability systems connect different links in the (global) chain to ensure the safety of food and prevent fraud.

New food processing technologies focus on increasing process efficiency, environmental impact and increasing nutritional quality. Investments in technology and logistics systems to move to circular production are moderate. The use of sustainable packaging by food industries is still limited. Connection with consumers through social media is limited to the small group of local and small and medium-scale producers.

The European forest cover and growing stock have further increased, although **ownership is highly scattered**. In the forestry sector, a high frequency of large-scale forest disturbances is observed, including extreme droughts, heat waves, extensive insect outbreaks, and more extensive forest fires. These natural disturbances, fostered by climate and land use change, create devastating consequences for humans and nature. In addition, as regards the forest-based sector, disruption in wood/biomass supply is leading to overload of sawmills and/or shortages.

Lack of data makes it difficult to monitor changes in ecosystem usage and how this affects biodiversity. **Illegal logging** is still ongoing in the EU, resulting in lost revenues and other foregone benefits. In environmental terms, illegal logging causes environmental damage, retards sustainable development and is associated with deforestation, climate change and a loss of biodiversity.

Bioeconomy:

European and regional efforts have not been able to reduce emissions sufficiently to mitigate climate change. **Fossil fuel reserves** are an important source of energy. Climate change impacts European agriculture and forestry through e.g. extreme weather and its negative effects and the pressure on natural resources puts constraints on the European agriculture, food and forestry sectors.

Business models leading to negative environmental impacts and pressure on natural resources remain. Agricultural activities have impacted negatively **biodiversity** throughout Europe. Climate changes put further pressure on **water availability** for agriculture and the food industry. Moreover, increasing irrigation requirements, in particular in Mediterranean countries, have put enormous pressure on water reserves, water availability for farming activities and on water quality in general.

A mix of energy saving, energy efficiency and decarbonisation initiatives, both public and private, has resulted in a moderate increase in **energy efficiency**. At farm level, production of bioenergy and use of solar and wind energy improve the farm's sustainability index and is an extra source of income. This has led to reduction of the farm's dependency on fossil fuels. Although, there is a need for subsidies from the member states. The share of renewable energy in electricity generation in the EU increases.

Innovations in **biomass production** for food and feed are moderate but steady (new ingredients, new food improvement agents). Replacement of plastic packaging by bio-plastics is ongoing. The application of biotechnology in food industries develops steadily such as the search for alternative proteins in food products. Technologies to minimize waste and stimulate reuse of packaging materials have increased throughout the food chains, leading to cost reductions for retail and food industry. Also, **biobased production** has increased and may improve environmental quality and enhance the stocks of ''natural capital'' such as soil, water and air (Dalea, 2003).

Market realisation of **forest ecosystem services** and integration of bio-economy remains underdeveloped, although forests supply the main share of biomass for energy production. Moreover, forests are increasingly used for leisure and tourism.

Digitalisation:

The **pace of digitalisation** varies across Europe and within countries and sectors, where large-scale farming, food industries and forestry businesses are extensively supported by different digital technologies (IoT, AI, big Data, Robotics etc.). These technologies are used both in-company as well as in food chain applications. Small and niche market companies that are not part of the large international chains are limited in the use of these technologies and focus on in-company applications to optimise operations (sensors, drones, data processing), and on social media applications to reach (potential) consumers.

As the agri-food sectors are characterised by **long complex international food chains** product safety assurance has become a key issue for these industries. Identification, block chain technology and traceability systems have developed fast and are applied on a large scale in these food chains to ensure product safety, authenticity and quality, and to prevent fraud as well as to enable assessment of supplier performances. Third party logistics providers support these global supply chains with advanced sensor technology in container transport (temperature, moisture, etc.), GPS systems and tracking & tracing systems supported by RFID and DNA technology. In-company risk assessment and monitoring, based on IoT application and decision support (management) systems are key for safe and smooth production processes and product flows. However, data integration in more complex chains with varying partners remains a challenge and the proliferation of labeling schemes and the complexity of the information provided makes food labels often confusing to consumers.

In the forestry sector, the **larger producers** are supported by advanced digital technologies and systems. These producers are integrated into international wood production chains, supported by advanced digital technologies for forest management (site, inventory, water, etc.) and for wood supply chain management, connecting harvesting planning with international logistics and marketing flows. Most forestry producers are small-scaled, however, and the economic feasibility of digitalisation investments is low.

<u>Business models:</u>

Urbanisation has further increased and global **trade is liberalised**. Agri-food chains are characterised by **concentration of businesses** in every link of the chain. Enduring pressure on margins has led to larger farms and the food industry is dominated by large companies. Consequences are increasing agricultural production in mono-cultures and loss of agro-biodiversity throughout European food systems. The focus is on cost-effectiveness and efficiency in complex (Global) food chains.

Vertical coordination between food industry and (large) farming, in long food chains, has increased, supported by an extensive system of food safety, quality and environmental standards. Transparency of these food chains is supported by advanced traceability systems.

Overall, however, **farm structures remain diverse**, ranging from large, highly capitalized industrial farms to small family farms. Small farms have a limited share in agricultural production, though, and become multifunctional, complementing agricultural activities with activities such as care, tourism, farm sales and provision of energy for urban dwellers. These farms mostly supply local and/or niche markets and face the need to manage contacts and activities with end-users with direct, short loop interaction with the consumers. Sharing logistics and related information become important to cut costs and provide better service for the consumers. Urban agriculture remains very limited.

Consumer engagement by food industries remains limited, only small companies mostly focusing on artisanal production engage in direct sales to consumers and communication through social media. Short food chains only exist between small farms and small (artisanal) industries and local retail and consumers.

In forestry, only **owners with large holdings** integrate with other partners in the wood chain, supported by digital technology. Small-scaled forest holdings have difficulty to create a viable business, as margins remain low.

AKIS:

The European AKIS is characterised by a generic agro-system orientation of food and non-food. Research and development themes circle production and supply chain efficiency and cost-effective sustainable production. The system includes **multiple business models**, where financing is mixed public-private and steered at country and regional level. Training is mostly organised in face-to-face daily classes, in short courses, and combined with online instruction lessons. The AKIS is decentralised and it reflects dynamic regional agri-food policies in research and development and agricultural knowledge management. The role of the EU commission is limited.

3.3.3 Scenario 3: Agriculture, Food Industry and Forestry on High-Tech Pathways

Sustainability:

Market forces and liberalized Global trade are leading economic development. Consumers strive for a healthy lifestyle with **personalised diets** through consumption of functional, processed foods. This is supported by continuous innovations in products and novel technologies. Meat consumption remains high throughout Europe. Consumer demands for a wide variety of high-quality products from around the world remain, implying further increase of international product flows and regional specialisation, going together with the enforcement of monocultures and loss of biodiversity.

Genetical innovation has spurred intensification of livestock and cropping systems. Intensive livestock farming is dependent on animal feed sourced from large producers both in Europe and other key production places around the world. Production specialisation, use of external/chemical inputs, genetically improved seed and precision farming bring high yields per hectare. Although synthetic pesticides, biocides, and fertilizers are commonly applied to assure yields, integrated pest management practices, including the application of biopesticides and introduction of disease-resistant crops, are also used to reduce pressure on long term soil health and biodiversity.

Climate-smart agricultural systems are dominant, with development of innovative production techniques, particularly in Mediterranean countries. However, environmental considerations remain moderate as the belief is that technical progress can mitigate the impact of Global climate change. Nevertheless, droughts in the Southern part of Europe make agricultural production more dependent on irrigation and drought and temperature-resistant crop varieties. A shift to more adapted crops, from deserted regions, is seen.

Food industry investments focus on **personalised nutrition**, functional foods, foods with medical characteristics ("phoods") and new technologies in processing such as 3D food printing, synthetic biology or nanotechnologies, and intelligent packaging. Products of New Plant Breeding Techniques have been accepted in food production and innovation. Alternative protein sources, such as in-vitro meat, algae, are products accepted by consumers and taking an increasing market share. Synthetic biology and IPR are important in this scenario.

Forest cover and growing stock have increased vastly compared to 2020. A strong concentration of forestry businesses in **larger commercial units** has taken place, leading to viable forestry businesses. Illegal logging has been tackled. Increased knowledge of tree genetics, including how the genotype impacts on the quality and value of wood products, has led to optimal sustainable commercialisation of EU forests. Besides suppliers of wood for furniture and construction, woods provide important eco-system services and leisure and tourism services.

<u>Bio-economy</u>:

Technological development focuses on **precision farming** and food processing and is still supported by fossil fuels. Precision farming ensures efficient use of water, fertilizers and pesticides.

Pressure to reduce food waste and losses is limited, although, new effective technologies have been developed for the **use of by-products and underutilized side-streams** from agriculture and food industries and cutting the losses throughout the food chain. Reduction in food waste is caused by increased efficiency in food processing, high tech food manufacturing, recycling of products, intelligent packaging and reduction of the consumption of fresh foods.

Food supply chains are modernized with technologically **advanced storage and logistics facilities**. Relationships between farming and food industry are close. The development of circular systems and circular product design is strengthened, however, mostly steered by economic objectives.

Although large investments in the bio-economy and energy innovation drive fast developments in the use of renewable energy sources, **fossil fuels** remain a production factor in agriculture, forestry and food industries. At the same time **bio-based** chemical, pharmaceutical and rubber/plastics sectors grow fast. Bio-based industries also develop high added-value food products and ingredients, such as starch-derived products, sugar-derived products, new proteins, new food improvement agents, etc., and new bio-based packaging that fast replace conventional plastics packaging. Biotechnology is the main technology for these bio-based applications.

In general, **biodiversity** in agriculture is impacted negatively and the pressure on resources further increases. Forestry activities for energy production have increased across Europe, commercialised by large businesses.

<u>Digitalisation:</u>

Digitalisation of activities has taken off in farming, forestry and food industries. At farming level, precision farming aims at optimisation of yields on large farms with intensive production systems. Intensive use of IoT applications (infield sensors, sensors on machines and equipment) and automation of farm operations have turned farmers into **managers/entrepreneurs**, building business strategies based on market developments and big data analysis. Some devices that require large investment and abilities to be used are operated by commercial service organisations.

At consumer level, **health and diet data** are collected and stored so as to design the right, personalised, product for the consumer. Biomarkers and biosensors allow for targeted and personalized solutions for consumer groups.

Food processing is supported heavily by RFID, biosensors and IoT applications, robotization, artificial intelligence, Big Data applications and advanced decision support systems. **Industry 4.0** optimizes production processes and flows of products, by-products and waste streams. New technologies in processing and packaging as well as 3D printing are integrated into these smart factories, while the needs for a more specialised labour force have increased considerably.

Food supply chain information systems, directly linked to farm and industry (digital) systems support a smooth flow of products throughout the food chain. Moreover, **food safety and quality attributes** and traceability are assured throughout the food chain by the use of block chain technology and food supply chain information systems.

Commercial forest management activities are largely supported by digital technologies including sensors and IoT applications, robotics, AI, Big Data and integrated management systems. Digitalisation in forestry supports site-specific management, inventory management, water management and integral supply chain management connecting wood harvesting to logistics, timber transportation and sales. Higher investments in training and new, safer machinery and infrastructure have led to a reduction of accidents /occupational risks.

Business models:

Concentration at various stages of EU food supply chains has further increased, the European food sector is characterised by large industrialized farms and the dominance of multinational food companies, collaborating in **Global food chains**. As family farms are under pressure of succession challenges, corporate farms become the dominant legal form. However, in urban environments vertical farming has developed fast, focusing on high-end urban markets.

Strong collaboration between farms and food industry has given easier access to capital for farmers to move to intensification and energy-efficient production. This has led to high-tech, highly controlled, **transparent food chains**, ensuring both technology acceptance and trust among consumers. Equipment and technology sellers and service providers are strongly embedded in the food system. These provide services related to precision farming and forestry and also lease capital intensive equipment.

Novel foods based on innovations in new isolated food ingredients, micro-organisms, or novel animal ingredients like insects require new marketing and business models and new consumer interaction. But also joint ventures of food and health industries have emerged swiftly including initiatives focusing on conservation and preparation technologies, nitrogenic and personalized foods. The traditional agro-food industry is facing fierce competition from the high-tech emerging “phood” sector.

Forestry businesses are integrated in **international wood production chains**.

AKIS:

The European AKIS has an international, specialised technological orientation and is supported by **large private R&D.** Intellectual property rights and data ownership issues are of key importance for (private) investors. Research and development themes focus on product improvement (genetics), mechanisation of farming processes on large-scale farms, precision farming and integrated food chain management. In training activities virtual tours are of paramount importance to the uptake of new technologies and systems. Advisory services and consultants are highly trained in digital learning and customer communication technologies. These services are increasing, to cover demands from the large and highly specialised farm and forestry businesses. In general the AKIS is centralised and privatised with a minor role for governments (both on national and EU levels)

3.3.4 Overview scenarios

On the next page, Table 9 gives an overview of key characteristics of the three scenarios.

Table 9 Overview of key issues in the tree scenarios

	Sustainable paths	Established paths	High-tech paths
Sustainability			
	High consumer awareness of sustainable production. Move towards plant based products.	Cost, taste and convenience are key attributes in consumer purchasing. Consumption of meat remains high	Consumers strive for healthy diets and functional foods. Consumption of meat remains at high level.
	Strict environmental legislation and business policies	Little progress in environmental standards and policy instruments	Market forces and liberalised trade are at the basis of policy making
	Ecological intensive production and diverse cropping systems	Intensive cropping and livestock production prevail	Genetical innovation and intensification of cropping and livestock systems.
	High attention for biodiversity	Biodiversity has further declined	Biodiversity remains under pressure. Of interest if it adds to productivity.
	Food industries focus on new proteins, sustainable processing technologies, circular production	Food industries focus on mass food production, productivity and efficient use of resources	Food industries focus on functional food and ''phoods'' and advanced processing technologies for efficient production
	Development of agroforestry and sustainable multifunctional forest management	Further development of forestry sector, although scattered ownership. Illegal logging is a key problem	Increase of forest cover and ongoing concentration in commercial viable units
Bio-economy			
	Orientation on bio-energy and non-biological renewables for electricity generation. Farms are energy autonomous to high degree	Fossil fuels remain a major source of energy. Moderate increase renewable energy and energy efficiency	High attention to precision farming and industry 4.0, still supported by fossil-based energy. However, efficient use of water, fertilizers and pesticides
	Use of reusable and recyclable packaging materials throughout the value chain	Moderate innovations in reusable and cyclable packaging materials. No integrated value chain approach	High tech and intelligent packaging, decreasing waste streams.
	Strong development of biobased sectors (chemical, pharmaceutical, plastics)	Moderate development of biobased industries	Strong development of biobased sectors, incl. high value food products
	Food industry moves to a (high level of) circular production	Technologies to minimize waste are used throughout food chains.	Move to circular product design and circular systems (economic incentives)
	Increasing wood consumption and use of wood as building material. Development urban green spaces and ecosyst. services	Forests supply a main share of biomass for energy production. Eco-system services develop slowly	Forestry activities for energy production have increased across Europe, commercialised by large enterprises
Digitalisation			
	Precision farming for sustainable production at most farms. Short chains with farmer-consumer interaction supported by social media develop fast	Precision farming and integrated farm management in particular at large farms. Digitalisation supports coordination in international value chains	Precision farming aiming at optimisation of production at large farms, integrated into modern international value chains
	Industry 4.0 supports development towards sustainable and circular production, including small scale artisanal production	Food industries integrated into international value chains move towards Industry 4.0. Much attention to logistics and quality assurance systems	Industry 4.0 optimises production processes and flows of (by)products and waste streams. Supply chain information systems coordinate intern. food chains
	In forestry digital technology is integrated into sustainable forest (and biodiversity) management	In forestry larger producers are supported by advanced digital systems, and integrated into modern wood value chains	Fastly developing commercial forest activities are largely supported by digital technologies.

Business models			
	Small scale farms focusing on production in short chains. Strong connection with consumers, including consumer participation in farm activities.	Concentration of businesses (incl. farms) throughout the value chains. Increasing vertical coordination, led by retail. Small farms focus on multifunctional production	Concentration throughout the food value chain. Large industrialized and corporate farms prevail. Small farms are disappearing
	The food industry consists of a mix of large companies and SMEs (e.g. artisanal production), closely collaborating with the farming sector	Food industries have a strong position towards farmers. Relationships focus on transaction management and profits	Strong collaboration between farms and food industry support intensification and efficiency of production. Collaboration between food and heath industries
	Multifunctional forests provide ecosystem services, leisure, etc.	Large holdings integrate into modern (international) wood value chains. Small holdings cannot create a viable business.	Forestry business are more and more integrated into international wood value chains

3.4 Country level scenarios and skill needs

In this study seven country-specific scenario analyses were executed. The country reports in Annex 3 include a country trend analysis and a country scenario analysis. Further, for every scenario at country level skill needs were identified by the country teams of the FIELDS project. These are included in the country reports (last page of every country study). In chapter 2 we showed a comparison between the different country trends (Table 8). In this section, we focus on the differences in skill needs between countries for every scenario. Based on the interpretation of the trend studies, the country teams selected max 5 skills per dimension per scenario. In the tables below the identified skill needs per country are depicted, one table for every scenario[5].

3.4.1 Skill needs for scenario Sustainable Pathways

Table 10 presents typical skills of 7 countries for the Sustainable Pathways scenario. Although we see a distribution of diverse skills, some of the skills are among the selection of several countries. The sustainability and bio-economy dimensions skills that were selected multiple times are Soil nutrient and health management, Crop diversification and crop rotation, Biodiversity, Renewable energy, New (biobased) products, Sustainable packing, and Sustainable and multifunctional forest management. However, there are also clear differences between the country selections, such as the specific attention to water management-related skills in Spain.

In the digitalisation dimension skills like Everyday usage of digital technologies were selected multiple times, next to advanced digital skills like Precision farming, Precision animal health management, Field operations

[5] Skill descriptions in this table sometimes have been abbreviated in order to keep the readability of the table. In the country reports in annex 3 the skill descriptions are presented completely

and Robot and drone technology. In the business model dimension communication and learning skills prevail, such as Networking, Learning skills, Direct marketing and New value chains.

Table 10 Skill needs per country for the scenario Sustainable Pathways

Netherlands	Ireland	Finland	Austria	France	Spain	Italy
Sustainability						
-Minerals and emissions accounting - Improved agrifood system productivity -Renewable energy -Multifunctional forests/eco-system services -Sustainable packaging	-Mitigation/ adaptation to climate change -By/co-products valorisation -Good Agricultural Practices. -Soil Nutrient and Health Management	-Soil nutrient and health management -By/co-products valorisation -Organic production -Mitigation/adaption climate change -Multifunction forests/eco-system serv.	-Biodiversity -By/co-products valorisation -Generation renewable energy -Soil nutrient and health management -Protective role of forests	-By/co-products valorisation (circularity) - Sustainable packaging -Organic farming - Agricultural biodiversity -Animal care and welfare	-Water management -Organic farming -Agricultural biodiversity -Animal care and welfare -Biofertilizers, compost, bio digestates	-Mitigation/ adaptation to climate change -Improved agrifood system productivity -Identification of renewable energy systems -Water management. -Soil Nutrient and Health Management
Bio-economy						
-Biobased production -Crop diversification and crop rotation -Biodiversity -Sustainable forest management -Ethics for food	-Planning and coordinating production -Agricultural biodiversity -Sustainable forest man. -Reforest. restoration -Multifunct. forests/eco system-services	-Carbon sequestration and carbon balance -Crop divers. and rotation -Biodiversity -New bioproducts -Sustainable forest management	-Organic farming -New crops for bioeconomy -Plant/animal breeding resilience -Forest disease control -Food security	-Crop diversification and crop rotation -Biodiversity -By/co-products valorisation -Generation renewable energy -Sustainable packaging	-Biobased production -Reclaimed water management -By/co-products valorisation -Generation of renewable energy -Sustainable packaging	-Conventional and Organic farming -Controlled Environment Agriculture -Agricultural biodiversity -Farming operations -Sustainable forest managem. and planning

Digitalisation						
-Stakeholder communication -Digital entrepreneurship -Precision animal health -Field operations management -Robot and drone technology	-Precision animal health and product. -Field operations man. -Traceability systems -Robot /drone technology -Data handling and analysis	-Precision farming and animal health -Everyday usage digital techn. -Smart connected devices -Digital information and services -Field operations management	-Everyday usage digital technology -Data handling -Digital pest control systems -Farm Management IS -Precision animal health system	-Digital entrepreneurship -Precision animal health system -Field operations system -Robot and drone technology -Food industry 4.0	-Stakeholder communication system -Food Industry 4.0 -Food traceability -Precision animal health and productivity -Robot and drone technology	-Digital entrepreneurship -Warehouse management systems -Digital food traceability system -Precision animal health and productivity -Field operations management
Business model						
-Multi-functional farming -Change man. -Learning continuously -Innovative thinking -New value chains	-Communication -Analytical, and creative thinking -Business planning and strategy -Cooperatives -Specific sector legislation	-Networking -Digital tools to support learning -Farm environmental management -Cooperatives -STEM knowledge	-Being resilient, and proactive -Networking -Learning at work -New value chains -Collab. across sectors	-Networking -Learning continuously -Direct marketing -New value chains	-Multi-functional farming -Networking -Cooperatives -Direct marketing -New value chains	-Cooperatives -New value chains - Collaboration across all sectors in the food chain -Social expectat. Consumer science & behaviour -Product development

3.4.2 Skill needs for scenario Established Pathways

Table 11 presents typical skills for the Established Pathways scenario. The sustainability and bio-economy dimension skills that were selected typically relate to Good agricultural practices (and Production management), Integrated pest management, Water management and how to turn to Organic production. Another item selected several times is skills related to Biodiversity, probably related to the ongoing decrease of biodiversity in several countries. Interesting to see is that multiple country teams have selected reforestation, afforestation and restoration of forests and forest ecosystem services as a key skill to pay attention to in this scenario. Further, traceability and labeling/certification are considered key skills for the Established Pathways scenario.

In the digitalisation dimension skills are, in comparison with the Sustainable Pathway scenario, more related to farm management practices, such as Farm management information system, Everyday usage of digital technology, Traceability. Although, also in this scenario there is attention, although less prominent, to skills related to Robots and Drones and Precision farming. Similarly, also the business model skills relate more to business management practices, such as Financial business planning and (working with) Cooperatives. However, also in this scenario we see Multifunctional farming as an important subject that needs skill development, as this is an ongoing trend in several countries.

Table 11 Skill needs per country for the scenario Established Pathways

Netherlands	Ireland	Finland	Austria	France	Spain	Italy
Sustainability						
-Minerals and emissions accounting -Integrated pest management. -Generation renewable. energy -Soil nutrient and health -Water management	-Improved Agri-food production -Environmental regulation and support -Management of resources -Biodiversity -Equipment in the pulp, paper, timber and cork industry	-Soil nutrient and health management -Mitigation and adaption of climate change -Active man. of natural resources -Biodiversity -Identification of renewable energy systems	-Mitigation and adaptation to climate change -Efficient use of resources -Integrated pest man. -By-products and co-products valorisation -Water man.	-By-products valorisation -Sustainable packaging -Organic farming -Agricultural biodiversity -Good agricultural practices	-Water management -Good agricultural practices -Agricultural biodiversity -Animal care and welfare - Biofertilizers, compost, bio digestates	-Improved agri-food system productivity -Management of natural resources -Environmental policies, regulation, etc. -Good Agricult. Practices -By/co-products valorisation
Bio-economy						
-Convent. vs organic -Controlled agriculture systems -Reforestation, afforestation, restoration forests -Traceability -Food labelling	-Performing farming operations -New bioproducts -Reforestation restoration forests -Production managem. -By/co-products valorisation	-Biobased production -Carbon sequestration -Biodiversity -Sustainable forest management - Reforestation restoration forests	-Traceability -Organic farming -Sustainable forest management -Forest disease control -Food labelling	-Conventional vs organic production -Controlled agriculture systems -Traceability -Food labelling -Sustainable packaging	-Reclaimed water man. -Reforestation, restoration forests -By/co-products -Generation renewable energy -Sustainable packaging	-Planning and coordinating production -Calculating, handling and managing risk -Logistics and storage -Quality management, -Management of inventories

Digitalisation						
-Everyday usage digital technology. -Digital food traceability system -Farm MIS -Precision animal health system -Field operations management system	-Farm Management Information Systems (FMIS) -Decision support systems (DSS) -Data handling and analysis -Robot and drone technology	-Precision farming & animal health technologies -Everyday usage digital technology -Farm MIS -Field operations system -Data handling and analysis	-Everyday usage digital technology -Data handling and analysis -E-commerce and e-marketing -Digital services -Precision animal health system	-Everyday usage digital technology -Digital food traceability system -Farm management IS -Precision animal health system -Robot and drone technology	-Food Industry 4.0 -Everyday usage digital techn. -Digital food traceability system -Precision animal health and productivity -Robot/drone technology	-Everyday usage digital technology -E-commerce and e-marketing -Warehouse management systems -Farm MIS -Precision animal health and productivity
Business model						
-Multi-functional farming -Organisation, strategic thinking -Financial business planning -Coops -knowledge to assess value chain	-Networking -Collaboration across the food chain -Social expect. /Consumers science -Knowledge transfer in the bioeconomy chains	-Networking -Learning continuously -Business planning and strategic man. - Collaboration/ across the food chain -Managing personnel	-Communication -Analytical and creative thinking -Financial business planning -Funding opportunities -Project management	-Organisation and strategic thinking -Financial business planning -Coops -Food labeling/certification	-Multi-functional farming -Organisation and strategic thinking -Innovative thinking -Cooperatives -Food labeling/ certifications	-Monitoring market activity and conditions -Customer's service -Cooperatives -Project management -Specific sector legislation

3.4.3 Skill needs for scenario High-Tech Pathways

Table 12 presents typical skills of 7 countries for the High-Tech Pathways scenario. For the sustainability and bio-economy dimensions skills that were selected typically relate to new and innovative products and processes; for products and by-products valorisation, Biobased products, New industrial crops, Forest products and Multifunctional forest, and for processes new Technologies (e.g. in the paper industry). Further, it is interesting to see that several country teams selected Continuous improvement as a skill needed for the High-Tech Pathways scenario.

In the digitalisation dimension typical skills like E-commerce & Marketing, Supply chain information systems, and Digital information and services are selected, next to high-tech Cloud technology and Robots and Drones. Business model skills for this scenario relate to Innovative thinking, (Food/Wood) Supply chain management, Monitoring of markets, New Value chains and IPR protection.

All three scenarios present a diverse set of skill needs for the seven countries selected. However, every scenario has its unique accents, just as every country has its typical skill selection.

Table 12 Skill needs per country for the scenario High-Tech Pathways

Netherlands	Ireland	Finland	Austria	France	Spain	Italy
Sustainability						
-Efficient use of resources -Improved agri-food production -By-products valorisation. -Renewable energy -Sustainable packaging	-Environmental Management Systems (EMS) - Renewable energies -Sustainable metrics -Sustainable forest man. -Multifunctional forests and ecosystem-serv.	-Improved agri-food system productivity -By-products valorisation -Generation renewable energy -Integrated pest management - Environmental Management Systems (EMS)	-Improved agri-food system productivity -Sustainable metrics -Energy consumption -Multifunctional forests and ecosystem-serv. -Sustainable packaging	-By-products valorisation (circularity) -Renewable energy - Sustainable packaging -Organic farming -Agricultural biodiversity	-Personalized functional foods -Circular production -Water management -Digital irrigation systems - Biofertilizers compost, bio digestates	-Efficient use of resources and logistics -Improved agri-food system productivity -Management of natural resources -By/co-products valorisation -Identification of renewable energy
Bio-economy						
-Biobased production -New industrial crops -Products of forestry -Traceability. -Emerging technologies	-New bioproducts -Quality management -New techn. in the paper industry -Continuous improvement -Emerging technologies -Food Labelling/ Certifications	-Carbon balance methods -New industrial crops and bioproducts -Products of forestry -Automation in paper industry -Biofertilizers, compost, bio digestates	-Controlled Environment Agriculture -Livestock efficiency/ biosecurity -Handling and managing risks -Continuous improvement -Management of inventories	-By-products and co-products - Sustainable packaging - Traceability -Emerging technologies	-Biobased production -reclaimed water man. -digital tools for energy use -By-products and co-products -Sustainable packaging	-Genetically Modified Crops -New crops and bioproducts for the bioeconomy -Plant and animal breeding -Food safety management -New technologies in paper, pulp etc. manufacturing

Digitalisation						
-Supply chain information systems -Digital services -E-commerce and e-market. -Climate control systems -Robot and drone technology	-E-commerce and e-market. -Field operation management -Digital supplier man. systems -Warehouse systems -Digital quality management systems	-Robot and drone technology in agriculture -Farm management IS -Data handling and analysis -Field operations management system -Cloud technology	-Cloud technology -Digital services -Precision animal health system -Field operations management systems -Robot and drone technology	-Data protection -E-commerce and e-marketing -Climate control systems -Robot and drone technology	-Supply chain IS -Food Industry 4.0 -Digital business management -Precision animal health and productivity -Robot and drone technology	-Data handling and analysis -Cloud technology -Decision support systems (DSS) -Farm Management Information Systems (FMIS) -Precision animal health and productivity
Business model						
-Wood Supply Chain Man. -Innovative thinking -New value chains -Innovation management -Protection intellectual property rights	-Change management -Innovative thinking -New value chains /new business models -Funding opportunities -Innovation management and its deployment	-System intelligence -Learning continuously -Scenario analysis -Knowledge and stakeholder management -Key Performance Indicators (KPI)	-Equality skills -Managing personnel -New value chains -Protection intellectual property rights -Specific sector legislation	-Innovative thinking - Monitoring market activity and conditions -Business planning/model and strategic management -Protection intellectual property rights	-Food supply chain management -Logistics and storage -Monitoring market activity -Business planning, strategic man. -New value chains	-Monitoring market activity and conditions -Sales and marketing -Business planning/model and strategic management -New value chains -Product development

4 Conclusion

This report of Deliverable 1.8 of the Erasmus+ FIELDS project includes a trend and scenario analysis for EU agriculture, food industry and forestry sectors, addressing the dimensions Sustainability, Bio-economy, Digitalisation and Business models. Three scenarios were defined for Agriculture, Food Industry and Forestry on, namely Sustainable Pathways, Established Pathways and High-tech Pathways. The trend and scenario analysis are executed at EU level and country level, for 7 selected countries. Moreover, at country level, the Fields project country teams have identified the 5 main skills needed per dimension for every scenario. The detailed country reports, including trend, scenario and skill analyses are presented in Annex 3 of this report.

Next to the outputs of Task 1.3 (Country and EU focus groups) and Task 1.4 (Bottom-up survey) of the FIELDS project, the results of this study will be used as input for the selection and prioritisation of skills to be included in job profiles and training modules in WP 2 of the FIELDS project. In this regard, this report aims to support these selection decisions. Furthermore, the specific country studies (Annex 3 of this report) can be valuable input for strategy and roadmap formulation, as well as for training design at country level, further on in the project.

