Inclusive REskilling and upSkilling Toward competitive Agrifood and veterinary sector: European agenda Strategy

Deliverable 3.8 Trends and Scenario analysis	
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• Deliverable summary

The I-RESTART project aims at upskilling the workforce in the agri-food sector, including veterinary activities, and at reskilling people from other industries to have them subsequently enrolled in the sector. Another aim is to attract qualified students and to train them to enter the agri-food labour market. For this purpose, the project did an inventory of future trends and scenarios and future skills needs in the animal production, food industry and veterinary activities, in areas of knowledge that respond to social and labour market needs: digitalisation, sustainability/bioeconomy, business models, One-Health. The method applied is building on the partner project Fields. First of all trends in the three respective sectors are identified per country. These trends are summarized in this report and prepared for the three scenarios. Aside from the trends analysis per country, more generic future scenario studies were used to construct the scenarios. In the end three scenarios were identified with the common characteristic that they all strive towards sustainability. Building on reports of for example IPCC the climate is changing drastically and swiftly, and sustainability should a goal in all scenarios. The three scenarios are as follows: local route for sustainability, route continued for sustainability and tech route for sustainability. Based on these scenarios, skills for each sector are identified. These skills can be used in the remainder of this I-Restart upskilling and reskilling project.

1 Introduction

The I-RESTART project aims at upskilling the workforce in the agri-food sector, including veterinary activities, and at reskilling people from other industries to have them subsequently enrolled in the sector. Another aim is to attract qualified students and to train them to enter the agri-food labour market.

For this purpose, the project did an inventory of future trends and scenarios and future skills needs in the animal production, food industry and veterinary activities, in areas of knowledge that respond to social and labour market needs: digitalisation, sustainability/bioeconomy, business models, One-Health.

The FIELDS blueprint sister project has already tackled part of this work, by identifying trends and constructing scenarios, including future skill needs in the agriculture (including animal production) and food industry sectors in the areas of digitalisation, sustainability/bioeconomy, business/entrepreneurship and soft skills. Considering this context, I-RESTART is complementing the work done in FIELDS in these sectors and areas of knowledge. For the veterinary sector, I-RESTART is adapting and complementing the activities done in FIELDS to the specific needs of the veterinary professionals. For One-Health, I-RESTART is carrying out the trends and scenario analysis without a FIELDS reference.

I-RESTART WP3 has two main objectives. Identifying the current skills needs and this is done in tasks 3.1 – task 3.3. The other objective is to identify future skills needs. Based on trends and scenario analyses, future skills are identified. Where possible, the outcomes of Fields were taken as starting point. Where not possible, the trends analysis and scenario analysis was done from scratch.

This report presents the main findings of the trends and scenario analysis, as well as some recommendations for skills necessary to focus on in the remainder of the I-Restart project.

2 Method

To understand the changes affecting the European and national food industry, animal production and veterinary sectors, a trend study is conducted. Results from the trend study are used to create scenarios (see chapter 7.6) on present and future skills needs, which then inform the European Strategy developed in chapter 8.

At European level, the trend study is conducted by FDE (food industry sector), UNITO (animal production sector) and EVBS (veterinary sector). Recently defined trends in the FIELDS-project (Trienekens et al., 2021) are taken as a starting point for the food industry and animal production sectors (the veterinary sector was not included during FIELDS) and supplemented with new data. Additionally, nine country-specific trend analysis are performed by LVA (Austria), FOOD (Denmark), Hohenheim (Germany), SEVT (Greece), UNITO & CONFAGRICOLTURA (Italy), CONFAGRI (Portugal), GZS (Slovenia), UME (Spain), and WUR (The Netherlands), with the support of other project partners. Here, specific attention is paid to key trends within countries to understand geographical differences.

Both the European and country-level trend studies are conducted through in-depth desk research. This includes an analysis of scientific literature, sector and policy documents in the four dimensions of the I-RESTART project: sustainability, digitalisation, one health and business models. The study includes deep analysis of new technologies and innovation in the sectors following COP21 and UN 2030 SDGs, Pact for Skills roadmap, Akis SCAR scenarios and foresights, interested ETPs strategies and implementation plans, Food 2030 and DG AGRI and DG Research communications and analysis, BBI and Bioeconomy 2050, FACCE and HDHL JPI, SUSFOOD. Trends are linked to main drivers (i.e., influencers of change), such as the COVID-19 pandemic, emerging technologies, consumers, and the industry and retailer's needs (Wepner et al., 2018). Discussions were held with relevant stakeholders to broaden and confirm discovered trends.

We distinguished between megatrends and trends. A trend is defined as a general direction of a development or change over time on small (e.g., regional or sectoral) scale (Wepner & Giesecke, 2018). Although a trend may affect (parts of) society in the next few years, there is no guarantee that it will continue in the future (Wepner et al., 2018; Wepner & Giesecke, 2018). Megatrends, however, are large-scale (e.g., global) social, economic, political, environmental or technological changes that will likely affect human activities, processes and perceptions over the next 10-15 years (Wepner & Giesecke, 2018). From the Horizon2020-project (Fit4Food2030, 2020), 11 megatrends are specified for their EU-level impact (see Table 1).

Megatrend	Definition
Big Data	Massive data volumes, covering a wide variety, captured, analyzed and used for decision-making
Climate change	Long-term temperature and weather shifts, primarily due to burning of fossil fuels
Demographic change	Changes in population size and structure due to changes in mortality, fertility and migration
Economic globalisation	Free movement of goods, services, capital, technology and information globally
Industry 4.0	Use of recent, (often) interconnected digital technologies in industrial production, enabling new and more efficient processes
Malnutrition	Nutrition intake imbalances, due to: undernourishment (lack of sufficient food), micronutrient deficiencies (inadequate intake of vitamins and minerals), or overnutrition (food with low nutritional

	value and high calories)
Migration	Movement of people within national and across international boundaries
Rise in energy consumption	Rises in energy use resulting from increasing population numbers and global economic growth
Rise of non-communicable diseases	Chronic diseases (e.g., cardiovascular diseases, diabetes and cancer), mostly resulting from unhealthy diets
Urbanisation	Population shift from rural to urban areas
Scarcity of natural resources	Lack of natural resources (e.g., water, rare elements) following world population growth and a global economy

Table 1 Megatrends that Impact European Food Industry, Animal Production and the Veterinary Sector (Wepner et al., 2018; https://www.un.org/en/climatechange/what-is-climate-change)

Trends were then identified for the categories of sustainability, digitalisation, one health and business models in the European food industry, animal production and veterinary sectors (see Table 8). These trends are discussed further in paragraphs 3.1 (trends in sustainability), 3.2 (trends in digitalisation), 3.3 (trends in One-Health), and 3.4 (trends in business models). Trends that are shared by three sectors, are described in a table at the beginning of the paragraph. Trends that are shared by two sectors, are described for the first sector it applies to and only mentioned as trends for the second sector in Table 2. Regional differences in trends are explored in paragraph 3.5.

Category	Sector Trends
Sustainability	**Food Industry:** environmental footprint reductions, energy efficiency developments, circular economy, sustainable packaging, new processing technologies, new products, reducing food waste and loss, dietary shift, “clean and green” label, **Animal Production**: organic agriculture, alternatives to conventional pesticides, alternatives to synthetic fertilizers, decrease of Greenhouse emissions, organic animal farming, food waste and loss concerns, scarcity of natural resources, biodiversity and conservation of eco-systems, animal welfare, aquaculture **Veterinary Sector:** pet food
Digitalisation	**Food Industry:** Internet of Things (IoT), Unmanned Aerial Vehicles (UAV/Drones), Artificial Intelligence (AI) and Machine Learning (ML), Big Data, Blockchains (BC), Management Information Systems (MIS), 3D printing, robotics, digital twins, smart sensors, new processing and packing technologies **Animal Production:** monitoring, smart farming, precision livestock farming, productivity, farm management information system. **Veterinary Sector:** telemedicine, augmented reality (AR) & virtual reality (VR), single camera markerless motion capture
One Health	**Food Industry:** antimicrobial resistance management, zoonotic disease monitoring, food safety, animal welfare standards, reducing food waste, nutrition and health **Animal Production:** antimicrobial resistance management, zoonotic disease monitoring, food safety, animal welfare standards, societal pressure, farm size/scale **Veterinary Sector:** nutrition and health

Business Models	**Food industry:** circular economy models, dietary shift, new consumer interaction strategies, traceability, food logistics 4.0, e-commerce, augmented reality, novel foods, smart packaging, short supply chain, agroecology **Animal Production:** urban farming, consumer health and food consciousness, on-farm diversification, rural employment, traceability, animal health and welfare monitoring, agroecology **Veterinary Sector:** Animal health and welfare monitoring

Table 2 Identified Trends in European Food Industry, Animal Production and the Veterinary Sector

3 Trend results

3.1 Trends in sustainability - general

The World Commission on Environment and Development defined sustainability as ”development that meets the need of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). Sustainability may be assessed along three dimensions: environmental (impact on environmental aspects), economic (ability of a business operation to generate a favorable return on investment consistently over time) and social aspects (contribution to health and well-being, Brundtland, 1987; Ohlsson, 2014). Therefore, we focus on environmental, economic and social trends that intend to improve future well-being of the planet, humans and animals.

3.1.1 Sustainability trends in food production

The food industry encompasses producing, processing and selling agricultural raw materials (Bigliardi & Galati, 2013). The industry has a significant impact on the planet (Ritchie, 2022). For example, the production of food requires large amounts of water, is responsible for approximately 25% of global greenhouse gas emissions and uses 50% of the world’s habitable land. Therefore, reducing the **environmental footprint** is of major concern in the industry (Ritchie, 2022). The following efforts are undertaken to reduce resource consumption, improve supply chain sustainability and promote environmentally friendly production practices:

- Developments in **energy efficiency**: optimizing energy consumption throughout the value chain, including adopting renewable energy sources and innovative approaches such as the Product Environmental Footprint: an EU-wide multi-criteria tool which assesses the environmental impact (e.g., through carbon dioxide emissions, water depletion, waste management) of a good or service throughout its life cycle (FoodDrinkEurope, 2017; Menon et al., 2020; Trienekens et al., 2021).
- Adopting **circular economy** models and tools (Esposito et al., 2020). These business models replace the ‘end-of-life concept’ with reducing, reusing, recycling and recovering materials in production, distribution and consumption processes, with the aim of accomplishing sustainable development: environmental quality, economic prosperity and social equity for current and future generations (Kirchherr et al., 2017).
- **Sustainable packaging**: environmentally friendly and edible solutions that reduce waste (Petkoska et al., 2021). Through active functionalities, such as the release of antimicrobials and antioxidants, these solutions improve food quality and shelf life and preserve nutritional value (Petkoska et al., 2021).
- **New processing technologies** that reduce environmental impact, increase nutritional quality, and maintain safety and the enjoyable experience of consuming, such as water-beam or laser cutting, radio-frequency heating and cold plasma preservation technologies (Lázaro-Mojica et al., 2018, 2020; Trienekens et al., 2021).
- **New products** with high productivity/low environmental impact, such as a higher use of legumes, algae and insects in food products (ETP Food-For-Life SRIA, 2017).
- Sustainable approaches for re-utilizing food industry wastes as industrial substrates for production of valuable bioproducts (such as biofuel, enzymes or biodegradable plastics) to **reduce food waste and loss** (Ng et al., 2020).

Another trend that supports environmental footprint reductions, while meeting nutritional needs and maintaining food security, is a growing interest of consumers in a healthy and sustainable diet (Fasolin et al., 2019; Hassoun et al., 2022a; Noguerol et al., 2021). This **dietary shift** includes a growing demand for plant-based and more sustainable protein sources (e.g., vegetables, insects and micro-organisms), whole and natural options (in contrast to processed and high-sugar foods), and environmentally friendly processing techniques

(Fasolin et al., 2019; Hassoun et al., 2022a). A related trend is the use of a **"clean and green"** label in food products that contain natural, organic ingredients, are free from artificial ingredients, allergens and GMOs, are minimally processed and packaged transparently (Noguerol et al., 2021; Trienekens et al., 2021). This consumer trend shapes the food market, as it changes how foods are produced and advertised (Trienekens et al., 2021; Wepner *et al.*, 2019).

3.1.2 Sustainability trends in animal production

Organic agriculture refers to a production management system that produces food using natural substances and processes, such as crop residues, animal manure and off-farm organic waste (Meena, 2014). It has a limited environmental impact and promotes agro-ecosystem health, including biodiversity, biological cycles and soil biological activity (FAO/WHO Codex Alimentarius Commission, 1999). Trends within organic agriculture are the following:

- The Farm to Fork (F2F) strategy, with the aim to increase EU organic agriculture to 25% of total farmland by 2030 (European Commission, 2020).
- The identification and use of pesticides derived from natural substances (such as plants and animals), i.e., biopesticides (NPIC, 2020). Examples are: microbial organisms (i.e., bacteria and fungi), plant-derived substances (e.g., garlic compounds, essential oils, extracts from leaves), nanoparticles of biological origin (e.g., silver and gold), and fusion proteins: a combination of toxins, not toxic to higher animals, with a carrier protein (Ayilara et al., 2023). Biopesticides are less persistent than synthetic pesticides, which means they break down and leave no residual activity in the environment after a relatively short time (McCoy, 2020). Thus, the use of biopesticides does not only seem promising for the long-term protection of plants, but may also be of interest for organic livestock farming (Deguine et al., 2021).
- The design and development of synthetic fertilizer alternatives, based on the recovery of plant-available nutrients from bio- or organic-based substances from animal, plant or microbial origin, residues, organic wastes, et cetera (Albert & Bloem, 2023). Organic fertilizers are as effective as synthetic fertilizers over longer periods of time (Sharafzadeh & Ordookhani, 2011). Animal manure is considered the oldest organic fertilizer (Kostic et al., 2020).
- Increasingly high standards of animal welfare in organic farming, including nutrition, health and environment (EC, n.d.a; EFSA, 2023a; Trienekens et al., 2021). For example, in 2023 legislation minimum standards for the protection of laying hens, broilers, pigs and calves, and protection of animals during transport and at slaughter is revised (EC, n.d.a).

Both the trends on alternatives for pesticides and animal welfare are broader trends than just under the umbrella of organic agriculture. They are mentioned under this heading, but also without the claim of organic stakeholders might work on these trends.

Agricultural emissions are globally expected to increase with 7.5% over the period of 2022-2032, with livestock production accounting for 80% (FAOSTAT, 2022). However, only a third of this increase will occur at European level, due to the large-scale adoption of GHG emission-reducing strategies, such as: using legumes in feed production, smart use of manure, appropriately preserving meat from production until consumption, and precision feeding (Ponnampalam & Holman, 2023; Peyraud & MacLeod, 2020).

Increased attention to food loss and waste (FLW). Whereas food loss refers to a reduction in edible food weight throughout the stages of production, handling and storage, and processing of food, food waste includes the distribution and marketing, and consumption of food (Ishangulyyev et al., 2019). A strategy for reducing food loss is using food products that have lost commercial value on the human consumption market for livestock

feed (Dou et al., 2018; Trienekens et al., 2021). Using food with production errors that don't affect their nutritional value in animal diets, retains food losses in the food chain with the potential of converting into high-quality meat, eggs, and milk for human consumption (Dou et al., 2018; Trienekens et al., 2021). However, there are challenges that need to be resolved in the management of FLW to guarantee the nutrient supply for animals and feed safety, which asks for training and education initiatives and policy changes (Spang et al., 2022).

A scarcity of natural resources and the animal production sector mutually influence each other (Trienekens et al., 2021). For example, expansion of animal farming may increase land scarcity and water scarcity, which in turn burden animal farming (Doreau et al., 2012; Trienekens et al., 2021). This way, it is difficult to meet the human demand for produce (Mekonnen et al., 2015). Land scarcity also drives intensive production systems, which challenge sustainability and animal welfare. New technologies (such as precision nutrition, precision livestock management) may provide tools to promote animal welfare, productivity, and quality meat products. For example, insects, which require less water, may replace (a portion) of fish in animal feed (Van Huis & Gasco, 2023; Van Huis & Oonincx, 2017). Insects, in turn, can be fed with fruit and vegetable waste, and even manure by deploying these residual streams as high-quality feed for animals (Van Huis & Gasco, 2023).

Animal farming converts species' ecosystems to arable land and pastures, contributing to the loss of habitats, pollution, ecosystem threats and, ultimately, disappearance of biological diversity (Crist et al., 2017; Trienekens et al., 2021; Turner et al, 2007). This not only threatens the health and functioning of natural ecosystems, but also drives the emergence of infectious diseases (O'Donovan, 2010; FAO, 2022). A strategy that supports biodiversity conversation in grassland-based livestock systems is enabling heterogeneity, which can be done through diet composition and grazing behaviour, for example (Fraser et al., 2022).

Lastly, aquaculture is one of the fastest growing food sectors. Innovative systems increase the productivity of fish and crustaceans while reducing the environmental impact (Joffre et al., 2017). Innovation is technological (e.g., breeding systems, vaccines, feeds) and non-technological (e.g., market standards, regulatory frameworks, organisational structures, Joffre et al., 2017).

3.1.3 Sustainability trends in veterinary sector

Environmental impact is a growing concern in the veterinary sector (Marcombes, 2022). An example refers to the production of **pet food**. As protein is the most ecologically demanding macronutrient, commercial pet foods are developed that use insect proteins, as their production is more sustainable (Marcombes, 2022).

3.2 Trends in digitalization in general

As Trienekens et al. (2021), we define digitalisation as tools that collect, store, analyse and share electronic data. The average use of digital technology in EU-agriculture is low and challenged by inadequate information about existing technologies, a lack of digital skills, limited availability of reliable cost/benefit analysis of new technologies, and basic infrastructure shortcomings, such as access to high-speed internet connections (Digibyte, 2019; Digital Day 2019). However, facilitating the development of new technologies and digitisation is on the EU-agenda, aiming to optimize all types of farming, improve decision making and reshape the functioning of agri-food markets (Digibyte, 2019; Digital Day 2019). Next, specific trends for each sector are discussed.

3.2.2 Trends in digitalisation in the food industry

Precision Agriculture (PA) is a solution for current agricultural challenges, such as the rapid growth of the global population, climate change, limited availability of arable lands and a growing necessity for fresh water

(Radoglou-Grammatikis et al., 2020). PA refers to the adoption of Information and Communications Technology (ICT) services which may aggregate and process information provided by multiple sources, improving farming safety and efficiency as a result (Radoglou-Grammatikis et al., 2020; Rejeb et al., 2022). PA solutions are the advent of Internet of Things and related digital developments.

Internet of Things (IoT) generally refers to network connectivity and computing capability in objects, sensors and everyday items not normally considered as computers, which allows these devices to generate, exchange and consume data with minimal human intervention (Rose et al., 2015). IoT enables agriculture to become data-driven, improve efficient production and management of farms and reduce their environmental impact (Villa-Henriksen *et al.*, 2020). IoT is increasingly applied in areas such as food processing control, food quality assessment, food supply chain monitoring, consumer insight gathering, and food safety (Misra et al., 2020).

A **Management Information Systems** (MIS) stores, processes and exchanges operations data into useable information for the decision maker (Trienekens et al., 2021). Functions include site-specific operations management, inventory management, and harvest management (Trienekens et al., 2021; Tsiropoulos et al., 2017). MISs can be improved using IoT (Nam et al., 2021).

New processing technologies that enable milder processing (improving nutrient preservation), increased efficiency and higher food safety (Misra et al., 2017). Examples of such technologies are cold plasma, pressurized fluids, ultrasonics and high-pressure homogenization. These technologies allow milder processing (Misra et al., 2017; Uçar et al., 2021).

Smart sensors are equipped with various technologies (including IoT connectivity and AI algorithms) to monitor real-time parameters such as temperature, humidity, pH, and contaminants. Smart sensors enable rapid detection of anomalies, facilitate traceability, and contribute to better inventory management, ultimately improving overall food safety, quality and production efficiency (Islam, 2016; Hassoun et al., 2022c).

A **Wireless Sensor Network** (WSN) is a network of (smart) sensors (e.g., solar powered field sensors, robots, sensors on tractors), connected through cloud technology, providing various information, such as crop yields, soil mapping, fertilizer applications, weather data, and machinery. (Misra et al., 2020; Trienekens et al., 2021; Villa-Henriksen *et al.*, 2020).

Remote Sensing techniques, such as the use of **Unmanned Aerial Vehicles (UAVs/Drones):** autonomously operating or remotely controlled flying machines that acquire aerial images, thus allowing distant monitoring (Radoglou-Grammatikis et al., 2020; Trienekens et al., 2021).

Artificial Intelligence (AI) refers to a collection of technologies that combine data, algorithms and computing power (European Commission, 2020). **Machine Learning (ML)** is an application of AI which enables computers to mimic human-like behavior, such as learning as it uses each performed action as a learning experience for the next (Alzubi et al., 2018). AI and ML are mostly used in areas like data modelling, classification and analysis (e.g., to predict microbial growth and food shelf life, Addanki et al., 2022).

Blockchain (BC) is defined as “a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records” (Treiblmaier, 2018). BC is increasingly applied in the food industry, with main benefits including improved food traceability,

collaboration, operation and food trading processes (Rejeb et al., 2020). BC is expected to provide consumers with the means to verify product claims (such as sustainably sourced), thereby preventing food fraud (Rejeb et al., 2020; Singh & Sharma, 2022).

3D printing refers to the robotic process whereby a product is built up layer by layer, using a 3D computer design program (Bedoya et al., 2020). It enables the possibility to produce customized food items with intricate designs, tailored textures, and specific nutritional profiles that would not be possible using other technologies (Bedoya et al., 2022).

Digital Twin (DT) refers to a virtual replica of the real process operation, connected to the real world by sensor data and device metadata from IoT (Jacoby & Usländer, 2020; Verboven et al., 2020). In the food industry, DTs mainly focus on monitoring and prediction regarding production and processing of food (Henrichs et al., 2021).

Whereas IoT applies to anticipated virtual environments, **robots** are generally used in well-defined, physical situations. Robot deployment is trending, as robots can substitute humans in repetitive jobs, often with higher precision and speed, thus enabling improvements in food processing, handling, and packaging (Iqbal et al., 2017). However, a current trend involves the merge of IoT and robotics: **Internet of Robotic Things** (IoRT). In IoRT, sensor data from a variety of sources are fused, processed using local and distributed intelligence, and used to control and manipulate physical objects, for example in intelligent transportation (Kara & Carlaw, 2014; Simoens et al., 2018). Here, from the IoT technologies give robots a wider situational awareness, improving their task execution (Simoens et al., 2018).

New packaging technologies. For example, smart packaging involves the development of eco-friendly, biodegradable packaging materials, derived from natural sources and enhanced with advanced technologies (Yan et al., 2022).

3.2.3 Trends in digitalization in animal production

A **Farm Management Information System** (FMIS) supports farm management by enabling central collection, processing, connection and storage of various data relevant for on-farm activities (Trienekens et al., 2021). Examples are health management and feed intake information.

Smart Farming refers to the application of information and data technologies (including GPS, sensor technology and robotics) to optimize farm management (Kopler et al., 2023). Smart farming does not focus on precise measurement perse (Banhazi et al., 2012), but they can have similarities.

Smart Farming can be applied in **Precision Livestock Farming** (PLF). PLF, however, is a resource-efficient technology which aims to make livestock farming more economically, socially and environmentally sustainable through observation and interpretation of behaviors and, if possible, individual control of animals (Banhazi et al., 2012; Tullo et al., 2019).

PLF allows the **monitoring** of livestock in real-time, enabling better management (Jiang et al., 2023). Data that can be monitored, are:

- feed intake (precision feeding): tracking of feed and water intake via animal identification tags and feed station sensors, serving as input for (ammonia) emission reduction policies and precision mineral and medicine supplementation (Berckmans, 2017; Groher et al., 2020);

- animal health (udder, claw, longevity), fertility, and welfare, through mounted sensors (that track temperature, weight, position, animal behaviour, etc.), real-time image analysis or sound analysis (Berckmans, 2017; Molina et al., 2020);
- productivity: For example, on-farm productivity data may be integrated with slaughterhouse data to detect meat quality and disease (Roodenburg, 2017; Wolfert & Poppe, 2019).

Traceability. An example of the EU system of traceability is the trade control and expert system TRACES: an online management tool for all sanitary requirements on intra-EU trade and importation of animals, semen, embryos, food, feed and plants (Fejzic et al., 2019). The aim of the increasingly widespread electronic animal identification (e.g., ear-tags) is to quality control food production establishments and ensure prompt reactions to health threats (Fejzic et al., 2019).

3.2.4 Digitalization trends in veterinary sector

Digitisation includes development of predictive, monitoring and diagnostic technologies (Borisov et al., 2023). These technologies provide more, better and faster data on signs and symptoms of ill health, supporting prediction, prevention and treatment. Example applications are microphone systems that identify fluctuations in pet vocalizations, pet activity tracking and computerized patient records. Developments extend to farm animals. For example, there are tools that collect and crossreference animal health data and alert the farmer or veterinarian when behavioral signs, biological markers or diagnostic results refer to an emerging problem (Borisov et al., 2023; Fejzic et al., 2019).

An example is the EMPRES Global Animal Disease Information System (EMPRES-i), developed by the European World Food and Agriculture Organization, which supports veterinary services by facilitating the organization and access to national, regional and global level disease data and information (Borisov et al., 2023). Smartphone apps allow for clinical-quality, single-lead electro-cardiograph (ECG) recording, 3D-printed models of a patient's anatomy are used for planning surgery, radiotherapy, customised prosthetics and veterinary education, live cells and tissues are printed to be implanted without autoimmune reaction using bioprinting techniques, and a Livestock Barn Monitoring System (LBMS) as Automatic Veterinary System (AVS) can monitor parameters such as temperature, heart rate, humidity and stress level (Fejzic et al., 2019; Umega & Raja, 2022). Limitations of new innovations include challenges in integrating new technologies into existing veterinary practices, ensuring these innovations are effectively used to enhance animal care, and possibly resistance to change within the industry. Challenges include effectively digitizing various aspects of veterinary practice, such as diagnostics and monitoring, while ensuring data security and privacy. There may also be limitations in terms of accessibility and usability of digital tools for all practitioners. Examples of specific digitization applications are:

- Advancements in Information and Communications Technology (ICT), increasing internet access and measures for tackling the COVID-19 pandemic (e.g., social distancing, quarantine, lockdown) supported the development and (limited) use of **telemedicine** in the veterinary sector. Here, high-quality clinical data including video and pictures, are exchanged to facilitate diagnoses, treatments and the provision of expert advice (FVE, 2020; Weich, 2021). Advantages of telemedicine include workflow efficiency, less stress for customers, patients and veterinarians, and environmental footprint reductions (Diez et al., 2023). Additionally, allowing better exchange of medical information between specialists may improve the accurateness and speed of diagnosis and treatment (Becker et al., 2023). Limitations of telemedicine include regulatory challenges, ensuring the quality and effectiveness of remote veterinary care, and addressing any skepticism or resistance from both practitioners and clients towards telemedicine.
- **AI. Augmented reality** (AR) and **virtual reality** (VR) are emerging concepts that influence diagnostic, therapeutic, and pedagogic aspects of veterinary education and practice (Aghapour & Bockstahler,

2022). Use of AR and VR improves productivity, and provides an alternative to animal trials. Examples are: training simulators for intravenous (IV) injection using AR (Lee et al., 2013), performance of a femoral nerve block in dogs using mixed reality (Wilkie et al., 2020), watching surgical videos before performing ovariohysterectomy surgery using VR (Hunt et al., 2020), and EZ Anatomy, an anatomy training tool (Fejzic et al., 2019). Shimada et al. (2022) even developed an AR-prototype designed to superimpose 3D CT scans on real animals in the field of view. However, limitations regarding veterinary education involve the effectiveness of AR and VR tools, their integration into existing educational curricula, and ensuring they provide practical, hands-on experience comparable to traditional methods.

- Another new virtual service is the use of **single camera markerless motion capture** to analyse complex movement patterns and impairments (Scott et al., 2022). An example use is the assessment of equine lameness (Lawin et al., 2023) or pain responses (Lencioni et al., 2021), using images from a smartphone camera video stream. Here, deep neural networks (i.e., multi-layered computer algorithms that can be trained to perform classification and regression tasks) are applied on the input video stream to analyse movements (Lawin et al., 2023). Without the necessity of applying markers, decreasing unnecessary surgery and reducing medical costs, SC-systems thus have many advantages (Scott et al., 2022). However, main limitations of all virtual services revolve around the effectiveness of remote services, such as remote diagnosis and inspections, and integrating these services seamlessly into existing veterinary workflows.

3.3 Trends in One Health

One Health is an approach that explains global health challenges, such as food system failures, infectious diseases, and antimicrobial resistance, with the interdependence of human, animal and environmental health (WHO, 2017). One Health requires a collaborative effort, interconnecting disciplines on local, national and global level. For example, educational institutions around the world are implementing educational frameworks that integrate One Health and transdisciplinary competencies in order to enhance food safety, animal health, and public health (WHO, 2017). Table 3 describes the European One Health trends that are shared by the food industry, animal production and veterinary sector. Different trends are identified in the separate sectors.

Trend	Definition
Antimicrobial Resistance Management	The emergence and spread of antimicrobial resistance among human, animal and zoonotic pathogens form a serious global health threat (Vidovic & Vidovic, 2020). The extensive use of antibiotics in human and veterinary medicine contributes to the rise of antibiotic-resistant bacteria. Therefore, there is a growing concern about the responsible use of antibiotics, in part to prevent the spread of antibiotic-resistant bacteria through the food chain (Vidovic & Vidovic, 2020).
Animal Welfare	In May 20th, 2020, the **Farm to Fork Strategy** (F2F) was adopted by the European Commission, which aims to make food systems fair, healthy and environmentally-friendly. As a result, protecting and improving farm **animal welfare** has become an increasingly important component of livestock systems and animal-based food supply chains (Buller et al., 2018). An animal is in a good state of welfare when it's healthy, comfortable, well-nourished, safe, able to express innate behaviour, and not suffering from unpleasant states such as pain, fear, and distress. (Trienekens et

	al., 2021). **One Welfare** is an extension of One Health and aims to enhance the direct and indirect connection between animal welfare, human well-being, and eco-friendly animal farming systems (Pinillos et al., 2016). From a One Welfare perspective, improved living conditions, reduced stress and proper handling result in healthier animals and safer food products (Broom, 2022; Buller et al., 2018). Additionally, actions that improve animal welfare may also be beneficial to the environment, such as the use of straw from cereal production for bedding instead of burning it (Broom et al, 2019). **Precision Livestock Farming** (PLF) is a valuable approach for livestock holistic welfare assessment, considering physical and mental health of animals and food safety for humans (Buller et al., 2020; Scholten et al., 2013).

Table 3 One Health Trends in European Food Industry, Animal Production and the Veterinary Sector

3.3.2 One Health trends in food industry

Zoonotic Disease Monitoring. Surveillance systems are implemented to track and manage zoonotic diseases that can be transmitted from animals to humans through the food supply (Kelly et al., 2020).
Pathogens may spread at any stage of the animal production process: breeding, processing, packaging, storing, transporting, marketing, and consumption (Qian et al., 2022). The use of antibiotics can promote animal growth and fight food-borne zoonotic pathogens, but potentially contributes to the transmission of antibiotic-resistant microorganisms and genes. Instead, hygiene measures and systematic monitoring strategies are implemented to promote **food safety** (Qian et al., 2022).
Concerning **nutrition and health**, (functional) foods and supplements that contribute to overall health and well-being are being promoted (Aghajanpour et al., 2017). Evidence suggests that functional food consumption may support prevention of diet-related diseases such as cancer (Aghajanpour, 2017). Additionally, following the increasing incidence of food-related illnesses and non-communicable chronic diseases and inflating medical costs, consumers often take a holistic approach to making food choices (Szakály et al., 2011). When choosing food products, they consider factors such as health history, emotional state, lifestyle habits, and animal welfare (Szakály et al., 2011).
Toxic pollutants from waste management can cause respiratory diseases (Nevárez-Moorillón et al., 2022). Thus, **reducing food waste** not only protects the environment, but also plays a critical role in lowering potential health risks (Nevárez-Moorillón et al., 2022).

3.3.3 One Health trends in animal production

There is growing **societal pressure** for animal welfare (FVE Vet Survey, 2018). Animal welfare is considered an essential factor sustainability and development of the animal product sector (FVE, 2018).

Although evidence for such a relationship is lacking, **farm size or scale** has been criticized for its influence on animal welfare (Statham & Greene, 2015).

3.3.4 One Health trends in veterinary sector

Different measures aim to **reduce the use of antimicrobials** (Rojo-Gimeno et al., 2018). Firstly, prescription and delivery are decoupled in some countries, so that a veterinarian can't prescribe and deliver antibiotics and will be less likely to prescribe antibiotics (Fortané, 2021; Minviel et al., 2019). Secondly, a stricter framework is implemented, which may include limitations on margins of antibiotics sale, absence of retail prices fluctuations, mandatory antimicrobial susceptibility tests for the prescription of critically important antibiotics, and changing

the perception of the veterinary profession as guardians of antibiotics through holistic treatment and preventative approaches such as immunizations and regular check-ups (Ašmenskaitė & Astromskienė, 2015; EuroDev, 2023; Fortané, 2021; Frątczak-Rudnicka, 2015).

Challenges regarding the One Health approach include the effective integration of the approach into veterinary practices and ensuring that veterinarians' roles in public health are sufficiently addressed in training programs and market awareness.

3.4 Trends in Business Models

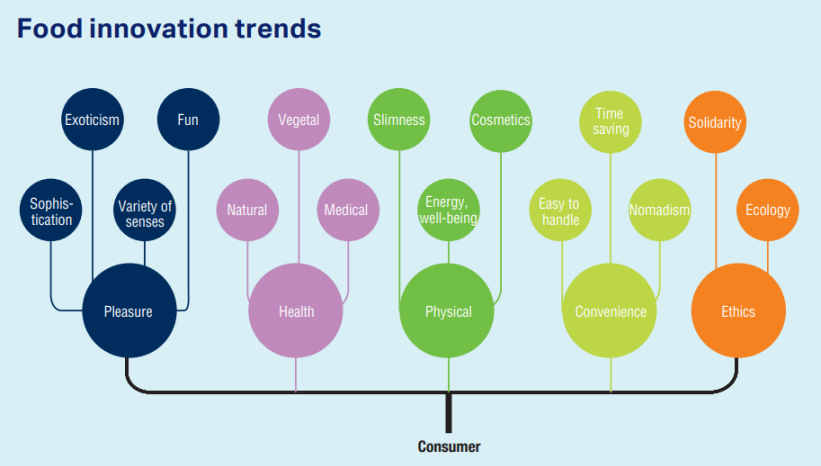
Essentially, a business model reflects management's beliefs about what customers want and how they want it, and how the business can best organize to meet those needs in order to make profit (Teece, 2010). Changes that affect sustainability, digitalisation and one health create new business model opportunities which may support the sector's development (Biancone et al., 2022; Shukla & Sengupta, 2021).