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Annex 1 Trends identified in Horizon2020 project Fit4Food2030

MEGATRENDS

• Climate Change

• Malnutrition

• Rise of Non-Communicable Diseases

• Urbanisation

• Demographic Change

• Migration

• Scarcity of Natural Resources

• Rise in Energy Consumption

• Industry 4.0 – Digitization in Food Production

• Big Data Analysis

• Economic Globalisation

AGRICULTURAL PRODUCTION

• New and Game-Changing Digital Technologies in Agriculture

• Alternatives to Conventional Pesticides

• Changes in Farm Structures

• Agricultural Pollution

• Biodiversity Loss

• Transboundary Pests and Diseases

• Organic Farming

• Genome Engineering

• Bio-Fortification

• Indoor Cultivation Systems

• Urban Agriculture / Urban Farming

• Food from the Sea

• Closing the Loop in Aquaculture

CONSUMER TRENDS

• Health and Food Consciousness

• Responsible Consumers

• Special Diets like Vegetarian, Vegan or Low Carb

• Destabilized Consumer Trust

• Fast and Convenient Food

• Low Prices, High Calories

• "Free-from" Products

• Smart Personalized Food

• Changing Households and Food

• Globalisation of Diets

• Consumer Engagement

• Traditions and Do It Yourself

• Social Media and Food

MARKET ECONOMY, RETAIL AND LOGISTICS

• Concentration in Food Retail Markets

• New Shopping Behaviour

• Short Food Supply Chains

• Chain Clustering Along the Food Supply Chain

• Physical Internet (Logistic)

PACKAGING AND WASTE

• Biobased Packaging

• Packaging 4.0

• Reduction of Plastic Packaging

• Packaging & Health

• Food Waste Recovery Up-Cycling /

- Permaculture

FOOD PROCESSING

- Blockchain Technology for Secure Food

Supply Chain

- Cultured / In-Vitro Meat
- New Technologies in Food Production
- High/Ultra Processed Food
- Clean Eating / Transparent Labels
- Novel Food
- Natural Preservatives & Milder Processing

Methods

- Alternative Protein Sources
- Functional Foods incl. Pro&Prebiotics

Waste Cooking

POLICY AND OTHER TRENDS

- Women’s Empowerment
- Responsible research and innovation (RRI)
- Food Regulation

Annex 2 Scenario studies from other projects

1. SureFarm project

The Horizon2020 SureFarm project (Surefarmproject.eu), applies the SSPs (O'Neil, 2014) to European agriculture (Mathijs *et al.*, 2018). In the trend analysis the project takes consumer trends as a starting point (see section 1 of this report) and derives specific (''food'') trends and how these impact on European farming systems. Thereby the project adds specific elements to the 5 SSP scenario narratives. Narrative elements of the SureFarm scenario analysis exercise are: international trade, demand for meat, land productivity, feed import, feed production, meat production, prices and price volatility, land availability, labour availability, food industry structure, vertical coordination, consumer trends, food waste.

Box 1 gives a description of the scenarios. Scenario 2 is not worked out in the SureFarm deliverable report, as this scenario reflects a combination of elements of the other 4 scenarios.

EU-Agri-SSP1 Sustainability: Environmental awareness has led to environmental action in the form of strict environmental legislation, pro-environmental corporate strategies and sustainable food consumption. The consumption of meat has been drastically reduced and substituted for by plant-based alternatives. In addition, fruit and vegetables are sourced locally and consumed in season. Food

waste and losses are also drastically reduced. High yields are obtained through precision agriculture, genetic improvements and ecological intensification. EU-based meat production has decreased and is primarily based on own feed production, as soy imports have been drastically reduced. Food industry consists of a mix of multinationals and SMEs and collaborates closely with the farming sector due to the stringent environmental requirements.

EU-Agri-SSP3 Regional rivalry: Environmental awareness is low and international trade is strongly constrained by protective border measures. Consumption patterns have not changed a lot in terms of composition, but more attention is given to convenience and locally produced food. As a result of the relatively high meat consumption and the reduced import of soy and other feedstuffs, own feed production as well as the use of by-products and waste streams for animal nutrition has increased. Due to the reduction of trade, the concentration of livestock production and the accompanying air and water pollution in North Western Europe has decreased, while livestock production in Central and Eastern Europe has increased. SMEs play a relatively large role in the food industry as many multinationals are non-European.

EU-Agri-SSP4 Inequality: Environmental awareness focuses mainly on local issues while ignoring global issues. Diets are rich in meat for the elites, while the poor cannot afford high meat consumption. Meat is both imported and produced in the EU using imported feedstuffs. The pressure to reduce food waste and losses is low. The concentration of livestock production and the accompanying air and water pollution in North Western Europe remains, while reliance on imported feedstuffs even increases. Land and labour are relatively abundant due to the high levels of productivity and the openness of trade. Technological development is mainly oriented at large-scale farms. The concentration in the agri-food industry increases. Vertical coordination between farming and food industry remains limited, except for high-value niche markets serving the elites.

EU-Agri-SSP5 Fossil-fuelled development: Environmental awareness focuses mainly on local issues while ignoring global issues. International trade is very open, resulting in regional specialisation in production. Diets are rich in meat which is both imported and produced in the EU using imported feedstuffs. The concentration of livestock production and the accompanying air and water pollution in North Western Europe remains. Technological development is still supported by fossil fuels, such that there is a high emphasis on resource efficiency through precision agriculture. The concentration in the agrifood industry increases. Vertical coordination between farming and food industry remains limited, as global spot market transactions prevail.

Box 1 EU-Agri-SSP scenarios, selected items, derived from (Mathijs et al, 2018)

2. Horizon2020 Transmango project

The Horizon2020 Transmango project focuses on the vulnerability and resilience of European food systems in a context of socio-economic, technological, institutional and agro-ecological change (Transmango.eu). In its scenario analysis it includes the following narrative elements: Consumption patterns (meat, sugar, processed food consumption), Environmental degradation (biodiversity loss, water pollution, soil degradation), Poverty and economic inequality (levels of poverty and inequality), Social and technical innovation (level of innovation public and private sectors, local innovations), Urban and rural population dynamics (increase/decrease in rural, resp. urban population), Power and market concentration (centralisation/decentralisation; domination by large companies or SMEs), Trade agreements (protected market/free market, Basic resource availability (resource use and availability) (water, energy, raw materials).

The study arrives at 5 scenarios with characterisations on: Food and nutrition security, Agricultural systems, Post-farm food system activities, Interactions with global food security, Environmental impacts of the food system.

Fed-up Europe: Few people are undernourished, but other malnutrition and NCDs are common. Large-scale industrial agriculture grows, with little innovation, among other reasons because cheap labour is available; smaller farmers fail. Several companies control post-farm food system activities. Locked into historic patterns Europe struggles with competition from other global regions, but trade agreements remain open and free, offering market opportunities due to low European wages and lax regulations. Environmental policies are weakened. Land and resource use becomes more indiscriminate and damaging.

Retotropia: Poverty and food insecurity are low. Meat consumption has dropped, but NCDs are common as sugar consumption is high and not a policy priority. Mediterranean countries become a hub for climate-smart agriculture. Environmental policies have shifted Europe toward more sustainable agricultural practices. Robotization has increased in all food system activities with decreasing labour availability. This innovation has been facilitated by public policies. Trade with the outside world has decreased. Large food companies are increasingly focusing on other global regions. Strict policies ensure low environmental impacts of food system activities.

The protein Union: People are not wealthy, but are able to meet basic needs. Innovations in meat and meat-like products ensure protein consumption. Agricultural systems are increasingly industrialized, and integrated economically and technologically with the rest of the food system. Smaller farmers leave the market because of competitive pressures and food crises and scares. Major companies work closely with governments to innovate and intensify in food systems, and integrate agricultural production with other aspects. Strict policies on food products and processes, and a highly European focus limit market interactions with the rest of the world. Concerns about environmental impacts are driving the innovation into new modes of production and processing of meat and meat-like products.

The price of health: Many are poor in terms of income, but rural lifestyles, smart and diverse agricultural, trade and distribution practices results in good food and nutrition security for most. Cost and preferences have lowered the consumption of meat and animal products considerably. Food produced by farmer cooperatives, and mediumsized farms, bolstered through flexible and climatesmart agricultural technologies, is integrated into short food chains, and supported by home-produced crops. Post-farm food system activities are highly integrated with agricultural production, managed by small to mediumsized enterprises, supported by flexible agricultural, processing, transport and information technology.

Box 2 Transmango primary scenarios, selected items, derived from Vervoort *et al.*, 2016

3. The JRC policy report on EU Food Safety and Nutrition in 2050

The EU-JRC published the policy report on EU Food Safety and Nutrition in 2050 – Future challenges and policy preparedness (Mylona, 2016). The report includes a scenario study.

Main drivers (i.e. narrative elements) selected for scenario development are: Global trade (liberalisation, level of fragmentation, regional focus), EU economic growth (high, medium, stagnation), Agro-food chain structure (concentration, diversification, alternative food chains), Technology uptake (level of uptake, focus on sustainability/nutrition&health), Social cohesion (low, high, local), Food values (level, focus, e.g. health/sustainability/...), Climate change (temperature increase 2050), Depletion of natural resources (World population growth)

These drivers lead to 4 scenarios: Global Food, Regional Food, Partnership Food, Pharma Food.

"Global Food" is in some way a projection to 2050 of the situation in which the EU finds itself in 2015; an even more interconnected global food chain with increased global trade and a more concentrated food industry. However, climate change and depletion of natural resources have a significant impact on primary production and sourcing of raw materials. Global trade, technologies and innovation compensate for the barriers these factors pose to the food system. The mainly urban population in Europe, with its increased sedentary behaviour, decreased physical activity and over-consumption of highly processed foods rich in energy, fats, sugar and salt, faces significant health challenges, such as increased prevalence of obesity and non-communicable diseases''. (Mylona, 2016)

"In **"Regional Food"**, the 2050 EU food chain looks quite different from the current one. Climate change and depletion of natural resources, coupled with an increasingly aware and concerned population, result in significant EU policy changes towards self-sufficiency, a circular economy model and the abandoning of major international trade agreements (the focus of this scenario has been the EU (as in 2015). In this scenario, food is highly valued and is produced locally or regionally employing advanced technologies. Citizens are involved in food production even in urban settings and peer-to-peer trade becomes increasingly prevalent in this society. Food waste reduction and re-use are of particular importance, while diets are more environmentally sustainable through reduced consumption of animal protein and short food chains '' (Mylona, 2016)

"Partnership Food" is characterised by an economically weak EU with close trade and food policy ties with a strong global player (for this scenario the US and Canada were used assuming that the existing ties would facilitate such a move) and little trade with the rest of the world. The stagnation of the European economy contributed to the EU losing importance in geopolitics and trade, especially in agriculture and food. EU citizens embrace technological innovation in the agro-food sector, which is however mostly developed in the US and Canada, since food technology innovation and R&D investments are at an all-time low in the EU. The European society in 2050 does not value food highly; food choice is driven by price and convenience and characterised by a food culture focused on the consumption of highly processed foods and out-of-home eating. Activities in the agro-food chain concentrate on efficiency, mass production and climate change resilience.'' (Mylona, 2016)

"Pharma Food" describes a world with globalised trade and a strong EU economy, and a population that strives for a healthy lifestyle. To achieve this in a context where fresh produce may be limited due to climate change effects, people turn to functional, processed foods and even foods with added pharmaceutical substances ("phoods"), in a personalised diet regimen aimed at optimising their health status. Multinationals control most of the food chain as the investments needed for research and placing such foods on the market are too high for small and medium sized enterprises. Decades of careful attention to food safety, as well as inspiration from the rigorous quality and safety controls applied in the pharmaceutical sector, result in a highly controlled, transparent and traceable EU food chain and this ensures trust and technology acceptance by the consumers.'' (Mylona, 2016)

Box 3 Food Safety and Nutrition scenarios, selected items, derived from (Mylona, 2016)

4. Agrimonde Terra foresight report

Agrimonde-Terra is an initiative of INRAE and CIRAD. The foresight project Agrimonde-Terra "Land uses and food (in)security" explores - on regional scales and on a world level - how food security can be ensured taking into account possible changes in land uses.

It takes as main drivers: Global context, Climate change, Food diets, Urban-rural relationships, Farm structures, Livestock systems and Cropping systems. The project arrives at 5 scenarios: Community, Household, Regionalisation, Metropolisation and Healthy.

The first three scenarios are based on current trends identified in most regions of the world.

-The first ("**Land use drive by metropolisation**") links the development of megacities at a global level with a nutrition transition led by global agri-food companies selling ultra-processed foods, in a global context of development through market force and rapid climate change, leading to the marginalizing of small farmers.

-The second ("**Land use for regional food systems**") relates the increase of medium-size cities and their networking with rural areas to the emergence of regional food systems based on traditional foods, family farming and a set of regional agreements.

-The third scenario ("**Land use for multi-active and mobile households**") links strong individual mobility between rural and urban areas and a development of non-farm employment to the emergence of hybrid diet based on traditional and modern value chains, in an globalized world where family farms and cooperatives are majors actors in land use.

The last two scenarios involve potential breaks that could change the entire system.

-The fourth scenario ("**Land use for food quality and healthy nutrition**") assume that due to the increasing cost of malnutrition, a radical move towards healthy diets occur fuelled by global cooperation and public policies, in a context of climate change stabilization, involving a re-configuration of agricultural systems backed by new alliances between stakeholders.

-The fifth scenario ("**Land as commons for rural communities in a fragmented world**") assume that in a context of repeating multiple crises, development based on small towns and rural communities occurs, focusing on managing common property in agriculture in order to ensure food security

Box 4 Agrimonde Terra scenarios, summary taken from (Mora et al, 2016, p4).

Annex 3 Country reports: trend and scenario analysis

Annex 3.1 Ireland: trend and scenario study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

1. Sector structure

Agriculture:

In Ireland, the agri-food sector is Ireland's largest indigenous industry. The Annual Review and Outlook for Agriculture, Food and Marine 2020 estimates that the sector employed 164,400 people or 7.1 % of the total workforce in 2019[6]. Outside of the greater Dublin region, the sector provides between 10 % and 14 % of employment. The Irish agriculture sector is export orientated, with almost 90 % of the food produced sold to markets in over 180 countries worldwide.

There are approx 137,500 farms covering 4.45 million hectares, according to the Census of Agriculture in 2016, down marginally from 139,860 farms in the 2010 Census of Agriculture[7]. The average farm size is 32.4 hectares. The majority of the agricultural land area, some 4.1 million hectares is devoted to grassland. In December 2019, there were 6.5 cattle, 1.6 million pigs and 3.9 million sheep. The ending of milk quotas in 2015 has seen a notable increase in dairy cow numbers, largely due to Ireland's competitive position in terms of milk production. There has been a decline in suckler beef production observed in recent years. In 2010, there were over 1 million dairy cows, with dairy cow numbers increasing to 1.4 million dairy cows in 2019. The number of suckler cows have decreased from 1.09 million cows to 956,900 cows over the same period.

According to the Teagasc National Farm Survey, the average family farm income was €23, 678 in 2019. The most profitable farm enterprise is dairy farming with an average income of €65,828 in 2019. In 2019, the average tillage farm income stood at €32,700, while the average income on sheep farms stood at €14,780. The beef sector is Ireland's largest agriculture sector with income at €9,008 on cattle rearing farms and €13,761 on other cattle farms in 2019. Irish cattle and sheep farms are highly dependent on EU direct payment support under the Common Agricultural Policy.

The 2016 "Brexit'' referendum in the UK was a significant disruptor for the Irish agri-food sector due to its reliance on the UK market for beef and to a lesser extent dairy. However, specific dairy products such as cheese are heavily dependent on the UK market. The UK-EU free trade agreement concluded in late 2020 has brought some degree of certainty by avoiding the introduction of harmful tariffs and quotas but there are now considerable non-tariff barriers in place as the UK is no longer a member of the Single Market or Customs Union.

The Irish agri-food sector has managed the immediate effects on Covid-19 on the marketplace and supply chain, but the long-term impact on the foodservice sector is a significant concern.

[6] https://www.gov.ie/en/publication/91e7e-annual-review-and-outlook-for-agriculture-food-and-the-marine-2020/
[7] https://www.cso.ie/en/releasesandpublications/ep/p-fss/farmstructuresurvey2016/

The Dairy Sector:

The trends in the Irish dairy industry following the abolition of milk quotas requires specific mention. A recent study by Teagasc and CIT on the dairy sector post quotas reported that from 2014 to 2019 domestic milk production has increased by almost 41.4 % to 8.7 billion litres (milk processed).[8] By way of comparison, over the same period, EU-28 volume increased by more than 7 % (10.4 million tonnes). Ireland has a highly seasonal milk supply curve, linked to grass growth. This makes Ireland a highly competitive place to produce milk. Ireland's net margin in milk production due to its grass-based system is 40 % higher than the UK and almost 3 times higher than the Netherlands according to the Teagasc/CIT report. The limitations of seasonality however results in a lower processing plant utilisation in Ireland compared to our EU counterparts. Ireland's capacity utilisation is 62 % with other EU countries achieving over 92 %. Seasonality also results in a more limited product portfolio, more focused on storable products.

Forestry

The area of forest is estimated to be 770,020 ha or 11 % of the total land area of Ireland. The Irish Government has established a target to increase the total area under forestry to 18 % by 2046[9]. This involves an afforestation target of 8,000ha per year. It must be noted that annual afforestation rates in recent years are below 5,000 ha per year[10]. Forestry is seen as an important means to sequester and store carbon and its role in bioenergy by replacing fossil fuels is strategically important.

Bio-economy:

The bioeconomy covers all sectors and systems that rely on biological resources and is a relatively new sector in an Irish agriculture context. The development of the bioeconomy is a strategic priority of the Irish Government who published a national policy statement on the bioeconomy in 2018[11]. The development of new biobased industries has the potential to create new employment opportunities in rural areas, growth and investment, the modernisation of primary production systems, and the protection of the environment. The bioeconomy is expected to play an integral part in Irish agriculture becoming more circular and environmentally sustainable.

2. AKIS (Agricultural Knowledge and Information System)

Ireland has a sophisticated and varied agricultural education and training sector, populated by a mix of publicly funded and private bodies providing advice, training and knowledge transfer forums for farmers.

Teagasc – the Irish Agriculture and Food Development Authority – is the national body providing integrated research, advisory and training services to the agriculture and food industry and rural communities. Teagasc's mission is to support science-based innovation in the agri-food sector and wider bioeconomy so as to underpin profitability, competitiveness and sustainability. They achieve this through a number of avenues:

- Peer-to-peer learning through the Knowledge Transfer programme;

[8] https://www.teagasc.ie/media/website/publications/2020/An-Analysis-of-the-Irish-Dairy-Sector-Post-Quota.pdf
[9] https://www.gov.ie/en/publication/01381-forestry-programme-2014-2020-ireland/
[10] https://www.gov.ie/pdf/?file=https://assets.gov.ie/25419/c97cdecddf8c49ab976e773d4e11e515.pdf#page=null
[11] https://www.gov.ie/en/publication/c1e596-national-policy-statement-on-the-bioeconomy/

- A network of third level agricultural colleges offering a range of courses and training programmes for farmers and those in the agribusiness sector;
- An advisory service providing farmers in each sector with one-to-one advice on business models and technical matters.

Teagasc has an annual research portfolio of approximately 300 research projects, carried out by 500 scientific and technical staff in our research centres throughout Ireland. Over 300 Teagasc advisory staff provide tailored advice to farmers based on this research, helping farmers understand the strengths and weaknesses of their farms and make better decisions.

Ireland's network of over 400 private agricultural advisors also plays a significant role in advising and disseminating knowledge and information to the sector, with more than 55,000 farmers using the services of a private agricultural adviser.

The Irish agricultural co-operative sector has a history of prioritising education and training of its farmer members up to the present day where training and guidance is provided via their own in-house advisory teams. The Co-operative structure of the Irish dairy industry has ensured that it has developed a significant degree of vertical integration with its farmer members, and it surrounds and supports them with the systems and expertise to deliver on safe and sustainable milk production. Included in this support is a huge investment in milk quality, animal health and environmental sustainability.

3. Notable trends in sustainable production

Environmental sustainability and addressing key issues such as global climate change, water quality, air quality, soil health, animal welfare and AMR prevention are important priorities for the Irish agri-food industry.

Environmental sustainability:

Irish agriculture has built up a very strong and reliable reputation for the production of environmentally sustainable food. Ireland has a number of inherent advantages such as a long grazing season with favourable climatic conditions.

The Irish agri-food sector has been to the fore in terms of demonstrating its environmental credentials through the innovative Origin Green Sustainability Programme operated by Bord Bia since 2013[12]. At farm level, the Bord Bia Sustainable Dairy Assurance Scheme and the Sustainable Beef and Lamb Assurance Scheme were developed and externally accredited in cooperation with farmers, processors and regulatory authorities. Farmers participating in the programme are audited every 18 months to ensure that they meet a range of requirements related to quality assurance and sustainability.

Ireland's large livestock population and its low proportion of heavy industry in its overall economy means that the agricultural sector contributes up to one third of Ireland's total Greenhouse Gas Emissions. This is above both the global and EU average. However, the sector has one of the lowest carbon footprints globally for the production of milk and meat products due to its grass-based system. As part of the Origin Green Programme, each individual farm's carbon footprint is assessed through the Carbon Navigator Tool. The

[12] https://www.origingreen.ie/what-is-origin-green/

sector through Bord Bia is currently developing a new grass-based standard to help demonstrate the unique environmental and welfare benefits of pasture-based farming.

In December 2020, the Department of Agriculture, Food and the Marine published a Roadmap towards Climate Neutrality called "Ag Climatise"[13]. The new roadmap sets out a strategy to achieve a carbon neutral economy by 2050 and reinforces Ireland's commitment to the Paris Climate Change Agreement and the EU's Green Deal agenda including the Farm to Fork Strategy.

Forestry -

The total estimated economic output (direct and indirect) of the forest industry to the Irish economy is approximately €2.3 billion annually and 11 % of Ireland's land area is currently under forestry, amounting to 770,020 hectares. 83 % of the forests planted since 1980 have been planted by farmers.

Like many other sectors of Irish Agriculture, Irish forestry is very export oriented. Approximately 86 % of the output from Ireland's panel products sector is exported along with almost 80 % of our sawn timber production. Most private forests were planted over the past 30 years, consequently many are at or approaching the thinning stage and the output from these woodlands is set to increase significantly in the coming years. There is a significant potential for wood fuel to displace fossil fuel in Ireland, particularly in the generation of heat in industrial, commercial, domestic and institutional markets.

Ireland's National Forestry Program has targeted:

- Promoting the uptake of technology, building skills and collaborative working through advice and knowledge transfer activities, to promote the forestry sector to become more competitive and economically sustainable.
- Support knowledge and innovation and contribute to future increases in employment and value added in the forestry sector.
- Increase of biomass energy in the forestry sector, which will assist in the Europe-wide push to promote the use of renewable energy.
- Additional afforestation to secure carbon sequestration for the longer term.
- The sustainability of the forest ecosystem, which includes action to increase habitat and other actions which will improve environmental quality.

The National Biodiversity Action Plan has also targeted a move from coniferous to slower growing, native trees in the coming years, possibly moving the focus from productive output alone to supporting biodiversity and carbon mitigation.

4. Notable trends in Bio-economy

Bioeconomy policy as indicated in the national policy statement on the bioeconomy in Ireland is strongly coupled with the Climate Action Plan (2019) as well as Rural, Regional and Enterprise Policy. The Government's vision for the bioeconomy is to grow Ireland's ambition for the bioeconomy through a co-ordinated approach that harnesses Ireland's natural resources and competitive advantage and that fully

[13]https://www.gov.ie/en/press-release/a8823-publication-of-ag-climatise-national-climate-air-roadmap-for-the-agriculture-sector/3

exploits the opportunities available while monitoring and avoiding unintended consequences. The bioeconomy also has a close relationship with the circular economy and represents an area where Ireland has some crucial advantages and developments should promote circularity through solutions and innovations that reuse and recycle materials, maximising resource efficiency through the use of unavoidable wastes and environmental sustainability. Irish bioeconomy policy development has been developing based on three pillars: Investments in research, innovation and skills; Reinforced policy coordination and stakeholder engagement; and Development of markets and competitiveness.

Key research and innovation developments have included Farm Zero C examining the development of carbon neutral farming led by Carbery and AgriChemWhey a flagship biorefinery development which is building a first-of-a kind, industrial-scale bio-refinery which will take by-products from the dairy processing industry and convert them into cost competitive, sustainable platform bio-based chemicals led by Glanbia. Key education and skills development includes the availability of a postgraduate diploma in bioeconomy and business led by IT Tralee and UCD. The Government has also established a high-level implementation group to coordinate across government and its agencies on bioeconomy policy development and has developed an information week to raise awareness of the bioeconomy and its products.

A bioeconomy stakeholders forum will also meet for the first time in 2021. Leading Irish bioeconomy companies such Monaghan Biosciences (mushrooms), Hexafly (beverage processing by-products), NutraMara (seaweed), Beotanics (plant varieties), and BioMarine Ingredients (fisheries) have been developing new products and markets based on scaling up biorefining technology.

5. Notable trends in Digitalisation

Improvements and investments in digitalisation are leading to what is referred to as the "Fourth Industrial Revolution". Approximately $1 billion (€920 million) has been invested in Irish agri-food-tech companies since 2012. This investment has been supported by the presence of key agri-tech accelerators as well as State and European investment. In particular, a number of Agri-Tech centres have been developed, enabled through Enterprise Ireland and the Regional Technology Clustering Fund. These hubs aim to bring together Ireland's wider AgTech community and help with the launching and scaling of AgTech companies by providing access to on-farm research collaboration opportunities, as well as a location to test and trial products and services in a real-world environment.

Despite this, the innovation ecosystem is still at a relatively early stage and the uptake and application of technology to the sector has been slow and not had the impact on innovation, productivity and sustainability that is evident in other areas of the economy.

One of the chief debilitating factors is the lack of high-speed broadband infrastructure in rural Ireland. This is hoped to be addressed in the coming years, through the roll-out of the National Broadband Plan, which will be a key enabler of the adoption of new technologies at farm level and within industry settings. Additionally, for a digital transition in the agri-food sector to occur, training and access to advisory services by farmers will be critical.

Concerns around data ownership and the sharing of data are also responsible for the slow uptake of new digital technologies. To combat this, Teagasc, the national agriculture and food advisory service is currently undertaking a project on the digitalisation of the agriculture and forestry sector through data security, called AgriDISCRETE. The project aims to contribute good data governance practices in the sector.

There is a chief focus on the utilisation of digital technologies to enhance the sustainability of the sector, for example through the use of Robotization, Artificial Intelligence (AI) and Big Data, while technologies such as Blockchain are already being used within international trade supply lines.

An example of such digital innovation from the farmer-owned co-operative, FRS (Farmer Relief Services) Network, is farm herd management tool, Herdwatch. The platform is used as an aid for compliance recording, including for animal remedies, movements and calf registrations, allowing for informed decision making, improved transparency and a reduction in on-farm administration.

6. Notable trends in business models

Irish agriculture's well established, predominantly grass based agriculture business models look set to continue for the foreseeable future, albeit with a move towards specialisation in dairy farming in particular, driven by better returns in that sector.

Factors such as the EU Farm to Fork Strategy and the EU Green Deal agenda will certainly influence Irish agricultural business models in the future, with increased sustainability obligations being placed on farmers and the wider food sector. Considering Irish Agriculture's export orientation, programmes such as Origin Green become even more central to how Ireland's €14 billion worth of agrifood exports are marketed throughout the world.

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Ireland Scenarios

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimension for every scenario. In this table the skill list developed in workpackage 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

Ireland: Scenarios sustainability – key issues

Sustainable paths	Established paths	High tech paths
▪**Climate Change/GHGs:** A sustainable path involves the adoption of key mitigation measures identified under the Teagasc MACC curve related to animal breeding, grassland management, soil fertility, animal health, renewable energy, energy efficiency and land use measures.	▪Established path involves the adoption of the Teagasc GHG MACC curve through the rollout of the Signpost Farm Initiative and other Knowledge Transfer actions and the adoption of actions identified under the DAFM Ag Climatise Roadmap for Climate & Air.	▪High tech paths involves the adoption of new research and technologies into the future related to animal breeding, methane reduction, new grasslands such as mixed species swards and adoption of feed additives.
▪**Ammonia Emissions:** A sustainable path involves the adoption of key mitigation measures related to the Teagasc Ammonia MACC curve related to Low Emission Spreading Equipment and Protected Urea.	▪Established path involves the adoption of the Teagasc Ammonia MACC curve through the rollout of the Signpost Farm Initiative and other Knowledge Transfer actions and the adoption of actions identified under the DAFM Ag Climatise Roadmap for Climate & Air. Ongoing research related to Protected Urea requires completion.	▪High tech paths involves the adoption of new technologies and practices related to slurry injection, spreading and slurry additives. Also reducing crude protein in diets and covering slurry stores.
▪**Water Quality:** A sustainable path involves intensive engagement with farmers to ensure the Right Measure in the Right Place is adopted to prevent nutrient losses and sedimentation.	▪Established path involves the continued rollout of the ASSAP programme identifying the key N and P mitigation measures on farms, farmyard management and preventing sedimentation. Continued focus on soil fertility, NMP and slurry management is essential.	▪High tech paths involves the adoption of LESS equipment and usage of NMP online tools including mapping technology and precision agriculture.

Ireland: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
The Government's vision for the bioeconomy is to grow Ireland's ambition for the bioeconomy through a co-ordinated approach that harnesses Ireland's natural resources and competitive advantage and that fully exploits the opportunities available while monitoring and avoiding unintended consequences	Irish bioeconomy policy development has been developing based on three pillars: Investments in research, innovation and skills; Reinforced policy coordination and stakeholder engagement; and Development of markets and competitiveness.	Key research and innovation developments have included Farm Zero C examining the development of carbon neutral farming led by Carbery and AgriChemWhey a flagship biorefinery development which is building a first-of-a kind, industrial-scale bio-refinery which will take by-products from the dairy processing industry and convert them into cost competitive, sustainable platform bio-based chemicals led by Glanbia.
The bioeconomy also has a close relationship with the circular economy and represents an area where Ireland has some crucial advantages and developments should promote circularity through solutions and innovations that reuse and recycle materials, maximising resource efficiency through the use of unavoidable wastes and environmental sustainability	Key education and skills development includes the availability of a postgraduate diploma in bioeconomy and business led by IT Tralee and UCD.	Leading Irish bioeconomy companies such Monaghan Biosciences (mushrooms), Hexafly (beverage processing by-products), NutraMara (seaweed), Beotanics (plant varieties), and BioMarine Ingredients (fisheries) have been developing new products and markets based on scaling up biorefining technology.
	The Government has also established a high level implementation group to coordinate across government and its agencies on bioeconomy policy development and has developed an information week to raise awareness of the bioeconomy and its products.	

Ireland: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
▪ Development of Carbon Neutral Farming approaches in research projects ▪ Dairy Farm Zero C – BiOrbic, Bioeconomy SFI Research Centre. ▪ Beef & Sheep Heartland (heartlandproject.eu) ▪Need for demonstration on a wider scale	▪ BioMarine Ingredients who are a producer of speciality marine Proteins, Mineral and Lipid powders providing advanced nutritional & functional ingredients which deliver sustainable products, bringing better marine nutrition to people, pets & planet. From natural sources and with a fully integrated supply chain in the most advanced, food-grade, bio-refinery in the World.	▪ NXTGENWOOD is a collaboration between BiOrbic, AMBER and others to extract high value materials from wood. ▪Need for demonstration on a wider scale
▪ EIP-AGRI project Biorefinery Glas has outlined the techno-economic model for the development of a green biorefinery approach in Ireland ▪ need for commercialisation	▪ Nutramara is a 100% Irish owned and operated blue bioeconomy company, located on the south-west coast of Ireland. Nutramara is a leader in the blue revolution, harnessing the power of biotechnology, biology and the ocean to develop next generation phytochemical ingredients and formulations. ▪ Need for large scale development	▪ The AgriChemWhey project is building a first-of-a kind, industrial-scale bio-refinery which will take by-products from the dairy processing industry and convert them into cost competitive, sustainable lactic acid to make value-added bio-based products for growing global markets, including biodegradable plastics, bio-based fertiliser and other minerals. ▪Need for large scale deployment & replication
▪The Irish Nutrient Sustainability Platform aims to promote sustainable nutrient management on the island of Ireland in the context of the United Nations Sustainable Development Goals Agenda. ▪Need for demonstration on a wider scale	▪Meade Farm identified that the by-product from a food service peeling process which was initially fed to beef cattle, was all surplus to requirement potatoes. The company installed a starch extractor to provide food grade starch that can be sold on the open market from Ireland's only indigenous starch ingredients.	▪The ICT Biochain project has developed the South East Region in Ireland as a High-potential Model Demonstrator Regions and as a test bed location for biomass mobilization including linking with the Irish Bioeconomy Foundation and their development of a pilot biorefinery. ▪Need for increased data availability
▪ Research on the U-Protein projects spans the entire production process, from the identification and characterisation of proteins from crops and the marine, to the processing of these proteins, clinical studies and finally incorporation into a consumer product. In support of the circular bioeconomy, the residual biomass from these protein sources will be assessed for bioactive components or valorised to novel or renewable products through microbial biotransformation. ▪Need for demonstration on a wider scale	▪Monaghan Biosciences used the EU funded FungusChain project to develop proteins are used as complements to enrich food supplements for the elderly and sportsmen. ▪Need for further market development	The BioCrop Research project on Biostimulants and Biopesticides for Crop Production aims to produce new algal and fungal derived biopesticides and biostimulants while engaging with industry and collaborators to test existing biofertilisers (algal and bacterial based) and biostimulants (endophytes) for efficacy. The existing products will be compared to fossil fertiliser applications and ability to control disease (focussed on aphid -borne disease and Ramularia Leaf Spot, RLS) in Barley in field trials.