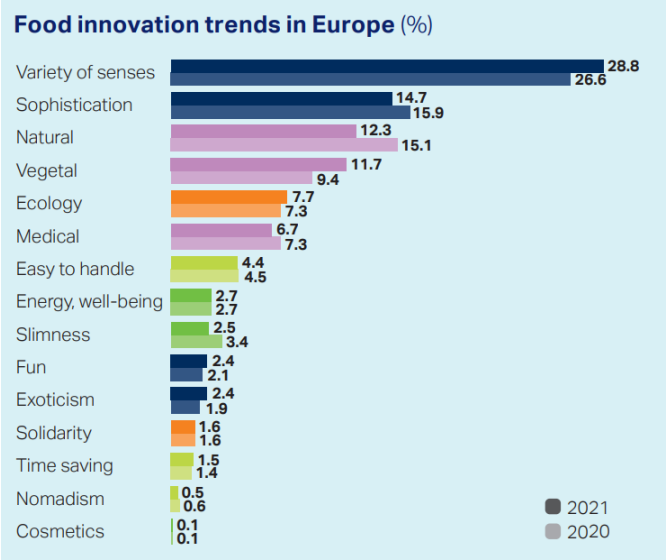
3.4.2 Business model trends in food industry

A trending business model in the food industry is a **circular economy model** (European Commission, 2014). Here, resources are re-used when a product has reached the end of its life, hence creating further value, to keep added value in products as long as possible and eliminate waste (European Commission, 2014). This approach supports organisations in reducing environmental impacts and reaching more sustainable economic outcomes and is thus crucial for sustainable business management (Barros et al., 2021).

Urban agriculture (UA) is defined as the production, process and distribution of (food) products by plant and/or livestock from and around cities (Game & Primus, 2015). In 2050, approximately 68% of the world's population is expected to live in cities. To meet the needs of approximately 9.73 billion people, almost 50% more food is needed than in 2012 (UN, 2018a). Consequently, UA is increasingly considered an important contributor to future urban food security (Armanda et al., 2019).

The dietary shift towards more healthy and sustainable food options drives innovation in food production and marketing strategies, see figures 1 and 2 (Hassoun et al., 2022a; Lázaro-Mojica et al., 2020). This leads to **new interaction strategies** with consumers, as their engagement shifts from passive purchasers into active players who shape the food system with their values and preferences, such as the labelling information regarding environmental impact (Nosratabadi et al., 2020; Trienekens et al., 2021).





Figures 1 and 2 Food innovation trends (source: FoodDrinkEurope, 2022)

Food Logistics 4.0 encompasses the role of Industry 4.0 technologies in the context of food logistics (Jagtap et al., 2020). Using real-time information, novel technologies and interconnectivity, Food Logistics 4.0 has the potential to increase transparency, improve flexibility, improve delivery time, and reduce the costs of high-quality food (Jagtap et al., 2020). Thus, these developments change the way business is performed. Example trends that occur in the context of Food Logistics 4.0 are:

- The need for food **traceability** is reinforced by the COVID-19 pandemic and aims to control food hazards and prevent food fraud (Hassoun et al., 2022b).
- The emergence of **e-commerce**, as consumers increasingly use online platforms for grocery shopping and meal delivery (Din et al., 2022).
- The use of **augmented reality** (AR) applications for optimizing order picking in warehouses through quick identification of item location and the shortest route (Jagtap et al., 2021).
- The emergence of **novel foods**, such as insect and algae foods or cultured meat (Wepner et al., 2019; Trienekens et al., 2021).
- **Smart packaging**, driven by a growing demand for healthier foods with extended shelf life (Ahari & Soufiani, 2021). Two packaging solutions, which also ensure consumer safety, are active food packaging (using degradation and antibacterial properties), and smart food packaging (connected to sensing and scavenging, Ahari & Soufiani, 2021).

Lastly, as a response to the increasing demand of consumers for sustainable alternatives to the global agri-food system, **short food supply chains** are trending (Benos et al., 2022). Short supply chains foster a closer and more direct relationship between consumers and producers while significantly reducing the number of intermediaries in the value chain (Benos et al., 2022).

Agroecology is defined as a farming and food systems approach that integrates ecological principles and biological cycles methods to design and manage sustainable agriculture (Gargano et al., 2021). The aim of agroecology is to provide a holistic and inclusive food production and distribution system through direct, fair and self-governing chains of sale. Strategies limit the dependence on external inputs and may include the adoption of adequate hygiene and health regulations and horizontal and intergenerational knowledge exchange (Gargano et al., 2021).

3.4.3 Business models trends in animal production

Despite the growth of modern agriculture and farm size, the prevailing organizational type in the European animal production sector remains a small, **family-owned and operated firm** (Doherty & Kittipanya-Ngam, 2021; Nuthall & Old, 2017; Sadovska et al., 2023). Such firms are characterised by an informal and self-regulatory organisational structure, limited resources (e.g., knowledge), independent decision-making, and not mainly focusing on high profitability (Sadovska et al., 2023). However, different trends are emerging to empower small-holders. An example is the concept of Inclusive Value Chain Development (IVCD), which integrates competitiveness with poverty reduction for small-holders (Doherty & Kittipanya-Ngam, 2021). Example practices are contract farming, spot market selling, and improved integration with large agribusiness (Doherty & Kittipanya-Ngam, 2021).

Short supply chains are also emerging in the animal production sector, connecting local producers and consumers (Trienekens et al., 2021). Examples are direct farmer-to-retailer, farm shops, and farmers' markets (Galli & Brunori, 2013). The FAO (2017) encourages countries globally to implement measures for food security. Short supply chains serve as a strategy (Abdoellah et al., 2023) to meet the need of the consumers for more transparency (Van Bussel et al., 2020).

Another business model trend is **diversification**, where farmers diverse on- or off-farm activities to increase their income (Salvioni et al., 2013, 2020). The combination of agricultural diversification (e.g., production of livestock goods) with non-agricultural activities (e.g., tourism services) is a resilience strategy of small European farms (Zanetti et al., 2022). On-farm diversification has another advantage: increasing **rural employment** (FAO, 2014). Remote work, co-working, social farming and start-ups improves employment possibilities, particularly for young people, besides green policy measures (EU CAP NETWORK, 2023; Unay-Gailhard et al., 2019).

Traceability-driven food supply chain management, implementing novel technologies, such as sensors, improves credibility, efficiency, and safety of produce from farm to fork (Patel et al, 2023). Effective traceability also affects **animal health and welfare**, as it significantly reduces response times after animal disease outbreaks by providing information that helps determine the source and location of implicated produce rapidly (Trienekens et al., 2021; ITC, 2015).

3.4.4 Business model trends in Veterinary sector

Europe is the world's second-largest **animal health market**, generating over 28% of the global market since 2021, with an increase of 6.4% expected between 2022 and 2027 (EuroDev, 2023). The rising animal adoption, growing prevalence of animal diseases, and an increase in preventative care leading to an increase in demand for veterinary healthcare services, primarily driving the growth of the European veterinary market. The market is characterized by a range of products including vaccinations, parasiticides, antibiotics, et cetera (EuroDev, 2023). In 2023, an estimated total of 328.494 veterinarians were caring for 340.000.000 companion animals and 654.000.000 cattle, sheep, pigs, laying hens and goats, and 6.000.000 horses (FVE, 2023). Medicines are the biggest source of income in the market, followed by health and production monitoring activities and providing advice to farmers (Rojo-Gimeno et al., 2018). Most veterinarians (67%) work in the private sector, followed by the public sector, education and research and private research and industry (FVE, 2023).

Firstly, there is a trend of decline in small, independent, private veterinarian businesses, due to a rise of **collaboration**. Farmers and veterinarians increasingly merge their efforts in joint ventures or franchised practices (Henry & Treanor, 2015; Rojo-Gimono et al., 2018). These partnership arrangements give (new) veterinarians the opportunity to start a business with less risks and financial costs involved (Henry & Treanor,

2012). Furthermore, corporatisation is gaining popularity, where groups and large corporate structures (chains) share resources and buying powers. In fact, 25% of companion animal practices are expected to be corporate owned by 2023 (Zak, 2021). Corporatisation opens new career opportunities, such as managerial positions within clinics (Henry & Treanor, 2012).

The **separation of drug prescription and delivery** also affects veterinarians' business models. For example, livestock vets may increase revenues of medical acts, switch their activities to the companion animal sector, or support selling vaccinations to maintain their level of profit after reducing antimicrobials usage (Minviel et al., 2019; Rojo-Gimeno et al., 2018). Also related to AMR-policy is the increasing popularity of **preventive medicine** (Fortané, 2020; Frątczak-Rudnicka, 2015 in Ašmenskaitė & Astromskienė, 2015). This includes increases in educating and training efforts (synchronised between policy and sector, and presented through an academic network) for vets to judiciously prescribe antibiotics, popularity of regular check-ups, widely available immunization clinics and wellness programs, holistic treatment, as well as creating economic incentives and systems that discourage antibiotic use (EuroDev, 2023; Fortané, 2021). This also contributes to the **shift in the role of the veterinarian**: from reactive, addressing immediate health crisis, to more advisory and preventive (Fortané, 2021).

Animal keepers have growing expectations regarding the scope and quality of veterinary services (Beyer, 2019). To increase their competitive potential (also in respect of the reduced sale of pharmaceuticals), veterinarians **diversify** their services and incomes: expand the range of their services including prevention, comprehensive medical examination (with modern equipment, such as bacteriological analysis), treatment (including more specialization as well), dietary advice, rehabilitation and animal psychology services, and selling (including hygiene, nutrition, accessory) products and grooming/kennelling services (Beyer, 2019; Fortané, 2021; FVE, 2023). Veterinary offices' profit is mainly driven by drug delivery in farm animal activities, while mainly generated by medical acts and products in companion animal activities (Minviel et al., 2019).

Pet insurance becomes increasingly popular due to the high lifetime costs of owning pets, partially caused by increasing veterinarian costs and pet life expectancy (EuroDev, 2023b). The market was estimated to be around 820.000.000 USD in 2022, with an expected increase of 12.8% before 2028.

The veterinary business market is **competitive**. This relates to an increasing focus on animal welfare, growth in small and companion animal care, and a reduction in large animal work (Henry & Treanor, 2015). Reduction in large animal work partially follows farmers having less disposable income to spend on veterinary services due to reductions in governmental support, which supports a trend of farmers doing more for themselves than immediately referring to the vet. This affects turnover and profit margins and further supports the competitiveness within the sector, having veterinary practices revisiting operational costs to ensure viable offers that align with their clients' needs (Henry & Treanor, 2015). Veterinarians refer to a "war" to keep medicines' prices lower than their competitors to retain old and engage new clients (Rojo-Gimeno et al., 2018). This war is supported by the increase in and improved access to online veterinary pharmacies that 'squeeze' practices' profit margins on the sale of veterinary medicines (Henry & Treanor, 2015). Additionally, various form of contractualization with clients emerge, such as an annual flat-rate model covering all veterinary services from advice to medication (Fortané, 2021).

The competitive nature of the current veterinary business landscape necessitates veterinary practices to operate as viable business entities more than ever before (Henry & Treanor, 2015). This increases the **demand**

for training in communication, business (e.g., marketing, management, finance, entrepreneurship) and digital skills (FVE, 2023). This follows increased competitiveness of the sector, and, specifically for the farm animal veterinary sector, lowering livestock numbers and a reduced demand for services, requiring closer engagement with the client base to adapt the provided veterinary offerings appropriately (Henry & Treanor, 2015).

The **customer focus**, including helpfulness, attentiveness and communication with animal and owner, secures successful activities for veterinary practices (Ašmenskaitė & Astromskienė, 2015).

Age and digital skills. The average age of a European veterinarian is 44 years (FVE, 2023). The majority of vets are aged under 45 (FVE, 2023). Age relates to digitalization challenges, as older people less easily acquire computer skills (Borisov et al., 2023). On average, 56% of the European population possesses basic digital skills at least, and only 34% possesses skills above the basic (Borisov et al., 2023).

Pay gaps. Salaries increase with age, as older veterinarians receive a greater pay (FVE, 2018). The median annual salary for veterinarians older than 60 years is €60,000 while the equivalent for those veterinarians aged under 40 is €38,400 (FVE, 2018). The highest-paid veterinarians work in education and research (median annual salary €59,000), followed by government or public service veterinarians (€57,600) and in corporate veterinary practice (€52,490). Furthermore, the veterinary profession in Europe has undergone extensive feminization across the last two decades, with two thirds of veterinarians being females (Henry & Treanor, 2015). Yet in business ownership, male veterinarians still dominate with 29% of male veterinarians being business owners compared to 20% of female veterinarians. This is impacted by the gender pay gap within the profession with a median salary gap (corrected for working hours) of 15%. This gap prevents women from acquiring the capital needed to buy into a partnership or establish a practice (Henry & Treanor, 2015).

Retention issues are notable, especially in retaining farm veterinary surgeons, which often turn to companion animal practice after an initial period of general practice (Statham & Greene, 2015). Challenges include job security concerns (following declining livestock populations, farm size/number reductions, new legislation and a changing relationship between government and veterinarians), the need for a defined career structure, and job satisfaction to prevent disillusionment among professionals (Henry & Treanor, 2015; Statham & Greene, 2015).

3.5 Regional differences in trends

In this section some key differences in trends in sustainability, digitalisation, One-Health and business models at country level are shown. Where some countries are more in a reactive state (e.g., consumers demand for animal welfare; lack of knowledge on waste management) are other countries more pro-active (e.g., cooperative, local and close to the consumer production, local food sharing out of solidarity). The selection of aspects is not complete, this selection is to illustrate the differences per country and show unique trends. In contrast to Fields, the trends in the Agricultural Knowledge and Information System (AKIS) are not included as they will be included in WP7, more specifically Task 7.3 as in this task the educational infrastructure for I-Restart will be discussed. The full country reports are included in Appendix 1.

	Austria	Greece	Germany	Portugal	Slovenia	Italy	Denmark	The Netherlands
Sustainability	- Consumer expectations - Soy and animal feed production - Reusable solutions	- No knowledge on waste management - Circular economy -	- Aquaponics - insect-based food - balance excessive expectations dairy cows	- Feed efficiency - Waste management - Biodiversity - Alternative medicines	- Animal welfare - Biodiversity - Environmental sustainability - Food innovation	- closed-cycle farming - resource efficiency - Better conditions in livestock in general	- Resource efficiency - Waste management - Protein transition	- Biodiversity - Waste management - Decreasing environmental pollution
Digitalisation	- Smart materials - 3D printing - Work enhancement - Precision animal health	- Non-changing farmers adapt technologies - No knowledge on precision farming - telehealth	- individual animal observation - challenge for SMEs - telemedicine	- Promote technology transfer - Traceability - Smart farming practices - Big data	- Smart farming - Smart agriculture	- Precision livestock farming - Traceability - monitoring of medication usage and overall health	- Precision livestock farming - technology to secure food safety, quality and sustainability - data to create cohesive services	- Digital transition - Smart farming - Advanced diagnostic techniques
One-Health	- Mindful eating and healthy lifestyle - Ethical consumerism - antibiotics		- antibiotic resistance - prevent epidemics and pandemics - collaboration of all relevant stakeholders	- Antimicrobial use - Nutraceuticals and health claims - New treatment approaches	- Reduce and monitor the use of use of antimicrobials	- collaboration between the human and animal health sectors - food waste - Animal health and welfare	- Disease surveillance - foodborne zoonoses - reducing antibiotics and resistance	- Animal health and welfare - Disease prevention - Preventive healthcare and advice
Business Models	- Cooperatives - Solidarity food sharing - Strengthening farmer consumer relation - Joint practices	- Intelligent organizations	- public's attitude toward large farms - local producers - pasture farming declines	- Farm size increase - Creativity and design thinking - communicatio n	- Work from home - Data and privacy security - Personal approach	- real, more sustainable local communities - plant-based diets - digitalization in vet	- Competitive livestock production - Plant-based food production - Innovation in vet	- Cooperatives - Organic businesses - Short supply chain - Collaboration and multidisciplina ry care in vet

4 Scenario analysis

4.1 Introduction and method

Another aim of task 3.4 was to develop scenarios. Three scenarios are developed; the local route, the route continued and the tech route. First these scenarios are developed on a rather global scale and next they are more specified to the countries involved in this project.

The starting point was the trend analysis of the previous chapter, performed by a broad group of partners from the I-RESTART project; both representing countries and the sectors are used. The EU level analysis was predominantly performed by WUR in close cooperation with ISEKI.

Based on the FIELDS Deliverable 1.8, it is known that a scenario describes a possible future based on an internally consistent set of assumptions about key trends and their interrelationships (Trienekens et al., 2021). Furthermore, based on Trienekens and colleagues it is known that scenarios should be plausible, meaningful, consistent across trends and regions, and relevant for multiple stakeholders. In addition, scenarios should reflect maximum internal and minimum external cohesion. It is important to realize, that scenarios do not predict but explore possible future pathways. And these are possible future pathways, as no one can predict future and therefore there are always multiple scenarios presented. In general scenarios aim to capture uncertainties in major socio-economic, technological, political and environmental trends. To develop meaningful scenarios both national and European analysis are used.

This project is of course not the first to work on scenarios. As stated before, FIELDS is being used as one of the starting points. In addition and although it was used in FIELDS as well, the importance of IPCC AR5, called Shared Social economic Pathways (SSP) (O'Neil et al., 2014, 2017) should be recognised. FIELDS took the scenarios identified by Mitter et al. (2020) as starting point and in addition they worked with recent Horizon2020 projects, 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).

This scenario study includes a description of three scenarios on EU level as well as a comparison of these three for seven EU countries: Italy, Austria, Denmark, the Netherlands, Spain, Portugal, and Germany.

Although the SSPs on which several scenario studies mentioned built have taken climate change as point of departure, 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 4.2 presents underpinning resources from policy reports. Section 4.3 presents the outcome of FIELDS. Section 4.4 presents the three adjusted scenarios for the project I-Restart. Section 4.5 presents the results of the country level scenario analyses. Finally section 4.6 identifies skill needs per scenario in general and a comparison based on the different countries.

4.2 Underpinning sources for scenarios

We are in the midst of multiple crises – energy, wars, climate, biodiversity, etc. Human-caused climate change is there (IPCC, 2023) and we all noticed it during the summer of 2023. Therefore, we cannot afford any longer to solely focus on economic value. Other values come into play, such as social value, environmental values, etc. The challenge these coming years is to design ways to make these other types of value (in addition to economic) value an equal partner and balance out the different values. EU governmental policies all are directed towards the aim of sustainability – not because of ideology, but because of necessity. We cannot continue the way we do/did. Farm to Fork, Biodiversity strategy, CSRD and other more general reports like IPCC do put the emphasis on the need of sustainability. Policies, such as at the level of the EU, do show some adaptation across all sectors and regions, with documented benefits and varying effectiveness. However, according to IPCC, despite progress, adaptation gaps exist, and will continue to grow at current rates of implementation. Hard and soft limits to adaptation have been reached in some ecosystems and regions. It is certainly not enough. According to IPCC (2023) the following elements have a relatively huge potential in reducing net emission by 2030: 1) carbon sequestration in agriculture, 2) shifts in sustainable healthy diets, 3) reduce methane and N_2O in agriculture and 4) reduce food loss and food waste. With regard to equity and inclusion, the IPCC (2023) states that adaptation outcomes are enhanced by increased support to regions and people with the highest vulnerability to climatic hazards. According to IPCC (2023) Enhancing technology innovation systems is key to accelerate the widespread adoption of technologies and practices. Enhancing international cooperation is possible through multiple channels.

4.2.2 IPCC report

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

Figure 3 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)

SSP1 **Sustainability – Taking the Green Road** (Low challenges to mitigation and adaptation)

- The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.

SSP2 **Middle of the Road** (Medium challenges to mitigation and adaptation)

- The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.

SSP3 **Regional Rivalry – A Rocky Road** (High challenges to mitigation and adaptation)

- A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.

SSP4 **Inequality – A Road Divided** (Low challenges to mitigation, high challenges to adaptation)

- Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas.

SSP5 **Fossil-fuelled Development** – Taking the Highway (High challenges to mitigation, low challenges to adaptation)

- This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local

environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary

4.3 Scenarios as presented in FIELDS

As stated before, FIELDS delivered three scenarios, knowing the sustainable scenario, the established scenario and the high-tech scenarios. Whereas the sustainable scenario focuses predominantly on getting the sectors less polluting and taking more care for sustainable production and biodiversity, the tech route is mainly focused on efficiency by means of innovation and technology. The established route has the main character of continuing the route we are already heading for. In the table below, table 5, one can read the summaries of the three different routes for the four different developments that were selected within FIELDS.

	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 on 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 being 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 in modern international value chains
	Industry 4.0 supports development towards sustainable and circular production, including small scale artisanal production	Food industries integrated in 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 in sustainable forest (and biodiversity) management	In forestry larger producers are supported by advanced digital systems, and integrated in 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	Concentration of businesses (incl. farms) throughout the value chains. Increasing	Concentration throughout the food value chain. Large industrialized and

	consumers, including consumer participation in farm activities.	vertical coordination, led by retail. Small farms focus on multifunctional production	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 in modern (international) wood value chains. Small holdings cannot create a viable business.	Forestry business are more and more integrated in international wood value chains

Table 5 FIELDS scenario (Trienekens et al., 2021)

4.4 I-Restart Scenarios

As stated before, the year 2023 is the warmest and wettest year ever measured; it had most extreme types of weather (www.nos.nl). As shown in figure 4 below, the deviating temperature worldwide is significantly more deviant in 2023 in comparison to other years. According to American climate expert James Hansen of the Columbia University, global warming was underestimated for about 50 years (www.nos.nl). The CO2 emissions were not expected to have such an huge impact. But it does.

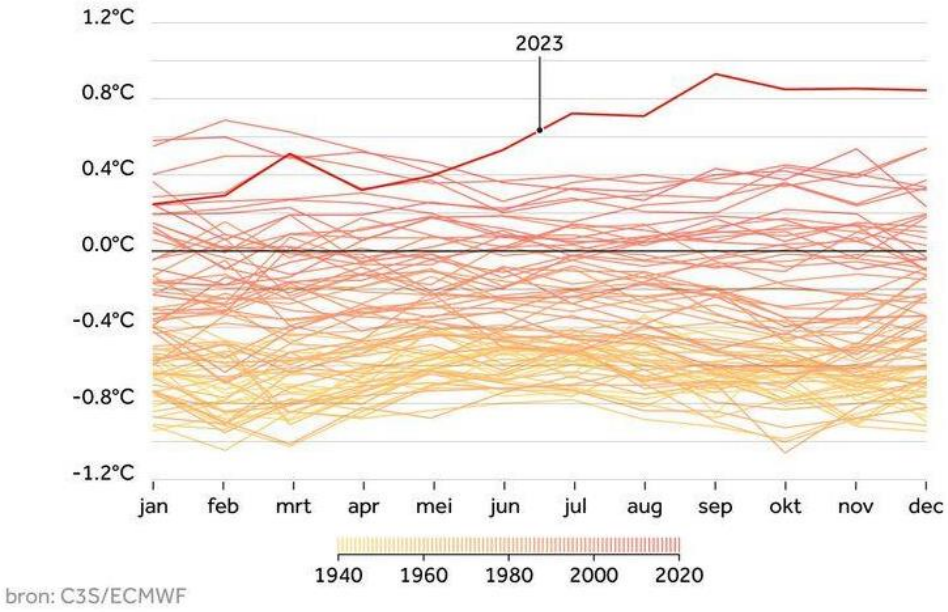


Figure 4 – Deviating temperature in 2023 (source: www.nos.nl).

This given forces to make a change and well immediately. And therefore in I-Restart sustainability is not a scenario or a trend; it is of utmost importance in all scenarios and should be integrated in all our businesses and activities as a goal in itself. In contract with Fields, we embrace the purpose of sustainability in all our scenarios. We realize that this way of thinking might be perceived as less objective, but looking on the trends and developments going on, it is the only way forward. Building scenarios without sustainability mentioned explicitly, would give the late adopters still the possibility to ignore what is going on. And we cannot ignore that. Countries, businesses, sectors cannot afford oneself not to go for sustainability. The trends, as collected on the national levels (and presented in chapter 3 of this document) do also point out in that direction; scarcity of natural resources, climate change, rise in energy consumption, malnutrition are all examples of trends that only point in one direction: sustainability. In addition to these megatrends, trends in technology are mentioned, such as big data, Industry4.0, Industry5.0. These trends will continue, however increasingly these trends will be applied to make the operations and the production less polluting and more sustainable. Finally, megatrends with regard to people are mentioned: urbanisation, migration, demographic change. Therefore, three scenarios

are developed; they are based on FIELDS but with an inescapable I-Restart twist

- Food Production, Animal Production and Veterinary on a **sustainable local route**
- Food Production, Animal Production and Veterinary on a **sustainable route continued**
- Food Production, Animal Production and Veterinary on a **sustainable tech route**

Below the three scenarios are presented shortly.

4.4.2 Scenario 1 Sustainability via the local route

Scenario 1 Sustainability via the local/regional route. In this scenario sustainability is the aim, to work towards a resilient and adaptive agrifood system on a small and local scale. Globalization, also due to the current stress and tensed relations in the world, is less and less the case and the national or EU level is increasingly the level to work with. Sustainability will be achieved via the so called local route. And local can mean different things, but in this case it means more focus on local production, organic agriculture, closer involvement of consumers, social businesses, short food supply chains, small scale farms and production, agroecology. Of course there will remain some global players, however the trend in the agrifood system is to go more locally, close to the communities, so people are more interested for the sector to work in because it is meaningful or has a purpose to work in the agrifood sector. This scenario is comparable with the Erasmus+ Fields scenario (sustainable production), however with a focus on the local approach. And the focus is less on growth, but on working together to provide locally the necessary supplies. Animal and food production go back to a more local approach. Countries or regions focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Current digital technologies enable that local producers get in contact with their local customers and that these customers buy locally. Consumers like to change their diet in a more plant-based diet, they are also open for locally produced meat or other protein-based products, as long as they know where it comes from and they can trust the producer that they are acting within the sustainability scenarios. Consumers find it difficult due to a lack of transparency to assess what is sustainable or not. These short and local chains, make it better understandable for them. This holds both for food and animal production. Community-based food production is another illustration in this scenario, which holds for both the animal production and the food production sector. And increasingly veterinarians are part of this community as they have close contact with the farmers. Advantages of this route is that viruses like Covid 19 are spread less, that there is less transport, less waste (food and packaging). Consequence for producers is that they produce more diverse products based on what their local customers like to prevent that customers do not have a choice at all. Additional (food)waste will be reduced as due to close contact customers are either part of the production process and see what products are available or farmers are in close contact with the customers and know better what they like. For customers it means that the products become a bit more expensive, however they know and appreciate the origin of the products and are willing to pay more. Veterinarians provide more services and closely collaborate (or run even a business with multiple disciplines) to serve the farms with different animals. Furthermore, they try to work with alternative medicines to lower the pressure on resistance of any medicine. Also for this activity, veterinaries work more together, also with other disciplines in the health sector. Customers are so aware of the value of local production, that they support, initiate or develop businesses based on crowdfunding.

4.4.3 Scenario 2 Sustainability via continuing the existing route

Scenario 2 is striving for sustainability via the existing route. Again, in this scenario sustainability is the aim, but the core of the route is that it continues the route as it is already taking right now. At the level of the EU and also on national levels, multiple programs do support to work towards sustainability in agrifood. Striking difference with scenario 1 is that in this second scenario the drive to become more sustainable comes from outside, whereas the drive to in scenario 1 comes from within the sectors and farmers, and the same holds for

scenario 3. Within this second scenario, the desire to work more sustainable is there, but not at the cost of the richness of the products and the always present growth strategies. The core of the scenario is doing less harm, without making a significant change in anything. Production facilities do attempts to save energy, reduce their waste and will reduce their transports. With the help of Industry4.0 or Industry5.0 data can be collected to actually make these changes. With regard to One-Health the monitoring will improve, however real prevention will not take place. Business models will not change that much and the business case will be the dominant strategy. Governments and sectors try their utmost best to make rules and regulations and offer funds to make a change towards more sustainable practices. This also holds for the food waste. Regulations will be less tight so food waste can be prevented and enables donating left-over food. Customers do appreciate that not so much is changing. They are willing to pay a bit more for some kind of sustainability label or accreditation, but they will not change their behaviour drastically; except for a minority within society. This group of consumers, which will grow steadily but not that fast, tends to push all sectors to make progress with regard to sustainability. For both the animal production and food production sectors holds that innovation and change is driven by external pressures. Like quota on emissions or use of medicines or resource scarcity (raw materials for packaging are becoming less and less). Aside from governmental regulations (both on the level of EU as the national level), the pressure will come from the society or NGOs on behalf of society. They push these sectors to innovation and be less harmful for their animals, humans and the environment. This development will help farmers in some countries to adapt their business and adopt more technology, whereas first they were quite reluctant on changing their businesses. Within the veterinary sector the focus in this scenario is on reusing and recycling of products, telemedicine tend to continue to develop and be more efficient with materials; lowering the ray of materials.

4.4.4 Scenario 3 Sustainability via the tech route

Again this scenario strives for sustainability via the tech route. This scenario is comparable with the Erasmus+ Fields scenario high tech pathways, n this I-Restart scenario sustainability is the aim as it is in any other scenario. However, in this scenario globalization, efficiency and technological developments all over the world aim to make the agrifood sector more sustainable. Trends like precision farming, circular economy, big data, and Industry4.0 support this. Sustainability will thrive through technological inventions, new and more efficient ways of working. More tech also means oftentimes less employees necessary, however the speed to catch up as employees will become higher. And it is important to take the employees on board when the innovations take place, otherwise the chance is there they will not adopt it (and you still do not have the benefit as anticipated). And to repeat, this route does not have the sole intention to make production more efficient (which is probably the intention in the second scenario), but the core intention is to make production more sustainable by means of technological innovations. In the food sector the relationship and contact (via digital platforms or big data of personal health devices or apps) between producers and customers is much more intense. Waste is prevented, because only what is ordered digitally will be produced. Customers also do want to become more sustainable and will only buy food and products that suit them, via personal and wearable technology they know better what they need and they will ask the producers to produce that. And not just the production process within the food sector will benefit, also the distribution and logistics can make sustainability gains quite easily because more clustering, working together with other producers and being more efficient. Within the animal production sector, precision livestock farming is the way to go. Aside from optimizing existing businesses, the production technology of cell culture meat and 3d printing will reduce the pressures on the environment by creating meat in another, laboratory-based, way. Furthermore, relevant digital technologies include invasive as well as remote sensors for livestock monitoring. Within the food industry, technological developments will produce improved energy efficiency and (biodegradable) packaging and reduce waste. With regard to the veterinary sector telemedicine will develop further. Furthermore, the aid of computerization and robotization of procedures will

lead to the elimination of the risk of overdose, abuse and improper use of the drug, in a more sophisticated analysis and anticipation of the needs of the breeding, in a better quality in terms of health and efficiency in leaders and management. Veterinarians use diverse technical tools to improve and monitor constantly animal health and welfare and this eventually big data will help prevent the spread of diseases and viruses.

4.5 Country level scenarios

In this section a short summary is provided of all country scenarios. These country reports, at least the core of them, are presented in appendix 2. Per scenario for each sector the most striking elements will be provided.

4.5.2 Local route for sustainability

In most countries the focus is on smaller, more local enterprises which use digitalization to promote transparency and to get in contact with their customers. In some countries, such as Italy more improving the existing system in favour of sustainability is more at stake instead of turning the whole business around more into smaller businesses and cooperatives. More connection with the customer is considered important in all countries. For some countries, such as Denmark, ethically produced food is becoming important for customers and not so much the protein transition is at stake, but ethics are key. Appendix 2 shows the details.

4.5.3 Route continued for sustainability

The differences between the countries are less in this scenario. This is because this is the continuation of the route we already follow. The emphasis is on making rules and regulation to make a necessary change in both industries and in the veterinary sector. The same holds for the consumer. This stakeholder will not change either as long as there are no incentives or regulations to force the change. These two ingredients make that the industry will not change, because the customer does not ask for it. One cannot trust that the industry will take up this responsibility itself, so outside stakeholders, like national governments, sectors and the EU have to push to make a change. Appendix 2 shows the details.

4.5.4 Tech route for sustainability

The third scenario is based on technology development as a way out of current crises. Technology in the sense of digitalization, but also in reusing materials or using big data to monitor developments. Down side of almost all technological developments is the enormous investment necessary to develop it and the insecurity whether or not it holds its promise. Consequence of this is that in this scenario, in contrast to the first local oriented scenario, business and farms become only bigger. Only these bigger companies and farms can afford the investment and risk of these new technologies. Appendix 2 shows the scenarios per country. There are not big differences, except that some countries, like Denmark, explicitly also mention the customer in their tech route.

4.6 Skills needs per scenario

Finally, the scenario specific skills per sector for each country are presented below. Based on the information as presented below, one can conclude that for the local sustainability route especially skills such as circular economy, short food supply chains, digital ways to connect to customers, disease prevention, livestock waste management and food safety are important. For the route continued skills like waste management, also circularity, traceability and transparency, animal welfare and disease prevention are important. Finally, for the technological support route towards sustainability the skills AI solutions for quality control, precision livestock farming, IT solutions for health control, the use of telemedicine apps, using data and data management are really important skills. These should be developed in lines of competence in WP4.