Ireland: Scenarios Digitalisation – key issues

Sustainable paths	Established paths	High tech paths
•Precision agriculture to support optimal use of resources for improved productivity, quality and sustainability of all agri-food systems.	•Digital innovation is aiding compliance recording and on farm administration.	•Digital technology enables farmers to build short, medium and long term businesses strategies based on market developments and to manage their risk through participation in futures markets.
•Precision agriculture results in high yields, improved genetics, animal health and welfare and food quality. Inputs are minimised bringing ecological improvements. Food losses and waste are minimised.	•Precision technology is optimising genetic improvements and input usage such as in animal remedies, animal nutrition, crop protection products and fertiliser, with environmental and animal health and food quality benefits. However uptake is currently limited by cost .	•Precision agriculture results in high yields, improved genetics, animal health and welfare and food quality. Inputs are minimised bringing ecological improvements. Food losses and waste are minimised.
•Digital technologies enable instant track and trace systems to provide greater information to partners in the food supply chains and enable the instant and smooth flow of products throughout the chain, both final products to consumers and on-farm inputs to farmers.	•Communication and collaboration between farmers and food industry is increasingly digitalised. Food chain partners often rely on blockchain technology to provide transparency and security.	•Digital technologies enable instant track and trace systems to provide greater information to partners in the food supply chains and enable the instant and smooth flow of products throughout the chain, both final products to consumers and on-farm inputs to farmers.
• The application of robotization and AI have led to smart factories supporting efficient use of resources and full circularity of production. Food losses and waste are minimised.	•The pace of robotization and AI applications in food industries is moderate. However processes are is largely circular, where economically viable, in terms of energy and water use optimisation and self generation and food and biproduct waste minimisation.	•Smart factories are common. Production is circular if economically viable.
•Digital technologies enable track and trace systems to provide greater information to consumers and partners in the food supply chains as well as enable	•Existing and utilised technologies such as Blockchain provides security and transparency to international trade as well as local supply chains.	•Digital technologies (e.g. real time monitoring of physiological functions and nutritional needs through biomarkers and biosensors) support personalised

Ireland: Scenarios Forestry – key issues

Sustainable paths	Established paths	High tech paths
•**Afforestation:** A sustainable path involves moving towards more habitat and biodiversity friendly species and methods with greater ability to sequester carbon in addition to a greater focus on growing biomass for renewable energy. National Biodiversity Action Plan has also targeted a move from coniferous to native trees.	Established path involves following Ireland's National Forestry Program targets for the increase of biomass energy in the forestry sector, Additional afforestation to secure carbon sequestration for the longer term and the sustainability of the forest ecosystem, which includes action to increase habitat and other actions which will improve environmental quality.	•High tech paths involve the adoption of new research and technologies into the future related to planting and maintenance of forestry in Ireland such as site management, mechanisation and forestry management information systems.
•**Forest owner engagement:** A sustainable path involves promoting the uptake of technology, building skills and collaborative working through advice and knowledge transfer activities, to promote the forestry sector to become more competitive and economically sustainable. Support knowledge and innovation and contribute to future increases in employment and value added in the forestry sector.	•Established path involves adopting the measures set out Ireland's National Forestry Program to help Ireland's fragmented private forest owners adopt new technology, build skills and collaborate.	•High tech paths involve the adoption of new technologies and practices that support innovation and contribute to added value in the forestry sector such as more advanced harvest, processing and logistical management tools.
Biomass: A sustainable path involves maximising the potential for wood fuel to displace fossil fuel in Ireland, particularly in the generation of heat in industrial, commercial, domestic and institutional markets.	•Established path involves maintaining the current level of export orientation while allocating some of the anticipated increase of output from private forests, generally planted approximately 30 years ago, for biomass/wood fuel in commercial heating systems.	•High tech paths involve the adoption of new processing, drying and boiler technologies to maximising the potential for wood fuel to displace fossil fuel in Ireland, particularly in the generation of heat in industrial, commercial, domestic and institutional markets.

Ireland: Scenarios Business Models – key issues

Sustainable paths	Established paths	High tech paths
▪ **Generational Renewal:** A sustainable path involves the current and next generation of farmers adopting techniques and key mitigation measures related to animal breeding, grassland management, soil fertility, animal health, renewable energy, energy efficiency and land use measures and work life balance.	Established path involves farmers adopting techniques, practices, initiatives and collaboration models to ensure a smooth transition to generational renewal within agriculture.	▪High tech paths involve farmers exploring new research and technologies into the future related to animal breeding, methane reduction, new grasslands.
▪**Consumer Trends:** A sustainable path involves educating the current and next generation of farmers on practices and technology, digitisation and AI that minimises inputs, provide greater information to consumer and more efficient use of resources.	▪Established path involves the current and next generation of farmers for the increased technological, reporting and communication demands of their sector.	▪High tech paths involve preparing the current and next generation of farmers to maximise the opportunities presented by instant tracking and tracing of supply chains, AI and robotisation, labour and input saving technologies.
Diversification: A sustainable path involves educating farmers on the opportunities to offset emissions and improve biodiversity on-farm through alternative businesses.	▪Established path involves farmers taking opportunities offered by current government schemes promoting renewable energy generation and alternative land use.	▪High tech paths involve farmers implementing technologies to maximise opportunities offered in renewable energy generation and other enterprises that complement the core farm enterprise.

Ireland: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
▪ **Generational Renewal:** A sustainable path involves educating current and prospective farmers on techniques and key mitigation measures related to animal breeding, grassland management, soil fertility, animal health, renewable energy, energy efficiency and land use measures.	Established path involves educating and advising farmers and agricultural science students on techniques, practices, initiatives and other Knowledge Transfer actions to ensure generational renewal within agriculture.	▪High tech paths involve educating the current and next generation of farmers on new research and technologies into the future related to animal breeding, methane reduction, new grasslands such as mixed species swards and adoption of feed additives.
▪**Digitisation:** A sustainable path involves educating the current and next generation of farmers on technology, digitisation and AI that minimises inputs, provide greater information to consumer and more efficient use of resources.	▪Established path involves educating and advising the current and next generation of farmers for the increased technological, reporting and communication demands of their sector.	▪High tech paths involve preparing the current and next generation of farmers to maximise the opportunities presented by instant tracking and tracing of supply chains, AI and robitisation, labour and input saving technologies.
Diversification: A sustainable path involves educating farmers on the opportunities to offset emissions and improve biodiversity on-farm through alternative businesses.	▪Established path involves educating farmers on opportunities offered by current government schemes promoting renewable energy generation and alternative land use.	▪High tech paths involve educating farmers on how to implement technologies to maximise opportunities offered in renewable energy generation and other enterprises that complement the core farm enterprise.

Ireland: Scenario specific skill needs (categories from WP1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Sustainability	Sustainability	Sustainability
1.1 Mitigation and adaptation to climate change incl. 1.11. By-products and co-products valorisation 1.17. Good Agricultural Practices incl. 1.19. Soil Nutrient and Health Management I	1.03 Improved Agri-food system production 1.10. National, EU and international environmental policies, regulation, subsidy and support programmes 1.04 Active Management of Resources	1.08 Environmental Management Systems (EMS) 1.12 Generation, storage and use of renewable energies 1.07 Sustainable metrics & certification
Bio-economy	Bio-economy	Bio-economy
3.a.1 Planning and coordinating production 3.a.15 Agricultural biodiversity 3.b.2 Sustainable forest management practices and planning	3.a.2 Performing farming operations 3.a.17 New bioproducts: Biofuels, Bioplastics, Biochemicals, Textiles, Cosmetic & Pharmaceuticals 3.b.3 Reforestation, afforestation and restoration of forest ecosystems 3.c.4 Production operations and management	3.a.17 New bioproducts: Biofuels, Bioplastics, Biochemicals, Textiles, Cosmetic & Pharmaceuticals 3.c.1 Quality management, quality assurance and quality control 3.b.9 Process operations in the pulp, paper, timber and cork industry 3.c.10 Continuous improvement 3.c.17 Emerging technologies 3.c.18 Food Labelling/Certifications
Digitalisation	Digitalisation	Digitalisation
2.18 Precision animal health and productivity management systems 2.19 Field operations management systems 2.12 Digital food traceability systems 2.24 Robot and drone technology in agriculture 2.2 Data handling and analysis	2.17 Farm Management Information Systems (FMIS) 2.15 Decision support systems (DSS) 2.2 Data handling and analysis 2.16. Robot and drone technology	2.6 E-commerce and e-marketing 2.19 Field operations management systems 2.9 Digital supplier management systems 2.11 Warehouse management systems 2.10 Digital product quality management systems
Business model	Business model	Business model
4.1 Communication	4.16 Networking	4.13 Change management

Ireland: Scenario specific skill needs (categories from WP1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Forestry	Forestry	Forestry
3.3 Reforestation, afforestation and restoration of forest ecosystems 1.22 Multifunctional forests and ecosystem-services	1.6 Biodiversity 1.11 By-products and co-products valorisation 3.10 Equipment/machinery and maintenance in the pulp, paper, timber and cork industry	3.2 Sustainable forest management practices and planning 3.12 New technologies in pulp, paper, timber and cork manufacturing 1.22 Multifunctional forests and ecosystem-services

o Annex 3.2 The Netherlands: trend and scenario study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

Sector structure

Agriculture

The Netherlands has a strong agri- and food sector and is currently the second largest exporter of agricultural products in the world (>90 billion euros in 2020). Most important sub-sectors for export are: floriculture, dairy, eggs, meat (chicken, pork), vegetables. Although, also other products like fish, fruits deliver important income flows.

The number of farms in Dutch agriculture is decreasing fast. In the year 2000 there were still 97389 farms, while in 2020 this number had decreased to 52.711. Only the category farms larger than 50 hectares increased in this period.

Table 1: Number of companies in main agricultural subsectors in the Netherlands, in 2000 and 2020. (CBSc, 2020; Agrimatie, 2020).

Sector	2000	2020
Total	97.389	52.711
Arable farming	14.799	11.217
Horticulture	16.910	7.025
Grazing animals*	45.102	25.808
Indoor animals*[14]	10.444	4.144

At the same time as the number of farms decreased, the average size of farms increased, for example arable farming from 33.6 to 43 ha, dairy farms from 57 to 105 cows, pigs from 900 to 3400 per farm. (CBSc, 2020). Most farms in the Netherlands are family farms in which different family members take part in the farming activities (in 2018 only 10 % of total costs of farm companies were labour costs; Agrimatie, 2020).

In general farm continuation in the Netherlands is jeopardised. In 2016 (most recent available data) 62 % of companies in agriculture and horticulture did not have a successor. Moreover, ground prices are high in a densely populated country like the Netherlands, and, at the same time labour opportunities outside agriculture are good for the highly educated farmers. The expectation is that the number of farms will further decrease in the future. (Berkhout *et al.*, 2019)

Forestry

[14] Animal farming comprises an important part of Dutch agriculture, with in 2018, 3,9 mln. (dairy) Cows, 12 mln. Pigs, almost 1,5 mln. other grazing animals like sheep and goats, and more than 105 mln. Chicken. (www.cbs.nlc)

The forest area in the Netherlands covers 373.480 ha. 48,2 % of this area is public property, 19.4 % is property of nature preservation organisations, the rest is private property (in many cases properties < 5 ha). 45% of the forest area is certified (Forest Stewardship Council or the Dutch PEFC Forest standard). Income from forestry activities varies, but in most years most companies work with a financial deficit (average deficit of 38 euros per ha over the period 1989-2017). Sales of wood and preservation subsidies are the highest sources of income (Silvis en Voskuilen, 2019).

Bio-economy

The Netherlands, with a well-developed agriculture, transport and chemical industry has a solid basis for the development of the bio-economy. The biobased industry consists of around 1200 businesses (most SME), focusing on production of chemicals, bio-polymers, bio-fuels and electricity. The bio-economy sector in the Netherlands grows, the estimated turnover in 2018 was between € 114 and € 120 mld. The turnover of the bio-based economy was € 21 mld. With these figures the Netherlands takes an average position in the EU. (Ministry of Economic Affairs and Climate, 2019).

1. Dutch AKIS (Agricultural Knowledge and Information System)

The Dutch agri- and food sector is recognized as very innovative and technologically advanced, with many start-ups and a strong position of SMEs. OECD (2015) characterised the Dutch AKIS as a Global frontrunner in product technology and innovation processes, aiming at input efficiency and sustainability. The strength of the Dutch AKIS is reflected by a history of public-private investments and collaboration between knowledge institutes, businesses, government and societal organisations. (Geerling-Eiff, 2019). Average education level of farmers is high, most young farmer-starters followed higher education. Collaboration between farmers, especially in dairy and arable farming is strong. The Netherlands has one of the highest shares of farmers in cooperatives in agriculture in the EU.

The Dutch system is fragmented but strong; many small scale AKIS-subsystems exist in various sectors and regions, covering the knowledge needs of specific farmers. A disadvantage of the fragmentation is the limited collective vision. (Hermans *et al.*, 2018)

An important trend in the Dutch AKIS is upscaling and intensification, going together with more private investments in knowledge and innovation, but at the same time to a growing gap between large companies and SMEs. This development goes hand in hand with further commercialisation of knowledge. (Geerling-Eiff, 2019)

2. Notable trends in sustainable production

In general the Dutch agriculture is characterised by large scale intensive production with high pressures on environment, landscape and society. The main aim of current Dutch government agricultural policies is to remain competitive on the world market and, at the same time, move towards a circular agriculture in 2050, focusing on sustainable production and bio-economy principles. Currently major challenges are, to cope with a nitrogen emission crisis, the Corona crisis and uncertainties related to Brexit. At the same time public support for agriculture decreases because of agricultural pollution, health issues, pressure on land and the decrease of biodiversity in the Netherlands.

Environmental pollution

Strict regulations exist regarding phosphate and nitrogen emissions. After the end of the EU milk quota system in 2015, production of milk and thereby emissions of phosphates have increased considerably for several years, but has decreased again to acceptable levels after government intervention. However, many dairy farmers had invested considerably in animals and stables, leading to financial problems for many of these farmers.

Since 2019 the Netherlands is caught up in a nitrogen crisis where nitrogen emissions exceeded permitted levels, impacting on air quality and biodiversity and in particular jeopardising Nature 2000 areas. As a consequence government put a halt on thousands of construction projects, including homes and roads, implemented speed limits on highways and further restricted expansion of animal farming (dairy, pig, and poultry farms). Animal farming forms a major source of nitrogen pollution, in particular in the form of ammonia emissions.

Therefore, agriculture is considered by the Dutch government the major sector where gains in nitrogen emission reduction can be achieved. Policy has and is being developed to on the one hand reduce animal farming activities in the Netherlands through buy out actions (the government reserved 350 million euros to buy out farms), in particular farms close to Nature 2000 areas, and on the other hand make farming more sustainable, through financial support for farmers that transit to more sustainable (circular) agriculture. Aim is that in 2030 at least half of the Natura 2000-areas have a healthy nitrogen level below the critical deposition value.

As ammonia reduction is one of the challenges for Dutch farmers, there is a strong development towards alterations in feed composition, separation of manure, in many cases implying considerable investments in new stables and equipment. Also other investments in more sustainable production see a fast increase. For example, pig farmers more and more apply air washers, thereby reducing emissions, but also odour nuisance and negative health impacts for nearby living citizens. Similar solutions are used in chicken farming, which is the sub sector with most micro dust emissions, also impacting on the health of nearby living citizens.

Animal welfare

In all animal farming sectors there is increased attention to animal welfare, enforced through pressure of government and retailers. For example, several large retailers more and more focus on meat and eggs with sustainability labels. In this respect many initiatives for niche products (new brands, new labels) have emerged in the last decade in different sub-sectors, related to sustainable production, animal welfare and others. The sales of food with sustainable labels had increased to more than 11 % in 2019. Improvement of animal welfare is also an important part of the sustainability strategy of EU (Farm-to-Fork strategy) and Dutch government, where new norms for animal welfare and animal transport are being developed.

At national level, the government takes additional measures by e.g. investigating improvements for animal welfare in slaughterhouses, for example reduction of the speed of the slaughtering process. Further, in the animal farming sector there is continuous effort to reduce the use of antibiotics. Since 1990 antibiotics use in cattle breeding has decreased considerably, to below European average.

Protein sources

Part of the road to sustainable agriculture is to make the animal feed sector less dependent from import streams. Currently a strategy is being developed to develop crops high in protein, for animals in the Netherlands. Also gaining protein from residual streams is part of this strategy (from plants, kitchen waste etc.).

Moreover, the development of alternative protein sources for human consumption is part of the ''National Protein Strategy''. For example, gaining proteins from seaweed or the use of vegetable proteins as substitute for meat.

Biodiversity

Only 4.3 % of the surface of the Netherlands is Nature 2000 area while the EU average is 10 %. The Netherlands scorers lowest of all EU countries in several Biodiversity indicators such as % of habitats with stable or positive biodiversity trends (only 3.8 %), number of farm birds, insects (75 % less insects in 2020 compared to 1990), etc. Causes are too high N-deposition (manure), fragmentation and disappearance of semi-natural area (disappearance of borders of plots, landscape elements, etc.), drought, monocultures, use of chemicals for crop protection. As biodiversity in Dutch agriculture and nature has decreased considerably in the last decades, the Dutch government plans to invest in nature reserves, including hydrological measurements and acquiring ‘’key hectares’’ to re-enforce the robustness of nature reserves. (Ministry LNV, 2020)

Forestry

Dutch policy aims to extend the forest acreage with 10 % (37000 ha) by 2030. Afforestation should contribute to climate goals and biodiversity. Also extension of agroforestry will be supported to link agriculture and nature, focusing on small scale and climate smart forest management, and at the same time increase recreational areas in the Netherlands. Also smaller initiatives like planting of trees in urban areas and development of so-called ‘’tiny-forests’’ (IVN.nl) are stimulated. (Ministry of LNV, 2020a).

In general Dutch food industry follows the trends towards more sustainable production, including more attention to environmental impact, animal welfare (e.g. in slaughtering), packaging (alternatives for plastic packaging), food miles (moving to locally produced products), human health (e.g. salt and sugar content and moving towards less processed products), and food waste (the Dutch government wants to reach complete circular production in 2050)

Food industry

Trends in consumer demands are convenience (ready-to-eat, one-person packagings), fresh (unprocessed, local), healthy (less salt and sugar) and sustainable (impact on environment, packaging, animal welfare, short chains, organic).

Concentration in the chain continues, in the Netherlands there are only 5 large food purchasing organisations. For the long term the expectation is development towards local-for-local chains (800-1000km range), except for unique products and very cost competitive products. Consumers also ask for transparency, implying the requirement of robust traceability systems. Further, social media will be increasingly used for promotion and to stay connected with the company’s consumer base.

In the supply chain we see increasing scarcity of resources, implying increasing importance of strategic sourcing (of sustainably produced products).

Innovation is in the development of online and in products with themes such as allergens, traceability, clean label, robotization and AI, automation and internet of things (IoT), circular, and flexibility in production.

In processing the trend is towards smart industries, where combinations of technologies enable ‘self’working’’ factories with minimal human intervention and maximum circular production.

(Rabobank, 2021)

3. Notable trends in Bio-economy

Bio-economy policy in the Netherlands is strongly coupled to the transition agenda Circular Economy (Ministry of Economy and Climate, 2020). The bio-economy must contribute to the objectives of sustainable production, maintenance of bio-diversity, afforestation, reverse land degradation, recovery of eco-systems and improvement of food production and water security. Dutch innovation policy focuses on optimal valorisation of biomass and waste streams to circular biobased products, closing of nutrient cycles and preservation of soil quality, diminishing of food waste, increasing the supply of sustainable produced biomass, protein transition.

Various organisations put efforts in further development of the bio-economy. For example, the Federatie Bio-economie (Federation Bio-economy in English). This is a public-private collaboration between companies, knowledge institutes, governments and NGOs, aiming to fasten the transition to a sustainable bio-economy in the Netherlands. (Federatie Bio-economie Nederland, 2020)

A bio-economy trend in agriculture is the production of biogas from manure. Further, many farms have started with production of wind and solar energy (on dedicated plots and stable roofs), use of plant based raw materials for energy supply, supply of raw materials for the chemical industry, supply of biomass production for energy production or for production processes in the chemical industry.

4. Notable trends in Digitalisation

In the near future most data flows in Dutch agriculture will be digitalised: invoices, supply messages, laboratory results, samples, etc. This will give a solid basis to further connect to the fast emerging on-farm IoT (Internet of Things) applications on farms. To support:

- Precision agriculture (more efficient use of inputs and reduction of emissions and waste)
- Circular agriculture (be able to localize, align and utilize product and rest streams)
- Transparency (and certification) in the chain, making sustainability efforts of entrepreneurs more visible, which again offers marketing opportunities
- Enforcement of innovation and competitive power in the agri- and food sector because companies can more easily switch from one service provider to another.
- Increase of on-farm knowledge of soil, water management, etc.

(Berkhout *et al.*, 2019)
The Dutch agricultural sector, with its highly educated farmers, high level of organisation and well-functioning knowledge infrastructure can play a leading role in Europe in the digitalisation of the agricultural sector. In fact the Netherlands already plays this role through the coordinating role of Wageningen university in large Horizon2020 projects like IoF2020 (Internet of Farm and Food 2020) en Smart Agri Hubs. Major challenge regarding digitalisation in the Netherlands is the incentive of suppliers and customers of farmers to implement EDI (electronic data exchange).

In the Dutch food industry digital innovations focus traceability, labelling; robotization and Artificial Intelligence, automatization and Internet of Things (IoT).

5. Notable trends in business models

42 % of Dutch farmers in 2020 had developed multi-functional farms, including activities like health care, childcare, farm sales/shop (with also products from outside the own farm), tourism activities, farm education, nature management and increasingly energy production (wind, solar). Farm sales is the largest activity (271mln in 2018), followed by health care and recreation. The highest growth is in care farms and energy production (Meulen et al, 2019)
The distance between countryside and cities in the Netherlands is low, which brings opportunities to the development of short chains, focusing on locally produced products. Although the number of short chain initiatives is still limited, many regional governments are starting programs to support farmer entrepreneurs to sell local products to local markets. Apart from locally produced products we see increasingly differentiation of agricultural products, including sales of traditional vegetables and fruits (''forgotten vegetables''), vegetables and fruits not meeting common retailer standards (''ugly vegetables and fruits''). These products are sold at farm gate, special shops and increasingly also at larger retailers.

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The Netherlands Scenarios

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimension for every scenario. In this table the skill list developed in workpackage 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

Netherlands: Scenarios sustainable production – key issues

Sustainable paths	Established paths	High-tech paths
▪High social and environmental consumer awareness, plant based diets prevail. Consumers prefer for local products including traditional vegetables.	▪Cost, taste and convenience are most important product attributes for consumers. Niche markets for local and traditional foods remain but have a small market share. Consumption of meat remains high.	▪Consumers value healthy and personalised (functional) processed foods. Meat consumption is high.
▪Livestock levels have been decreased by 50%, arable land by 15%. Extensive livestock production.	▪Livestock levels decrease by 10%, arable farming by 5%. Intensive livestock production is under strict regulation.	▪Livestock levels decrease by 5%, arable farming by 5%. Large intensive production prevails.
▪Strict emission quota (phosphates, ammonia, CO2 for greenhouses have been established by Dutch government.	▪Emission quota are established (phosphates, ammonia, CO2 for greenhouses).	▪Emissions are minimized with the help of climate smart technology. E.g. geo-thermal energy use in greenhouses.
▪Throughout agriculture biodiversity has improved through mosaic/strip crop planting, flower borders, diversified crop rotations etc. Nitrogen levels of Nature2000 areas are well below critical levels.	▪Biodiversity has moderately improved since 2020. Nitrogen levels of half of Nature-2000 areas are well below critical deposition levels.	▪Biodiversity levels have deteriorated. Nitrogen levels of Nature-2000 areas are at 2020 levels.
▪Livestock sector has invested vastly in sustainable and circular production and alterations in feed composition. Livestock production systems with free run-out options for animals are common. Local sourcing of feed.	▪Livestock sector has invested vastly in sustainable production. Livestock production systems with free-range (indoor) options for animals are common. Feed sourcing is combined local and Global.	▪The livestock sector has invested vastly in technology for sustainable and circular (indoor) production, focusing on limitation of emissions. Feed sourcing is Globally oriented.
▪Use of antibiotics has been individualised and minimized.	▪Use of antibiotics had decreased at moderate pace.	▪Use of antibiotics has been completely individualised.
▪A strict EU+ animal welfare policy has been implemented for slaughterhouses (resting locations, slaughter pace, stunning).	▪Slaughterhouses comply with EU legislation.	▪Slaughterhouses comply with EU legislation.
▪Arable farming and horticulture have moved to agro-ecological climate smart production techniques and application of bio-pesticides and organic fertilizers, supplied by the livestock sector.	▪Arable farming and horticulture (incl. flowers) increase use of bio-inputs next to use of chemical pesticides and synthetic fertilizers which decrease moderately due to EU legislation.	▪Arable farming and horticulture (incl flowers) use optimal mix of bio- and chemical inputs, based on economic incentives to ensure high yields. Regional specialisation and monocultures limit biodiversity potential.
▪The food industry is strongly moving towards circular production. The connection with the consumer base (e.g. through product information and promotion) has been strengthened.	▪Food industry slowly moves to more circular production. Connection with consumers is through retailers.	▪Product innovations are strong and continuous, focusing on functional foods, healthy food, 3D food printing and GMOs. Food industry moves to circular production as far as this is of economic interest. Strong connections in the supply chain are very important to manage Global food chains and assure safety and quality of products.

Netherlands: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
•Dutch agriculture has made a strong move towards circular production with optimal use of by-products and waste streams. Farm and household waste is used in livestock production.	•There is only moderate development towards circular production in Dutch agriculture. Livestock and crop production are not well connected.	•High tech agriculture and precision farming lead to a strong move towards circular production (the rationale for changes is economic).
•Agriculture contributes to a fast growing biobased sector (e.g. to chemical industries). Decentralised bio-refinery and renewable energy installations.	•Agriculture only contributes to a limited extend to biobased production.	•The biobased sector (chemical, plastics) has grown fast, supported by biomass from agriculture. •Concentration of processing facilities.
•Agriculture is self sustaining in energy production through production of bio-gas, wind and solar energy, and delivers a considerable part of Dutch energy needs.	•Agriculture is still for the largest part dependent on fossil based energy sources, only moderately supported by renewable energy sources which are also supplied to some niche markets.	•Agriculture is still strongly based on fossil fuel, however supported by cost-effective renewable energy production.
•Biobased chemical, pharmaceutical and rubber/plastics sectors are an important part of the Dutch economy. Sector is closely linked to farming; production partly by SMEs.	•Biobased chemical, pharmaceutical and rubber/plastics sectors have moderately increased in importance.	•Biobased chemical, pharmaceutical and rubber/plastics sectors are an important part of the Dutch economy. Production in large industries.
•Forest acreage has been increased by well above 10%. Sustainable forest management with certified wood production is common. •Agroforestry and small-scale forestry including so-called "tiny" forests are integral part of the rural and uran landscape. Degraded land has been afforested. Forestry strongly contributes to biodiversity. Most forest is "nature forest".	•Forest acreage has increased very moderately, with less than 10%. Planting of trees in urban and rural settings increases slowly. Most forest is "production forest".	•Forest acreage has increased moderately. Degraded land has been afforested. Forestry and agriculture are functioning separately. Most forest is "production forest" with around 50% of the harvested wood used for energy production.
•The food industry has moved strongly to circular production supported by new technologies, including the introduction of sustainable packaging materials.	•The Dutch food industry is largely dependent on fossil fuel energy sources and struggles with valuation of by products and handling of waste	•The Dutch food industry is moving swiftly to smart factory solutions where use and recycling of resources is based on economic incentives alone.

Netherlands: Scenarios digitalisation – key issues

Sustainable paths	Established paths	High tech paths
•Precision agriculture to support optimal use of resources and circular agriculture in small scale sustainable production systems is common in the Netherlands.	•Precision agriculture is used in many subsectors to optimise use of resources in, particular, large farms. There is limited attention to circular production.	•Precision agriculture to support optimal use of resources and circular agriculture in large corporate farms is common in The Netherlands.
•Precision agriculture results in high yields, genetic improvements and ecological intensification. Losses and waste are minimized.	•Precision agriculture, moderately, results in high yields, genetic improvements and ecological intensification.	•Precision agriculture results in high yields and genetic improvements. Losses and waste are minimized.
•Digital technology and systems also enable optimal connection to chain partners and consumers (e.g. through social media). Local (complex) traceability is supported by traceability systems.	•Although, collaboration between farmers and food industry remains limited, traceability by block chain technology and supply chain information systems has become a main field of attention.	•Digital technologies support a solid connection between the large farmers and food industries so as to ensure a fast and flexible flow of products and assure safety and traceability in long food chains.
•In the Dutch food industry application of robotization and AI have led to smart factories supporting efficient use of resources and circularity of production.	•The pace of robotization and AI applications in food industries is moderate.	•Smart factories are common in Dutch food industries. Production is circular if economically viable.
•Digital technologies ensure transparency of production for consumers and partners in the food chain.	•In this scenario overload of product information for the consumer emerges, often implying misleading information.	•Digital technologies (e.g. real time monitoring of physiological functions and nutritional needs through biomarkers and biosensors) support personalised solutions for individual consumers.
•Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection and supply chain management applications.	•There is a moderate increase of the application of digital technologies in forest management.	•Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection, but a focus on supply chain management applications (sales, logistics, distribution).

Netherlands: Scenarios business models – key issues

Sustainable paths	Established paths	High tech paths
▪Concentration of farming has come to a halt. Dutch agriculture is characterised by medium size and small family farms focusing on ecological production in balance with landscape and nature.	▪There is further concentration of the farming sector with large farms along small and medium sized farms.	▪Strong concentration of farms, move away from family farms to corporate farms. Monocultures remain, although sophisticated inputs try to keep fertility of the soil and emissions low.
▪Far most of the farms are multi-functional with side activities in tourisms, health care, energy production, etc.	▪There is a combination of large specialised farms with small-medium size farm. Small and medium size farms are in many cases multifunctional.	▪Large specialised farms make up Dutch agriculture. Multifunctional farms have largely disappeared.
▪Collaboration of farmers in cooperatives and producer organisations has further increased. ▪Local-to-local production is common and most farms participate in (online) sales to consumers in short , local, food chains.	▪Collaboration of farmers in cooperatives remains a key characteristic of Dutch agriculture. ▪Further collaboration in local-for-local producer organisations is limited. Sourcing is combined local and Global.	▪Agricultural production and consumption is Globalised. ▪Products are produced where this is most cost efficient.
▪On food industry level, besides multinationals still operating, many small and medium size food industries have emerged closely working with farmers for sustainable and local-to-local and artisanal production.	▪ Food industry is concentrated in multinational companies. Collaboration between (large) farmers and food industries has increased. Safety and quality are key issues in food chain management	▪Food supply chains have advanced storage and logistics facilities and work in strong collaboration with (large) farms. Safety assurance and traceability systems are of key importance. ▪Joint ventures of food and health industries have emerged swiftly

Netherlands: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
▪Farmers, forestry and food industry employees are highly educated, in sustainable business management and ethics.	▪Farmers , forestry and food industry employees are highly educated in sustainable business management.	▪Farmers, forestry and food industry employees are highly educated, in business management, entrepreneurship and innovation.
▪The Dutch AKIS is fragmented but strong, many small scale AKIS-subsystems exist in various sectors and regions.	▪The Dutch AKIS is characterised by upscaling and intensification, going together with increasing private investments in knowledge and innovation.	▪European AKIS is centralised and strongly interconnected and has a highly technical orientation. Support is mostly from large scale private investments of multinational food companies in collaboration with large farms. ▪Intellectual property rights are key in investment decisions.
▪The Dutch AKIS functions largely independent, EU provides connections between the various systems.	▪The Dutch AKIS functions largely independent, EU provides connections between the various systems.	▪Dutch AKIS is integrated with European AKIS. Minor role for government(s).
▪Collaboration of farmers (in cooperatives/producer organisations), foresters and food industries with public and private knowledge providers of the food system: research organisations, government, NGOs, consumer organisations, etc.	▪Collaboration of farmers, foresters and food industries with public and largely private knowledge providers. Knowledge has been largely commercialised.	▪Collaboration of (large) famers, foresters and food industries with private knowledge providers/R&D suppliers. Role of public knowledge organisations is limited.

Scenario specific skill needs, the Netherlands (categories from WP1.3 – focus groups)

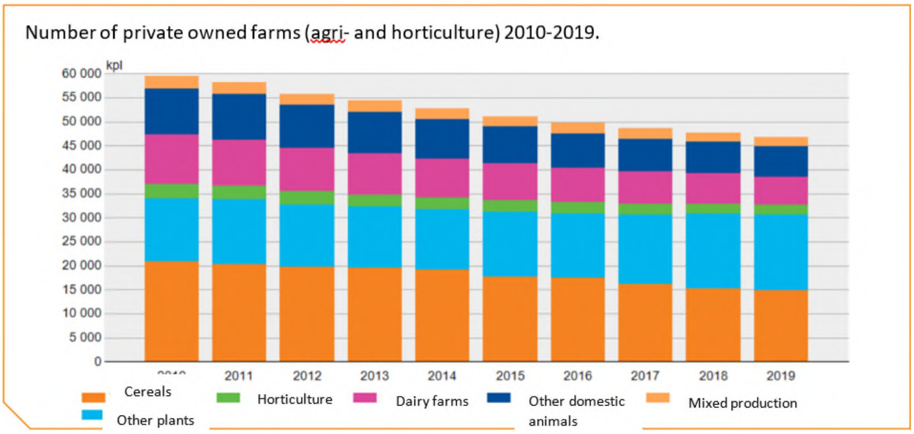
Sustainable paths	Established paths	High-tech paths
Sustainability	Sustainability	Sustainability
…… *Minerals and emissions accounting* 1.3 Improved agrifood system productivity 1.12 Generation renewable energy 1.22 Multifunctional forests and ecosystem services 1.25 Sustainable packaging	…… *Minerals and emissions accounting* 1.5 Integrated pest management 1.12 Generation renewable energy 1.19 Soil nutrient and health management 1.18 Water management	1.2 Efficient use of resources and logistics 1.3 Improved agri-food system productivity 1.11 By products valorisation (circularity) 1.12 Generation renewable energy 1.25 Sustainable packaging
Bio-economy	Bio-economy	Bio-economy
…… *Biobased production* 1.11 Crop diversification and crop rotation 3a.13 Biodiversity 3b.2 Sustainable forest management 3c.16 Ethics for food	3a.9 Conventional vs organic production 3a.10 Controlled environment agriculture 3b.3 Reforestation, restoration forests 3c.14 Traceability 3c.18 Food labelling	…… *Biobased production* 3a.15 New industrial crops and bioproducts 3b.7 Products of forestry 3c.14 Traceability 3c.17 Emerging technologies
Digitalisation	Digitalisation	Digitalisation
….. *Stakeholder communication system* 2.7 Digital entrepreneurship 2.18 Precision animal health system 2.19 Field operations management system 2.24 Robot and drone technology in agriculture	2.1 Everyday usage digital technology 2.12 Digital food traceability system 2.17 Farm management information system 2.18 Precision animal health system 2.19 Field operations management system	….. *Supply chain information systems* 2.8. Digital information and services 2.6 E-commerce and e-marketing 2.23 Climate control systems 2.24 Robot and drone technology
Business model	Business model	Business model
….. *Multi-functional farming* 4.13 Change management 4.20 Learning continuously 4.17 Innovative thinking 5.11 New value chains	….. *Multi-functional farming* 4.6 Organisation, planning, strategic thinking 5.7 Financial business planning 5.10 Cooperatives 5.14 Interdisciplinary knowledge to assess the whole	….. *Wood supply chain management* 4.17 Innovative thinking 5.11 New value chains 5.19 Innovation management 5.21 Protection intellectual property rights

o Annex 3.3 Finland: trend and scenario study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

1. Agri-food industry and structure



In 2019, there were approximately 46,800 agricultural and horticultural enterprises in Finland. Since 2010, **the number of farms has decreased** by around a fifth, and the average farm size has increased by 10 hectares. In 2019, farms had on average 49 hectares of arable land. A good third of this area is rented.
One of the reasons for the decline in the number of farms is the **decreasing trend in generation renewal.** As fewer farms are passed on to the next generation, the proportion of young farmers is decreasing, and the **farming population is ageing.** Especially the number of farmers over 65 is increasing. Last year, the average age of farmers was 53 (Kyyrä *et al.* 2020).

Table 1. Number of Farms in Finland (Lehtosalo et al. 2020).

Number of Farms	1995	2000	2010	2018	Diff 1995-2018 %/year	**Estimated 2030**
Dairy farms	32 715	22 564	11 136	6 854	-6,6 %	3 000
Beef farms	9 394	5 206	3 789	3 271	-4,6 %	1 900
Swine prod	6 249	4 303	2 036	1 080	-7,4 %	400
Poultry	2 329	1 220	724	514	-6,5 %	250
Plant cultivation	42 287	38 113	41 114	35 241	-0,8 %	29 000
All farms	95 562	77 896	62 388	49 500	-2,9 %	35 000

Despite the increase in the enterprise size, the **profitability trend** in agriculture and horticulture has been declining throughout the 2000s. According to a profitability study by Luke (Institute of Natural resources), both the cultivation area of farms and the number of animals on farms have increased, as has the gross revenue of agriculture. Nevertheless, the average real value of revenue per hectare has decreased. This development is due to poor producer price development, price fluctuations and increasing input prices.

The entrepreneurial income of agriculture and horticulture has remained stagnant for years. In 2019 the entrepreneurial income decreased again, and it was sufficient to cover just under 40 % of the target hourly salary of EUR 16 from agricultural work, as well as of the target net interest income from equity.

The effects of the **coronavirus** pandemic on the agri-food sector can be divided into short- and long-term effects. At first, the coronavirus triggered a demand shock in the food market, which occurred as a shift in demand to grocery stores and long-life basic foodstuffs. In the long term, the agri-food industry may be affected by an economic downturn or recession, which would result in layoffs, increased unemployment, loss of earnings and growing uncertainty. As a result, **demand for value-added products would fall**, and consumption would increasingly shift to basic foodstuffs. Consequently, less money would be entering the food supply chain, which in turn would reduce the profitability of the sector.

For Finland, **safeguarding agricultural funding** in the EU budget negotiations has been one of the political priorities. A successful result in agricultural funding is directly linked to Finland's net contribution position, because agriculture accounts for more than 60 % of total EU expenditure in Finland. In addition, the importance of support in agricultural income formation in Finland is significantly higher than the average in the EU Member States, because production costs in Finland are higher than market prices due to natural constraints.

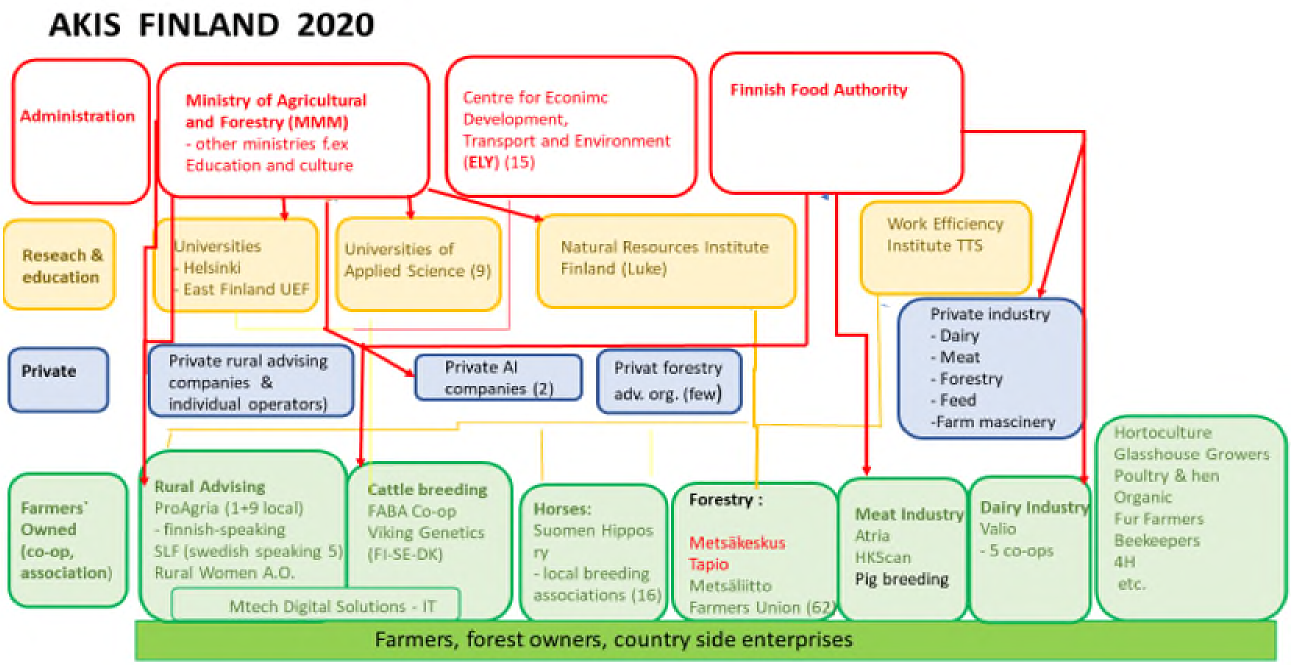
Oat products are the only product group in the Finnish milling industry that have realistic opportunities on the international market. The greatest potential is found in products made from special oats, such as pure oats or organic oats. The consumption trends of recent years are also expected to continue in 2020. Beef consumption is estimated to fall by 2 %, and pork consumption by 4 % in the current year, while poultry meat consumption is estimated to increase by almost 3 %. total meat consumption has decreased for two consecutive years. The production of milk has decreased slightly year by year, but **dairy farming is the largest agricultural sector in terms of turnover.** (Latvala et al 2020)

Finland has FOOD2030 -policy, which partly derives from Farm to Fork -policy and UN´s SDGs. It underlines **the main trends in AgriFood sector** by saying: "**Sustainable, ethical** and **competitive primary production of a high quality** is the foundation of the Finnish food system. **Skilled and motivated farmers** who apply the latest **research-based knowledge and technologies** in their work are the backbone of profitable primary production. Farmers, now and in the future, will use **safe and high-quality production** inputs in line with the principles of sustainable development, **use resources efficiently, look after animal welfare, recycle nutrients, utilise the possibilities of generating renewable energy, and openly seek new opportunities for cooperation and business.** The factors will underpin the building of competitive and profitable Finnish agricultural production which in this report also includes horticultural production." https://mmm.fi/en/food-and-agriculture/policy/food-policy).

The future of primary production will be shaped by the trends referred to in the introduction, including urbanisation, digitalisation and climate change.

2. Finnish AKIS (Agricultural Knowledge and Information System)

The Ministry of Agriculture and Forestry steers the policy on sustainable use of natural resources. Legislative work is carried out as part of the Finnish Government and the EU institutions and decision-making. The Finnish Food Authority operates under the Ministry of Agriculture and Forestry for the good of humans, animals and plants, supports the vitality of the agricultural sector, and develops and maintains information systems. It is responsible for the use of the funds provided by the European Union's agricultural guarantee and rural development funds in Finland, operates as the EU's paying agency and monitors the implementation of EU and national grants – farming subsidies, project, entrepreneurship and structural subsidies as well as market subsidies.



ProAgria is the main operator in this area, serving more than 80 % of all Finnish farms and rural businesses. (Kiljunen 2020). From the beginning of Year 2020 started AgriHub network which co-ordinates knowledge transfer between research, advising and education sectors. LUKE (Natural Resources Institute Finland) has the chairman role in this network. (www.luke.fi)
BSAG Foundation (Baltic Sea Action Group) has strengthened its role in Finnish AKIS with building a joint co-operation between research, business, advisory services and farmers. (www.bsag.fi/en). BSAG opened in February 2021 a free e-learning platform in sustainable and regenerative cultivation for farmers and advisors. AKIS actors should co-operate more to improve profitability, competitiveness, management and environmental awareness of the future farms. Specially we need more efficiency to disseminate the research results to practice.

3. Trends in sustainable production in Finland

Primary production in Finland should be capable of responding to many different challenges. **Extreme weather phenomena** caused by climate change, such as increased amounts of rain, floods and drought, pose challenges for primary production and affect harvest volumes. The risks associated with the occurrence of animal diseases and plant pests that threaten production will increase and could result in the use of increased amounts of plant protection products and drugs in animals in primary production and thus result in a significant challenge for food safety and the profitability of production. In addition, not all the risks of recycled fertilisers are sufficiently well recognised (Koikkalainen et al 2019).

The interest of **improving the soil health** is increasing due to achieve better yields and less adverse environmental impacts on soil, water systems and the atmosphere. Several projects are going on for example: phosphorus load, regenerative cultivation, emissions and green house gases from organic soil, biodiversity etc.

Finnish dairies have started to calculate carbon footprints on farm level what increases interest on how to reduce emissions. Valio, the Finnish leading dairy company, wants to be a carbon neutral company including milk production at farm level until year 2035. To achieve the target, Valio has organised a very large project (Zero carbon Footprint by 2035) which aims to find solutions how to **bind more carbon to the soil** by grass, use **recycle manure into fuel and reduce emissions from fields that have been cleared on dried swampland.** The ministry of agriculture has launched a wide program called "catch the carbon" to support financially research projects under this theme.

The increase in farm size since the 1950s, coupled with the increased input intensity and farm-specific and regional specialisation, has led to a decline in the **biodiversity** in farming environments and to an increase in the number of threatened species and habitats. For some wild species, changes in habitats. In addition to biodiversity, the protection of ecosystems and the **ecosystem services** they produce are considered vital.

The countryside and rural margin areas around cities and towns with arable lands offer important recreational environments for people. Farming environments are important for outdoor recreation, particularly in areas with a high proportion of agricultural land (Rantamäki-Lahtinen 2020).

Animal welfare and sustainability

Finland has been quite isolated from farm animal imports last decades. This has given us very good situation in animal health. We are free from serious animal deceases as well as free from salmonella. Antibiotics are used only to sick animals under vet control. It is forbidden to cut piglets tails or hens' and broilers' beaks according to animal welfare act. Finnish farmers are very keen on **operating with environmental subsidies**, almost 90 % of Finnish farms belong to an official agri-environmental program.

Finnish food industry follows the trends by introducing new products which are said to be healthier and climate friendly than traditional products e.g. meat. We have several projects aiming to enhance the use of vegetable protein (Faba beans, peas, oat) as substitute for meat in human diets as well as in piglets and poultry feeds. Finnish cattle don´t eat soya at all what means an increasing demand to find **new domestic protein sources** for ruminants on grass silage-based diets.

4. Notable trends in Bioeconomy

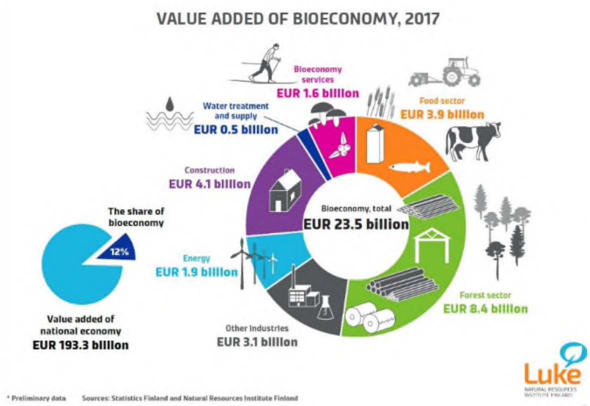
In Finnish Bioeconomy strategy resources, sectors and products which are considered are:

Finland	resources	agriculture, aquaculture, fisheries, forestry, wastes, industrial side streams
	sectors	agriculture, forestry, fishing and aquaculture, manufacture of food, manufacture of wood products and furniture, manufacture of paper, manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels), manufacture of liquid biofuels, health sector, nature tourism, water treatment and distribution, biomass harvesting technologies
	products	bio-based products, biochemical methods, pulping technologies and enzyme production for refining of biomass, wood-based transport fuels, side streams from agriculture and food industry, wood for construction

The comparison of Finnish strategy with other can be found in study several strategies is found in Lier, Markus; Soini, Katriina; Kniivilä, Matleena. 2021. Bioeconomy strategies of nine countries: six European [countries (Austria, France, Finland, Germany, Italy and the Netherlands) and South-Africa, Canada and USA](#). (The results of study in English).

Table 6. Overview of studied countries and their main focus of a bioeconomy definition within a national bioeconomy strategy. Score given if at least one of the subtopics is included.

Country	Primary sources (sub-topics e.g. Agriculture, Forestry, Aquaculture, Fisheries)	Manufacturing primary products (sub-topics e.g. bio-based, feed, food, energy productions, novel products, processes, waste)	Future challenges (sub-topics e.g. replacing fossil, climate, pollution, sustainability, circularity, biodiversity, increasing population, benefits, economic growth)	Research and development (sub-topics e.g. science-based, knowledge, bio-technology, developing)
Austria	■	■	■	■
Canada	■	■	■	■
Finland	■	■	■	■
France	■	■		
Germany	■	■	■	■
Italy	■	■	■	
Netherlands	■	■	■	■
South Africa	■	■		
USA	■	■	■	



The objective of the **Finnish Bioeconomy Strategy** is to generate new economic growth and new jobs from an increase in the bioeconomy business and from high added value products and services while securing the operating conditions for the nature's ecosystems. The leading idea of the strategy is that competitive and sustainable bioeconomy solutions for global problems will be created in Finland, and that new business will be generated both in the Finnish and international market, thus boosting the welfare of the whole of Finland.
At more than 16%, the share of bioeconomy in the Finnish national economy is high. The output of the Finnish bioeconomy currently exceeds EUR 60 billion, and more than **300,000 people are employed** in the sector.

Primary production also has an important role **in the transition from the fossil economy towards the bio- and circular economy**. At farm level there are a lot of activities in bioreactor and biogas production, as well solar energy. Good examples are Palopuro Agroecological symbiosis where researchers (University of Helsinki, https://blogs.helsinki.fi/palopuronsymbioosi/english/) and different farms (organic farm, poultry farm, horticulture company) works together and Valio´s carbon neutral mission on dairy sector (see earlier in this text).

5. Notable trends in Digitalisation

Digitalisation can be seen a promotor to achieve:

- Better usage of data, when new technologies create new possibilities to gather, process and deliver the data from several resources (machines, equipments, sensors, drones, open data)
- Better profitability in Agri-business. Data from several Farm Management systems is always on-line available and AI-based applications helps in decision making and managing e.g. optimizing processes like in industry business.
- Better services for farmers in the agricultural sector in their production process including authority affairs
- More reliable, traceable and sustainable (climate friendly) food chain, when data collected from different parts of chain can be used more widely.
- Better accessibility of products of SMEs in our country where we have long distances between towns and countryside

It is estimated that 70 procent of milk produced in Finland is produced by milking robots until 2030. Dairy farmers are very familiar with digitalisation and ready to introduce new applications, services and methods. The future topics in Digitalisation can be divided into three sections:
1) Developing digital applications and operational models at farm level (everyday work)
2) Clarifying the business models and rules in digital business
3) Improving the digital competence in the changing environment

6. Notable trends in business models and soft skills

The food system is global, and many of its actors are large international corporations. The **level of professionalism** in primary production is increasing further, which will encourage integration between different actors in the production chain and structures based on **contract production**. Internationalisation will increase in the production chain.

Subsidies and regulation systems seems to get more complicated. Public voice and social media is blaming the whole agricultural on climate change and brings up new demands on farming systems and animal welfare. This stresses farmers a lot and the **well-being of the farmer** needs to be taken care of more intensive (Kiljunen 2020).

The role of the farmer is **changing into the role of entrepreneur rather than the classic farmer as a way of living.** The developing farm looks more and more like any business, with a strategy, vision, mission, budgets and action plan for short and long time period. The transition is very fast and farmers need more knowledge **in economics and leadership.** Demands for advising is changing as well. Future farmers are more educated and need more specialized advice. The role of an advisor is looking more like a business coach, **working as a consultant using new methods in an interactive way**. There must be more Digitalisation and automatization in "back-office" services to save the human time and costs for that type of work that cannot be done with machines so far.

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Finland Scenarios

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimensions for every scenario. In this table the skill list developed in workpackage 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

Finland: Scenarios sustainable production – key issues

Sustainable paths	Established paths	High-tech paths
• There is a moderate amount of environmentally friendly and sustainable produced meat.	• The overall consumption of meat keeps decreasing. • At the same time the consumption of environmentally friendly produced poultry meat increases.	• Meat is produced in bioreactors and meat factories without live animals.
• The production of plant-based protein as a human nutrient is increasing.	• New plant-based protein products are available at stores. The large group of human beans have not found them yet, but it keeps raising its demand.	• Plant-based raw materials are made into meat-like products to make consumers easier to approach them as "meat substitute".
• A diverse crop rotation increases (includes cereals, special plants, legumes, grasses, etc.). There is a rotation also between field plots, especially between different kind of farms (crop farm and vegetable farm etc).	• New environmental solutions like cultivation planning and operations in growing seasons in a changing climate (profitability, precise farming, environment and carbon farming)	• There is a monoculture in agricultural production. Only a few biomass-efficient crops are cultivated. • Large coherent areas with little diversity.
• Large interest of improving soil health. • The characteristics of the field are known at the zone level: soil type, soil quality, nutrients, etc.	• Soil health is well-known and much debated theme. • Farmers have begun to accept the thoughts of soil health also in practice.	• There are several farmers who doesn't take soil health into account. Monoculture limits biodiversity potential.
• Inputs are used efficiently. • Precision agriculture is supporting the optimal use of resources and circular agriculture. • Recycled nutrients and the necessary number of mineral fertilizers are used in fertilization.	• There is relatively strict restriction using nutrients, although the permitted amount of fertilization bends with the yield. • Livestock farms are using livestock manure from their own farms for fertilization. • Crop farms are not taking enough advantage of using recycled nutrients, but the use is increasing, and better and more processed recycled nutrient products are constantly entering the market.	• Precision agriculture results in high yields and genetic improvements
• The organic production sector is increasing. Organic food is being produced more efficiently and yield levels are rising. • Water and climate emissions are reducing per kilogram of the food produced.	• In Finland, the organic area is growing relatively evenly by the time (13% in 2019), but the share of food production does not correspond to the share of arable land (3% in 2019).	• New technology (machine vision, field robots etc.) is used e.g. in weed management. • There is a full use of precision agriculture also in the organic production. • Precision management strategies for fertilization are used to get more accurate amount of nutrients per plant.
• Arable farming and horticulture are moving towards more climate-friendly, more ecological and more environmentally friendly production.	• CO2 emissions from production are at a reasonable level on a global scale. Phosphorus emissions to water bodies are still a major problem.	• The use of IPM cultivation and biological control is increasing.

Finland: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
▪ There is no more deforesting in Finland and all the waste land is reforested. ▪ There is improvement in the forest growth and carbon sequestration. Food production is more intensified.	▪ In the volumes of the bioeconomy, forestry is dominant in Finland, as 70% of Finland's land area is forest (versus 7% is arable land).	▪ High-tech solutions can reduce the need for biomaterials, freeing up forest area and field biomass for other purposes, such as environmental issues and carbon sequestration.
▪ Oil-based materials have been replaced by sustainably produced bio-based materials. ▪ Bigger amount of wood is used in higher value-added products, such as building construction or the clothing industry.	▪ The use of sustainably produced wood and plant-based materials is still low. ▪ New types of bio-based materials are developed and produced, which are replacing e.g., cotton and plastic.	▪ New technology and innovation is constantly emerging. For example, oil-based unsustainable products are repaired using high technology.
▪ An increase of forest-based bioenergy without a vast loss of biodiversity. There is also great potential for an increase in energy production from agricultural biomass. ▪ The use of dried swamp land as an energy resource is decreasing.	▪ 30% of the energy produced in Finland is bioenergy and most of it is produced with wood. ▪ Agriculture produces some bioenergy, such as biogas and combustible fractions.	▪ Renewable energy solutions replaces completely non-renewable energy sources. ▪ The base for energy production is diverse and decentralized (hydrogen, electricity, wind, gas, nuclear).
▪ New production methods enables improved biodiversity.	▪ The finnish agriculture and forestry needs improvements in biodiversity.	▪ High-tech production improves biodiversity. ▪ Technological development produces more products and services with fewer human resources.
▪ A complete circular economy is achieved. Once the products have reached the end of their life cycle, the materials can be reused.	▪ The production in bio-based products is increasing. ▪ Product development and recycling is more intense, but consumption in the national economy is still largely based on fossil sources.	▪ A complete circular economy with quality products with a long lifecycle.
▪ Carbon sequestration in forests is improved by forest management methods. ▪ There is a maximization of the carbon sequestration potential.	▪ Finnish forests are a major carbon sink. The forest grows is bigger than derestation.	▪ Products are made directly from carbon dioxide using various technologies. Emissions are recovered from their sources and, for example, plastics or any materials are made in them.

Finland: Scenarios business models – key issues

Sustainable paths	Established paths	High tech paths
•Large, highly efficient farms where the production is efficient but environmentally safe. •Speciallised small and medium sized farms who produce premium products *(special plants, meat and cheese)*. •Multifunctional farms which offer for example, *welfare tourism services*.	•Structural development is relatively rapid. There are 45 thousand farms in Finland (2020). The number of business close downs per year is 1000-2000 farms. •At the same time as the number of farms decreases, their average size increases. The total field area will not decrease.	•Farms are even more specialized. •Possibility to acquire larger and more specialized equipment when the farm specializes in a particular production.
•There are strong producer cooperatives that are equal negotiating partners for the processing industry. •Larger trade lots are being negotiated, the quality of operations is improving, predictability is improving, the financial position of producers is improving, the utilization rate of machinery and buildings is increasing, and efficiency is improving.	•New EU legislation calls for more co-operation between farmers and even more producers' cooperatives.	• Negotiations on larger trades dominates the competitive field. •Resource efficiency and scalable synergies are common in the Finnish agricultural sector.
•Food chains are fully outsourced and focused. •Environmental friendliness is emphasized when the quantity of goods is reduced, and resource efficiency is achieved.	•The concept of ownership and sharing economy is changing. Ownership of goods is declining, material is moving more and more, and it is no longer owned. Specialization in owning certain products. •For example, corn cultivation in Finland. No one owns the equipment themselves, but certain people at Berner have ownership from which the equipment moves around Finland.	•Digitization enables smart movement, exchange and use of goods and materials ("Airbnb" and "uber" revolution in agriculture → cloud platforms). •Individuals focusing on a particular plant and a particular specialty who manage large entities.
•On food industry level, besides multinationals still operating, many small and medium size food industries have emerged closely working with farmers for sustainable and local-to-local and artisanal production.	•Safety and quality are key issues in food chain management.	•Joint ventures of food and health industries have emerged swiftly.

Finland: Scenarios digitalisation – key issues

Sustainable paths	Established paths	High tech paths
•Precision agriculture techniques and technologies are widely used on farms and are utilized for proper allocation of resources.	•Data, applications and technology is easily available. •Large scale farms are already utilizing digitalization and knowledge intensive management.	•Work in the fields is handled by autonomous robots, whose effort farmer is controlling remotely.
•The use of data improves the utilization of resources. •When resources are used more efficiently, the environmental footprint can be reduced.	•Data analytics is developing a bit slowly. The farmer needs analytical tools and software to support the decision making. •Data is already used for example in precision management strategies for fertilization.	•The farmer makes decisions about farming activities using various artificial intelligence analysis programs. •Analytics crushes data from the satellite, weather data, soil moisture properties, etc. •Multi copters combine the data and forms snapshots and recommendations for the farmer.
•Digital technologies are integrated in forest management, including biodiversity.	•There is an increase of the request of digital technologies in forest management. •In Finland, all forest resource information is in digital form. Every piece of forest is laser cut and the data is transferred digitally to the buyer directly.	•The technology and applications used in forest management are evolving even better.
•Digitalization and new technologies enables better animal welfare and precise utilization of nutrients.	•By 2030, 70 % of milk produced in Finland is produced by milking robots.	•Intelligent milking robot automation enables better profitability in dairy farms. Integration with Farm Management technology and AI (precise feeding).
•Finnish farmers are using high tech and sustainable farming techniques and technologies in order to improve the efficiency of their day-to-day work (e.g., sensors placed in fields or climate forecasts to predict weather patterns).	•Smart farming and technological innovation in farming are growing. •Data collected is helping combining production and economy.	•IoT sensors are creating a more efficient precision agriculture industry.

Finland: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
▪ Farmers, forestry and food industry employees are highly educated in sustainable business management.	▪ Farmers, forestry and food industry employees are highly educated, in sustainable business management and production economy.	▪ Farmers, forestry and food industry employees are highly educated in business management, entrepreneurship, innovation, strategic and future- oriented thinking.
▪ Collaboration of farmers (in cooperatives/producer organisations), foresters and food industries with public and private knowledge providers of the food system: research organisations, government, NGOs, consumer organisations, etc.	▪ There is a high potential and many expectations for the AgriHub network, which co-ordinates knowledge transfer between research, advising and education sectors.	▪ With co-operation and system intelligence between the AKIS partners competitive and synergy advantage to the whole value chain is achieved.
▪ The Finnish AKIS functions largely independent, EU provides connections between the various systems.	▪ The Finnish AKIS functions day by day in more co-operative way.	▪ Fasilitation and problem-solving skills are key elements in the AKIS- sector. ▪ Integration between data management and emotional intelligence.
▪ Free eLearning platforms are established by NGO's (*e.g.*, *the e-college for regenerative farming*).	▪ Competition is growing in the advisory sector. More and more individual actors and SMEs are involved in the advisory sector.	▪ Equipment suppliers and technology manufacturers have the power to export new knowledge to farmers.

Scenario specific skill needs, Finland (categories from WP1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Sustainability	Sustainability	Sustainability
1.19 Soil nutrient and health management 1.11 By products valorisation (circularity) 1.23 Organic production requirements 1.1 Mitigation and adaption of climate change 1.22 Multifactual forests and ecosystem-services	1.19 Soil nutrient and health management 1.1 Mitigation and adaption of climate change 1.4 Active management of natural resources 1.6 Biodiversity 1.13 Identification of renewable energy systems suitable for the farm / business enterprise	1.3 Improved agri-food system productivity 1.11 By products valorisation (circularity) 1.12 Generation renewable energy 1.5 Integrated pest management 1.8 Environmental Management Systems
Bio-economy	Bio-economy	Bio-economy
.......*Carbon sequestration and carbon balance* 3a.13 Crop diversification and crop rotation 3a.15 Biodiversity 3a. 17 New bioproducts: Biofuels, Bioplastics, Biochemicals, textiles, cosmetics & pharmaceuticals 3b.2 Sustainable forest management practices and planning	...... *Biobased production* ....*Carbon sequestration* 3a.15 Biodiversity 3b.2 Sustainable forest management practices and planning 3b. 3 Reforestation, afforestation and restoration of forest ecosystems	...... *Carbon balance methods and calculations* 3a.19 New industrial crops and bioproducts 3b.8 Products of forestry: high quality logs.... 3b.12 Automation in the pulp, paper, timber and cork industry 3a.18 Biofertilizers, compost, bio digestates
Digitalisation	Digitalisation	Digitalisation
Precision farming techniques and technologies 2.1 Everyday usage digital technology 2.5 Smart connected devices 2.8 Digital information and services 2.19 Field operations management system	*Precision farming techniques and technologies* 2.1 Everyday usage digital technology 2.17 Farm management information system 2.19 Field operations management system 2.2 Data handling and analysis	2.24 Robot and drone technology in agriculture 2.17 Farm management information system 2.2 Data handling and analysis 2.19 Field operations management system 2.4 Cloud technology
Business model	Business model	Business model
4.16 Networking 4.18 Digital tools to support learning and distance learning 5.25 Farm environmental management plan 5.10 Cooperatives (value, legal framework and management) 4.22 STEM knowledge	4.16 Networking 4.20 Learning continuously 5.7 Business planning/model and strategic management 5.12 Collaboration/cooperation across all sectors 4.15 Managing personnel	*System intelligence* 4.20 Learning continuously 5.7a Scenario/foresighting/forecasting 5.7de Knowledge and stakeholder management 5.7c Key Performance Indicators (KPI)

o Annex 3.4 Austria: trend and scenarios country study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

1. **Sector structure**

Austria has a total area of 8,39 Mio. ha. There are approximately 160.000 agricultural and forestry holdings (figures 2016) which are managing 7,26 Mio ha (arable land, grassland, forests]. Since 1999 approximately 54.000 farms broke up their operation. This process is still ongoing. There are big differences concerning the farm types. There are specialized vegetables, fruits producing or viticulture farms, farms with arable land only, mixed farms (arable land, grassland and animal production) and in the mountainous regions in western and south Austria dairy farms with forestry.