Country	Local route	Route continued	Tech route
Austria	- Food industry: circular economy - Animal production: digital business tools	- Food industry: waste management - Animal production: circularity/ sustainability in livestock farming	- Food industry: AI solutions for quality control - Animal production: precision livestock farming

	- Veterinary sector: disease prevention/risk prevention	- Veterinary sector: inter-professional collaboration	- Veterinary sector: IT solutions for health control/disease prevention
Greece	- Food industry: sustainable packaging, food safety - Animal production: animal health & welfare, Product environmental footprint of agri-food products - Veterinary sector: Food legislation, Team management	- Food industry: circular food system (waste management), Emerging technologies in packaging - Active packaging - Animal production: circular production (livestock waste management), Emerging technologies - Veterinary sector: Animal welfare & certified skills, interdisciplinary / interprofessional collaboration	- Food industry: data management-analysis, New alternative protein sources (plant-based) - Animal production: data management, Agriculture policy - Veterinary sector: Prevention of animal health risks, interdisciplinary / interprofessional collaboration
Germany	- Food industry: Short food supply chains and technical applications to connect consumers with nearby farmers - Animal production: Automation technology in animal production and decreasing demand in meat - Veterinary sector: Educational workshops on topics such as nutrition, hygiene, and disease prevention for animal owners and animal medical care centers will come up	- Food industry: Traceability and transparent and sustainable food chains - Animal production: Precision livestock farming and foster the strategy of premium meat which is ethically produced - Veterinary sector: Veterinary practices are bought up by large, specialized investment funds and use of antibiotics is being increasingly regulated	- Food industry: App-based consumer approach and utilize blockchain technology to enhance transparency and traceability - Animal production: AI-supported camera systems track farm animals in real time, detect changes that could indicate health problems and wearable health monitoring devices for livestock - Veterinary sector: Telemedicine apps and a lack of digital knowledge among vets needs to be tackled with offered courses
Portugal	- Food industry: sustainable business management, food chain & innovation (production, processing, distribution, business model, organization), food safety - Animal production: circular production (livestock waste management), use of digital solutions, animal health & welfare - Veterinary sector: Cooperation, (online) communication (telemedicine, social media management), interdisciplinary / collaboration treatment	- Food industry: circular food system (waste management), food chain, food safety and food security - Animal production: circular production (livestock waste management), animal health & welfare - Veterinary sector: Cooperation disease prevention and control (use of antimicrobials and antiparasitics)/ interprofessional collaboration, (online) communication	- Food industry: data-driven business management, e-commerce - Animal production: data-driven business management (PLF), animal health & welfare - Veterinary sector: advanced diagnostics, interdisciplinary / interprofessional collaboration, online communication and electronic prescription
Italy	- Food industry: sustainable business management & innovation (production, processing, distribution, business model, organization), food safety - Animal production: circular production (livestock waste management), animal health & welfare, monitoring	- Food industry: circular food system (waste management), food safety - Animal production: circular production (livestock waste management), animal health & welfare, advanced monitoring - Veterinary sector: disease prevention and control, introduction to AI technologies	- Food industry: data-driven business management, e-commerce and e-marketing, sustainable packaging - Animal production: data-driven business management (PLF), animal health & welfare - Veterinary sector: advanced diagnostics, AI for prevention and control

	- Veterinary sector: (online) communication (telemedicine, social media management), holistic treatment, digitalization of data		
Denmark	- Food industry: Sustainable use of resources, - Animal production: Livestock waste management - Veterinary sector: Livestock waste management	- Food industry: Data management - Animal production: Animal handling and welfare - Veterinary sector: Responsible use of medicines	- Food industry: Innovations in circular economy context - Animal production: Precision livestock farming - Veterinary sector: Digital tools for traceability
The Netherlands	- Food industry: sustainable business management & innovation (production, processing, distribution, business model, organization), food safety - Animal production: circular production (livestock waste management), animal health & welfare - Veterinary sector: (online) communication (telemedicine, social media management), interdisciplinary / interprofessional collaboration (holistic treatment)	- Food industry: circular food system (waste management), food safety - Animal production: circular production (livestock waste management), animal health & welfare - Veterinary sector: disease prevention and control, interdisciplinary / interprofessional collaboration	- Food industry: data-driven business management, e-commerce and e-marketing - Animal production: data-driven business management (PLF), animal health & welfare - Veterinary sector: advanced diagnostics, interdisciplinary / interprofessional collaboration

Table 6 Skills needs per scenario per country

5 Conclusions

The aim of this report was twofold. Firstly the aim was to identify the trends amongst Europe, based on documents and trend reports for the different countries involved. Based on this exercise long lists of trends are identified. Secondly the aim was to develop scenarios for the food industry, animal production and veterinary sector. Based on IPCC, FIELDS and all trends collected before three scenarios were identified. All three scenarios strive for sustainability, as this is necessary as there is no Planet B. The first scenario to reach sustainability is based on the local approach. Based on local business, closely connected to the customer, without any form of packaging and transport, sustainability can be guaranteed. The second scenario to reach sustainability, is the way forward as we go these days. Mostly based on rules and regulations (e.g. Green Deal) businesses and consumers change their patterns and step by step they become more sustainable. There is hardly any internal drive to change, as there is in scenario 1. The third scenario to reach sustainability is based on technology development. Based on new technologies for data collection, modelling and application or new techniques for the circular economy, sustainability is reached in the end. In contrast with the first scenario, this third scenario requires bigger companies and organisation, as the investments in data modelling and technology development are immense and small scale producers cannot afford that. So, the scenarios are rather different and require rather different skills. To make sure that we reskill and upskill employees within the three sectors food production, animal production and veterinary digital skills are essential to move forward in either three of the scenarios.

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Appendix 1 Trends analysis country reports

• Austrian trends analysis

1. Introduction

The Austrian agriculture is small structured and has high quality standards. The aim is to supply high-quality food and to maintain a multifunctional, sustainable, competitive and nationwide agriculture and forestry (Regierungsprogramm 2020-2040). During the COVID19 crisis, consumer behaviour changed, but simultaneously with the decrease of COVID19 restrictions the food market also decreased, back to pre-pandemic numbers. The strongest reduction could be observed for meat (especially beef and veal) and fresh vegetables, but also on fruits. There was less money spent on higher priced foods and the percentage of spending on trade brands compared to producer brands (RollAMA_Factsheets 2022).

Animal breeding is regulated by the provincial animal breeding laws and organized by the breeding association in Austria. In international comparison, Austria is one of the countries with the highest animal welfare and food standards. The transition to better animal welfare must be enabled for all company sizes. In Austrian politics, focus is laid on (1) GMO-free food production, (2) strengthening of regional and seasonal production, (3) the expansion of consistent quality and origin systems, on behalf of the consumer and a vital and sustainable agriculture (Regierungsprogramm 2020-2040).

The veterinary care in Austria is basically covered (https://www.tieraerztekammer.at/oeffentlicher-bereich/berufsinformation/ihs-studie), however, an east-west divide in income and specialisation in the small animal and livestock sectors can be observed (further description in table of dimension one health - veterinary sector).

Digitalisation got a strong push during the pandemic years and provoked a much faster digitalisation and expansion of digital infrastructure in the agricultural sector (Grüner Bericht 2022) which also affects the animal production sector. The "Digital Competence Initiative for Austria" was launched in February 2023. A holistic stakeholder initiative supported by four ministries (BMF, BMKOES, BMAW, BMBWF), which, pursues the goal of improving basic digital skills in the population and IT skills for the economy in a targeted manner. (https://www.digitalaustria.gv.at/Strategien/DKO-Digitale-Kompetenzoffensive.html)

According to current calculations, greenhouse gas emissions in Austria are likely to have fallen by around 6.4%. In the agricultural sector, GHG emissions have decreased slightly in 2022. (https://www.bmk.gv.at/service/presse/gewessler/20230817_treibhausgasemissionen.html)

Within the framework of the Austrian Air Pollution Inventory (OLI), emissions are collected according to international guidelines and reported in accordance with international formats. (https://www.umweltbundesamt.at/klima/emissionsinventur)

A generally observable trend of interest regards land sealing in Austria. A surface is considered "sealed" if the soil loses important functions, such as the ability to store and evaporate water (cooling effect) or to filter, bind or decompose pollutants, by being covered with an impermeable layer. This usually means that the area is built over, concreted over or asphalted. In order to determine the degree of sealing of the occupied areas, the Federal Environment Agency (UBA) determined a sealing coefficient for each DKM type of use (https://www.flaechenversiegelung.at/).

An Austrian trend analysis performed by the Lebensmittelcluster Niederösterreich in 2023 faced the following Mega and Macro-Trends (https://www.lebensmittel-cluster.at/news-presse/detail/news/trendsetter-statt-nachzuegler).

• Trends defined by the Austrian Lebensmittelcluster in 2023	
Mega Trend	**Macro Trends**
Conscious Eating	Food for climate; food experience; performance food; bioengineering; purification
Consumerism 2.0	Experience showroom culture; higher society; healthy habits; ageing consumers; direct to consumer; modern families; omnichannel; total transparency

Data driven business	AI assistants; predictive analytics; user profiling; smart data; robotics
Marketing	Valuetising; purpose driven marketing; social channel evolution
New Technologies & Materials	Human enhancement; flexible production; 3D-printing; smart materials
Sustainability	Resilient supply chain; agriculture innovations; ethical consumption; circular econo alternative materials; emission handling. The Innovation Map (WKO, Envisioning) is an interactively visualised tool display show 105 emerging technologies expected to affect major industries by 2035. They w clustered into five trends, disclosing the main interactions between society, companies, these technological tools. (https://site.wko.at/innovationmap/about/105-ausblicke-in-zukunft.en.html).

2. Sustainability Trends

2.1 Sustainability and Food industry

• Sustainability in the food industry	
Energy efficiency	Austrias main strategy is not only to promote the use of renewable energy sources, but to reduce the demand for energy, through sound use of energy and by improving the efficiency with which energy is employed (https://www.bmk.gv.at/en/topics/energy/energy-efficiency.html, https://www.bmk.gv.at/themen/energie/effizienz.html).
Alternative protein sources: meat alternatives	The category of alternative protein sources includes plant sources (legumes, cereals, or oilseeds), animal sources (insects or cell cultures), and other protein sources (microalgae, macroalgae, fungi, bacteria, and yeasts) (https://www.kern.bayern.de/recherche/312473/index.php#:~:text=Zur%20Kategorie%20der%20alternativen%20Proteinquellen,%2C%20Bakterien%20und%20Hefen. Austria is informing about alternative proteins via an information platform (https://alternativeproteine.org/), meat alternatives in Austria (Iglo-Trendstudie, 2023) and protein sources (https://www.donausoja.org/de/home/, FIELDS Austria country report). We also refer to dimension sustainable – animal production.
Waste management, waste reduction	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, FIELDS - deliverable 1.8 chapter on trend). To reduce waste caused by consumer packaging, Austria is going to implement a single-use deposit return system in its waste management with a dedicated programme of action, starting in 2025 (Österreich isst informiert 2023, Lebensmittelverpackungen; https://www.bmk.gv.at/themen/klima_umwelt/abfall/abfallvermeidung/lebensmittel/initiative/aktionsprog.html; Aktionsprogramm “Lebensmittel sind kostbar!”).

Prevention of environmental pollution	Process-related and energy-related emissions are emissions resulting from industrial transformation processes and combustion of carbonaceous energy sources respectively (https://www.bmk.gv.at/dam/jcr:0ac604d1-7928-492f-991a-4845dce78c27/Begleitstudie_Endbericht.pdf). This trend has the following impact in Austria: (1) pollution of groundwater with nitrate decreases slightly, (2) despite increasing traffic volume NOx emissions from the transport sector are decreasing due to advances in automotive technology, (3) Nitrogen oxide emissions from industry and energy supply decrease in industry due to the use of new technologies, and (4) Green Chemistry Austria should set a sustainability standard in the chemical industry (umweltbundesamt.at/fileadmin/site/publikationen/rep0821_trends_ukb13.pdf). The objective of a "fossil free agriculture and forestry" was launched (https://dafne.at/, FIELDS Austria country report).
Consumer expectations (climate friendly products, e.g. palm oil free, rainforest initiatives, CO_2-neutral)	The Austrian population increasingly demands cost efficient, environmentally friendly produced and healthy products (www.bmk.gv.at/themen/klima_umwelt/luft/umweltsituation.html). These may imply gentle conservation (high pressure treatment, pulsed electronic field (PEF) - Induction), smart food packaging and zero-waste efforts (Österreich isst informiert, 2023, Trends: Das tut sich in der Lebensmitteltechnologie). This leads to consumer related production development (nutritional focused, ethical related) and transparent label products (nutritional focused, ethical related) (FIELDS - deliverable 1.8 chapter on trend).
Organic standards	The organic share shows yearly growth, from 2021 to 2022 the organic percentage reached 11,5 %. In 2021 the income from agriculture and forestry of organic farms increased by 17%. An increasing environmental consciousness of consumers may be derived from observable rising numbers of in glass bought products (RollAMA_Factsheets 2022). In the future, the Austrian Organic Action Plan will be oriented towards the new Organic (EU) Regulation 2018/848 and the one from 2023. Since June 2020, in addition to the AMA Quality Seal and the AMA Organic Seal, the "AMA Genuss Region" quality seal was implemented, a certificate for businesses (Grüner Bericht 2022). Organic shares by product groups: (https://amainfo.at/fileadmin/user_upload/RollAMA_Marktentwicklung_Bio_Q1_2023.pdf)
Pesticides	There were more plant protection products registered and increasingly applied (Grüner Bericht 2022). However, 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. (FIELDS Austria country report).
Nearshoreing; regional production urban agricultures (vertical farms)	Nearshoring refers to regional proximity: the outsourcing of work (working steps/ procedures) to the vicinity to one's location or a neighbouring country (https://rightpeoplegroup.com/de/nearshoring-definition-vorteile-beispiele-und-wie-sie-wissen-ob-es-das-richtige-fuer-ihr-unternehmen-ist/). The VFI (Vertical Farm Institut) in Vienna - an Austrian pioneer institute - was founded in 2016 and is well integrated in the international research network (Kulturpflanzenproduktion 7/2020).
Craddle-to-Craddle/ circulate production	There is a high potential for circular economy: products return to the production cycle after use as secondary raw materials (Trendradar – Lebensmittelcluster; https://public.trendmanager.com/trendradar/49944854-d057-4f42-8eea-45dca607e2d2/de/view). Strategies (biodiversity strategy, circular economy strategy) including legislative frameworks (e.g. the Renewable Energy Expansion Act or the eco-social tax reform), key measures for a good and climate-friendly future

	have already been implemented in Austria (https://www.bmk.gv.at/themen/klima_umwelt/luft/umweltsituation.html).
Plastic reduction	This includes for Austria (1) the reuse of packaging (within companies): deposit systems and disposable material to recycle, (2) digital incentive models and packaging, (3) glass recycling and rePET bottles (increasing share of rePET) and (4) plant-based packaging (renewable raw materials), (Österreich isst informiert 2023, Best Practice: Lebensmittelverpackungen im Kreislauf halten).
Convenience products	There is a rising demand for convenience products (naturally, as little processed as possible), simple to prepare, low in calories, very nutritious, easy and fast to consume, this implies less effort for cooking and demand for snacks (Österreich isst informiert, Convenience Food – das steckt dahinter; Iglo-Trendstudie 2023). Food innovations goal: enjoyable experience, high productivity/low environmental impact; eg higher use of legumes in the diet (FIELDS - deliverable 1.8 chapter on trend)

Due to high numbers of food waste not only from private households, but the food industry the action programme "Lebensmittel sind kostbar!" (Food is precious) wants to support the prevention and reduction of food waste. It is an initiative from the Federal Ministry for Sustainability and Tourism (BMNT) in close cooperation with industry, federal provinces, municipalities and waste management associations, employees, consumers and social institutions. There is a collection of measures until 2025. These strengthen the tendency for more transparency and aim at (consumer) education regarding food and the processes connected to it (Aktionsprogramm "Lebensmittel sind kostbar!").

2.2 Sustainability and Animal production

• Sustainability in the animal production sector	
Consumerism, expectations (Austrian/ local animal production)	On average, Austrians eat around 70 kg of meat (incl. fish) per year. The share of organically produced meat between 2018 and 2020 reached around 5,6 %; this means an increase of about 1% since 2018, whereas the share of sausage and ham remains stable at about 3.2%. The organically held livestock units range up to 17%, the poultry production and the share of organic milk in the food industry is constantly rising (Fleischatlas 2021).
Animal welfare and organic standards	• **According to the Terrestrial Code, animal welfare means 'the physical and mental state of an animal in relation to the conditions in which it lives and dies (https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-welfare/). Welfare is given when the animal does not suffer pain, disstress, harm or severe fear (www.sozialministerium.at/Themen/Gesundheit/Tiergesundheit/Tierschutz.html)** 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; FIELDS Austria country report). Around 24% of animal INVECOS farms (= integrated management and control system) are run according to organic standards. Regarding pig farming, in addition to the economically important criteria of fertility, sustainability and animal welfare are firmly anchored in the new breeding objective (Grüner Bericht 2022). We also refer to dimension one health – animal production.

Soy and animal feed production	Austria is still dependent on the import of protein-rich food. The share of imported soy meal from GMO soy beans (mainly from South America) for conventional animal production was still 80 % in 2021 (Fleischatlas 2021). For this reason, initiatives such as "DonauSoja", domestic seed breeding companies and others are demanded and promoted (https://www.donausoja.org/de/home/).
Development of farm structure	Austrian agriculture has a comparatively small structure, but the trend toward, larger farms continues constantly (Agrarstrukturerhebung 2020; Hauptergebnisse der Vollerhebung; https://www.statistik.at/fileadmin/pages/155/PK_AS2020_220712_final_web.pdf). This trend is also reflected in animal husbandry: whereas an Austrian farm kept an average of 28 cattle ten years ago, herd size has risen steadily since then to 34 cattle per farm. The average number of pigs has increased from 85 to 112 since 2010. For sheep, it grew from 27 to 33 animals and for goats from 8 to 12 head in the same period. (https://www.tgd.at/netautor/napro4/wrapper/media.php?filename=archive%3D%2F2022.05.23%2F1653294210.pdf&rn=03_Herzog_%D6TGD_Stand_Tiergesundheit%D6_.pdf) Some smaller farms have given up keeping wild animals. Farms that consider the use of grassland with wild animals and the direct marketing of game meat as an alternative and want to professionalise game keeping, are newcomers. These farms keep 17,353 head of red deer and 31,057 head of fallow deer. In addition, there are still small stocks of sika and mouflon deer as well as David deer (Grüner Bericht 2022).
Fight against loss of biodiversity	Biological diversity (biodiversity) is not only about the diversity of species of free-living plants, animals and microorganisms, but also about the diversity of habitats and thus of the ecosystems in which the species live, as well as about genetic diversity within the species. Breeds or cultivated varieties are also in demand (BMK-Hintergrund zur biologischen Vielfalt, August 2023). In Austria, around 16% 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). 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 (FIELDS - – deliverable 1.8 chapter on trends).
Environmental pollution – reduction of GHG Emissions	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) (FIELDS - deliverable 1.8 chapter on trend).
Increase in livestock - animal feed production	Due to the increasing number of animals, negative developments (e.g. over-thinning of meadows and soils, water pollution, etc. are also being driven forward. In Austria more than half of the emissions produced in agriculture are due to livestock farming. This also devours unbelievable amounts of feed and the land needed for its production (Grüner Bericht 2022).