	1999	2016
Agricultural and forestry holdings (total)	215.224	161.317
Full time business farms	80.046	57.447
Part time business farms	127.441	89.352
Companies, cooperatives	7.737	14.518
Average size [ha/holding]	34,9	45,0
Managed area (arable land, grassland, forests), [Mio. ha]	7,52	7,26

[Statistisches Jahrbuch Österreichs 2021, Kap. 17]

There are presently more than 24.000 organic farmers in Austria. That is 22 percent of all farmers. 26 percent of the utilised agricultural area (670.000 hectares including Alpine pastures and mountain meadows managed according to organic farming criteria) are managed according to the criteria of organic farming. About 20 percent of the livestock farms are managed according to organic farming principles, 38 percent of all suckler cows and 20 percent of the dairy cows are kept in organic farms. Half of the goats held in Austria are in organic farms. In sheep keeping the organic share amounts to about 28 percent. [Grüner Bericht 2020, Tab. 2.4.1.] [BMLRT: Organic Farming in Austria; reprint 2020; page 36]

A big more and more addressed challenge is that approximately 13 ha of farmland are lost daily. These areas are used for roads, buildings, shopping centres, etc.

In 2019, the primary sector contributed about 1,3 % to the gross value added of Austria's national economy. According to the preliminary results of the Agricultural and Forestry Accounts the production value of agriculture and forestry amounted to approx. 9,64 billion euros in 2019. Of this amount, 7,48 billion euros accounted for agriculture and 2,16 billion euros for forestry. [Grüner Bericht 2020, Summary]

<u>Agriculture</u>

In the following table figures for the main field crops and grassland are listed. The values are the respective cultivated area in the years 2000 and 2019.

	2000	2019		2000	2019
	[tsd ha]			[tsd ha]	
Wheat	293,8	277,3	Sugar beet	42,8	27,9
Rye	52,5	43,7	Soy bean	15,5	69,2
Barley	223,8	137,2	Rape	51,8	36,0
Triticale		59,8	Clover	70,2	78,9
Oats	33,00	20,6	Silage corn	74,0	85,7
Corn	187,8	220,7	Egart	56,8	53,1
Potato	23,7	24,0	Grassland		753,8

[Statistisches Jahrbuch Österreichs 2021]

In these nearly two decades a strong decrease can be observed for barley, sugar beet and rape. On the other hand the areas for corn and soy bean show the biggest increase.

Furthermore some 45 600 ha of vineyards and 14 100 ha of fruit growing plantations are cultivated.

Concerning animal production several essential figures are shown in the following table. In general the number for bovines and pigs decreased in the last two decades. A great number of farms have finished their animal production.

	2000	2019	change
	[tsd pieces]		[%]
Bovine	2155,4	1879,5	-13
Pigs	3347,9	2773,2	-17
Sheep	339,2	402,7	+19
Goats	56,1	92,5	+65
Chicken	11077,3	n.a.	--
Poultry	709,3	n.a.	--

<u>Forestry</u>

The actual Austrian forest area is approximately 3,4 Mio. ha. The annual forest area growth is around 4.500 ha. The total annual wood increment is 32 Mio. solid cubic meters. In average 18 to 20 Mio. solid cubic meters of wood are harvested. Due to dry conditions and higher temperature mainly in the north eastern part of

Austria (Lower and Upper Austria) the bark beetle is causing huge damages in spruce forests. The price for round wood is under big pressure.

Bio-economy

The wood based bio-economy is a powerful sector in Austria. Besides construction wood, fibre boards, paper and textile fibre production are well established as well as the energetic use of the by-products. Austria is the second biggest importer of round wood. [https://www.forstholzpapier.at/index.php] [https://www.lenzing.com/]

Further branches are the sugar and starch production as well as the production of vegetable oils. There are few bigger oil mills and a lot of small individual farms and cooperatives who are producing vegetable oils (rapeoil, sunfloweroil, special niche products – Styrian pumpkin seed oil, etc.). [https://www.agrana.com/en/] [https://pflanzenoel-austria.at/ueber-den-bpa.html]

2. Agricultural Knowledge and Information System (AKIS)

The Austrian AKIS relies on strong public support, reaches out to almost all farmers in the country and covers a wide range of topics in training, research and development. It rests on 3 cornerstones: a) an education system built on vocational, secondary and adult education, b) a wide range of advisory services, and c) close cooperation between research and development with practice as well as education. Austria is unique for its agricultural vocational education building on an apprenticeship system and combining both general and specific agricultural education and practical experience. Noteworthy are the Federal Colleges and Research Institutes which unite teaching, applied and research competence under one roof. The 9 Chambers of Agriculture are the backbone of Austria's AKIS since they provide for around 75 % of all extension services and – in cooperation with their own training institute – adult training activities. The Federal Institutes and Offices cover a number of issues of public and private interest. Farmer associations and NGOs provide services on very specific topics and in niches. Private organisations play only a minor role. The AKIS plays an important role to help the development of agriculture in Austria. In view of the evolving social, environmental and global challenges the AKIS is required to adapt. Stepping up cooperation and information flow among actors, taking on issues of social and public interest, further increasing the level of education of farmers, considering a methodological and systemic review of the AKIS, and securing its financial base are some challenges the AKIS is confronted with in Austria. [https://proakis.webarchive.hutton.ac.uk/sites/proakis.hutton.ac.uk/files/Country%20Report%20Austria%2002%2006%202014.pdf]

The general trend in agriculture and forestry is that there is a need for lifelong learning as in any other branch. That means that knowledge updates and new ways of knowledge transfer have to be developed and used. In Austria are several institutions which are offering webinars, farminars and advice. [https://www.lko.at/] [https://www.lfi.at/] [https://oekl.at/]

3. Notable trends in sustainable production

Environmental pollution

The future challenges are the steady concentration and growth of animal production farms in favoured regions with the manure management, odour emissions and air pollution. The optimization of the applied type and amount of fertilizers and pesticides is a steady target for reducing costs and environmental pollution (air, soil, water).

Animal welfare

There are several national and European laws and regulations which are addressing animal welfare. Recurrent controls and audits are installed. Special brands or seal of approval programmes, especially in organic farming, are supporting animal welfare too. [https://amainfo.at/] [https://www.bmlrt.gv.at/land/bio-lw.html]

Protein sources

The protein sources for the animal production is based to approx. 80 % on national plant production. To reduce the import of soy meal the so called "Donausoja" initiative has been started [https://www.donausoja.org/de/home/].

Biodiversity

To support and strengthen the biodiversity is one of the main pillars of the European green deal. There are several ongoing research projects in which the development of e.g. the insect population is analysed. The intensity of grassland utilisation has a higher impact on the number of insect species or birds than a conventional or organic production. [https://www.zukunftsraumland.at/veranstaltungen/9656/]

The general required goal to set 10 % of the whole agricultural and forest area out of production is not supported by the Austrian agricultural chamber.

In Austria, around 16 percent of the federal territory is strictly protected as a Natura 2000 area, national park or nature reserve. [https://www.oerok-atlas.at/oerok/files/summaries/64.pdf]

Forestry

The climate change is effecting the Austrian forests heavily. Especially the Nordic spruce forests are threatened by the bark beetle in north eastern Austria. Recently a 350 Mio. Euro supporting programme for the Austrian forest sector has been started. Several measures are addressing the creation of a so called "climate fit forest" with tree species which withstand draught and higher temperatures. [www.waldfonds.at]

4. Notable trends in Bio-economy

The general objective of the bio-economy is to use a raw material (e.g. round wood) as far as possible. Beside the main product also the residues and side streams of the production are used for biomass based products and energy. This principle is generally acknowledged, realized and optimized since decades.

The Austrian Bioeconomy Strategy act as a framework for the reinforced use of renewable raw materials. Bioeconomy aims to replace fossil resources (raw materials and energy) with bio-based raw materials in as many areas and applications as possible. It covers all industrial and economic sectors that produce, process, handle or use biological resources. Finally, bioeconomy is aiming to create economic value and prosperity as well as solutions for environmental issues throughout low carbon and renewable materials. Among Austrias strongest fields are for instance the paper and pulp industry, the wood-based sectors, the chemical industry such as fibres, plastics or biofuels as well as the use of bioenergy.
[https://www.bmk.gv.at/en/topics/climate-environment/climate-protection/bioeconomy-strategy.html]

The Austrian know how in realizing high wooden building has been demonstrated with the "HoHo-Haus" which was for a short period the highest wooden skyscraper worldwide. [http://www.hoho-wien.at/Standort/Smart-City?lang=en]

Last year the objective of a “fossil free agriculture and forestry” was launched. Especially concerning the transportation fuels this sector is dependent heavily on fossil resources. In a study information about the suitable technique of gasification and different downstream processes (Fischer-Tropsch synthesis – “Holzdiesel”; Synthetic natural gas – SNG, Holzgas; renewable Hydrogen) have been shown. For covering the whole amount of transportation fuels and natural gas used in this sector ten 100 MW gasification plants demanding for 3,3 Mio. solid m^3 wood are needed. [https://www.dafne.at/dafne_plus_homepage/index.php?section=dafneplus&content=result&come_from=homepage&project_id=3769]

A crowing branch is also the production of herbs for health supporting substances and raw materials for the pharmaceutic industry e.g. pickled thistle [https://www.waldland.at/de]; CBD-oils from Cannabis [https://biobloom.at/].

5. Notable trends in Digitalisation

The first considerations and trials in precision farming started several decades ago. At the beginning big farms cooperated with scientists and agricultural machinery manufacturers. Meanwhile all manufacturers of agricultural machinery have integrated different tools for data collection (e.g. sensor data from the machinery combined with georeferenced data, properties of harvested crops, amount of harvested crops). These collected data are further processed and used for reporting and planning.

Digitalisation plays an important role in Austrians agriculture, the same like in other counties and other branches. Due to the small sized farms structure digitalisation did not really arrive in practice in predominant number of farms so far. This considering a platform “Digitalisation in Agriculture” has been established in the Ministry of Agriculture in 2017. Aim of the working group was to define the state of the art of digitalisation in agriculture and the further necessary steps. The main results were published in a report in November 2019 including the status quo of digitalisation in different areas and recommendations for actions as well. Besides others, the main results are:

- Installation of a digital test and experimentation farm for digital developments in agriculture
- GNSS correction signal for RTK (=real time kinematics)-receiver free of charge
- Improved data management in animal husbandry
- Development of simplified methods for environmental assessment
- Clarification of legal aspects in dealing with agricultural data
- Improved access on Open Government Data.

[https://www.bmlrt.gv.at/service/publikationen/land/digitalisierung-in-der-landwirtschaft.html]

Some of the recommendations are realised already:

- In 2020 the Austrian “Innovation Farm” has been started [www.innovationfarm.at]. The innovation farm demonstrates new technological and digital developments for a better understanding in practice.
- The GNSS correction signal for RTK is offered free of charge since February 2021
- Projects were started aiming at animal husbandry data, environmental assessment, legal aspects of data,…

Notable trends at farm level:

- Use of automatic guidance systems: Due to public means many farmers invested in guidance systems which become more important for precision farming application
- Farm management and information systems (FMIS): The interest in FMIS systems in arable farming is low due to many small farms and less benefits. Otherwise digital recording via FMIS is common used in animal husbandry (dairy, hog feeding,..)

- Interest in precision farming applications like in site specific fertilizer management is improving now. More and more farms start with the creation of fertilizer maps based on satellite data.

6. Notable trends in business models

New special machinery is very costly. For reaching more operating hours per year and getting some possible additional income the idea of the machinery services [www.maschinenring.at] has been developed many years ago. There is a network over the whole country. More and more special services are offered e.g. garden maintenance, winter service etc.

As there is a steady decrease of workers in the agricultural and forestry sector more and more cooperation, cooperatives and limited companies and other creative business models are coming up. The sales via internet ordering are increasing rapidly e.g. [https://myproduct.at/].

Due to the COVID 19 pandemic the from the farm sales and 24/7 self service sales possibilities are increasing. Also the marketing of these businesses is getting more and more professional, e.g.

[www.lebensmittelpunkt-efi.at].

Since several decades the owners of forests installed district heating plants mainly fuelled with wood chips. These entrepreneurs are accompanied by professional advice organisation and planning engineers. New technologies are combined heat and power plants. [https://abina.biomasseverband.at/]

7. Summary

Following the trends and challenges are summarized which are subjects to improve the skills of employees of these sectors:

- The European Green Deal has several targets and discussion points which are interacting with agriculture and forestry e.g. decarbonisation of the whole industry, reduction of green house gases (CO_2, CO_2-equivalents) trough renewable energy utilisation etc.
- Number of farmers and farms decrease.
- How to interest and involve young and skilled people for agriculture and forestry?
- Optimization of fertilizers and pesticides (type, amount, application time and techniques) Digitalisation
- Combinations: Agriculture and Forestry Agroforestry; Agriculture and renewable Energy Agrar-PV; Forestry and heat and power delivery.
- Internet of things: Marketing and Organisation of direct sales.

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Country scenarios Austria

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimension for every scenario. In this table the skill list developed in workpackage 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

Austria: Scenarios sustainable production – key issues

Sustainable paths	Established paths	High-tech paths
▪ High social and environmental consumer awareness exists. Consumers prefer local products including traditional vegetables.	▪ Cost, taste and convenience are most important product attributes for consumers. Niche markets for local and traditional foods remain but have a small market share. Consumption of meat remains high.	▪ Consumers value healthy and personalised (functional) processed foods. Meat consumption is high.
▪ Livestock levels have been decreased by 30%, arable land by 5%.	▪ Livestock levels decrease by 10%, arable farming by 5%. Intensive livestock production is under strict regulation.	▪ Livestock levels decrease by 5%, arable farming by 5%. Large intensive production prevails.
▪ Throughout agriculture biodiversity has improved through mosaic/strip crop planting, flower borders, diversified crop rotations etc. Nitrogen levels of Natura2000 areas are well below critical levels.	▪ Biodiversity has moderately improved since 2020. Nitrogen levels of Natura2000 areas are well below critical deposition levels.	▪ Biodiversity levels have deteriorated. Nitrogen levels of Natura2000 areas are at 2020 levels.
▪ Livestock sector has invested in sustainable and circular production. Livestock production systems with free run-out options for animals are common. Mainly local sourcing of feed.	▪ Livestock sector has invested in sustainable production. Livestock production systems with free-range (indoor) options for animals are common. Feed sourcing is combined local and global.	▪ The livestock sector has invested in technology for sustainable and circular (indoor) production, focusing on limitation of emissions. Feed sourcing is globally oriented.
▪ Use of antibiotics has been individualised and minimized.	▪ Use of antibiotics has decreased at moderate pace.	▪ Use of antibiotics has been completely individualised.
▪ A strict EU+ animal welfare policy has been implemented for slaughterhouses (resting locations, slaughter pace, stunning). ▪ Mobile individual on-farm slaughtering systems are available.	▪ Slaughterhouses comply with EU legislation.	▪ Slaughterhouses comply with EU legislation.
▪ Arable farming has moved to agro-ecological climate smart production techniques and application of bio-pesticides and organic fertilizers, supplied by the livestock sector.	▪ Arable farming increases the use of bio-inputs next to use of chemical pesticides and synthetic fertilizers which decrease moderately due to EU legislation.	▪ Arable farming uses optimal mix of bio- and chemical inputs, based on economic incentives to ensure high yields.
▪ The food industry is strongly moving towards circular production. The connection with the consumer base (e.g. through product information and promotion) has been strengthened.	▪ Food industry slowly moves to more circular production. Connection with consumers is through retailers.	▪ Product innovations are strong and continuous, focusing on functional foods, healthy food, 3D food printing. Food industry moves to circular production as far as this is of economic interest. Strong connections in the supply chain are very important to manage global food chains and assure safety and quality of products.

Austria: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
▪ Austrian agriculture and forestry have made a strong move towards circular production with optimal use of by-products and waste streams.	▪ There is only moderate development towards circular production in Austrian agriculture.	▪ High tech agriculture and precision farming lead to a strong move towards circular production (the rationale for changes is economic).
▪ Agriculture contributes to a fast growing biobased sector (e.g. to chemical industries). Decentralised bio-refinery and renewable energy installations exist.	▪ Agriculture only contributes to a limited extend to biobased production.	▪ The biobased sector (chemicals, plastics) has grown fast, supported by biomass from agriculture.
▪ Agriculture is self sustaining in energy production through production of biomass, biogas, wind and solar energy, and delivers a considerable part of the Austrian energy needs.	▪ Agriculture is still partly dependent on fossil based energy sources, supported by renewable energy sources which are also supplied to some niche markets.	▪ Agriculture is still strongly based on fossil fuel, however supported by cost-effective renewable energy production.
▪ Biobased chemical, pharmaceutical and rubber/plastics sectors are an important part of the Austrian economy. Sector is closely linked to farming; production partly by SMEs.	▪ Biobased chemical, pharmaceutical and rubber/plastics sectors have moderately increased in importance.	▪ Biobased chemical, pharmaceutical and rubber/plastics sectors are an important part of the Austrian economy. Production in large industries.
▪ Forest acreage has been increased. Sustainable forest management with certified wood production is common. ▪ Degraded land has been afforested. Forestry strongly contributes to biodiversity.	▪ Forest acreage has increased. Planting of trees in urban and rural settings increases.	▪ Forest acreage has increased moderately. Degraded land has been afforested. Forestry and agriculture are functioning separately.
▪ Sustainable produced wood is a major raw material for construction wood, pulp and paper and renewable energy purposes.	▪ Sustainable produced wood is a major raw material for construction wood, pulp and paper and renewable energy purposes.	▪ Sustainable produced wood is a major raw material for construction wood, pulp and paper and renewable energy purposes.
▪ The food industry has moved strongly to circular production supported by new technologies, including the introduction of sustainable packaging materials.	▪ The Austrian food industry is largely dependent on fossil fuel energy sources and struggles with valuation of by products and handling of waste streams. Slow move to sustainable packaging.	▪ The Austrian food industry is moving swiftly to smart factory solutions where use and recycling of resources is based on economic incentives alone. Intelligent packaging lead to lower cost production with less waste.

Austria: Scenarios digitalisation – key issues

Sustainable paths	Established paths	High tech paths
▪ Precision agriculture to support optimal use of resources and circular agriculture in small scale sustainable production systems is common in Austria.	▪ Precision agriculture is used in many subsectors to optimise use of resources in, particular, large farms. There is limited attention to circular production.	▪ Precision agriculture to support optimal use of resources and circular agriculture in large farms is common in Austria.
▪ Precision agriculture results in ecological intensification. Losses and waste are minimized.	▪ Precision agriculture, moderately, results in improved fertilization efficiency.	▪ Precision agriculture is broadly used in large and medium farms. It results in higher yields, losses and waste are minimized.
▪ Digital technology and systems also enable optimal connection to chain partners and consumers (e.g. through social media). Local (complex) traceability is supported by traceability systems.	▪ Although, collaboration between farmers and food industry remains limited, traceability and supply chain information systems have become a main field of attention.	▪ Digital technologies support a solid connection between the farmers and food industries so as to ensure a fast and flexible flow of products and assure safety and traceability in long food chains. Production is transparent for costumers.
▪ In the Austrian food industry application of robotization and AI have led to smart factories supporting efficient use of resources and circularity of production.	▪ The pace of robotization and AI applications in food industries is moderate.	▪ Smart factories are common in the Austrian food industries. Production is circular if economically viable.
▪ Digital technologies ensure transparency of production for consumers and partners in the food chain.	▪ In this scenario overload of product information for the consumer emerges, often implying misleading information.	▪ Digital technologies support personalised solutions for individual consumers.
▪ Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection and supply chain management applications	▪ Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection and supply chain management applications	▪ Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection and supply chain management applications

Austria: Scenarios business models – key issues

Sustainable paths	Established paths	High tech paths
▪ Concentration of farming has come to a halt. Austrian agriculture is characterised by medium size and small family farms focusing on ecological production in balance with landscape and nature.	▪ There is further concentration of the farming sector with large farms along small and medium sized farms.	▪ Strong concentration of farms, move away from family farms to corporate farms. Monocultures remain, although sophisticated inputs try to keep fertility of the soil and emissions low.
▪ Far most of the farms are multi-functional with side activities in direct sales, energy production, tourism, health care, etc.	▪ There is a combination of large specialised farms with small-medium size farm. Small and medium size farms are in many cases multifunctional.	▪ Large specialised farms make up the Austrian agriculture. Multifunctional farms have largely disappeared.
▪ Collaboration of farmers in cooperatives and producer organisations has further increased. ▪ Local-to-local production is common and most farms participate in (online) sales and self-service shops to consumers in short , local, food chains.	▪ Further collaboration in local-for-local producer organisations is limited. Sourcing is combined local and global.	▪ Agricultural production and consumption is globalised. ▪ Products are produced where this is most cost efficient.
▪ On food industry level, besides multinationals still operating, many small and medium size food industries have emerged closely working with farmers for sustainable and local-to-local and artisanal production.	▪ Food industry is concentrated in multinational companies. Collaboration between (large) farmers and food industries has increased. Safety and quality are key issues in food chain management.	▪ Food supply chains have advanced storage and logistics facilities and work in strong collaboration with (large) farms. Safety assurance and traceability systems are of key importance. ▪ Joint ventures of food and health industries have emerged swiftly.

Austria: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
▪ Farmers, forestry, wood and food industry employees are highly educated, in sustainable business management and ethics.	▪ Farmers , forestry, wood and food industry employees are highly educated in sustainable business management.	▪ Farmers, forestry, wood and food industry employees are highly educated, in business management, entrepreneurship and innovation.
▪ The Austrian AKIS is well organised, specific AKIS-subsystems exist in various sectors and regions. ▪ Regional peer groups are dealing with specific upcoming questions and challenges (e.g. viticulture).	▪ The Austrian AKIS is characterised by upscaling and intensification, going together with increasing private investments in knowledge and innovation.	▪ European AKIS is centralised and strongly interconnected and has a highly technical orientation. ▪ Intellectual property rights are key in investment decisions.
▪ The Austrian AKIS functions largely independent, EU provides connections between the various systems.	▪ The Austrian AKIS functions largely independent, EU provides connections between the various systems.	▪ The Austrian AKIS is integrated with European AKIS. Minor role for government(s).
▪ Collaboration of farmers (in cooperatives/producer organisations), foresters, wood and food industries with public and private knowledge providers (research organisations, government, NGOs, consumer organisations, etc.) is established.	▪ Collaboration of farmers, foresters, wood and food industries with public and private knowledge providers exists. The knowledge has been largely commercialised.	▪ Collaboration of (large) famers, foresters, wood and food industries with private knowledge providers/R&D suppliers prevails. Role of public knowledge organisations is limited.

Scenario specific skill needs, Austria (categories from WP1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Sustainability	**Sustainability**	**Sustainability**
1.6 Biodiversity 1.11 By-products and co-products valorisation 1.12 Generation renewable energy 1.19 Soil nutrient and health management 1.21 Protective role of forests in mountainous areas	1.1 Mitigation and adaptation to climate change 1.2 Efficient use of resources and logistics 1.5 Integrated pest management 1.11 By-products and co-products valorisation 1.18 Water management	1.3 Improved agri-food system productivity 1.7 Sustainable metrics and certification 1.15 Identification of energy consumption 1.22 Multifunctional forests and ecosystem-services 1.25 Sustainable packaging
Bio-economy	**Bio-economy**	**Bio-economy**
3a.8 Organic farming 3a.19 New industrial crops for bioeconomy 3a.25 Plant and animal breeding for resilience 3b.16 Forest disease control and prevention 3c.15 Food security	3a.7 Product traceability 3a.8 Organic farming 3b.2 Sustainable forest management practices 3b.16 Forest disease control and prevention 3c.18 Food labelling/certifications	3a.12 Controlled Environment Agriculture 3a.21 Livestock efficiency/management/biosecurity 3b.6 Calculating, handling and managing risks 3c.10 Continuous improvement 3c.13 Management of inventories
Digitalisation	**Digitalisation**	**Digitalisation**
2.1 Everyday usage digital technology 2.2 Data handling and analysis 2.14 Digital pest control systems (robots) 2.17 Farm management information systems 2.18 Precision animal health system	2.1 Everyday usage digital technology 2.2 Data handling and analysis 2.6 E-commerce and e-marketing 2.8 Digital information and services 2.18 Precision animal health system	2.4 Cloud technology 2.8 Digital information and services 2.18 Precision animal health system 2.19 Field operations management systems 2.24 Robot and drone technology in agriculture
Business model	**Business model**	**Business model**
4.5 Being resilient, adaptable and proactive 4.16 Networking 4.19 Learning at work 5.11 New value chains 5.12 Collaboration/cooperatives across all sectors	4.1 Communication 4.3 Analytical, critical and creative thinking 5.7 Financial business planning 5.15 Funding opportunities 5.17 Project management	4.7 Equality skills 4.15 Managing personnel 5.11 New value chains 5.21 Protection intellectual property rights 5.23 Specific sector legislation

o Annex 3.5 France: trend and scenarios study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

1. Sector structure

Agriculture & food industry

France has a strong agri and food sector: production and processing activities related to agriculture, forestry, fisheries and agri-food industries (AFI) employ 1.4 million people (employed and self-employed) in full-time equivalent (FTE) in 2019, or 5.2 % of total national employment.

In 2019, French farms produced €68.7 billion worth of agricultural products. With a share of 17.2 % of the production in value terms of the EU 28 (and 18 % of that of the EU 27), France is the leading European producer. In 2018, agriculture covers 46 % of the 63.8 million hectares of French territory, including the overseas departments (DOM). The land devoted to agriculture is mainly cultivated areas and areas still under grass, but also livestock buildings, for example.

In 2016 (most recent available data), there was 436,000 farms in mainland France. This number fell by more than half in 30 years. Since 2010, the number of farms has been declining by an average of 1.9 % per year. But the situation differs according to the economic size of the farms. Between 2010 and 2016, the number of employees fell by around 4 % per year for small and medium-sized farms, while rose by 2 % for large farms. Large farms are now the most numerous (42 % of the workforce) and provide 87 % of the agricultural production potential. In 2016, in metropolitan France, 64 % of farms are sole proprietorships and 36 % are incorporated. The number of individual farms (278,000) has fallen by 19 % since 2010, a greater decline than that of all farms (-11 %). Individual farms are in the majority except for cattle, dairy or mixed farms, and pig and poultry farms. Individual status predominates on small and medium-sized economic farms (95 % and 78 % respectively) but is less common on large farms (32 %). In France, an average farm has 62 hectares. This is 7 hectares more than in 2010. Large farms, in the economic sense of the term, cultivate 74 % of the agricultural surface area. They use an average of 111 hectares, i.e. around 60 hectares more than average farms. Small farms value only 5 % of the UAA and have an average of 11 hectares[15].

Forestry

According to the National Institute of Geographic and Forest Information, the forest in metropolitan France covers 16.8 million hectares or 168,000 km2 (figures for the 2018 campaign), which corresponds to an afforestation rate of 31 % of the territory. It includes 136 species of trees. In the overseas departments, the figures differ according to sources (Ministry of Agriculture, DAAF) but the following figures can be put forward: French Guiana has almost 83,000 km2 of Amazonian forest, i.e. 96 % of its surface area; Reunion Island: 1,370 km2 of forest (53 % of its surface area); Martinique: 490 km2 of forest (46 % of its surface area); Mayotte: 140 km2 of forest (37 % of its surface area); Guadeloupe: 640 km2 of forest (39 % of its surface

[15] https://agreste.agriculture.gouv.fr/agreste-web/disaron/BulConj/detail/

area). In total, metropolitan France and the French overseas departments and territories therefore have 255,640 km2 of various types of forest, i.e. 38.10 % of the country's total surface area (approximately 670,922 km2). The French State owns 10 % of this forest (state forest), local authorities 15 % and private owners, who number 3.5 million, 75 %. The average surface area of the private forest is 3.3 hectares[16].

The French forestry sector represents 440,000 direct and indirect jobs. The Forestry sector is present on many current markets: forestry and forest mobilisation (for a turnover of 2.6 billion euros), woodworking (sawing, carpentry and joinery, veneer, panels, parquet flooring and pulp for 13 billion euros), consumer goods (wood processing, construction, furniture, paper, and cardboard for 42 billion euros) and wood energy (for 2.7 billion euros excluding wood-logs)[17].

Bioeconomy

The French national strategy on the bioeconomy dates from January 2017, and integrates all sources of biomass (agricultural, forest-wood, marine and aquaculture sectors), food and non-food use, the involvement of public and private stakeholders, the agro-ecological approach, and cutting-edge technologies such as industrial biotechnologies, research and development, dialogue with society, and consideration of the entire value chain with stakeholders upstream and downstream of production.

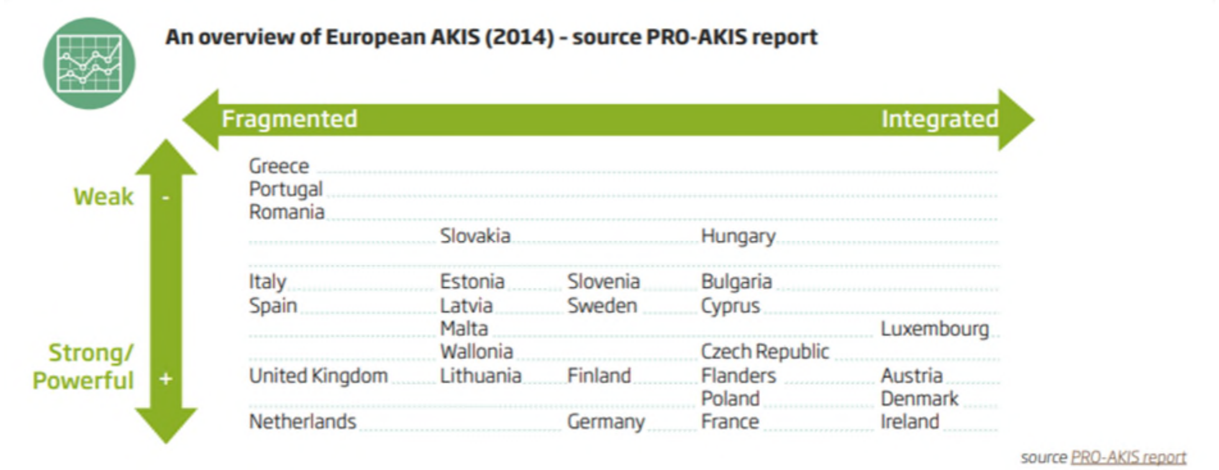
All bio-based industries supply around 5 % to 6 % of the French national consumption of energy, chemicals, and materials. These performances are expected to double by 2030-2040. France is already probably among the five most "bio-economic" nations in the world, with a significant contribution of bio-based industries to France’s energy and climate "roadmaps" (Energy Transition Law, COP 21). The bioeconomy in France generates significant positive externalities, including jobs created and "carbon avoided". Among a volume of bioeconomic jobs that can be evaluated in France, in the broad sense, at around 1,900,000 people (including agriculture, agri-food and the forest-wood sector), a total of ± 100,000 direct jobs linked to the bioeconomy is considered. Most of these 100,000 jobs would have been created over the past 20 years. Bioeconomy in France represented in 2018 a turnover of 316 € mld[18].

[16] https://agriculture.gouv.fr/sites/minagri/files/cgaaer_15056_2016_rapport.pdf

[17] https://fbie.org/foret-bois-filiere-davenir-france/

[18] https://www.lafranceagricole.fr/r/Publie/FA/p1/Infographies/Web/2018-10-23/Bio%C3%A9conomieAgrid%C3%A9es.pdf

2. **French AKIS (Agricultural Knowledge and Information System)**



The French agri- and food sector is considered to be both strong and integrated[19] : French agriculture is innovative and technologically advanced, with numerous agri-food schools and scientific centres focusing on its improvement: Agricultural education in France brings together more than 465,000 pupils, students, apprentices and trainees, and the average educational level of new farmers tends to rise. For the last twenty years or so, the level required to be authorised to start one's own farm has been level 4, or vocational baccalaureate, which is taken over three years, but more and more farmers are presenting a level 3 diploma (BTS) or even higher. The French agri- and food sector is also integrated, with powerful agricultural collectives and federations, and a common national vision. The collaboration between farmers is important, and farmer's networks are a raising trend in France.

3. **Challenges faced by the French Agricultural, Forestry and Bio-economy sectors**

At the end of December 2020, the European Commission published its recommendations for the national strategic plans under the Common Agricultural Policy (CAP). These strategic plans, which are expected to be finalised in early 2022, will enable each Member State to implement the new CAP from 2023 onwards.

To make its recommendations, the Commission has drawn up an inventory of French agriculture's challenges in economic, social and environmental terms.

Economic challenges:

- The income is unevenly distributed among different farmers and territories,
- The markets are increasingly subjected to price volatility,
- The farmers have a weak bargaining power in the value chain,
- There is an investment deficit, and the competitiveness is declining.

Environmental challenges: The size of the agricultural and agri-food sectors in France, and in particular the high share of livestock in agricultural production, poses several urgent environmental and climatic challenges. Livestock farming is also a major source of ammonia emissions, and France risks not meeting its emission reduction commitments for 2020-29 and for 2030 and beyond. According to the Commission, the priority is to combat the trend towards soil sealing and the shrinking of permanent grassland. "Agroforestry practices

[19] https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip agri_brochure_knowledge_systems_2018_en_web.pdf

could enhance the role of pastures and grasslands as carbon sinks and possibly strengthen the resilience of the agricultural sector. In addition, grasslands are essential for extensive livestock systems, which have a smaller environmental footprint," the EU executive analysed.

Among the various environmental challenges, water quality is also quoted by the European Commission: France has not achieved the Water Framework Directive objective of good status for all water bodies. On the issue of pesticides, although France has set ambitious objectives with the Ecophyto plans, it is struggling to reverse an upward trend and efforts will be needed to promote the use of low-impact pesticides. The preservation of biodiversity remains a challenge in many French agricultural areas. The state of conservation of agricultural habitats (grasslands) is widely assessed as unfavourable/inadequate or poor, whereas only 20 % of grasslands have a good state of conservation. There is a need to improve ecological connectivity (with hedges and other landscape features), protect plants and animal species characteristic of farming environments (birds, flora, pollinators...) and manage agricultural land in Natura 2000 sites.

4. Global trends in sustainable production

Animal welfare

Animal welfare is a growing concern in France: 85 % of French people say they are prepared to consume less meat and pay more for it if it comes from farms that respect animal welfare (NGO CIWF France with Ifop).

The desire of consumers to guide their consumption choices by taking animal welfare into account is reflected above all in the emergence and growth of the flexitarianism trend. According to 3W.relevanC, two entities of the Casino group, and OpinionWay, around 28 % of French people are in favour of this type of consumption, which consists of reducing the amount of animal proteins in the diet and increasing the number of proteins of vegetable origin, without eliminating meat.

A strategy has been initiated by the French Ministry of Agriculture and Food with the aim of placing "animal welfare at the heart of a sustainable activity" by making all those in contact with animals (breeders, veterinarians, transporters, farm technicians, slaughterhouse employees, etc.) responsible. To ensure its success, an action plan is implemented and is made up of different axes[20] (Create a French national animal welfare reference centre, encouraging innovation, raising stakeholders' awareness, Pursue the evolution of practices towards more animal-friendly production…).

Appearance of the "animal welfare" label: according to the CASDAR ACCEPT 2014-2017 project survey, 96 % of French people are in favour of labelling meat and dairy products according to the farming method. To answer this growing demand, several independent labelling methods have emerged, and are still under development (The French SME Obione, a specialist in animal nutrition, has developed an approach to measure the proper treatment of farm animals: the Happy label[21], the Casino chain, in partnership with CIWF France and two animal protection organisations, has set up a label that allows you to find your way around the living conditions of the animal thanks to different levels (A, B, C or D)[22].

[20] https://agriculture.gouv.fr/2016-2020-une-strategie-globale-pour-le-bien-etre-des-animaux-en-france

[21] http://www.happy-production.com/

[22] https://www.ciwf.fr/actualites/2018/12/lancement-du-1er-etiquetage-sur-le-bien-etre-animal

Forestry

Sustainable forest management can both contribute to the development of the bioeconomy and provide ecosystem services. Despite the large area covered by forests (31.5 % of the total territory), many French forests are not actively managed. This can hamper their role as carbon sinks, their resilience to extreme weather conditions and the provision of other goods and services. More attention must be given in the following years to the management of the forests.

Two major trends are emerging in the forestry sector in France for a virtuous, structured, modernised, and competitive forest-wood sector: i) Developing a competitive, high-quality resource by managing forests sustainably and by better exploiting their products and environmental services; ii) Enhancing the value of French woods and develop their uses.

Several dynamics are being put in place to respond to these trends[23] :

- A greater dynamic of renewal, with the aim of planting and regenerating 50,000 ha/year of adapted species; improving the diversity and density of stands of 60,000 ha/year to optimise the production of quality wood and environmental services.

- Adapting the resource to climate change: development of research programmes (genetics, ecosystems, role of water, etc.) and transfer of knowledge to education and forest management stakeholders. Modelling carbon sequestration or measuring the carbon footprint of wood products are among the important issues (considering the carbon footprint and carbon balances of economic players and communities, etc.).

- Increase wood mobilisation: generalise the implementation of sustainable management documents and encourage the grouping of land on a territorial scale.

Among other trends in French forestry, we also find i) Making better use of hardwoods, ii) Redefining wood energy policy (greater mobilisation of wood, facilitating the use of wood at the end of its life cycle), iii) Developing the use of wood in green chemistry and biomaterials[24]

Food waste

Several trends have developed around food waste in France in the recent years: In 2016, the law on the fight against food waste is enacted. Its main measure consists of obliging every supermarket of more than 400 m² to seek a partnership with a food aid association to sell its unsold food, instead of throwing it away or destroying it. In 2018, France took another step in its fight against food waste. Strengthening the fight against food wastage is at the heart of the law's third line of action "for balanced trade relations in the agricultural sector and healthy and sustainable food"[25] :

- The framework of application of the law relating to the fight against food waste is extended to collective catering and the food industry, which will also have to offer their unsold products for food donation.

[23] https://unece.org/DAM/timber/country-info/statements/france2018-v2.pdf

[24] https://fbie.org/foret-bois-filiere-davenir-france/

[25] https://agriculture.gouv.fr/la-france-pionniere-de-la-lutte-contre-le-gaspillage-alimentaire

- This ordinance extends to all operators in the collective catering and food industry the ban, which already applies to food sector distributors, on making unsold food that is still edible unfit for consumption.
- The ordinance also extends to operators in mass catering, preparing more than 3,000 meals a day, and those in the food industry with an annual turnover more than 50 million euros, the obligation to propose an agreement to authorised food aid associations for the donation of consumable and unsold foodstuffs.

The anti-waste trend is also developing at the private level: the catering industry is going to experiment with setting up a diagnosis and disseminating planning support tools. Private partners are also joining the national pact to combat food waste.

5. Trends in Bioeconomy

France is a country with significant agricultural resources, forestry and aquatic to feed a diversified bioeconomy and thus offers new opportunities to these primary sectors, creating added value and jobs.

The agricultural sector is involved in the production of renewable energies (methanisation, biofuels...), and this development is growing. Agri-food industries valorise their by-products in animal feed and energy, but also work on packaging and inorganic waste reduction and re-use, creating jobs and enhancing bioeconomy in the country. The forest-wood sector offers a variety of uses for biomass, from lumber to energy and innovative molecules: in the following years, the bioeconomy aspect of the forestry in France is expected to increase.

Trends in Digitalisation[26]

French agriculture, which had been lagging in terms of technology, has begun its digitalisation over the last years. According to the firm DigitalFoodLab, 227 million euros have been invested in French AgTech and FoodTech start-ups during the year 2018. France therefore ranks first in Europe, with 2.6 % of global investments in the sector. This development follows a strong governmental will: The Agriculture-Innovation 2025 report underlined the important stake that the exploitation of digital data represents for the agricultural world, as well as the need to set up an agricultural data portal[27].

The Digitalisation of French Agriculture is particularly notable on the following areas:

- Risk management: big data, data analysis, predictive models
- Research & Development: the arrival of more and more sensors in experimental stations opens up research prospects. Farms, which are increasingly connected, are also becoming places for collaborative experimentation.
- Connected objects: the development of robotics coupled with artificial intelligence (IoT on farms) supports the farmer in the management of herds and crops: decision support, increased precision, and less arduous work.
- Mutualisation: digital technology and its large-scale data collection - its cost - speeds up collaboration and the sharing of data, knowledge, and equipment.

[26] http://www.fao.org/3/ca4887fr/ca4887fr.pdf

[27] https://agriculture.gouv.fr/alimagri-la-revolution-numerique

- Advice and training: the smartphone, combined with decision support tools, contributes to the intellectual independence of the operator. Consulting and training do not disappear but can be virtual, relocated (formation via Virtual Reality).
- Consumer: the food chain becomes transparent. This traceability (blockchain technology) brings the producer closer to the consumer and facilitates their exchanges.

6. Trends in business models

French farms are diversifying[28]: the trend is towards the development of non-agricultural activities supporting the farm (Mondy et Terrieux, 2010). These service activities aimed at the public have a commercial dimension. Two main trends are emerging: the development of short circuits (direct sales on the farm, delivery, inter-farm cooperation), and para-agricultural activities (these activities are supported by the farm's buildings, production, and equipment). The most widespread para-agricultural activity is contract work (i.e. agricultural work carried out on behalf of other farms). Agritourism or "farm tourism" is also a growing activity: it mainly includes accommodation and leisure activities such as horse farms, educational farms, or farm visits[29]. On-farm catering is also developing, at a different pace depending on the region. Other para-agricultural activities (production of renewable energy, wood processing, forestry, crafts, renting buildings for the garage of motorhomes, etc.) are emerging trends.

[28] http://37.235.92.116/IMG/pdf/R3217A09.pdf : Agreste : La diversification des exploitations contribue au développement des territoires

[29] Mohamed Gafsi, «Les stratégies de diversification des exploitations agricoles. Enseignements théoriques et empiriques », *Économie rurale* [En ligne], 360 | juillet-août 2017, mis en ligne le 15 août 2019, consulté le 15 février 2021. URL : http://journals.openedition.org/economierurale/5257 ; DOI : https://doi.org/10.4000/economierurale.5257

France Scenarios

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimension for every scenario. In this table the skill list developed in workpackage 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

France: Scenarios sustainable production – key issues

Sustainable paths	Established paths	High-tech paths
▪High social and environmental consumer awareness, flexitarism prevail. Demand for local products is rising, and the consumers rediscover traditional and seasonal food products.	▪Cost, taste and convenience are most important product attributes for consumers. Niche markets for local and traditional foods remain but have a small market share. Consumption of meat remains high.	▪Consumers value healthy and personalised (functional) processed foods. Meat consumption is slightly reduced. Technological tools allow consumers to choose their diet and products with the utmost care. The accent is put on health and product quality.
▪Livestock levels have been decreased by 25%. Livestock production systems with free run-out options for animals are common. The sourcing of feed has been diversified. Use of antibiotics has been individualised and minimized.	▪Livestock levels decrease by 5%. Intensive livestock production is under strict regulation. Use of antibiotics had decreased at moderate pace.	▪Livestock levels decrease by 5 to 10%: a large intensive production prevails, but technology allows the emergence of alternative products to meat, synthetic proteins. Use of antibiotics has been individualised and rationalized.
▪Strict emission quota (phosphates, ammonia, CO2 for greenhouses have been established by French government.	▪Emission quota are established (phosphates, ammonia, CO2 for greenhouses).	▪Emissions are minimized with the help of climate smart technology. E.g. geo-thermal energy use in greenhouses. The improvement of cold chains through artificial intelligence allows a reduction in energy costs in the food sector.
▪Agriculture biodiversity has improved through diversified crop rotations, alternative production strategies etc. Nitrogen levels of Nature2000 areas are well below critical levels.	▪Biodiversity has moderately improved since 2020. Nitrogen levels of half of Nature-2000 areas are well below critical deposition levels.	▪Biodiversity levels have deteriorated. Nitrogen levels of Nature-2000 areas are at 2020 levels.
A strict EU+ animal welfare policy has been implemented for slaughterhouses (resting locations, slaughter pace, stunning).	▪Livestock sector has invested in sustainable production. Livestock production systems with free-range (indoor) options for animals are common. Feed sourcing is combined local and Global. Slaughterhouses comply with EU legislation.	▪The livestock sector has invested vastly in technology for sustainable and circular (indoor) production, focusing on limitation of emissions. Feed sourcing is Globally oriented. Slaughterhouses comply with EU legislation.
Arable farming and horticulture have moved to agro-ecological climate smart production techniques and application of bio-pesticides and organic fertilizers, supplied by the livestock sector.	Arable farming and horticulture increase use of bio-inputs next to use of chemical pesticides and synthetic fertilizers which decrease moderately due to EU legislation.	Arable farming and horticulture use optimal mix of bio- and chemical inputs, based on economic incentives to ensure high yields. Regional specialisation and monocultures limit biodiversity potential.
Product traceability is at the heart of consumers' concerns, blockchain techniques are developed.	The Connection with consumers is made through retailers, who drive change.	Technical progress has enabled the emergence of traceability tools, orienting consumer demand and profoundly modifying French livestock farms to meet domestic and export demand. This traceability also makes it

France: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
•French agriculture has made a strong move towards circular production with optimal use of by-products and waste streams. Farm and household waste is used in livestock production.	•There is only moderate development towards circular production in French agriculture. Livestock and crop production are not well connected.	•High tech agriculture and precision farming lead to a strong move towards circular production.
100% of the wastes produced in the agrifood industry are transformed into highly added value making way to a new highly-added value specialties business line.	40% of the wastes produced in the agrifood industry are transformed into highly added value making way to a new highly-added value specialties business line.	New by-products emerging from a novel specialty agrifood industry in which new technological approaches achieve more & more highly added products contributing to diversify the business model.
•Agriculture is self sustaining in energy production through production of bio-gas, wind and solar energy.	•Agriculture is still for the largest part dependent on fossil based energy sources, only moderately supported by renewable energy sources which are also supplied to some niche markets.	•Agriculture is still strongly based on fossil fuel, however supported by cost-effective renewable energy production.
• Water consumption and effluents are minimized in agrifood factories by recycling and reusing techniques.	• Demands of water are reduced because of recycling. Industrial effluents are treated efficiently before discharge. • Technologies can provide cheap reclaimed water	•Innovative systems allows to optimize the use of different sources of water and reclaimed wastewater for several applications in industry, agriculture and other uses.
•Forest acreage has been increased, the use of forest has been sustainably diversified. •Agroforestry and small-scale forestry including so-called "tiny" forests are integral part of the rural and urban landscape. Degraded land has been afforested. Forestry strongly contributes to biodiversity. Most forest is "nature forest" or regional parc.	•Forest acreage has increased very moderately. Planting of trees in urban and rural settings increases slowly albeit steadily. Most forest is "production forest".	•Forest acreage has increased moderately. Degraded land has been afforested. Forestry and agriculture are functioning separately. Most forest is "production forest" with around 50% of the harvested wood used for energy production.
•The food industry has moved strongly to circular production supported by new technologies, including the introduction of sustainable packaging materials.	•The French food industry is dependent on fossil fuel energy sources but gradually improves its valorisation of by-products and waste streams through research centres. Technology growth is moderate but increasing through French	•The French food industry is moving swiftly to smart factory solutions where use and recycling of resources is based on economic incentives and legal demands. Intelligent packaging lead to lower cost production with less waste.

France: Scenarios digitalisation – key issues

Sustainable paths	Established paths	High tech paths
•Precision agriculture to support optimal use of resources and circular agriculture in small scale sustainable production systems is common in France.	•Precision agriculture is used in many subsectors to optimise use of resources in, particular, large farms. There is limited attention to circular production.	•Precision agriculture to support optimal use of resources and circular agriculture in large corporate farms is common in The France.
•Precision agriculture results in high yields, genetic improvements and ecological intensification. Losses and waste are minimized.	•Precision agriculture, moderately, results in high yields, genetic improvements and ecological intensification.	•Precision agriculture results in high yields and genetic improvements. Losses and waste are minimized.
•Digital technology and systems also enable optimal connection to chain partners and consumers (e.g. through social media). Local (complex) traceability is supported by traceability systems. Many actors are involved.	•Although, collaboration between farmers and food industry remains limited, traceability by block chain technology and supply chain information systems has become a main field of attention.	•Digital technologies support a solid connection between the large farmers and food industries so as to ensure a fast and flexible flow of products and assure safety and traceability in long food chains.
•In the French food industry application of robotization and AI have led to smart factories supporting efficient use of resources and circularity of production.	•The pace of robotization and AI applications in food industries is moderate.	•Smart factories are common in French food industries. Production is circular if economically viable. Technology reduces the drudgery of agricultural work, allowing a renewal of French producers and a rejuvenation of the profession.
•Digital technologies ensure transparency of production for consumers and partners in the food chain. The technologies induct a high demand for French products.	•Product information is improved by digital technologies, but a generational gap is clear in the use of said tools, forbidding their global use. Overload of product information for the consumer emerges, often implying misleading information.	•Digital technologies (e.g. real time monitoring of physiological functions and nutritional needs through biomarkers and biosensors) support personalised solutions for individual consumers.
•Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection and supply chain management applications.	•There is a moderate increase of the application of digital technologies in forest management.	•Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection, but a focus on supply chain management applications (sales, logistics, distribution).

France: Scenarios business models – key issues

Sustainable paths	Established paths	High tech paths
▪Concentration of farming has come to a halt. French agriculture is characterised by medium size and small family farms focusing on ecological production in balance with landscape and nature. ▪Medium-big cooperatives balance with the power of corporations.	▪There is further concentration of the farming sector with large farms along small and medium sized farms.	▪Strong concentration of farms, move away from family farms to corporate farms. Monocultures remain, although sophisticated inputs try to keep fertility of the soil and emissions low. Crop diversity is encouraged.
▪Far most of the farms are multi-functional with side activities in tourisms, health care, energy production, etc.	▪There is a combination of large specialised farms with small-medium size farm. Small and medium size farms are in many cases multifunctional.	▪Large & medium specialised farms make up French agriculture. Multifunctional farms have disappeared.
▪Collaboration of farmers in cooperatives and producer organisations has further increased. ▪Local-to-local production is common and most farms participate in (online) sales to consumers in short , local, food chains.	▪Collaboration of farmers in cooperatives remains a key characteristic of French agriculture. ▪Further collaboration in local-for-local producer organisations is limited. Sourcing is combined local and Global.	▪Agricultural production and consumption is Globalised. ▪Products are produced where this is most cost efficient.
▪On food industry level, besides multinationals still operating, many small and medium size food industries have emerged closely working with farmers for sustainable and local-to-local and artisanal production.	▪ Food industry is mainly composed of SMEs and some international multinationals. Collaboration between (large) farmers and food industries has increased. Safety, quality and traceability are key issues in food chain management and are being constantly improved.	▪Food supply chains have advanced storage and logistics facilities and work in strong collaboration with (large) farms. Safety assurance and traceability systems are essential.

France: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
The French AKIS is still strong and more integrated.	The French AKIS is strong and integrated.	The French AKIS is very strong and integrated.
The link between state and farmers' associations is reinforced, as is the link between the different actors of French AKIS: Collaboration of farmers (in cooperatives/producer organisations), foresters and food industries with public and private knowledge providers of the food system: research organisations, government, NGOs, consumer organisations, etc.	Collaboration of farmers, foresters and food industries with public and largely private knowledge providers. Knowledge has been largely commercialised, data can be difficult to obtain for the producers.	Collaboration of (large) famers, foresters and food industries with private knowledge providers/R&D suppliers. Role of public knowledge organisations is limited.
Public support & co-management are important for the AKIS Diversification of the funding, inflection scenario (great stability of AKIS)	More contracting and delegation of services, support consists of both institutional mid-term funding and key actors of the system. Less involvement of the public administration in the supply of information. Liberalization scenario: strong withdrawal of the state	Contracting and delegation of services are the norm, the public administration is less and less involved. Competition between advisory organisations. Regionalization scenario.
Support of innovation, enhancing of the connections between AKIS organizations	Slower support of innovation and enhancing of the connection between AKIS organizations, with lock-in effects (access of small farms and farm workers to services)	Innovation is a priority and answers to the increase of the farms' sizes. Evolution of the tasks' distribution between the farms thanks to the innovation.
Farmers, forestry and food industry employees are highly educated, in business management, entrepreneurship and bio-economy. They are sensible to a sustainable agriculture and industry.	Farmers , forestry and food industry employees are educated in sustainable business management and resources diversification.	Farmers, forestry and food industry employees are highly educated, in business management, entrepreneurship and innovation.

Scenario specific skill needs, France (categories from WP1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Sustainability	**Sustainability**	**Sustainability**
1.11 By products valorisation (circularity) 1.25 Sustainable packaging 3.8. Organic farming 3.15. Agricultural biodiversity 3.20. Animal care and welfare	1.11 By products valorisation (circularity) 1.25 Sustainable packaging 3.8. Organic farming 3.15. Agricultural biodiversity 1.17. Good agricultural practices	1.11 By products valorisation (circularity) 1.12 Generation renewable energy 1.25 Sustainable packaging 3.8. Organic farming 3.15. Agricultural biodiversity
Bio-economy	**Bio-economy**	**Bio-economy**
3a.13 Crop diversification and crop rotation 3a.15 Biodiversity 1.11. By-products and co-products 1.12. Generation of renewable energy 1.25. Sustainable packaging	3a.11 Conventional vs organic production 3a.12 Controlled environment agriculture 3c.14 Traceability 3c.18 Food labelling 1.25. Sustainable packaging	1.11. By-products and co-products 1.25. Sustainable packaging 3c.14 Traceability 3c.17 Emerging technologies
Digitalisation	**Digitalisation**	**Digitalisation**
2.7 Digital entrepreneurship 2.18 Precision animal health system 2.19 Field operations management system 2.24 Robot and drone technology in agriculture Food industry 4.0	2.1 Everyday usage digital technology 2.12 Digital food traceability system 2.17 Farm management information system 2.18 Precision animal health system 2.24 Robot and drone technology in agriculture	2.3 Data protection 2.6 E-commerce and e-marketing 2.23 Climate control systems 2.24 Robot and drone technology
Business model	**Business model**	**Business model**
4.16 Networking 4.20 Learning continuously 5.2 Direct marketing 5.11 New value chains	4.6 Organisation, planning, strategic thinking 5.7 Financial business planning 5.10 Cooperatives 5.24 Food labelling/certifications	4.17 Innovative thinking 5.1. Monitoring market activity and conditions 5. 7. Business planning/model and strategic management 5.21 Protection intellectual property rights

o Annex 3.6 Spain: trend and scenario country study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

1. Sector structure

Agriculture

Spanish agriculture is a strategic sector, providing great economic, social, territorial and environmental value. In 2019, the sector employed directly more than 708,900 people (including livestock farmers), generating a production of more than € 50.65 billion in income. With agricultural exports of 53.18 billion €, it contributed to improving the Spanish trade balance by 14.21 billion € (MAPA, 2020[a])

From the territorial and social point of view, Spanish rural areas occupy 84 % of the land but only 16 % of the population live there. Spanish rural areas are under a significant threat from depopulation and have become elderly and male, since the first to leave are women and young people.

For lands type there are: 19.5 M ha of forestry, and 17 M ha of cultivated fields, of which 3,8 M ha area irrigated (22,5 % of the cultivated lands). Of this, 24 % use surface irrigation, 77 % of pressurized irrigation (23 % sprinkler irrigation and 53 % drip irrigation) (MAPA 2019[a]), with important requirement of investment an energy.

Sustainable production, bio-economy principles and irrigation modernization can be considered a priority because irrigation is a strategic asset to the farming sector and the national economy, since it produces most of the agricultural production, increases yields and ensures supply to the agri-food industry and other markets (MAPA, 2020[b]), also favouring the creation of new jobs and the integration of young people in the rural context (Martin de Sata-Olalla, 2001). A major drawback is the energy consumption, which by the other hand can boost the use of renewable energies.

Food and Beverage Industry

The Food and Beverage Industry is the country's leading industrial sector, an engine of growth that contributes to the wealth and development of the Spanish economy. During 2019 it reached a production of 119,224 million euros, which represents an increase of 2 % compared to last year's figures. The contribution of the food industry to the total economy is key and translates into a contribution of 2 % of the total economy and represents 15 % of the total industry and 19 % of the manufacturing industry (FIAB, 2019)

The food and beverage industry is made up of 30,730 companies (58 % 1 to 9 employees, 16 % 10 to 49 employees), distributed throughout the entire national territory, thus helping to backbone the country and generate wealth and fix the population in the most depopulated areas (FIAB, 2019).

Furthermore, more than 9 % of the companies in the sector are innovative, of which 82.3 % are small and medium-sized companies. Thus, research spent in the sector increased on 18 %.

Forestry

Spain ranks third in Europe, behind Sweden and Finland, in forested area with 27,664,674 hectares occupying 55 % of the territory. Spain is also the European country with the greatest increase in forest area with an annual growth rate of 2.19 %, (0.51 % is the EU average). 67 % of the Spanish forest area is privately owned by around 3 million private forest owners in Spain.

The harvest rate is 41 %, lower than the European average (69 %). The annual possibility (timber that could be harvested) is approximately 46 million m^3, while the volume of harvested timber is 19 million m^3. At least a third of the forestry areas is considered such as “Other Woody Lands-OWL” following the UN terminology due the fact that tree coverage suppose less than ten percent. (MAPA, 2014)

Forestry, the timber and paper industry generated a gross value added of EUR 7,039 million in 2017, representing a direct contribution to GDP of 0.63 % (UE-27 average: 1,04 % in 2005) The forestry sector employs in Spain some 18.000 people (COSE, 2020).

1. Spanish AKIS (Agricultural Knowledge and Information System)

Agricultural Knowledge and Innovation System (AKIS) is more fragmented in relation to other EU countries (EU SCAR AKIS, 2015). The approach is to consider that technology transfer and innovation should be promoted at the regional or local level, addressing the problems and opportunities of the sector from the grassroots. Another characteristic of AKIS in Spain is its underfunding (EU SCAR AKIS, 2019; INE 2020). In Spain, there are 74 universities dealing with agricultural, forestry, veterinary and food issues (www.universia.es). There are 16 Campuses of International Excellence linked to the agri-food sector, those campuses promote strategic aggregations between different universities.
At national level, two Public Research Bodies have co-existed at the state level, which have dealt with agri-food research: the Consejo Superior de Investigaciones Científicas (CSIC) and the Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA), the latter with a clear exclusive focus on the agri-food sector. CSIC is going to integrate INIA in a short future. At regional level 17 regional public research institutes in supporting agrofood sector on each NUT-2 region. Some of them are also involved in extension and advisory services to farmers and other interested end users. Each centre has evolved with respect to its regional capabilities (Montero Aparicio, A, 2014).
In the field of agricultural advisory services, the traditional public extension services linked with agriculture administration is no longer provided with some exception in Canary Islands. On the other side, some private organizations have emerged providing consultancy.
Finally, it is important to highlight the shortcomings in training of farm owners in Spain, where the percentage of those only with practical experience amounts to 78 %, 19.8 % have basic training and only 1.9 % have higher agricultural training. By the other hand, in recent years there has been a positive trend in the improvement of the training of farm owners (EUROSTAT, 2020).

2. Notable trends in sustainability

Agriculture
Based on that previous communications (European Commission, 2017), the European Commission has drafted regulations to define the future CAP. Article 6 of the Regulation proposal sets out the nine specific objectives of the CAP that must be considered for the agriculture sustainability, which are (EUR-Lex 2013):

1. Support **viable farm income and resilience** across the Union to enhance food security;
2. **Enhance market orientation and increase competitiveness,** including greater focus on research, technology and digitalisation;
3. **Improve the farmers' position in the value chain;**
4. Contribute to **climate change mitigation and adaptation, as well as sustainable energy;**
5. Foster **sustainable development and efficient management of natural resources** such as water, soil and air;
6. Contribute to **the protection of biodiversity**, enhance **ecosystem services** and **preserve habitats and landscapes;**
7. **Attract young farmers** and facilitate business development in rural areas;
8. Promote **employment, growth, social inclusion** and local development **in rural areas**, including bio-economy and sustainable forestry;
9. Improve the response of EU agriculture to societal demands on **food and health, including safe, nutritious and sustainable food, food waste, as well as animal welfare**.

Some of the main conclusions of Spain/Portugal focus group for addressing the current and future skill needs far sustainability, Digitalisation, and the bio-Economy in Agriculture were:

- **adequate legislation, planning and water management as well as good agricultural practices**
- Regarding climate and water availability: **tools and models to help decision-making, available on online platforms, to help improve and guarantee the economic and environmental sustainability of agroecosystems** in Europe and the Mediterranean, improving the agronomic and economic **efficiency of irrigation water and associated energy**.

It is therefore necessary to give an overview of the key technologies included in the literature that can contribute directly to improving the use of water and energy in irrigation:

a) **Tools and models for saving water and selecting the proper crop pattern at the farm level.**
b) **Tools and models for improving irrigation infrastructure design and management as a whole**, based on water and energy savings, such as: (b-1) optimal design, size and management of pressurized irrigation systems on the plot scale with low pressure sprinklers and emitters, (b-2) collective irrigation networks, (b-3) pumping systems.
c) **Actions to reduce energy consumption and/or cost** such as the use of: (c-1) benchmarking techniques, (c-2) energy audits, (c-3) models for optimal use of specific electricity tariffs, (c-4) telemetry and remote-control systems, (c-5) renewable energy.
d) **Proper design and management of irrigation systems,** promotion of the application and usefulness of Irrigation Advisory Services and web-GIS platforms to transfer and share real-time information with farmers in a feedback process are some of the best tools for improving consumption of water, energy, and other production inputs.

<u>Food Industry</u>

Transition towards a more sustainable energy model, driven by the majority **use of renewable energy sources and a more efficient management of the supply chain and distribution** (cold chains, supermarkets, warehouse), is accelerating to gain a greater control over costs and means of production.