2.3 Sustainability and Veterinary activities

• Sustainability in the veterinary sector	
Animal welfare	Here we refer to dimension sustainability in animal production and dimension one health in veterinary sector.

Reusable solutions	For the veterinary sector, circular product design (medical devices), waste prevention, reuse and refurbishment of resources is gaining importance (corporate.webassets.siemens-healthineers.com/Sustainabililty-Report-2022.pdf). Medical device manufacturing companies rely on multi-way/ reusable solutions (https://www.msd-tiergesundheit.at/verantwortung/mehrwegboxen/).

3. One Health Trends

3.1 One-health and Food industry

• One Health in the food industry	
Food safety and product transparency	This refers to increasing nutritional quality and food safety (FIELDS - deliverable 1.8 chapter on trend). The Federal Ministry of Social Affairs, Health, Care and Consumer Protection (BMSGPK) compiles information, links and recommendations regarding nutrition and food products, where food hygiene, food labelling, novel foods and other significant topics are transparently shown (https://www.sozialministerium.at/Themen/Gesundheit/Lebensmittel-Ernaehrung/Ernaehrungsstrategien-und-Gremien.html). Health monitoring programmes and projects are supported (by Austrian state institutions and private businesses) to improve the nutritional situation in Austria (https://www.richtigessenvonanfangan.at/eltern/ueber-das-programm; https://www.lebensmittellupe.at/kooperationen).
Mindful eating, healthy lifestyle	Mindful eating means to eat a meal without distraction. Your thoughts are not elsewhere, but completely in the moment - this allows you to perceive the taste with all your senses (https://www.alnavit.de/de-de/genuss-und-inspiration/mindful-eating/#:~:text=Mindful%20Eating%20oder%20achtsames%20Essen,Geschmack%20mit%20allen%20Sinnen%20wahrnehmen). In Austria, associations like “Land schafft Leben” work for rising awareness and the education about agriculture and food production in general society (https://www.umweltbundesamt.at/aktuelles/presse/news2019/news20190910). Initiatives such as “Lebensmittelaktionsplan “Wien isst G.U.T” “ support a more sustainable food handling on regional level by bringing together the different players and organization of activities. (Dialogplattform - SUM-FOOD, (https://www.umweltbundesamt.at/aktuelles/presse/news2019/news20190910), (https://www.wien.gv.at/umweltschutz/nachhaltigkeit/wien-isst-gut.html). A study shows that Austrian citizens are increasingly trying to consciously eat less meat. In return, the demand for frozen products, especially those for meat alternatives (products based on vegetable protein), increases (https://www.ots.at/presseaussendung/OTS_20201001_OTS0035/studie-bewusst-weniger-fleisch-zu-essen-liegt-im-trend-anhang). A growing branch is also the production of herbs for health supporting substances and raw materials for the pharmaceutic industry e.g. pickled thistle and CBD-oils from Cannabis (FIELDS - deliverable 1.8 chapter on trend).
Ethical consumerism (e.g. fairtrade)	Ethical consumerism can be defined as the practice of purchasing products and services produced in a way that minimises social and/or environmental damage, while avoiding products and services deemed to have a negative impact on society or the environment (www.igd.com/articles/ethical-consumerism/). A plus of 22% sales of fairtrade products was recorded from 2021 to 2022 https://de.statista.com/themen/5607/fairtrade-in-oesterreich/#topicOverview). Worldwide only Swiss buy more fairtrade products than Austrians (diePresse Artikel 2023: https://www.diepresse.com/6286948/nur-schweizer-kaufen-weltweit-mehr-fairtrade-produkte-als-oesterreicher).

Control and safety of nutritional supplements	Food supplements are food, not medicines. To ensure the safety of food supplements in Austria, an average of about 450 samples of food supplements are officially inspected annually in recent years. Results are published every year in the food safety report (https://www.verbrauchergesundheit.gv.at/Lebensmittel/lebensmittelkontrolle/LMSicherheit.html). About one third of the samples were objected mainly due to labelling deficiencies such as incorrect claims or unauthorised health claims. Frequent reasons for complaints based on composition were deviations of the analytically determined nutrient contents from the declared values. As for all foods, misleading and disease-related claims are prohibited when marketing food supplements. In addition to the labelling elements of foods there are additional mandatory rules for labelling of food supplements (https://www.ages.at/mensch/ernaehrung-lebensmittel/lebensmittelinformationen/nahrungsergaenzungsmittel).
Organic standards	We refer to dimension sustainability – food industry and dimension one health – animal production.
Diseases prevention	With the aim to collect data that contributes to diseases (pandemic) prevention, the VIS (Verbrauchergesundheitsinformationssystem) was established (https://vis.statistik.at/vis/schweine/haeufig-gestellte-fragen) (since 2001; https://www.statistik.at/fileadmin/publications/Statistik_der_Landwirtschaft_2020.pdf) we also refer to section one health - veterinary sector.

3.2 One-Health and Animal production

• One Health in the animal production sector	
Cultural landscape – resettlement of wolf population	Austria has committed itself to restoring a favourable conservation status for large carnivores, with various Conventions and Directives. The ÖZ (Austrian centre bear wolf lynx), founded in 2019 is responsible for the monitoring of large carnivores. With the aim to ensure a conflict-free coexistence of humans and animals in the future (https://baer-wolf-luchs.at/). Controversy does exist, e.g. about the wolf: on one hand, there are calls for the reintroduction of wolves in terms of biodiversity and ecological balance, on the other hand, especially farmers and hunters also see an economical threat, due to the threat that wolfs represent for their animals (https://www.diepresse.com/6287765/wolf-baer-luchs-wozu-der-grosse-aufwand).
Antibiotics and germs resistance (animal/human)	We refer to the dimension one health - veterinary sector.
Animal welfare – organic standards	We refer to the dimension sustainability - food industry and the animal production sector.
Medical health	Describes the health care, health promotion and prevention. In Austria, a large part of the health care systems resources is spent on health care. However, health promotion and prevention - which includes all measures to maintain health and avoid illness - are becoming increasingly important. In order to ensure high-quality health care throughout Austria also in the long term, comprehensive planning work

	is being carried out (https://www.gesundheit.gv.at/gesundheitsleistungen/gesundheitswesen.html).
Environmental pollution	We refer to the dimension sustainability – food industry and the animal production sector.

3.3 One-Health and Veterinary activities

• One Health in the veterinary sector	
Diseases prevention	Austria is officially free of certain diseases such as bovine tubercolosis, bovine brucellocis, enzootic bovine leucosis (all since 1999) and brucellosis of small ruminants (Brucella melitensis; since 2001) due to eradication programmes strictly implemented in the past and subsequent annual surveillance programmes. In February 2022, Austria also obtained free status for bovine viral diarrhoea (BVD). Data on non-resident mosquito species are recorded, which can have a negative impact on human and animal health (Jahresbericht 2022, 19. April 2023, https://www.ages.at/forschung/wissen-aktuell/detail/mosquito-alert-jahresbericht-2022). In the Austrian animal disease radar, information on the international situation and spread of the most important animal diseases and epizootics relevant for Austria is assessed and compiled. All feral pigs found dead must be reported and examined by AGES (Austrian agency for health and food safety) for the ASF virus. In addition, an examination of abortions as well as of clinically or pathologically conspicuous domestic pigs is also carried out (https://www.ages.at/mensch/krankheit/krankheitserreger-von-a-bis-z/afrikanische-schweinepest#:~:text=Das%20Afrikanische%20Schweinepestvirus%20(ASPV)%20ist,bis%20192.000%20Basenpaare%20gro%C3%9F%20ist). Another tendency is the rising importance of preventive check-ups in contrast to acute work, while at the same time, farmers are medically more experienced and adopt former activities of vets. These trends also influence the coverage of emergency and on-call services. Even though the situation is growing acute, the willingness and implementation of collaborations is low. (https://www.vetmeduni.ac.at/fileadmin/v/z/news/2019/Veterinaermedizinische-Versorgung-IHS.pdf).
Antibiotics and resistances, antibiotic monitoring, tendency to avoid antibiotics	According to the "OneHealth" strategy and common goals, the national action plan on antibiotic resistance was revised and expanded together with other experts (NAP-AMR: Nationaler Aktionsplan zur Antibiotikaresistenz; BMSGPK 2021). The distributed quantities of veterinary medicinal products containing antimicrobial active substances, are reported electronically by the pharmaceutical companies to the AGES (AURES_2021_-_BMSGPK_(Stand,_27.2.2023) stand lt. Impressum: 9. März 2023). In 2021, significantly fewer (-10.5%) antimicrobial substances for the treatment of farm animals were placed on the market in Austria by pharmaceutical companies and wholesalers (Bericht über den Vertrieb von Antibiotika in der Veterinärmedizin in Österreich 2016-2020, AGES 2021, NAP-AMR: Nationaler Aktionsplan zur Antibiotikaresistenz; BMSGPK 2021). In 2018, the Austrian animal health services (ÖTGD) approved a monitoring programme to reduce antibiotic use and prevent antibiotic resistance in poultry. Likewise, electronic monitoring programmes for bovine and pig production sector

	contribute to the monitoring of the reduction of antibiotic use (ZAR project "Elektronisches Stallbuch Rind", https://amainfo.at/fileadmin/user_upload/B2B/Documents/LW_Schwein/Handbuch_Schweine_-_Selbstevaluierung_Tierschutz.pdf). Active health management to reduce the use of antibiotics in agriculture is implemented mainly through improved husbandry and feeding conditions, targeted immune prophylaxis and preventive use of complementary treatment methods, whereupon continuous education and training possibilities of the veterinary profession are incorporated (NAP-AMR: Nationaler Aktionsplan zur Antibiotikaresistenz; BMSGPK 2021). We further refer to the dimension digitalisation – animal production and veterinary sector and sustainability – animal production (animal welfare and organic standards).
Shortage of veterinarians	An east-west divide in income and specialisation between the small animal and livestock sectors can be observed: adequate to overprovision on the small animal sector (exception: on-call services) whereas adequate to undersupply in the livestock sector is apparent. In medium to long term (next 5-10 years) a deterioration of this situation is predicted, due to the upcoming wave of retirements and the lack of attractiveness for younger veterinarians. The problem of undersupply is most evident in the area of ante-mortem and post-mortem inspections, as these tasks are seen as less attractive. There are also problems in filling on-call positions. In line with this, there is great interest in positions as official veterinarians (with regulated work-times). In the east of Austria, where small animal practices compared to live stock veterinarians are overrepresented, the percentage of women is higher. However, the livestock sector is definitely dominated by males (https://www.vetmeduni.ac.at/fileadmin/v/z/news/2019/Veterinaermedizinische-Versorgung-IHS.pdf, https://www.tieraerztekammer.at/zukunftstalk-2023). In 2022 the position for the lecture "Wiederkäuermedizin im Alpenraum" at the VetmedUni was raised to offer more options to veterinarians that are interested in the agricultural sector (near the alpine region; https://www.ots.at/presseaussendung/OTS_20221003_OTS0024/start-fuer-stiftungsprofessur-wiederkaeuermedizin-im-alpenraum).

To support and strengthen the biodiversity is one of the main pillars of the European green deal. There are several ongoing research projects in Austria 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 (FIELDS – Austria country report).
Regarding animal welfare, in 2023 the association "Animal Health Austria" was founded, who has internal control function and prescribe the control requirements (https://www.tieraerztekammer.at/oeffentlicher-bereich/medien-kommunikation/news/detail/newsarticle/detail/News/verein-tiergesundheit-oesterreich-gegruendet; https://www.ooe-tgd.at/2177.htm, https://www.rinderzucht.at/nachricht/20230207-verein-tiergesundheit-oesterreich-wurde-gegruendet.html). Animal welfare inspections during transport are carried out on the basis of the Animal Transport Act (TTG), in indirect federal administration. The target since 2020 is a number of 12,000 animal transport controls per year, of which at least 1,200 must take place on the road. In 2020, 8,805 inspections were carried out throughout Austria at the place of dispatch (90 infringements detected), 908 inspections during transport by road (209 infringements detected) and 129,572 inspections at the place of destination (870 infringements) (Grüner Bericht 2022).

4. Digitalization Trends

4.1 Digitalization and Food industry

• Digitalisation in the food industry	
Smart materials	Based on scientific findings and through the use of new technologies, intelligent materials are developed that adapt flexibly to their environmental conditions. In this way, the functional spectrum of a material can be expanded by reacting, for example, to temperature fluctuations, a change in the pH value or targeted mechanical stress. Sensor or actuator functions can be integrated into the material. To detect residues after the cleaning process of glass bottles for example is also the content of this development (https://public.trendmanager.com/trendradar/49944854-d057-4f42-8eea-45dca607e2d2/de/view).
Packaging as a communicatio n tool	This refers to product communication towards the consumer by using packaging and labelling (e.g. by the means of nutriscore, health claims, environmental claims, recyclability, QR information, etc.) (FIELDS – deliverable 1.8 chapter on trend).
3D-Printing	3D printing (AM-Additive Manufacturing), also known as additive manufacturing, is a method of creating a three dimensional object layer-by-layer using a computer created design (https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing). Also in Austria the 3D-Printing research, development and implementation respectively application in the industry are progressing. Especially 3D-printing with sustainable materials (powders) is an important topic (https://www.am-austria.com/de/presse). 3D-printer in Austria (3D-Bio-Drucker - MUI (MedUni Innsbruck); https://www.i-med.ac.at/bioprinting/3Dbioprinting.html.de). 3D printer association (education, workshops, develoment: (https://www.oeg3d.at/). WKO-Envisioning: Trend Radar - 72. 3D-printed food (https://radar.envisioning.io/wko/innovation/?pg=entity_f5DboZ8ESEBpp3PQc).

4.2 Digitalization and Animal production

• Digitalisation in the animal production sector	
Farm presentations (social media)	To use the high potential of social media for public relation work, e.g. farmers showed how they spent their busy times in summer with pictures and a hashtag (2023, #sommerambauernhof ("summer on the farm"), social-media challenge #sommerambauernhof, https://bauernzeitung.at/social-media-challenge-sommerambauernhof/). With a series (five short videos) of online seminars, an expert for digital communication shows how communication in agriculture really works and how farmers can make the best use of social media for their communication (rural training institute (LFI), DIALOGisch - Bauernhof goes online, https://www.baeuerinnen.at/social-media-am-bauernhof+2400+2736511+1000233+1046).
Work enhancements (Milking robotics, Animal sensors, stall	The use of digitalisation helps farmers increase their productivity and to improve animal welfare and health (https://boku.ac.at/universitaetsleitung/rektorat/stabsstellen/oeffentlichkeitsarbeit/themen/presseaussendungen/presseaussendungen-2022/14112022-smart-farming-am-boku-universitaets-und-forschungszentrum-tulln). In Austria, there exists a large market potential for digital production technology, at the top of the ranking are applications for automatic track following systems or

ventilation, feeding and water systems)	automated feeding techniques (survey 2021, LFI Austria). Expectations of many farmers are a reduction in workload and time savings. The associations of different agricultural sectors support their members with a variety of software programs and digital learning possibilities (e.g. "Rinderzucht Austria" - provides tools and online databases such as the "LKV-Herdenmanager" that also shares an interface to "EMED" an electronic medicine record (https://www.rinderzucht.at/app/lkv-herdenmanager.html). Digital recording via the farm management information system (FMIS) is commonly used in animal husbandry (dairy, hog feeding,..) (FIELDS Austrian country Report).
APPs and educational programs	The animal production sector uses mobile apps, such as the "LKV-Herdenmanager" in cattle farming (mainly for database queries (see field above; regarding trainings in this field: Ländliches Fortbildungs Institut [LFI] https://oe.lfi.at/startseite+2500+++2003). Another application area for IT systems regards legal shootings: hunting is strictly regulated and controlled by the regional associations for hunting and the umbrella organisation "Jagd Österreich" (https://www.jagd-oesterreich.at/ueber-uns/). Provinces increasingly install online register and digital registration systems (online register for hunting and kills, (e.g.: https://vorarlberg.at/-/digitale-abschussmeldung).

Digitalisation plays an important role in Austria's agriculture. Due to the small sized farms structure digitalisation did not really arrive in practice in predominant number of farms so far. A platform "Digitalisation in Agriculture" has been established by 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 (https://www.bmlrt.gv.at/service/publikationen/land/digitalisierung-in-der-landwirtschaft.html; FIELDS Austrian country Report). Already realised recommendations are the Austrian Innovation Farm 2020 (www.innovationfarm.at), the free of charge correction signal for real time kinematic (RTK), by the global navigation satellite system (GNSS) and projects for animal husbandry data, environmental assessment and legal data aspects (FIELDS Austrian country report).

Another Austrian project that works on the development of applications in practice, and numerous digital innovations (e.g. chips and sensors to improve animal welfare, in particular artificial intelligence) is "DiLaAg",https://boku.ac.at/universitaetsleitung/rektorat/stabsstellen/oeffentlichkeitsarbeit/themen/presseaussendungen/presseaussendungen-2022/14112022-smart-farming-am-boku-universitaets-und-forschungszentrum-tulln).

The main deterrents from using digital technologies/apps are high investment costs, ongoing licence fees and uncertain cost-benefit calculations. Other hurdles are the lack of compatibility between manufacturers. Here guidelines on data and compulsory standards for other systems would be beneficial (https://landforstbetriebe.at/meta/aktuelles/2023-02-20-precision-farming-vom-hype-zur-realitaet).

4.3 Digitalization and Veterinary activities

- **Digitalisation in the veterinary sector**

E-Health, precision animal health, telemedicine	Carrying out medical practice in which all or part of the veterinary activities, such as consultations and (suspected) diagnoses, are carried out as telemedicine (https://phaidra.vetmeduni.ac.at/open/o:1489). E-Health describes the fusion of three disciplines into a new field. These include medicine, health management and information- and communication technologies. E-Health is constantly evolving through advancing health information networks, telemedicine and new technologies (https://www.sozialversicherung.at/cdscontent/?contentid=10007.844373&portal=svportal). On farm Animal Practice 4.0: Digitization, Automation and Data in Farm Animal Practice (https://phaidra.vetmeduni.ac.at/open/o:1489; www.tieraerzteverlag.at.pdf). In this regard, the university of veterinary sciences implemented a new masters program called: "Digitalisierung im Tiergesundheitsmanagement – Precision Animal Health" (https://www.vetmeduni.ac.at/studium/studienangebot/master-digitalisierung-im-tiergesundheitsmanagement-precision-animal-health). The project d4dairy works on the digitalisation, data integration and decision making support for dairy farms (https://d4dairy.com/de/#projekt).
Chips, sensors	We refer to sector digitalisation – animal production.

Telemedicine has an impact on sustainability (less transportation costs): The possibility for telemedicine services is only possible for some areas. Despite the opportunities digital services bring more flexibility, less travel and more natural behaviour of patients in familiar surroundings. Digitalisation in the veterinary sector faces some legal obstacles: by law, an examination of the animal and diagnosis in person is obligatory. At this state only teleconsultation and teletriage are possible (https://phaidra.vetmeduni.ac.at/open/o:1489; https://www.hagel.at/presseaussendungen/webinar-digitalisierung-tierhaltung-2/).
Due to present challenges and the multitude of databases the AGES is currently working on the Animal Health Data Service (AHDS). The AHDS should connect all the information that farmers, vets and public authorities could use to improve the work situation and animal health (https://www.tieraerztekammer.at/zukunftstalk-2023).

5. Business model Trends

5.1 Business models and Food industry

• Business models in the food industry	
New food products/concepts produced by Start Ups	As an example, in the baking industry, interesting concepts draw their innovations from traditional crafts; the trend processing ancient grains such as emmer, einkorn and spelt continues constantly (Grüner Bericht 2022). Various small businesses/Start Ups were founded producing new food products (e.g. on alternative meat and fish products: https://revo-foods.com/de/, https://www.rebelmeat.com/%C3%BCber-uns, vegini.at; alternative cheese and milk products: http://www.sennsenn.at/, https://wunderkern.com/pages/unsere-wunderkerne; or other products: https://www.hutundstiel.at/ (mushrooms) and https://www.alpengummi.at/ (chewing gum)).
Inter-farm cooperations (machinery rings)	The machinery ring is a platform (1) to simplify the cooperations between farms to share machinery and labour on multiple farms and communities and (2) to strengthen the exchange of knowledge and knowhow. Especially smaller farms and communities profit from this service, which provides them an additional income. In Austria, the number of machinery ring members is fairly stable at around 73,300.

	Thus, the share of those Austrian multiple applicants who were members of the machinery ring was 67 % in 2020 (Grüner Bericht 2022; (www.maschinenring.at, FIELDS Austria country report).
E-commerce systems, automatic supermarkets	This trend refers to online orders and collection from a dedicated pick up point or door delivery. Increasing online sales (https://myproduct.at/) and self service sales possibilities (www.lebensmittelpunkt-efi.at) are available in Austria (FIELDS Austria country report).
Food cooperatives, direct sales	Food cooperatives are associations of several people/households who buy/order directly and collectively from farmers (https://www.umweltberatung.at/adressen-foodcoops-lebensmittelkooperativen). Here we also refer to Ex farm sale/purchase, directly from the farmer and in farm store (https://foodcoops.at/).
Food sharing and SoLaWis	The shared food distributions are organized via platforms: they are usually publicly available and people can put food, they know they won't eat anymore themselves, there; others can take it or a handing over can be arranged (https://verein.foodsharing.at/). SoLaWis is an umbrella term for "solidary agriculture", with the focus on regional and social aspects; organised as associations, whose aim is the enabling of access to fresh food for all members and the protection of their members (=producers), as they have secure sales respectively customers and are insured for possible damages/risks (https://www.umweltberatung.at/csa-landwirtschaft-nah-fair-und-frisch).

5.2 Business models and Animal Production

• **Business models in the animal production sector**	
Strengthening of the farmer consumer relationship	Regarding aquaculture farms, the majority specialise in direct marketing as part of agricultural production. Few medium-sized farms process fish and sale is done on a commercial level. The marketing of these products mainly takes place in chain stores and supermarkets, partly also directly to the gastronomy (Grüner Bericht 2022).
24/7, direct selling points	Direct marketing also enjoyed increased demand in the second year of the COVID19 crisis. This favours entry of new farms, the expansion of production volume at existing direct marketers and the development of new forms of distribution (vending machines, customer delivery, online). Direct marketing (including "Heurige" and "Buschenschänke") is an important alternative source of income for many agricultural and animal production enterprises. The production value in 2021, derived from the accounting results, was 242.4 million euros for direct marketing and 99.0 million euros for "Heurige" and "Buschenschänke" (Grüner Bericht 2022). The availability of public fridges, vending machines, and devices for transport (cool-boxes, sustainable packaging) is on the rise https://fleischerverband.at/trends).
Tourism as a businessmodel for farmers	Farm holidays are a relevant element of the Austrian tourism economy, 9,895 farms offering accommodation and agritourist provided 113,764 guest beds (Agrarstrukturerhebung 2010).

Farm holidays not only contribute to the (at least partial) utilisation of agricultural labour, they also ensure the continued existence of one third of the farms, with the importance of secondary tourism activities being particularly pronounced in tourismintensive regions. On the other hand, in a number of regions, agriculture – and thus also farms offering farm holidays – contributes significantly to the preservation of cultural landscapes that

are attractive to tourists. There are also socio-cultural spillover effects, agricultural ways of life and production can be communicated to guests (Evaluierungsbericht Cluster Urlaub am Bauernhof: https://info.bml.gv.at/dam/jcr:9ea29e67-a503-4685-8f1d-78912e19be66/Endbericht_Evaluierungsprojekt_Cluster_UaB.pdf).

5.3 Business models and Veterinary activities

• **Business models in the veterinary sector**	
Formation of joint practices	There is a rising tendency of cooperation between single practices and formation of joint practices (https://www.vetmeduni.ac.at/fileadmin/v/z/news/2019/Veterinaermedizinische-Versorgung-IHS.pdf). This implies a change in the organisation of working practice. From individualistic and available 24/7 vets, now there is a rising tendency of cooperation between single practices and formation of joint practices. This trend points out the growing importance of safety, work-life-balance and compatibility of family and work (https://www.vetmeduni.ac.at/fileadmin/v/z/news/2019/Veterinaermedizinische-Versorgung-IHS.pdf)

With the aim to improve the veterinary care of rural regions in the livestock sector, to support and encourage the return of highly educated alumni to their home state, and to raise the status of veterinarians in society, the VetmedRegio initiative was founded, a branch office of the veterinary university Vienna regarding the "Ruminants in the Alpine region" topic (https://www.vetmeduni.ac.at/universitaet/profil/vetmedregio).

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• Greek Trends analysis

1. Introduction into sector structure

The agri-food sector in Greece holds a major role in the manufacturing, economy, and social life for the country (Ragazou, 2021). According to Klonaris (2021), the agri-food sector's contribution to the country's GDP (Gross Domestic Product) is constantly declining. Specifically, in 2021, Greek GDP was higher (i.e., 4 %) than the EU-28 average (1.6 %), while agri-food sector employs 11.6 % of the country's workforce (EU-28: 3.9 %).

One of the major challenges that the entire Greek economy faced was the COVID-19 pandemic crisis. The spread of COVID-19 and the measures implemented to limit the infection have deeply affected all economic sectors in Greece. In fact, the agri-food sector just recovered from the recent economic crisis. For example, sectors, such as sheep farming, were affected by the pandemic since the seasonal demand collapsed during the Easter period. Due to the lockdown measures and shut of business, hotels and restaurants put a strain on the food system as a whole. However, the Greek agri-food chain has demonstrated great resilience to guarantee the supply of food to consumers (Klonaris, 2021).

Significant advantages of the Greek agri-food sector are summarized in the favorable climatic and soil conditions, the strong position in the Mediterranean diet products' market (mass-produced and traditional agricultural products), as well as in the rich biodiversity in species, ecosystems, and landscapes. On the other hand, the small farm size, the low degree of integration of innovation in the sector, the imperfect system of short food supply chains, the imperfectly developed system of organization of farmers, the low productivity in the agricultural sector and the agricultural trade deficit particularly in certain livestock products are some of the most important weaknesses of the Greek agri-food sector (Klonaris, 2021). Undoubtedly, the small size of the agri-food sector at all levels is the main drawback making most of the farms and enterprises non-competitive in terms of exports into international markets (Klonaris, 2021).

1.1 Animal production

In Greece, farmers and breeders must be aligned to the EU initiatives regarding sustainable development, entrepreneurship, marketing, and technological novelties, to benefit from European and national funds. The highest percentage of livestock industry is represented by the poultry farming, sheep, and goats breeding with sheep and goats having the biggest number of animals that were bred from 2000 until 2018, according to the Hellenic Statistical Authority (2019). On the contrary, cattle, brood (mother) cows, and poultry farming constitute intensive livestock (Aravani et al., 2022). For example, Greek meat production was estimated in 35.53 thousand tons for cattle in December of 2022, according to the Eurostat (2022).

In addition, according to FAO (2021), Greece is the 4^{rth} largest producer of milk, with 355.760 metric tons, and the 1^{rst} producer of goat meat, with 26.480 metric tons. Despite the importance of the goat farming in Greece, nowadays the sector is experiencing economic and structural difficulties due to the decrease in livestock numbers and the policy changes in public funding. By subsidizing the goat industry, the Greek government may be indirectly supporting an industry that has historically had negative environmental impacts. In many areas, especially in inland, low-accessibility mountainous districts, grazing has greatly increased with Common Agricultural Policy (CAP) subsidies (Tsiouni et al., 2021).

Another important part of livestock production, especially in the north part of Greece, is dairy sheep. There are 3 types of sheep farming systems in these areas: (i) intensive, (ii) semi-intensive and (iii) traditional semi-extensive. The farms using the intensive systems has been increased recently, in which no grazing is applied, automated milking equipment is used, and dairy sheep breeds are raised. Their diet is based on alfalfa hay and corn silage that are mainly locally produced by the farmers. On the other hand, in the semi-intensive system,

livestock feeding is based on pasture grazing and harvested forages. Generally, this system is not common in Greece (Manousidis et al., 2011).

1.2 Food industry

Agri-food sector in Greece dominates in manufacturing, covering 25% of all Greek manufacturing companies, which ranks it 1^{rst} among the manufacturing sectors, followed by metal products (13%) and clothing (12%) (Ragazou, 2021). The Greek Food Industry is a fundamental pillar of the Greek economy and the leading manufacturing sector in the country, in terms of turnover (28.8%), employment (37.3%) and value added (32.4%). It is a dynamic, competitive player and a major exporter worldwide (6 billion € exports) (IOBE, 2023). All the aforementioned indicate that the food industry is the largest employer in Greece in terms of manufacturing. Food industry companies providing water and spirits, bakery products, and wine products are the most competitive, followed by companies with sausage products, poultry, mills, beverages, and dairy products (Notta et al., 2010). Because of its significant role in the Greek economy, any development that takes place in the sector affects the entire manufacturing sector. Although the economic crisis has affected the food industry, with reductions, the food sector continued to be one of the most important employers not only of the Greek manufacturing sector, but also of the domestic economy (Ragazou, 2021). The agri-food sector is facing several challenges that require a re-evaluation of current practices in production, the cooperation between enterprises along the vertical chain supply and relationship between enterprises on similar stages of production or trade. These challenges include, but are not limited to, highly differentiated food production, complex requirements on quality assurance, reliability, and flexibility in the provision of food, sustainability in people's trust, control on environmental effects, and efficiency in the sector's organization and processes (Lakasas, 2022).

1.3 Veterinary sector

Currently, more than 4.000 veterinarians work in Greece. Most of them are employed in the central and regional departments of the Ministry of Agriculture, as well as in the veterinary services of the Prefectural Authorities. An important and ever-growing number of veterinarians practice as free lancers, while other work in the country's VET, in industries or commercial companies of veterinary products, in food industries, in livestock, poultry or fish farms or in other public sector services (University of Thessaly).

2. Trends in sustainability

2.1 Sustainability and Animal production

Considering the rather important agri-food sector in Greece, it is considered as an agricultural country with a high biomass potential. However, a significant lack of knowledge and information exists not only by farmers but also by industries and general public about the potential of energy recovery of biomass waste. Representative examples are the disposal of biomass waste in the environment without control or in landfills, while farmers usually proceed with the burning of residual biomass in their fields. (Aravani et al., 2022)

Anaerobic digestion is used as a waste management method and is not accompanied by biogas and energy production. The kind of exploitation currently performed by the farm owners for the generated manure, is mainly focused on selling it as fertilizer or simply spreading it onto agricultural and/or arable land. At the same time, in some rural areas, animal manure is still combusted for heat production. Both practices, i.e., spreading or/and combusting, are seriously implicated in environmental deterioration. (Aravani et al., 2022)

Most European countries use biomass as significant sources of electricity and thermal energy, such as crop residues and livestock manure. In Greece, only a small percentage of biomass is exploited to cover electrical energy needs, which it is mostly dependent on fossil fuels. Aravani et al., (2022) indicate that if the biomass were

exploited, the produced energy from agricultural (11 TWh) and livestock residues (66 TWh) would be enough to potentially cover the energy needs of Greece. Therefore, under a sustainability context, immediate implementation of environmentally friendly management of these wastes is considered of utmost importance.

2.2 Sustainability and Food industry

In Greece, agro-residues represent the biggest source of biomass. However, due to their ineffectual use, their contribution to the national energy demand is inadequate. The main industries that use agricultural crop or livestock by-products as raw material in Greece are orange, peach, tomato, olive, wine, beer, tomato, sunflower, sugar, potato, flour, cotton, tobacco, and cheese industries since they produce vast amounts of liquid and solid wastes. The average annual amount of agro-industrial residues produced in Greece was estimated to 13.2 Mt (metric tons)/year (solid and liquid waste). (Aravani et al., 2022)

Circular economy (CE) is related to Greek food industry, mainly to recycling procedures of products and materials for reuse purposes and more precisely for energy production and waste management; such activities correspond to the phase before the final disposal of the remaining waste. The lack of deep knowledge on CE issues within well-established companies, along with the absence of a core strategy of the leaders for the transition to the CE have been the key reasons for its misunderstanding and consequently its non-adoption by the food industry. The commitment of companies to a real shift is non-existent and therefore it is to be expected that the companies leading the Greek economy do not look for alternative strategies to grow (Trigkas et al., 2020).

Greek industry leaders have set the groundwork for a transition to the CE, as they acknowledge the new challenges posed by this emerging market situation. However, it is quite evident that the CE values and principles are treated more as environmental responsibility than a new way of entrepreneurship. The adoption of specific sustainable manufacturing techniques may be impeded by the lack of technical skills and relevant capabilities and consequently the inability to identify, assess, and implement the proper technical options that would facilitate a shift to the CE. Furthermore, it seems to reject eco-design and any type of sharing economy, since it is far against common beliefs, attitudes, and culture of Greek leading companies. CE practices, such as waste minimization and management, material flow analysis in the production process and product lifecycle analysis, seems to be valued and implemented in relation to specific legal requirements or imposed environmental policies. Greek companies take advantage of specific mechanisms and funding projects provided by the Greek National Strategy and EU regarding R&D and technical support but are rather skeptical regarding promotion and support of novel innovative models and systems as well as cross sector cooperation and soft skills. (Trigkas et al., 2020)

Despite the considerable number of policy measures and instruments at EU level for the facilitation of the CE implementation, leading Greek companies fail to switch to any CE model (existent or new one). They just adapt or develop specific CE procedures and policies that better suit their existing business activities or are commonly recognized as environmentally necessary such as waste minimization and management (Trigkas et al., 2020).

3 Trends in Digitalisation

3.1 Digitalization and Animal production

Extensive Mediterranean dairy sheep production and livestock, specifically in France, Italy, Greece, and Spain (FIGS) holds global importance in agricultural economics. The Mediterranean and Black Sea regions are concentrated *ca*. 27% of the world milk yielding ewes, providing more than 40% of total sheep milk production. Almost half of it is concentrated in 4 south European countries – FIGS with over 15 million ha of land used for grazing (Odintsov Vaintrub et al., 2021). Therefore, potential solutions and precision livestock farming options should be taken into consideration.