Other trends in sustainability:

- **Packaging: eco-design to achieve increasingly sustainable packaging**
  - Incorporation of recycled material as raw material, especially plastic
  - Increase in the use of compostable / biodegradable plastics
  - Increase in the use of plastics made from raw materials of renewable origin
  - Tendency towards the simplification of materials used in the same packaging
  - Use of sustainable raw materials, certificates of sustainable management of raw materials
- **Use of by-products from the food and beverage industry for animal feed (and for other industrial applications,** such as the pharmaceutical industry, cosmetics, etc.)
- **Sustainable water management:** efficient use of water, minimizing consumption; innovative technologies for wastewater treatment; regeneration and reuse of water; etc.
- **Sustainable mobility:** fleets of low-emission or electric vehicles
- Some sectors and companies have adopted commitments or have collaborated in projects to **protect natural ecosystems and biodiversity** (wetlands, steppe birds, etc.), together with environmental NGOs and other partners (Life projects for example)
- **Sustainable sourcing and rural development**: collaboration with the primary sector to apply good agricultural practices and improve the living conditions of farmers and

<u>Forestry</u>

Several **certifications** are already in the ground to assure that forest-based wood and materials don´t affect deforestation, desertification or endangered species. In Spain there is also a powerful trend that started with government regulations, "**Criteria and indicators of sustainable forest management in Spanish forests**" (MAGRAMA 2012). Also the international standards are being progressively uptake. **Forest certification systems worldwide** (PEFC, FSC). UNE 162002 Standard: Sustainable forest management. There is also a positive trend for widely implementation of **forestry planning and management instruments that include sustainability issues.**

3. Notable trends in digitalisation

General trends:

It is worth highlighting the Strategy for the Digitization of the Agri-food and Forestry Sector and the Rural Environment (MAPA, 2019[b]). This strategy describes the following: specific objectives:

- OBJECTIVE O1. To narrow the digital divide between rural and urban areas, as well as between small and large companies, aiming for all parties to be connected. To achieve this, work is to be done on **connectivity in order to narrow the physical digital divide as regards infrastructure**, and also **on training to narrow the divide in adopting new technologies.**
- OBJECTIVE O2. To foster data use as an engine to boost the sector, **addressing the interoperability of the sector's data and the openness of data**, understanding the latter concept in the widest sense so as to encourage this **openness in the Public Administration, in research and in the private sector**.
- OBJECTIVE O3. To **boost business development and new business models**, taking into account **Industry 4.0** and the opportunities for **economic diversification provided by new technologies**. To do so, it is essential to **bolster the digital innovation ecosystem** as a key aspect in modernising the sector, and to **provide advice for digital adoption in Knowledge and Innovation Systems** in the agri-food and forestry sector and rural areas, in addition to **fostering new business models**, which often arise on applying and adopting technologies in certain fields.

Agriculture

Some specific trends for the agriculture sector are:

- **Tools and models for saving water and selecting the proper crop pattern at the farm level**. This can be performed with the use of precision agriculture, information and communication technologies (ICT) or remote sensing at different resolutions for crop status determination, combined with decision support system (DSS) models and tools.
- **Actions to reduce energy consumption and/or cost by the use of telemetry and remote-control systems**.
- **Proper design and management of irrigation systems**: i) application and usefulness of Irrigation Advisory Services and web-GIS platforms to transfer and share real-time information with farmers in a feedback process; ii) application of new supervisory control and data acquisition (SCADA) systems in farms to optimize irrigation in term of the forecasting of weather conditions and green energy availability (Tarjuelo *et al.*, 2015).

Food Industry

Digitization has become another of the leitmotifs of 2020 in the food industry, taking steps in innovations based on emerging technologies such as **artificial intelligence or machine learning aimed at different phases of food production.** In addition, the covid-19 has put on the table the relevance of having **technologies that use the storage and treatment of large volumes of data**.

The development of technologies such **as Artificial Intelligence (AI), the Internet of Things (IoT), Big data analysis** or advanced applications in **robotics, automation, control software and cloud computing,** etc. enable a new factory concept, more flexible, automated, connected, social and intelligent (AINIA, 2020):

- **Optimal management of production processes**, making them safer, of higher quality and in less time.
- **Intelligent and efficient production systems**, which allow a better use of resources, minimize manufacturing defects, and save costs.
- A **more flexible production** that enables the design and manufacture of **hyper-personalized products** ("mass customization") and adapted to new customer demands.

Forestry

There are expectations about positive impact that the following techniques and technologies will bring to the forestry sector (COSE 2020):

- **Remote sensing and use of drones to prevent pests and diseases**
- **Early warning systems (BigData solutions for Agroforestry Health using satellite technology), prevention of fires due to accumulation of biomass canopy in forests.**
- **Forest inventories.**
- **Open data for forest statistics.**
- **Data collection systems in forests.**

4. Notable trends in Bio-economy

The new bioeconomy is focused on the benefits of use or **reuse of new raw materials from crops and animals**, different from traditional uses in food, beverage, and others, and looking at **substitution of current predominant fossil-based materials**, such plastics or other petrol derivates. Despite of this promising future, the sector linked with biobased chemicals (2017 turnover 11,6kM€), bio-based electricity (0,5kM€), liquid biofuels(1kM€) and bio-based textiles (5,5mK€) are in some way stagnated without relevant growth in the last decade (Centre of knowledge on Bioeconomy, 2020)

Agriculture

Reclaiming wastewater has been indentified as a way to increase the water availability (MITECO 2020[a], Spanish Government, 2007). Providing **high quality water,** particularly with efficient disinfection and low-cost technologies, is mandatory (MAPA, 2019[c]), not only irrigation but also for the agri-food industry.

Land application of stabilized sludge from municipal wastewater treatment plants has become a way to reduce the necessity of other soil conditioners within a circular economy

Policy for the distribution of water and the use of **desalination technologies** are also important trends.

Water scarcity and water quality in the context of implementing **practices for the sustainable use of phytosanitary products; promoting integrated pest management; and using alternative techniques to phytosanitary products such as control with non-chemical agents** MAPA, 2020[c]**). and transform this problem into a source of valuable material**.

In **waste production** some highlights are **waste management of important seasonal activities** (wineries, oil mills) and also **livestock waste management (vs. scarcity of water and other resources) and its environmnental impact** (MAPA, 2020[d]).

Biorefineries are also an important bet in which the **byproducts and wastes of the agricultural and livestock farms and, also, of agri-food industry** can provide raw matters within the circular economy strategies to preserve natural resources.

Last but not least, within a country with a high capacity of **production of green energies**, the use of **thermal, photovoltaic solar energies and mini-hydraulic and wind turbines** is seen as mandatory (MITECO, 2020[b]).

Food Industry

The bioeconomy proposes a new production model based on innovation and the **optimization of the use of energy sources and raw materials**, **prioritizing the use of those of a renewable nature n** (MINECO, 2015). Among the lines of work that are already a reality and that, above all, have the greatest development potential in the industry, the following stand out:

- The **use of waste and by-products** generated in the food industry, which are an interesting **source of energy, bioactive components, reusable materials**.
- The **generation of new healthy foods**, given the growing concern of consumers about the impact of a sedentary lifestyle and new consumption habits.

Forestry

Several trends have been identified (COSE, 2020):

- **Bioenergy**: high quality wood chips and pellets.

- **Bio-construction:** construction with wood, energy efficiency in buildings and passive or near-zero energy houses.
- **Biorefinery**: decomposition of woody material into high-value green chemicals (lignin, hemicellulose (sugars) and cellulose for pharmaceuticals, cosmetics, packaging and paper, food, textiles, industrial fibres and building materials.

5. Notable trends in business models

Agriculture

Some trends have been identified (Bankia Forward and Innsai Consulting, 2019), in the agriculture sector for 2025:

1) **Smart Agro**: Precision farming, Predictive agriculture, Agriculture automation of processes and tasks. Marketplaces for products and services
2) **Sustainable Agro**: Optimising the use of resources. The circular economy. Fertiliser reduction. Vertical farming. Organic farming
3) **New foods**: Source of vegetable protein. Reduction of food waste.
4) **Trust & transparency**: Blockchain. Communicating transparency.
5) **On-off channels**: On-line channels and agriculture. Off-line channels - agriculture of ultra-proximity

Food Industry

Some of the main drivers and key trends:

- **Smaller homes.**
- **Redevelopment of downtown spaces in cities**. This trend impacts consumption patterns and the demand for premium products increases
- **Increase in obesity and chronic diseases**, leading to consumers who prefer to buy more nutritious, natural and less processed foods, leading to **healthy lifestyle and sustainability.** This leads to new products, to buy brands positioned as natural, or changing the ingredients and presentations to make food products healthier and sustainable (Olivares-Bello and Lozano-Meade, 2019**).**
- **Change in the buyer's profile.** There are more and more male and young buyers.
- Another challenge for companies: consumer tastes and preferences are evolving with a focus on a **healthy lifestyle and sustainability.**

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Spain Scenarios

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimension for every scenario. In this table the skill list developed in workpackage 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

Spain: Scenarios sustainable production – key issues

Sustainable paths	Established paths	High-tech paths
• Scarcity of water makes essential to increase training of farmers and the development of web-tools & models to help decision-making. • Innovative technologies for wastewater reclaiming are applied in the agri-food sector.	▪Adequate legislation, planning & water management as well as good agricultural practices are essential to guarantee food production and the sustainability of agriculture in mediterranean countries, where irrigation is strategic. ▪Use of renewable energy and reduction in energy consumption are implemented in the agri-food sector.	▪Advanced design and management of irrigation systems and crop pattern at the farm level, promotion of Irrigation Advisory Services and web-GIS platforms to transfer and share real-time information with farmers are being applied for improving consumption of water, energy, and other production inputs.
▪High social and environmental consumer awareness, plant based diets are gaining relevance, with organic-based local products.	▪Cost, taste and convenience are most important product attributes for consumers. Niche markets for local and traditional foods remain but have a small market share. Consumption of meat remains high.	▪Consumers value healthy and personalised (functional) processed foods. Meat consumption is slightly reduced. ▪AI tools support consumers in the choice of food products/diets based on living stiles & health.
▪Agriculture biodiversity has improved through diversified crop rotations etc. Nitrogen levels of Nature2000 areas are well below critical levels.	▪Biodiversity has moderately improved since 2020. Nitrogen levels in most Nature-2000 areas are well below critical deposition levels.	▪Biodiversity levels have deteriorated. Nitrogen levels of Nature-2000 areas are at 2020 levels.
▪Livestock sector has invested vastly in sustainable and circular production and alterations in feed composition. Livestock production systems with free run-out options for animals are common. Local sourcing of feed.	▪Livestock sector has invested vastly in sustainable production. Livestock production systems with free-range (indoor) options for animals are common. Feed sourcing combines local&global.	▪The livestock sector has invested vastly in technology for sustainable and circular (indoor) production, focusing on limitation of emissions. Feed sourcing is Globally oriented
▪Arable farming and greenhouses have moved to agro-ecological climate smart production techniques and to the application of bio-pesticides and organic fertilizers, supplied by the livestock sector.	▪Arable farming and greenhouses increase use of bio-inputs. Use of chemical pesticides and synthetic fertilizers decrease moderately due to EU legislation.	▪Arable farming and greenhouses use optimal mix of bio- and chemical inputs, based on economic incentives to ensure high yields. Regional specialisation and monocultures limit biodiversity potential
▪The food industry is strongly moving towards circular production. The connection with the consumer base (e.g. through product information and promotion) has been strengthened.	▪Food industry slowly moves to more circular production. Connection with consumers is slowly growing through retailers.	▪Product innovations are strong and continuous, focusing on functional, 3-D printed and/or & healthy foods and GMOs. Food industry moves to circular production looking for economy benefits. Strong connections to manage the food chains and assure safety & quality

Spain: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
•Spanish agriculture has made a strong move towards circular production with optimal use of by-products and waste streams. Farm and household waste is used in livestock production.	•There is only moderate development towards circular production in Spanish agriculture. Livestock and crop production are not well connected.	•High tech agriculture and precision farming and integrated pest management lead to a strong move towards circular production (the rationale for changes is economic).
•Agriculture contributes to a fast growing biobased sector (e.g. to chemical industries). Decentralised bio-refinery and renewable energy installations.	•Agriculture only contributes to a limited extend to biobased production.	•The biobased sector (chemical, plastics) has grown fast, supported by biomass from agriculture. Concentration of processing facilities.
•Zero emissions agrifood industry. Power is provided by renewable sources connected to efficient energy storage devices. Biogas is produced from highly loaded wastes and used to minimize factories heat necessities.	• Power provided by the grid is each time less important and renewable energies contribute importantly for saving electricity cost	• Forecasting tools connected to SCADA systems allow the optimization in the use of green energies in industry and helps to maximize the benefit of agrifood industry.
•100% of the wastes produced in the agrifood industry are transformed into highly added value making way to a new highly-added value specialties business line.	•40% of the wastes produced in the agrifood industry are transformed into highly added value making way to a new highly-added value specialties business line.	•New by-produts emerging from a novel specialty agrifood industry in which new technological approaches achieve more & more highly added products contributing to diversify the business model.
•Degraded land has been afforested. Forestry strongly contributes to biodiversity.	•Forest acreage has increased very moderately.	• Degraded land has been afforested. Forestry and agriculture are functioning separately.
• Water consumption and effluents are minimized in agrifood factories by recycling and reusing techniques. Many of the effluents of the agrifood industry are reclaimed for agricultural irrigation.	• Demands of water are reduced because of recycling. Industrial effluents are treated efficiently before discharge. • Technologies can provide cheap reclaimed water	• SCADA systems allows to optimize the use of different sources of water and reclaimed wastewater for several applications in industry, agriculture and other uses
•The food industry has moved strongly to circular production supported by new technologies, including the introduction of sustainable packaging materials.	•Significant move to sustainable packaging.	•The Spanish food industry is moving swiftly to smart factory solutions. Intelligent packaging leads to lower cost production with less waste production.

Spain: Scenarios digitalisation – key issues

Sustainable paths	Established paths	High tech paths
•In Spain is common the precision agriculture and integrated pest management to support optimal use of resources and circular agriculture in small scale and cooperative sustainable production systems	•Precision agriculture and integrated pest management is used in many subsectors to optimise use of resources in, particular, large farms. There is limited attention to circular production.	• In Spain is common the Precision agriculture and integrated pest management to support optimal use of resources and circular agriculture in large corporate farms
•Precision agriculture results in high yields, genetic improvements and ecological intensification. Waste is minimized.	•Precision agriculture, moderately, results in high yields, genetic improvements and ecological intensification.	•Precision agriculture results in high yields and genetic improvements. Waste is minimized.
•Digital technology and systems also enable optimal connection to chain partners and consumers (e.g. through social media). Local (complex) traceability is attained. Strong participation of cooperatives	•Although, collaboration between farmers and food industry remains limited, traceability by block chain technology and supply chain information systems has become a main field of attention.	•Digital technologies support a solid connection between the large farmers and food industries so as to ensure a fast and flexible flow of products and assure safety and traceability in long food chains.
•In the Spanish food industry application of robotization and AI have led to smart factories supporting efficient use of resources and circularity of production.	•The pace of robotization and AI applications in food industries is moderate.	•Smart factories are common in Spanish food industries. Production is circular if economically viable.
•Digital technologies ensure transparency of production for consumers and partners in the food chain.	•Product information is improved by digital technologies, but some difficulties for elder consumers emerge.	•Digital technologies (e.g. real time monitoring of physiological functions and nutritional needs through biomarkers and biosensors) support personalised solutions for individual consumers.
•Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection and supply chain management applications.	•There is a moderate increase of the application of digital technologies in forest management	•Digital technologies are integrated in forest management, including biodiversity monitoring, fire detection, but a focus on supply chain management applications (sales, logistics, distribution).

Spain: Scenarios business models – key issues

Sustainable paths	Established paths	High tech paths
•Spanish agriculture is characterised by medium size and small family farms focusing on ecological production in balance with landscape and nature. •Medium-big cooperatives balance with the power of corporations.	•There is further concentration of the farming sector with large farms along small and medium sized farms.	•Strong concentration of farms, move away from family farms to corporate farms. •Crop diversity is maintained, with some proportion of horticultural crops due to their higher level of risk, although sophisticated inputs aim to keep soil fertility and emissions low.
•Far most of the farms are multi-functional with side activities in tourisms, health care, energy production, etc.	•There is a combination of large specialised farms with small-medium size farm. Small and medium size farms are in many cases multifunctional.	•Large & medium-sized specialized farms make up Spanish agriculture, with precision farming supporting production and digital tools/services for business management..
•Collaboration of farmers in cooperatives and producer organisations has further increased. •Local-to-local production is common and most farms participate in (online) sales to consumers in short , local, food chains.	•Collaboration of farmers in cooperatives remains a key characteristic of Spanish agriculture. •Further collaboration in local-for-local producer organisations is limited. Sourcing combines local & global.	•Agricultural production & consumption is globalised. •Products are produced where this is most cost efficient.
•On food industry level, besides multinationals still operating, many small and medium size food industries have emerged closely working with farmers for sustainable, local-to-local and artisanal production.	• Food industry is mainly made up small and medium companies. Safety, quality and traceability are key issues in food chain management.	•Food supply chains have advanced storage and logistics facilities. •Safety assurance & traceability systems are of key importance.

Spain: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
•Public spending on agricultural R&D is growing in recent years, which is allowing the increasing implementation of AKIS to foster sustainability in the agri-food sector.	•AKIS in Spain are underfunded given that public spending on agricultural R&D has been reduced in the last ten years	•Big farms and farms linked with corporation are technically monitored and supported by high tech decision systems
•Technology transfer and innovation in the agricultural sector has been implemented at regional and local level, having increased the capacity to address the problems and opportunities of the sector from the grassroots.	•Technology transfer and innovation in the agricultural sector is not sufficiently implemented at the regional or local level.	•Preponderance of private AKIS
•Forestry sector is strong ruled by strict regulations focused to improve biodiversity and carbon capture.	•Forestry sector is ruled by regulations focused to improve biodiversity and carbon capture, but the policies are not fully implemented.	•There is a strong need of training the forestry workforce on digital tools, applications and services
•Farmers, forestry and food industry employees are highly educated in sustainable business management and ethics.	•Farmers, forestry and food industry employees have a moderated educational level in sustainable business management.	•Farmers, forestry and food industry employees are medium or hight educated in business management, entrepreneurship and innovation.
•The Spanish AKIS is fragmented but strong, many small scale AKIS-subsystems exist in various sectors and regions.	•The Spanish AKIS is characterised by upscaling and intensification, going together with increasing private investments in knowledge and innovation.	•European AKIS is centralised, strongly interconnected, and highly technical orientation. Support is mostly from private investments of multinational food companies, large farms and cooperatives/producer organisations.
•The Spanish AKIS functions largely independent, EU provides connections between the various systems.	•The Spanish AKIS functions independent. EU provides connections between the various systems.	•Spanish AKIS is integrated with European AKIS. Minor role for government(s).
•Collaboration of farmers (in cooperatives/producer organisations), foresters and food industries with public and private knowledge providers of the food system	•Collaboration of farmers, foresters and food industries with public and largely private knowledge providers.	•Collaboration of (large and medium) famers, foresters and food industries with private and public knowledge providers/R&D suppliers.

Scenario specific skill needs, Spain (categories from WP1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Sustainability	Sustainability	Sustainability
1.18. Water management 3.8. Organic farming 3.15. Agricultural biodiversity 3.20. Animal care and welfare 3.18. Biofertilizers, compost, bio digestates	1.18. Water management 1.17. Good agricultural practices 3.15. Agricultural biodiversity 3.20. Animal care and welfare 3.18. Biofertilizers, compost, bio digestates	....personalized functional foods ...circular production in food industry 1.18. Water management 2.20 Digital irrigation control systems 3.18. Biofertilizers, compost, bio digestates
Bio-economy	Bio-economy	Bio-economy
...... *Biobased production* ....*Reclaimed water management* 1.11. By-products and co-products 1.12. Generation of renewable energy 1.25. Sustainable packaging	....*reclaimed water management* 3b.3 Reforestation, restoration forests 1.11. By-products and co-products 1.12. Generation of renewable energy 1.25. Sustainable packaging	...... *Biobased production* ....*reclaimed water management* ....*digital tools for optimization of energy use* 1.11. By-products and co-products 1.25. Sustainable packaging
Digitalisation	Digitalisation	Digitalisation
..... *Stakeholder communication system* ....*Food Industry 4.0* 2.12 Digital food traceability system 2.18 Precision animal health and productivity 2.24 Robot and drone technology	...*Food Industry 4.0* 2.1 Everyday usage digital technology 2.12 Digital food traceability system 2.18 Precision animal health and productivity 2.24 Robot and drone technology	..... *Supply chain information systems* ....*Food Industry 4.0* ....*digital business management* 2.18 Precision animal health and productivity 2.24 Robot and drone technology
Business model	Business model	Business model
..... *Multi-functional farming* 4.16 Networking 5.10.Cooperatives 5.2 Direct marketing 5.11 New value chains	..... *Multi-functional farming* 4.6 Organisation, planning, strategic thinking 4.17. Innovative thinking 5.10 Cooperatives 5.24 Food labelling/certifications	..... *Food supply chain management* 3a. 4. Logistics and storage 5.1. Monitoring market activity and conditions 5. 7. Business planning/model and strategic management

o Annex 3.7 Italy: trend and scenario country study

This country report consists of a trend and a scenario analysis. The scenario study is presented in a number of tables, after the trend study. The trend study has its own, separate, reference list.

Trends in agriculture, food industry and forestry sectors

1. Sector structure

Agriculture & food industry in the Bioeconomy

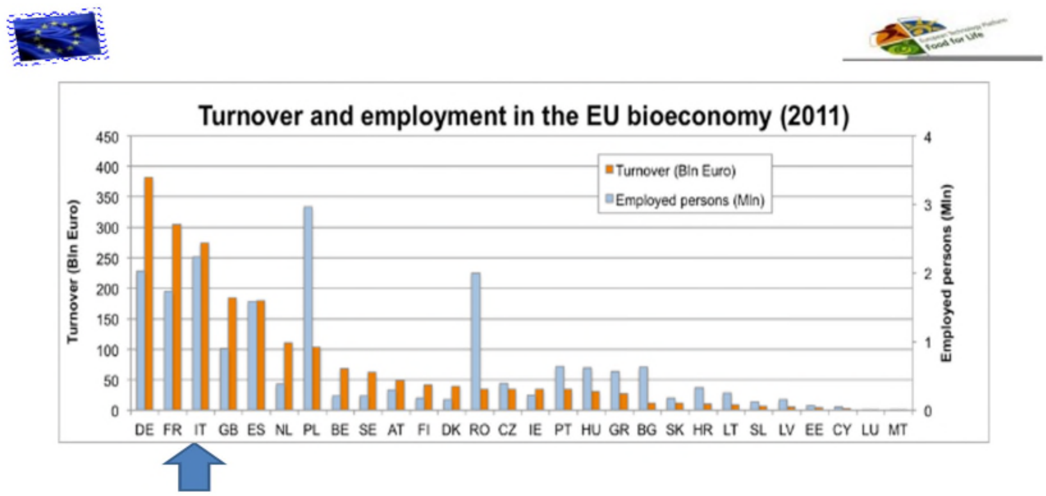
Bioeconomy in Italy has a different structure compared to the German, British, Spanish and Polish ones (see below table 1): Agriculture is still very important (45.2 %) in terms of employment; food industry is less intensive than Germany and France (22.6 %) but the no-food sector is more developed in Italy: textile (3.8 %), clothes/fashion (9.8 %), furniture (3.0 %).

Tab. 1 – Bioeconomy in Europe (employment structure 2018 % Eurostat 2019)

	Italy	**France**	**Germany**	**U.K.**	**Spain**	**Poland**
Bioeconomy	**100**	**100**	**100**	**100**	**100**	**100**
Agriculture, forestry	45.2	41.2	28.4	33.1	51.4	62.7
Food Industry	22.6	38.9	41.4	37.1	28.4	18.7
Wood Industry	5.0	3.5	6.3	7.6	3.5	5.6
Paper Industry	3.6	3.7	6.8	5.4	2.9	2.6
Textile Industry	3.8	0.6	1.0	0.9	1.1	0.4
Pharmaceutic bio	1.8	2.6	2.8	2.1	1.5	0.5
Chemicals bio	0.4	0.7	1.0	0.5	0.4	0.1
Biofuels/energy	0.1	0.1	0.3	0.2	0.0	0.1
Plastic bio-based	0.4	0.4	1.0	0.5	0.3	0.3
Clothes/Fashion bio	9.8	2.1	1.6	1.3	3.4	2.6

Furniture bio	3.0	0.8	3.1	3.4	1.7	3.1
Water cycles	2.2	3.4	3.8	5.1	3.5	2.8
Agrifood waste	2.1	2.1	2.6	2.8	1.8	0.5

Italy in bioeconomy has a strong agrifood sector and it is currently the 3rd agrifood /bioeconomy in Europe, after Germany and France, with 280 billion euro turnover and 2.2 million employees in 2017 (see below table 2: scar)



Source: SCAR – EUROSTAT 4th foresight 2017

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From the 2.2 million employees (units/year), in 2017 2.045 million are working directly in the agri-food sector: 1.146 are farmer's owners, 0.817 million are the agri-food labour force, 0.046 million are under 35 years old (young farmers) and 0.080 million are working at the extension services, consultants, advisors.

The total Utilised Agricultural Area (UAA) declines from 13.2 million ha in 2000 to 12.6 million ha in 2020 (- 4.5 %), losing in particular grasslands and woody crops. Soil consumption increases from 6.1 % in 2000 to 7.8 % (+ 20.1 %) of the total Italian surface (~ 300.000 km^2).

Individual farms are in the majority in Italy, except for cattle, dairy or mixed farms, and pig and poultry farms. Individual status predominates on small and medium-sized economic farms (95 % and 88 % respectively) but is less common on large farms (42 %). In Italy 2020, an average farm has 8.2 ha. This is 1.2 ha more than in 2000 (7 ha). Large farms, in the economic sense of the term, cultivate 54% of the agricultural surface area. They use an average of 41 ha, i.e. around 33 ha more than average farms. Small farms value only 15 % of the UAA and have an average of 4.3 ha.

See below the agri surface UAA per Regions and main crops: Emilia Romagna, Lombardia, Sicilia, Puglia, Piemonte and Veneto Regions are the most important territory in terms of agriculture arable crops.

Tab. 3 - UAA per Regions and main Crops (2017 - ha)

REGIONI	Seminativi	Coltivazioni legnose agrarie	Prati pascoli	Totale
Piemonte	533.376	91.326	222.925	847.627
Valle d'Aosta	678	681	67.344	68.703
Lombardia	793.825	35.220	227.513	1.056.558
Liguria	7.545	12.287	25.716	45.548
Trentino Alto Adige	14.304	40.642	258.977	313.923
Bolzano	*8.480*	*19.554*	*168.005*	*196.040*
Trento	*5.824*	*21.087*	*90.972*	*117.883*
Veneto	516.778	123.921	107.269	747.969
Friuli-Venezia Giulia	168.842	31.343	35.493	235.678
Emilia-Romagna	825.929	117.110	64.105	1.007.144
Toscana	461.870	151.445	32.950	646.265
Umbria	224.754	48.400	87.703	360.858
Marche	390.904	34.931	54.343	480.178
Lazio	362.853	123.744	150.689	637.286
Abruzzo	161.290	72.818	124.000	358.108
Molise	135.443	18.878	32.391	186.712
Campania	266.917	137.857	146.349	551.124
Puglia	656.834	526.431	144.785	1.328.051
Basilicata	305.825	45.308	165.799	516.932
Calabria	171.621	242.976	213.961	628.558
Sicilia	667.793	366.307	391.724	1.425.825
Sardegna	483.527	70.487	779.985	1.334.000
Totale	**7.150.908**	**2.292.112**	**3.334.021**	**12.777.044**

Source: Confagricoltura Study Center elaboration on ISTAT data.

While the number of farms in Italy is decreasing fast (less than 1 million in 2020; - 25.7 % from 2000, -2 % yearly, as in France -1.9 %), the number of food and drink companies with more than 9 employees is relative stable around 6.8 thousand units in 2020 (7.1 thousand units in 2000: - 4.2 %). See below the last decade 2011 -2019.

Around 0.427 million are working in the food and drink industry, a very stable employment (0.465 million in 2000) compared to the declining employment in the primary production (2.56 million in 2000 to 2.008 million in 2020 (- 21.6 % in 20 years, more or less – 2% yearly). The stable food industry employment and turnover (148 billion euro in 2020) are strictly related to the increasing exports of the made in Italy all over the world, compensating the internal consumption crisis from 2008 until now.

Italian Food Industry: 2011-2019 turnover

	2011 (Bil €)	2015 (Bil €)	2019 (Bil €)
FATTURATO (Valore)	124 (+2,3%)	133 (+2,4%)	144 (+2,5%)
PRODUZIONE (Quantità)	-0,3%	-0,9%	+0.5%
NUMERO IMPRESE INDUSTRIALI	6.957 (con oltre 9 addetti)	6.860 (con oltre 9 addetti)	6.810 (con oltre 9 addetti)
NUMERO ADDETTI	408.000	405.000	402.000
EXPORT	21,1 (+10,0%)	27,1 (+6,9%)	33,2 (+3,5%)
IMPORT	17,5 (+9,8%)	20,4 (+4,5%)	23,4 (+1,8%)
SALDO	4,6 (+7,0%)	6,7 (+19,7%)	9,8 (+26,2%)
TOTALE CONSUMI ALIMENTARI	206 (Variaz . Reale + 1,0%)	208 (Variaz. Reale -3%)	210 (Variaz . Reale + 0,3%)
POSIZIONE NELL'INDUSTRIA MANIFATTURIERA ITALIANA	2° posto (12%) dopo settore metalmeccanico	2° posto (14%) dopo settore metalmeccanico	2° posto (15%) dopo settore metalmeccanico

Pandemic did not help the consumption recovery in 2020. Imports are still declining: the positive trade balance arrives to 10 billion euro in 2019 (see below). It is the most interesting result in the last 10 years, giving to the agri-food sector a very important relevance and role in the Italian economy (2nd manufacturing sector after the mechanical one), with a forecasting of 200 billion turnover in 2030.

Italy has developed foreign markets of its food made in Italy, with some export excellences: wine, olive oil, sweets and cakes, pastas, canned vegetables, coffees, chocolates, rice, ham and cheeses (prosciutto di Parma and San Daniele, Parmigiano Reggiano, Grana Padano, Gorgonzola, stracchino, provolone, salame norcino) as below:

EXPORT ALIMENTARE - MONDO - I PRINCIPALI PRODOTTI
ANNO 2018

Prodotti	Milioni euro	Incid%
Prodotti vegetali	6.237,5	15,1
Prodotti zootecnici	1.337,0	3,2
Prodotti forestali	166,3	0,4
Prodotti pesca e caccia	348,8	0,8
Riso	551,8	1,3
Molitorio	384,3	0,9
Pasta	2.420,6	5,9
Dolciario	4.319,3	10,5
Zucchero	170,6	0,4
Carni preparate	1.719,2	4,2
Ittico	356,8	0,9
Trasfor. Ortaggi	2.303,1	5,6
Trasfor. Frutta	1.173,0	2,8
LattieroCaseario	3.119,0	7,6
Oli e Grassi	2.036,3	4,9
Alim. Animale	815,6	2,0
Vini, Mosti, Aceto	6.633,4	16,1
Birra	198,9	0,5
Acquaviti e Liquori	1.077,8	2,6
Alcool etilico	39,8	0,1
Acque minerali e gassose	742,3	1,8
Caffè	1.467,8	3,6
Altre Ind. Alimentari	3.680,0	8,9
Totale Ind. Alimentare	33.209,6	.
Totale Agroalimentare	41.299,3	100,0

Fonte : Elaboration and forecast Federalimentare on Italian Food for Life" NTP data

Forestry

According to the National Institute of Statistics (ISTAT), the forest in Italy covers 10.5 million ha (1/3 of the total surface: 105,000 km^2 - figures for the 2019 campaign), which corresponds to an afforestation rate of 34.7 % of the territory. The wooded area represents 83.7 % of the total forestry surface, the others the residual 16.3 %. The territorial districts with higher percentages of forestry are the Regions of Alto Adige Trentino, Friuli Venezia Giulia, Liguria, Toscana, Umbria, Abruzzo, Calabria and Sardegna. The wood, with an extension of 8,759,200 ha, concerns the 29.1 % of the total national surface. The Italian districts with the highest wooded area are the Regions of Liguria and Trentino, with a percentage of 62.6 and 60.5 %; the Regions with the lowest wooded area are Puglia (7.5 %) and Sicilia (10.0 %). The other residual surfaces – 1,708,333 ha resulting in 16.3 % of the total forestry surface – are Mediterranean shrubs for the 58.0 %. The forestry categories are mainly the oaks, downy oak, English oak, beeches and Turkey oak woods, Hungarian oak, Macedonian oak and Mount Tabor oak, with surfaces showing more than 1 million ha.

The Italian forestry sector represents the 12.4 % of the Bioeconomy employment: it means 273,000 direct and indirect jobs. The Forestry sector is present on many current markets: forestry and forest mobilisation (for a turnover of 2.1 billion euros), woodworking (sawing, carpentry and joinery, veneer, panels, parquet flooring and pulp for 10.6 billion euros), consumer goods (wood processing, construction, furniture, paper, and cardboard for 21.2 billion euros) and wood energy (for 1.7 billion euros excluding wood-logs).

Bioeconomy

The Italian national strategy on the bioeconomy dates from October 2018, and integrates all sources of biomass (agricultural, forest-wood, marine and aquaculture sectors), food and non-food use. The involvement of public and private stakeholders, the different Agro approaches, and cutting-edge technologies such as industrial biotechnologies, research and development, dialogue with society, and consideration of the entire value chain with stakeholders upstream and downstream of production.

All bio-based industries supply around 8 % of the Italian national consumption of energy, chemicals, and materials. These performances are expected to double by 2030. Italy is already probably among the ten most "bio-economic" nations in the world, with a significant contribution of bio-based industries to energy and climate "roadmaps" (The Bioeconomy Plan – MIUR/MISE – Italy 2020; Energy Transition to COP21). The bioeconomy in Italy generates significant positive externalities, including jobs created and "carbon avoided". Among a volume of bioeconomic jobs that can be evaluated in Italy, in the broad sense, at around 2,200,000 people (including agriculture, agri-food and the forest-wood sector), a total of ± 90,000 direct jobs linked to the bioeconomy is considered. Most of these jobs would have been created over the past 15 years. Bioeconomy in Italy represents in 2020 a turnover of 280 billion euro.

AKIS

The Agri and food sector is considered both strong and fragmented: the Italian agriculture is not enough innovative, nor so technologically advanced, despite numerous agri-food schools and scientific centres focusing on its improvement. Agricultural education in Italy brings together more than 245,000 pupils, students, apprentices and trainees, and the average educational level of new farmers tends to rise. From 2000, the level required to be authorised to start one's own farm was minimum level 4, or vocational bachelor, which is taken over 4 years, but more and more farmers are presenting a level 3 diploma or even higher. The Italian Agri food sector is also represented by powerful agricultural collectives and confederations with cooperative and collaborative attitudes between farmers and farmer's networks (Reti di Impresa) within a new juridical status/framework.

1. Challenges faced by the Italian Agricultural, Forestry and Bio-economy sectors

At the end of December 2020, the EU Commission published its recommendations for the national strategic plans under the Common Agricultural Policy (CAP). These strategic plans, which are expected to be finalised in early 2022, will enable each Member State to implement the new CAP from 2023 onwards.

To make its recommendations, the Commission has drawn up an inventory of 6 Italian agriculture's challenges in economic terms: 1. The income is unevenly distributed among different farmers and territories; 2. Markets are increasingly subjected to price volatility; 3. Farmers have a weak bargaining power in the value chain, notwithstanding the adoption of art. 62 norms in the Italian legislation and the Fair Trade Directive coming from European institutions; 4. There is an investment deficit, and the competitiveness is declining; 5. Young farmers are too modest in quantity and quality of their professional skills; 6. There is still a deep diversity from North to South of Italy, being the southern regions the basin of the agricultural production and the northern regions the area of the food and drink industry manufacturing/transformation/processors.

The 6 challenges on environmental terms: 1. The fragmentation and the small size of the average agricultural and agri-food sectors in Italy, and in particular the high share of horticultural greenhouses production, pose several urgent environmental and climatic challenges. 2. Italy, less than France, but risks not meeting its emission reduction commitments for 2030 and beyond. 3. According to the Commission, the priority is to fight the trend towards soil sealing and the shrinking of permanent grasslands, together with more resilience of the agricultural sector.

Among the various environmental challenges: 4. water quality and soil management and health are also quoted by the European Commission: Italy has achieved the Water Framework Directive objective of good status for all water bodies, but not for nitrogen status of soil. 5. On the issue of pesticides, although Italy has set ambitious objectives within the European rules, it is struggling to accelerate the decreasing trend and efforts by promoting the use of low-impact and bio active/bio stimulant pesticides. 6. The preservation of biodiversity remains a challenge in many agricultural areas. The state of conservation of agricultural habitats and landscapes is widely assessed as inadequate or poor and there is a need to improve ecological connectivity (with hedges and other landscape features), protect plants and animal species characteristic of farming environments (birds, flora, pollinators, etc.) and manage agricultural land.

2. Italian Trends on sustainable production

Animal welfare

Animal welfare is a growing concern in Italy. 63 % of the people said to consume less meat and pay more for it if it comes from farms that respect animal welfare. The desire of consumers to guide their consumption choices by considering animal welfare is reflected above all in the emergence and growth of the vegan trends. According to COOP analysis, around 22 % of Italian people are in favour of this type of consumption, which consists of reducing the amount of animal proteins in the diet and increasing the number of proteins of vegetable origin.

The Italian Ministry of Agriculture, with the aim of placing animal welfare at the heart of a sustainable agri-food activity by making all those in contact with animals (breeders, veterinarians, transporters, farm technicians, slaughterhouse employees, etc.) responsible. To ensure its success, an action plan is implemented and is made up of different goals: encouraging innovation, raising stakeholders' awareness, evolving best practices towards more animal-friendly production.

Appearance of the animal welfare label, 72 % of Italian people are in favour of labelling meat and dairy products according to the farming method. To answer this growing demand, several independent labelling methods have emerged, and are still under development (poultry has adopted one of them – see www.unitalia.com, the egg and poultry association).

Food industry

1. A resource efficient food supply, including food processing, advanced and environmental -friendly technologies, through food chain approach, increasing consumer acceptance of food products and industry best practices.

Research and application of improved and new technologies, advanced process control, manufacturing and ICT solutions, management systems, innovative solutions are necessary for:

- enabling productive, flexible food manufacturing practices, with low cost and low scale technologies;
- efficient use of energy, materials, water and labour to promote nexus and reduce waste and losses and to maintain existing/current environmental impact of food products and packaging;
- systematic approach to optimise the exploitation of limited raw material and other biological resources;
- reduction of production costs without compromising food safety and quality;
- improve and retain consumer confidence and trust in food supply chain processes and practices;
- development of accessible, affordable technologies and equipment for SMEs which can deliver the above listed functions.

2. Delivering nutritional and pleasurable food products that meet dietary needs and prevent non-communicable diseases.

Food products should contribute to the improvement of consumer health and well-being through understanding of the relationship between diet and health for individuals, groups and populations, at the genomic to physiological level.
Food products, assisting a balanced diet, should maintain the pleasure from eating. To achieve this, research should be carried out on:

- enhancing nutritional potential of new and not properly exploited raw materials and ingredients;
- to preserve and enhance nutritional value and sensory properties in processing, distribution and sale through optimisation of existing and new processes and technologies;
- reformulation of existing products and development of new concepts to create healthier alternatives without compromising product safety or quality and guidance and information for that;
- Helping consumption decisions through better understanding of consumer perception of nutrition and health issues and trade-offs with pleasure from eating and associated behaviours to facilitate innovation.

3. Promotion of transfer and accessibility of new and advanced knowledge and solutions and provision of skilled staff with updated, relevant competences.

There is a need for sustainable business models, systems and networks, which convert research results into practically applicable solutions data, information for SMEs on:

- efficient use of material, energy, water and labour resources and relative nexus on circular economy;
- adaptation and application of advanced process control including safety control, manufacturing, ICT, energy management solutions and value chain management methods for the food supply chain;
- preserving and enhancing nutritional value and pleasurable sensory properties in processing, distribution and sale and on reformulation of products to deliver food products which contribute to healthy life styles and prevent non-communicable diseases;

- methods, tools and operational models, which support to maintain and develop skills, knowledge and competence of staff in manufacture, distribution and sale of food.

4. The food human axis:

- Low Scale Low-Cost new technologies (ICT, pilots, niches, efficiency …)
- High quality stable and fresh food ready to eat with packaging extended shelf life;
- Consumer response to food price instability: from raw materials to retailer's supplier;
- Valorisation of genetic resources and technological improvements to increase the nutra-functional values of processed foods;
- New track systems and sustainable transportation and logistics, losses and waste reduction;
- Marker's identification, integrity of varieties used in the production of traditional materials and food and P.D.O./P.G.I.;
- Sustainable production and new business models and value chains strategies;
- effect of ingredients, processing and way of consumption on human wellbeing.

Forestry

Sustainable forest management can both contribute to the development of the bioeconomy and provide ecosystem services. Despite the large area covered by forests (34.7 % of the total territory), many Italian forests are not actively managed. This can hamper their role as carbon sinks, their resilience to extreme weather conditions and the provision of other goods and services. More attention must be given in the following decade to the management of the forests, and their bioeconomy products and services.

Three major trends are emerging in the forestry sector in Italy for a circular, modernised, and competitive forest-wood sector: 1. Developing a competitive, high-quality resource by managing forests sustainably and by better exploiting their products and environmental services; 2. Enhancing the value of oak/beeches woods and develop their uses; 3. Cleaning and exploiting the underwood products adding values by shorter chains/locally produce.

Some strategies being put in place: greater renewal, with the aim of planting and regenerating thousands of ha of adapted species; improving the diversity and density of stands to optimise the production of quality wood and environmental services; generating opportunities of local products/multi-functional agriculture in rural and peri-urban minor areas in Italy; adapting the resource to climate change through research programmes (genetics, ecosystems, role of water, etc.) and transfer of knowledge to education and forest management; modelling carbon sequestration and measuring the carbon footprint of wood products; increasing wood mobilisation by the sustainable management best practices; facilitating the grouping of land on a territorial scale.

Among other trends in Italian forestry, we may also find the making better use of hardwoods, the new wood energy policy and the use of wood in green chemistry and biomaterials, by our industrial bio facilities.

Food waste

Several trends have concerned food waste in Italy in the recent years: in 2018, the law on the fight against food waste is enacted, consisting of a moral suasion to the retailers to look for a partnership with a food aid association to sell its unsold food, instead of throwing it away or destroying it. In 2020, Italy took another step in its fight against food waste by strengthening the action for balanced trade relations in the agricultural and food sector.

The framework of application of the law relating to the fight against food waste was also extended to collective catering which will also have to offer their uneaten products for food donation, together with the volunteers of the *Banco Alimentare* active in Italy since 1982. The Food service/Catering sector preparing thousands meals a day had the obligation to agree with a food aid associations the donation of consumable plus unsold foodstuffs.

The anti-waste trend is also developing at the private level with the help of the agri-food industry by joining the national pact to combat food waste.

3. Italian Trends on Bioeconomy

Italy is a country with significant biodiversity, agricultural resources, forestry and aquatic to feed a diversified bioeconomy and thus offers new opportunities to these primary sectors, creating added value and jobs. The agricultural sector is involved in the production of renewable energies (biogas, methanisation, biofuels...), and this development is growing.

Agri-food industries valorise their by-products in animal feed and energy, but also work on packaging and inorganic waste reduction and re-use, creating jobs and enhancing bioeconomy in the country.

The forest-wood sector offers a variety of uses for biomass, from lumber to energy and innovative molecules: in the following years, the bioeconomy aspect of the forestry in Italy is expected to increase, by adopting technology of manufacturing no-food composites and materials for cosmetics, pharmaceutical, textiles and bio building.

4. Italian Trends in Digitalisation

Italian agriculture, which had been lagging in terms of technology, has begun its digitalisation over the last 15 years. According to the Ministry of Innovation, more than 150 million euros have been invested in Agri Tech and Food Tech start-ups during the year 2016. Italy therefore ranks third in Europe, with 1.8 % of global investments in the sector. This development follows a strong governmental will: the Agriculture 4.0 analysis underlined the important stake that the exploitation of digital data represents for the agricultural world, as well as the need to set up an agricultural big data harmonization and management.

The Digitalisation of the Italian Agriculture is concerning the following areas: risk management; big data, data analysis, predictive models; R & D investments; interconnectivity; decision support systems; the development of robotics coupled with artificial intelligence AI; IoT on farms supporting farmers in the management of herds and crops: increased precision agriculture; satellites data management.

Digital technology and its large-scale data collection - its cost - speeds up collaboration and the sharing of data, knowledge, and equipment; training with the smartphone, combined with decision support tools, contributes to the intellectual freedom of farmers; virtual reality helps more and more an educated farmer.

Food chains become more transparent with a better traceability, also through the block chain technology, taking the farmers and food industry closer to the consumer and promoting their exchanges and info/needed.

See below the most interesting digit areas to 2030:

- 3d Print
- Artificial Intelligence
- Virtual reality / Augmented reality Block chain
- Advanced automation
- Data analytics
- Portable devices – quality
- Internet of Things
- Cloud computing
- ERP
- Portable devices – production
- Portable devices - logistics and traceability
- Supplier management software

And the most interesting operational phases to be digitalized on the agrifood chain:

- Relations with Public Authorities
- Relations with centralization bodies and / or consortia
- Quality check
- Logistics
- Procurement of raw materials
- Food traceability and traceability
- Commercial enhancement of the product
- Product development and innovation
- Production

5. Italian Trends in business models

Italian farm structure is very fragmented: the trend is towards the development of non-agricultural activities supporting the farm (tourism, renewable energies, agri services, didactics, and education/recovery/socialization).

These service activities aimed at the public have a social and commercial dimension. Three main trends are emerging: 1. the development of short and simply chains through direct delivery and farm cooperation; 2. para-agricultural activities supported by the farm's buildings, production, and equipment; 3. organization and local skills.

The most widespread para-agricultural activities are the contract work carried out on behalf of other farms and the farmhouse or "farm tourism" as a growing activity, including accommodation and leisure activities such as horse farms, educational farms, or farm visits.

On-farm catering and restaurant/Horeca activity is also developing, at a different pace depending on the region and on the site if touristic or not. Other para-agricultural activities such as the renewable energies, the wood processing, the forestry underwood products, crafts, renting buildings and facilities for smart working on pandemic/hosting/garages are emerging trends.

Annex: Italian Trends in new skills needed

The main areas of interest in vocational education responding to the Italian trends on bioeconomy, digitisations and agri-food sector are well described by the following table:

Vocational Education main interest areas in 2020:

Adaptation and contrast to climate change	Techniques to combat climate change
	Techniques of adaptation to climate change
	Supporting technologies
Management and administrative capacity	Management and administrative skills
	Access to credit, financial instruments
	Evolution of the national and local regulatory framework
	Worker safety
Generational change	Business transmission
	Start-up of the agricultural enterprise
	Female entrepreneurship
	Development of new ideas in agriculture
Sustainability of production processes	Advanced defence techniques and crop management
	Enhancement of natural and agricultural biodiversity
	Protection of the soil and its fertility and reduction of hydrogeological risk
	Management of the traditional agricultural landscape
Market, quality and supply chain relationships	Strategic Marketing Skills
	Operational marketing and communication skills
	Opportunities and methods of productive requalification
	Operating mechanisms of supply chains and related tools
	Short chain and new commercial channels

	Food safety: risk control and prevention, animal welfare
Organic, conservation and precision farming	Disciplinary and techniques for integrated production
	Biodiversity and opportunities for agriculture
	The conversion to organic farming
	Innovative techniques and technologies in organic farming
	Naturalistic forestry
	The mechanization techniques of conservative agriculture
	Conservative management of the land
	Technologies 4.0
Productive and organizational diversification	Management of tourist reception services in the company
	Management of educational farms
	Management of services for the population (social agriculture)
Internationalization	Knowledge of outlet markets
	Support for production structures for exports
	Language skills
Competitiveness	Quality schemes and agricultural and food products
	Innovation of product transformation processes
	Development of short supply chains
	Safety in the company
	Risk management
	Extensive breeding and improvement of animal welfare
Local development	Extra-agricultural skills, enhancement of local heritage
	Production chains, cooperative networking

A recent Italian survey ranked the knowledge needs (vertical) and horizontal skills by the primary sector (2000 interviews by Confagricoltura - survey Enapra 2020):

KNOWELEDGE	IMPORTANCE		COMPLEXITY	
1. Food production	84	→	76	↑
2. Production and Process	77	→	65	↑
3. Business and business management	71	↑	65	↑
4. Marketing and sales	67	↑	63	↑
5. Human resources Management	57	↑	56	↑
6. Economics and accounting	57	↑	48	↓
7. Services to customers and people	56	↑	56	↑
8. Italian Language	53	→	51	→
9. Laws and Regulations	51	↑	45	↓
10. Chemistry	46	↓	42	→
11. IT, Computer science and electronics	/		/	
12. Foreign language	/		/	
SKILL	**IMPORTANCE**		**COMPLEXITY**	
1. Manage financial resources	84	↑	72	↓
2. Time management	78	↑	67	↑
3. Assessment and Decision making	76	↑	66	↓
4. Negotiation	75	↑	63	↑
5. Monitoring	72	↑	60	↓
6. Speaking	71	↑	60	→
7. Comprehension of texts	69	↑	62	→
8. Analytical skills	69	↑	62	↑
9. Persuasion	67	↑	58	→
10. Material resources	67	↓	66	↓
11. Complex issue, Problem solving	67	↑	60	↑

Italy Scenarios

We follow the distinction in three scenarios as in chapter 3 of this report: Sustainable Pathways, Established Pathways, High-Tech Pathways. These scenarios are specified for the dimensions sustainability, bio-economy, digitalisation, business models and the AKIS, in separate tables. The last table of this country report includes key skill needs derived from the trend and scenario analysis: 5 key skills per dimension for every scenario. In this table the skill list developed in work package 1.3 (EU and country focus group) is taken as starting point for the identification of key skills. Therefore, the numbering before the skills descriptions in the table is consistent with the numbering in this skill list; skills in the table without a numbering are skill needs that were not found in the skill list of WP1.3.

Italy: Scenarios sustainable production – key issues

Sustainable paths	Established paths	High-tech paths
•Arable farming and greenhouses have moved to agro-ecological climate smart production techniques and to the application of bio-pesticides and organic fertilizers, supplied by the livestock sector. Renewable Energy exploitation become an asset. Water and energy use are subject of optimisation.	•Arable farming and greenhouses increase use of bio-inputs. Use of chemical pesticides and synthetic fertilizers decrease moderately due to EU legislation. Local produce activities and distribution moderately increase. Renewable energy uptake moderately increase.	•Arable farming and greenhouses use optimal mix of bio- and chemical inputs, based on economic incentives to ensure high yields. Regional specialisation and monocultures limit biodiversity potential. Robots and autonomous machines appears to carry some tasks.
•While the number of farms in Italy is decreasing fast, the number of food and drink companies with more than 9 employees is relative stable	• increasing exports of the made in Italy all over the world, compensating the internal consumption crisis from 2008 until now.	•Italy has developed foreign markets of its food made in Italy, with some export excellences
•High social and environmental consumer awareness, plant based diets are gaining relevance, with organic-based local products.	•Cost, taste and convenience are most important product attributes for consumers. Niche markets for local and traditional foods remain but have a small market share. Consumption of meat remains high. meat consumption is linked to animal welfare. Balanced diet concern increase among consumers.	•Consumers value healthy and personalised (functional) processed foods. Meat consumption is slightly reduced. •AI tools support consumers in the choice of food products/diets based on living stiles & health. Personalised diet
•Livestock sector has invested vastly in sustainable and circular production and alterations in feed composition. Livestock production systems with free run-out options for animals are common. Local sourcing of feed.	•Livestock sector has invested vastly in sustainable production. Livestock production systems with free-range (indoor) options for animals are common. Feed sourcing combines local & global. • Animal welfare and organic meat production gain of importance.	•The livestock sector has invested vastly in technology for sustainable and circular (indoor) production, focusing on limitation of emissions. Feed sourcing is Globally oriented. Robot use is increased in livestock operations
•Despite the large area covered by forests, many Italian forests are not actively managed. This can hamper their role as carbon sinks, their resilience to extreme weather conditions and the provision of other goods and services.	•The Forestry sector is present on many current markets: forestry and forest mobilisation, woodworking (sawing, carpentry and joinery, veneer, panels, parquet flooring and pulp), consumer goods (wood processing, construction, furniture, paper, and cardboard) and wood energy.	• Greater renewal, with the aim of planting and regenerating thousands of ha of adapted species; improving the diversity and density of stands to optimise the production of quality wood and environmental services
•The food industry is strongly moving towards circular production. The connection with the consumer base (e.g. through product information and promotion) has been strengthened.	•Food industry slowly moves to more circular production. Connection with consumers is slowly growing through retailers.	•Product innovations are strong and continuous, focusing on functional, 3-D printed and/or & healthy foods and GMOs. Food industry moves to circular production looking for economy benefits. Strong connections to manage the food chains and assure safety & quality

Italy: Scenarios Bio-economy – key issues

Sustainable paths	Established paths	High tech paths
• Italian agriculture has made a strong move towards circular production with optimal use of by-products and waste streams.	•There is only moderate development towards circular production in Italy agriculture. Efficient use of material, energy, water and labour resources and relative nexus on circular economy;	•High tech agriculture and precision farming and integrated pest management lead to a strong move towards circular production (the rationale for changes is economic).
•Agriculture contributes to a fast growing biobased sector (e.g. to chemical industries). Decentralised bio-refinery and renewable energy installations.	• The involvement of public and private stakeholders, the different Agro approaches and cutting-edge technologies, dialogue with society, considering the entire value chain with stakeholders upstream and downstream of production.	•The biobased sector (industrial biotechnologies, chemical, plastics) has grown fast, supported by biomass from agriculture. Concentration of processing facilities.
•Zero emissions agrifood industry. Power is provided by renewable sources connected to efficient energy storage devices. Biogas is produced from highly loaded wastes and used to minimize factories heat necessities.	• Italy risks not meeting its emission reduction commitments for 2030 and beyond	• Forecasting tools connected to SCADA systems allow the optimization in the use of green energies in industry and helps to maximize the benefit of agrifood industry.
•100% of the wastes produced in the agrifood industry are transformed into highly added value making way to a new highly-added value specialties business line.	•40% of the wastes produced in the agrifood industry are transformed into highly added value making way to a new highly-added value specialties business line.	•New by-produts emerging from a novel specialty agrifood industry in which new technological approaches achieve more & more highly added products contributing to diversify the business model.
•Degraded land has been afforested. Forestry strongly contributes to biodiversity.	• Forest acreage has increased very moderately. Enhancing the value of oak/beeches woods and develop their uses. Cleaning and exploiting the underwood products adding values by shorter chains/locally produce.	• Developing a competitive, high-quality resource by managing forests sustainably and by better exploiting their products and environmental services. Wood waste stream for forestry maintenance is recycled as pellet
• Water consumption and effluents are minimized in agrifood factories by recycling and reusing techniques. Many of the effluents of the agrifood industry are reclaimed for agricultural irrigation.	• Italy has achieved the Water Framework Directive objective of good status for all water bodies, but not for nitrogen status of soil	• SCADA systems allows to optimize the use of different sources of water and reclaimed wastewater for several applications in industry, agriculture and other uses

Italy: Scenarios digitalisation – key issues

Sustainable paths	Established paths	High tech paths
•In Italy is common the precision agriculture and integrated pest management to support optimal use of resources and circular agriculture in small scale and cooperative sustainable production systems.	•Precision agriculture and integrated pest management is used in many subsectors to optimise use of resources in, particular, large farms. There is limited attention to circular production.	• In Italy is common the Precision agriculture and integrated pest management to support optimal use of resources and circular agriculture in large corporate farms,
•Precision agriculture results in high yields, genetic improvements and ecological intensification. Waste is minimized.	•Precision agriculture, moderately, results in high yields, genetic improvements and ecological intensification.	•Precision agriculture results in high yields and genetic improvements. Waste is minimized. The great flow of information allow to collect a lot of data and exert with data mining useful information and strategies.
• Italian agriculture has begun its digitalisation over the last 15 years with large investment in Agri Tech and Food Tech. More importance has been done in the exploitation of digital data and in the setting up an agricultural big data harmonization and management.	• Digital technology and its large-scale data collection speeds up collaboration and the sharing of data, knowledge, and equipment; training with the smartphone, combined with decision support tools, contributes to the intellectual freedom of farmers.	•The Digitalisation of the Italian Agriculture is concerning the following areas: risk management; big data, data analysis, predictive models; R & D investments; interconnectivity; DSS; the development of robotics coupled AI; IoT on farms supporting farmers in the management of herds and crops: increased precision agriculture; satellites data management. Increased adoption of FMIS.
•Food chains become more transparent with a better traceability, taking the farmers and food industry closer to the consumer and promoting their exchanges and info/needed.	• In Italy, Although, collaboration between farmers and food industry remains limited, traceability by block chain technology and supply chain information systems has become a main field of attention.	•Digital technologies support a solid connection between stakeholders in the agri-food supply chain so as to ensure a fast and flexible flow of products and assure safety and traceability in long/short food chains.
•In the Italian food industry application of robotization and AI have led to smart factories supporting efficient use of resources and circularity of production.	•The pace of robotization and AI applications in food industries is moderate.	•Smart factories are common in Italy food industries. Production is circular if economically viable. Virtual reality helps more and more an educated farmer and agri-food operators.
•Digital technologies ensure transparency of production for consumers and partners in the food chain. Product information is improved by digital technologies.	•Product information is improved by digital technologies, but some difficulties for elder consumers emerge.	•Digital technologies (e.g. real time monitoring of physiological functions and nutritional needs through biomarkers and biosensors) support personalised solutions for individual consumers.

Italy: Scenarios business models – key issues

Sustainable paths	Established paths	High tech paths
▪Italy agriculture is characterised by The fragmentation and the small size of the average agricultural and agri-food sectors in Italy, and in particular the high share of horticultural greenhouses production. New business models for selling of energy to the grid.	▪ Development of non-agricultural activities supporting the farm (tourism, renewable energies, agri services, didactics, and education/recovery/socialization).	▪development of short and simply chains through direct delivery and farm cooperation; ▪ para-agricultural activities supported by the farm's buildings, production, and equipment; ▪ organization and local skills. ▪Cooperatives to use high-tech equipment
▪Far most of the farms are multi-functional with side activities. On-farm catering and restaurant/Horeca activity is also developing, at a different pace depending on the region and on the site if touristic or not.	▪There is a combination of large specialised farms and small-medium size farm. Small and medium size farms are in many cases multifunctional.	▪Development of para-agricultural activities such as: renewable energies, wood processing, forestry underwood products, crafts, renting buildings and facilities for smart working on pandemic/hosting/garages
▪Collaboration of farmers in cooperatives and producer organisations has further increased. ▪Local-to-local production is common and most farms participate in (online) sales to consumers in short, local, food chains.	▪Collaboration of farmers in cooperatives remains a key characteristic of Italy agriculture.	▪Agricultural production & consumption is globalised. ▪Products are produced where this is most cost efficient. ▪New equipment allows cooperative growth for forestry exploitation with new services and products
▪On food industry level, besides multinationals still operating, many small and medium size food industries have emerged closely working with farmers for sustainable, local-to-local and artisanal production. ▪Business growth to produce sustainable packaging.	▪ Food industry is mainly made up small and medium companies. Safety, quality and traceability are key issues in food chain management.	▪Food supply chains have advanced storage and logistics facilities. ▪Safety assurance & traceability systems are of key importance. ▪Personalised diet delivery of food ▪Modified atmosphere packaging increase shelf life of product. Increasing ready to eat products.

Italy: Scenarios AKIS – key issues

Sustainable paths	Established paths	High tech paths
▪Public spending on agricultural R&D is growing in recent years, which is allowing the increasing implementation of AKIS to foster sustainability in the agri-food sector.	▪AKIS in Italy are underfunded given that public spending on agricultural R&D has been reduced in the last ten years	▪Big farms and farms linked with corporation are technically monitored and supported by high tech decision systems
▪Technology transfer and innovation in the agricultural sector has been implemented at regional and local level, having increased the capacity to address the problems and opportunities of the sector from the grassroots.	▪Every region has a specific extension policy regulated by regional laws that apply also to agricultural applied research. The main objectives regard technological transfer, farm competitiveness, cross-compliance, rural animation, diversification, food safety, environmental impact, more connected with the objectives of the CAP.	▪ Technology transfer and innovation in the agricultural sector has been implemented at the regional or local level. ▪AKIS high-tech services managed directly by universities
▪Forestry sector is strong ruled by strict regulations focused to improve biodiversity and carbon capture.	▪Forestry sector is ruled by regulations focused to improve biodiversity and carbon capture, but the policies are not fully implemented.	▪There is a strong need of training the forestry workforce on digital tools, applications and services
▪Farmers, forestry and food industry employees are highly educated in sustainable business management and ethics.	▪Farmers, forestry and food industry employees have a moderated educational level in sustainable business management. The Italian reform legislation has reduced the number of departments, increasing coordination of activities, and has proceeded towards simplification and greater administrative efficiency and transparency of the internal university management	▪Farmers, forestry and food industry employees are medium or hight educated in business management, entrepreneurship and innovation.
▪Although the Italian AKIS is driven by different policies, in the last decade an approach typical of an 'agricultural knowledge network' has emerged enhancing collaboration among the components.	▪The Italian AKIS has proceeded in the last decade towards specific objectives: connecting R&D and Higher EDU to the development policy through planning, evaluation and coordination; promoting the competition between public and private bodies;	▪ Italian AKIS promoting coordination between the regions; implementing the European policy especially with regard to the new agricultural functions and the environmental impact.
▪Collaboration of farmers (in cooperatives/producer organisations), foresters and food industries with public and private knowledge providers of the food system	▪Collaboration of farmers, foresters and food industries with public and largely private knowledge providers.	▪Collaboration of (small and medium) famers, foresters and food industries with private and public knowledge providers/R&D suppliers.

Scenario specific skill needs, Italy (categories from Task1.3 – focus groups)

Sustainable paths	Established paths	High-tech paths
Sustainability	**Sustainability**	**Sustainability**
1.01 Mitigation and adaptation to climate change 1.03 Improved agrifood system productivity 1.13 Identification of renewable energy systems suitable for the farm / business enterprise 1.18 Water management 1.19 Soil Nutrient and Health Management	1.03 Improved agrifood system productivity 1.04 Active management of natural resources 1.10 National, EU and international environmental policies, regulation, subsidy and support programs 1.17 Good Agricultural Practices 1.11 By-products and co-products valorization	1.02 Efficient use of resources and logistics 1.03 Improved agrifood system productivity 1.04 Active management of natural resources 1.11 By-products and co-products valorization 1.13 Identification of renewable energy systems suitable for the farm / business enterprise
Bio-economy	**Bio-economy**	**Bio-economy**
3a.09 Conventional versus /and Organic farming 3a.10 Controlled Environment Agriculture 3a.13 Agricultural biodiversity 3a.02 Performing farming operations 3b.02 Sustainable forest management practices and planning	3a.01 Planning and coordinating production 3a.05 Calculating, handling and managing risk 3a.04 Logistics and storage 3c.01 Quality management, assurance and control 3c.13 Management of inventories	3a.14 Genetically Modified Crops 3a.15 New industrial crops and bioproducts for the bioeconomy 3a.21 Plant and animal breeding for resilience and robustness 3c.02 Food safety management, hygiene and safety control 3b.12 New technologies in pulp, paper, timber and cork manufacturing
Digitalisation	**Digitalisation**	**Digitalisation**
2.07 Digital entrepreneurship 2.11 Warehouse management systems 2.12 Digital food traceability system 2.18 Precision animal health and productivity 2.19 Field operations management systems	2.01 Everyday usage digital technology 2.06 E-commerce and e-marketing 2.11 Warehouse management systems 2.17 Farm Management Information Systems (FMIS) 2.18 Precision animal health and productivity	2.02 Data handling and analysis 2.04 Cloud technology 2.15 Decision support systems (DSS) 2.17 Farm Management Information Systems (FMIS) 2.18 Precision animal health and productivity
Business model	**Business model**	**Business model**
5.10.Cooperatives 5.11 New value chains 5.12 Collaboration/cooperation across all sectors in the food chain 5.13 Social expectations/Consumers science & behavior 5.16 Product development	5.01 Monitoring market activity and conditions 5.06 Customers service 5.10 Cooperatives 5.17 Project management 5.23 Specific sector legislation	5.01 Monitoring market activity and conditions 5.03 Sales and marketing 5.07 Business planning/model and strategic management 5.11 New value chains 5.16 Product development