Moreover, the new circumstances such as global warming, consumer awareness, global and local economics

as well as European Union policies are forcing the otherwise non-accepting farmers to adopt new technologies and precision livestock farming systems (Odintsov Vaintrub et al., 2021).

Countries constitute FIGS are known for their production, which includes modern characteristics, with breed selection programs, commercial processing, and Protected Designation of Origin (PDO) nominations for their traditional cheese products (e.g., Greek "Feta"). Farming systems include traditional extensive farms based on pasture as well as intensive systems that take advantage of modern technologies and precise nutrition management. Despite that, the current state of extensive sheep farming in FIGS countries does not encourage such acceptance in new technologies. The increasing age of the farmers and low profit ability margins discourage the investment in new technologies. However, emerging trends and new standards could lead to some changes in the sector including Precision livestock farming technologies (Odintsov Vaintrub et al., 2021).

3.2 Digitalization and Food industry

Greek food industry companies are lacking in Research & Development activities, and more precisely in Digitalization. However, the emergence of the COVID-19 pandemic increased the use of digital technologies and the digital transformation of Greek companies, making it a necessary condition for growth, and maintaining their competitiveness. The crisis has also created some new conditions in the business environment, such as the growing role of innovation in the production process and the way it is organized, and the strategic use of technology (Ragazou, 2021).

The existing knowledge of the Greek agri-food experts about precision agriculture is not disappointing but it is still lacking. The more informed ones seem to be working in food industry companies that already have implemented precision agriculture and in those that own large areas for production (Lakasas, 2022). Enhancing the digital skills of staff became a priority for most businesses, while the areas where the emphasis is on digital technology are related to the continuous improvement and development of new products, the strengthening of the supply chain and the implementation of ERP (Enterprise Resource Planning) and CRM (Customer Relationship Management) systems. At the same time, pioneering digital technologies, such as cybersecurity and cloud computing technologies, are becoming increasingly important to businesses (Ragazou, 2021). Greek food industry companies are willing to adopt new technologies and the research on precision agriculture has developed significantly (Lakasas, 2022).

3.3 Veterinary sector

Tele-veterinary services were introduced and developed due to COVID-19 pandemic crisis. It is a dominant trend of the time especially in the countries of North America and Central and Northern Europe. The veterinary telehealth market size is expected to increase by USD 147 million from 2021 to 2026, registering a CAGR of 17.03%, according to the latest research report from Technavio (2022). In fact, 35% of the market's growth will originate from North America during the forecast period. In cases such as post-operative monitoring, chronic diseases, dermatology, ophthalmology, and monitoring of elderly animals it is an important tool for direct observation of the animal. New technology is an ally in the practice of veterinary sector, it is simply a matter of updating knowledge and developing new skills (Makris, 2021).

4 Trends in business models

Greek financial crisis, during the last decade, forced many businesses to operate in a new environment and pushed them to become more flexible in order to maintain their business activities until the crisis is over. Entrepreneurs faced a new reality and were forced to find creative ways to maintain their business continuity. The traditional strategies were replaced with new ones allowing companies to evolve into "intelligent"

organizations, namely organizations that can harness human resources to achieve their goals and cope with the new needs that a crisis can create. Some of the new strategies are the internal mobility of employees, training, and appraisal performance (Ragazou, 2021). Especially for the veterinary sector, the development of cooperation among veterinarians to create large clinics where all services are provided is a necessity.

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• German trends analysis

1. Trends in Sustainable Production

1.1 General trend

A strong trend regarding sustainable production in Germany concerns Germany's responsibility on production beyond the country's borders. Legislative action was therefore taken very recently in this area. Companies in Germany earn money from what is produced in other parts of the world. They therefore bear responsibility for ensuring that human rights are respected along their supply chains. "We need a shift to a way of doing business and living that respects the natural limits of our planet," says German Labor Minister Hubertus Heil. The so-called Supply Chain Act was therefore passed in this context. Child labor, exploitation, discrimination, and lack of labor rights: In trade and production, fundamental human rights are repeatedly violated in global supply chains. The Act on Corporate Due Diligence in Supply Chains obliges German companies to better meet their global responsibilities. At the same time, the law will also reduce competitive disadvantages for companies that have already invested voluntarily in sustainable supply chain management. From 2023, it will initially apply to companies with at least 3,000 employees, and from 2024 also to companies with at least 1,000 employees in Germany. According to the new law, the companies' responsibility is to extend to the entire supply chain, graded according to the degree of influence. The obligations must be implemented by the companies in their own business area as well as vis-à-vis their direct suppliers. Indirect suppliers are included as soon as the company receives substantiated knowledge of human rights violations at this level. The law specifies the form in which companies fulfill their human rights due diligence obligations. This includes that they must analyze human rights risks, take preventive and remedial measures, set up grievance mechanisms and report on their activities.
Environmental protection is also covered in the law to the extent that environmental risks can lead to human rights violations. Thus, environmental degradation is targeted, such as illegal logging, pesticide emissions, water, and air pollution. It also establishes environmental obligations arising from two international agreements to protect against the health and environmental hazards of mercury and persistent organic pollutants (Bundesregierung 2023: Lieferkettengesetz).
More broadly, sustainable production is subsumed under the term sustainable development. The German government has taken several measures to reverse the undesirable developments of the past. These include 1) phasing out the use of nuclear energy, 2) taxing environmentally harmful products (eco-tax), 3) promoting renewable energies, 4) a new consumer protection and agricultural policy, and 5) a more environmentally compatible transport policy. Sustainable development means that our lives and economies develop within the limits of the capacity of the natural balance. The German parliament has established four basic rules for this (recommendations of the Enquete Commission of the 13th German Bundestag "Protection of Man and the Environment"): 1) The use of raw materials and energy (resources) may only be as high in the long term as these resources can be renewed or replaced by others (restoration of their regeneration or substitution rate). 2) The release of substances must not exceed the carrying capacity of the environment and nature in the long term (carrying capacity of the environmental media or their assimilation capacity). 3) Hazards and unacceptable risks to humans and the environment from environmental pollution shall be avoided. 4) The timing of man-made interventions in the environment shall be balanced with the time needed for the environment to recover (self-stabilizing response) (Umweltbundesamt 2002: Besser leben durch Umweltschutz).

1.2 Sustainability and Animal production

Livestock farming is the biggest polluter for GHG worldwide, even surpassing GHG from transportation and energy. While committing to reduce GHG, Germany is one of the biggest producers and consumers of cattle. In

livestock farming, land and water are essential resources. However, the demand for both have severely adverse effects on ecosystems. Therefore, an early-stage trend in Germany is the use of Aquaponics, specifically Hydroponics, to grow the cattle feedstock in specialized facilities with minimum soil use and a dramatic reduction of water. While this trend is still in a research phase and only suitable for small-scale farmers, another important trend is grazing management. It is a land-based livestock management approach whereby livestock can be used to reverse the desertification process very economically, with or without fencing; a range- or planted pasture management approach whereby both land and livestock can be produced with greater profitability than conventionally raised livestock; and a method of making conventional range management techniques economically sound there they were economically unprofitable (Rivero et Daim, 2007).

1.3 Sustainability and Food industry

One trend in sustainable food production, apart from vegan and vegetarian trends, is insect-based food in Germany. Although most Western cultures do not view insects as an appropriate food source, and negative attitudes predominate, there are an estimated two billion people who incorporate insects into their traditional diets, the majority of whom are found in Asia, South America, and Africa. The major findings indicate that Germans are not very ready to try insects, and that psychological and personality barriers to eating, like food neophobia and revulsion, are common. It has been demonstrated that the most promising way to apply entomophagy is to concentrate on processed insect products since the visibility of the insects is a crucial barrier to consumption. It remains however unclear, whether or not this tactic might lessen the rejection of any insect product (Orsi et al., 2019).

1.4 Sustainability and Veterinary sector

One identified trend is the Veterinarian Herd Health Management (VHHM) especially in German dairy farms albeit VHHM is an EU wide law since 2017. In Germany, dairy farming is extremely important economically. Germany produced almost 33 million tons of milk in 2020, making it the top producer in the EU. A production value of about 10 billion euros was exported, or around half of the total amount produced. In addition to ensuring food safety and animal welfare for the future of German dairy farming, an all-encompassing strategy is required to balance the excessive expectations placed on dairy cows with the diseases linked to their production. This is important to satisfy consumer demands as well. Consequently, the establishment of Veterinary Herd Health Management (VHHM) programs has been largely attributed to the importance that prophylaxis rather than therapy plays in on-farm illness prevention and health management (Ries et al., 2022).

2. Trends in Digitalization

2.1 General trend

Undeniably, the Corona pandemic has created an exceptional situation in society and for the economy. For Germany, however, this can also represent an opportunity to catch up on the glaring backlog in terms of digitization at all levels of government, such as public authorities and schools, but also industrial companies. It has helped digitization in Germany advance since both individuals and businesses have mastered digital communication. Companies are now required to both plan and implement their usage of digital technologies. To ensure their capacity to operate and stay competitive, many businesses have made investments in digital technologies. Information and communications technology, vehicle manufacturing, electrical engineering, and mechanical engineering, as well as business-related service providers such as business consultancies, are well digitized sectors in Germany. The chemical and pharmaceutical industries are only averagely digitized. Bringing up the rear are trade, other manufacturing, transport and logistics, and other manufacturing, which includes

energy and water supply, wastewater and waste disposal, and construction (Stich et al., 2022). According to KfW Research's company study from 2020, numerous businesses have developed new products in response to the corona epidemic. advances in business models and products were also important, followed by advances in cost-cutting processes. The KfW poll found that the service sector, which also includes tourism, innovates the most. The digitization of processes in the tourism industry has made tremendous strides. The least number of developments linked to the Corona are found in the construction sector. This is also reflected in the sector's very modest increases in process digitalization as measured by the digitalization Index. Therefore, businesses that are particularly active in terms of innovation also see advancements in the digitization of processes (KfW, 2021).

An important trend, albeit a currently negative one, in Germany is the lack of human capital in the area of digitization. Concern should be expressed over the reductions in the qualification category and the partly modest rises in the human capital category. The ability of the German economy to act, develop, and compete is a requirement for digital sovereignty and, by extension, competence sovereignty. Therefore, a crucial priority for advancing the digitization of the German economy in a sustainable manner is strengthening digital skills in society. It's not just about having the right talents for the job market; it's also about having the right skills for taking part in digitization on a personal level (Stich et al., 2022).

Another clear trend is emerging in education and universities toward significantly more digitization. Digital education methods demand a commitment to lifelong learning. Both teachers and students need to be adaptable while using online educational resources. This calls for a less hierarchical, more inclusive, and, in the best sense, more experimental approach to education. University didactic training is crucial in general but especially important for online teaching. All universities must require teaching credentials as a supporting component of academic careers. The adoption of digital teaching methods can improve the quality of instruction. It is best to use individualization and flexibility options, particularly in lectures. The following holds true for the foreseeable future: For those events that no longer support true communication at the university, virtual lectures should be made available. Large lectures in front of a great number of students have nothing to do with the culture of interaction that is rightfully regarded as a unique characteristic of the academic institution. The best model for effective university teaching is blended learning. Direct attendance is essential for a course of study's success, hence digital courses should be made available as a supplement, but not exclusively. A decent balance of in-person and online components is ideal for most lectures and exercises. A model of the economy is not digital education. Politicians occasionally hold the incorrect belief that using digital technology in the classroom can save expenditures. The contrary would be true: The new teaching university needs greater funds for more lecturers due to its mix of attendance and absence rates, digital and analog courses. Anyone who wishes to permanently integrate innovations into the educational system frequently requires more financing. This is so because innovations in education are different from those in industry in that they frequently raise expenses rather than lowering them. This should be known by everyone who advocates for increased digital learning at our universities (Deimann, 2021).

2.2 Digitalization and Animal production

Another overarching trend is digitalization. The digitization of production processes supports the farmer in coping with various tasks and challenges. In animal husbandry, for example, individual animal observation is mandatory in Germany under the Animal Welfare Act. Using new techniques for animal localization, it is possible to digitally document individual animal behavior patterns and draw conclusions about oestrus or health status. The use of passive, battery-free transponders does not require an electrical source on the animal, which also has positive effects in terms of sustainability (Landauer et Baranowsky, 2022). Another trend in digitization is the three-dimensional measurement of animals. This makes it possible to perform objective measurements of body condition and the description of fat mobilization dynamics of dairy cows, for example, to the movement pattern

and body proportions automatically and without stress for animals and humans. Deviations from normal condition are detected by the system and displayed to the user. This procedure offers the animal owner new possibilities for health control (Sanchez et al., 2019).

2.3 Digitalization and Food industry

Small and medium-sized enterprises (SMEs) face special challenges in the course of digitalization. German SMEs are undergoing a digital transition, but they are still less digitized than large businesses and tend to be average digitalized when compared to SMEs in other European countries. Choosing among the burgeoning digital technologies and apps that are appropriate for their company environment and unique difficulties pose a challenge for SMEs. The following topics and technologies are expected to be highly relevant for SMEs in the future: Augmented and virtual reality, remote maintenance, chatbots and digital twins. Other possible significant technologies, which could have a somewhat lower relevance for SMEs from the experts' point of view, are: Blockchain/DLT, drones, laser scanning and robotic process automation. Further superordinate topics comprise artificial intelligence (e.g., image recognition, process mining, speech recognition), data collection and analysis, networking, and sustainability- (Papen et al., 2022).

2.4 Digitalization and Veterinary sector

What began as an emergency solution during the Corona pandemic quickly developed into a trend in veterinary medicine: telemedicine. As such, it is also part of the digital transformation currently taking place. Pet owners see clear advantages in a telemedicine consultation. One of the most common reasons for inquiries from new patients is to clarify the need for a veterinary visit, especially in a suspected or actual emergency. In addition, the usually unloved transport of the animals to the veterinary practice, with the associated stress factors, is initially eliminated. The consultation can take place comfortably from home. In addition to any findings already available, photos and videos stored on the smartphone can be transmitted, even in real time. Access to veterinary advice is fast and uncomplicated, regardless of where you live. Thus, telemedicine is one of the low-threshold and therefore very attractive offers for pet owners. It should not be overlooked that a "one click" mentality prevails today, so people are used to getting an answer/solution with one click and at any time. Additionally, most people use messenger apps for communication on a daily basis. For contact with a veterinary practice or clinic, pet owners have mostly had to rely on traditional media such as phone and email. However, many pet owners clearly prefer the much easier and direct communication via messenger apps or dashboards (Leopold-Temmler in Knopf, 2022).

3. Trends in One-Health

3.1 One-Health and Animal production

A significant trend under the One Health aspect in Germany concerns antibiotic resistance. Currently, there is a prioritization of human health over that of animals and thus the focus of research is often on the transmission pathway from animals to humans. However, under the One Health approach, the transmission pathway from humans to animals as well as the greater environment is also being investigated, which is of great relevance especially against the background of antibiotic resistance. One of the most important aspects in the emergence and spread of antibiotic resistance is their use in animals and humans. Throughout Germany, responsible use of antibiotics has been required by veterinary medicine through guidelines since the year 2000. In addition, there is the German Antibiotic Resistance Strategy (DART 2020), which also aims to reduce antibiotics in animal husbandry. The mutual transmission between pets and humans is obvious, although it has not been widely discussed in the public. Pets often live in close contact with humans and carry similar, more or less pathogenic bacteria that were most likely originally introduced by humans (Tenhagen at al., 2018).

The COVID-19 pandemic also impressively demonstrated the interaction between humans, animals, and the environment by transmitting viral zoonoses to us humans. This is closely related to our impact on the environment. Human populations are growing and increasingly encroaching on pristine areas, and in the process, climate change, land use change, and habitat modification, among other factors, are creating new opportunities for humans and animals to spread pathogens. In addition, people, animals, and food, including animal products, are on the move internationally more than ever before due to travel and trade. Communicating this holistic understanding to a broad population is another important trend of One Health in Germany (Fiack et al., 2023).

3.2 One-Health and Food industry

A final important trend for Germany is the prioritization of the One Health approach in development work and form the focus of technical strategic advice. In this context, food, and agriculture as well as land use issues are of particular importance. The aim is to reduce health risks for humans and animals in the long term to prevent epidemics and pandemics or to be able to detect and contain them at an early stage (GIZ, 2022).

3.3 One-Health and Veterinary sector

One trend is the need for a much stronger collaboration between all relevant stakeholders under One Health. In order to better understand diseases that affect both humans and animals, the One Health approach gives veterinarians the chance to work closely with physicians, public health officials, wildlife experts, and environmental health professionals. Medical professionals typically prioritize their personal health demands over those of other animals. Professionals in medicine are adept at specializing, which provides advantages but also limits their practice. They are now concentrating on issues that were previously disregarded, especially those related to food cleanliness, zoonoses, and veterinary public health. Public health schools could potentially serve as the hub for better coordinated efforts to enhance a community's public health conditions. There should be more coursework on zoonotic illnesses and zoonoses in medical schools. Indeed, it would be beneficial for these two professions to share coursework and real-world experiences, and this might be accomplished by using a comparative medicine approach (Pal et al., 2014).

Another trend is how the concept of One Health may evolve and what it all entails. International organizations, clinical settings, health and livestock/agriculture ministries, and academic curriculum are all beginning to take integrative thinking more seriously. There are still issues, mostly centered on important queries such how "one health" develops and what constitutes a contemporary theory of health. The idea of "human-environmental systems," also known as "social-ecological systems," is related to the intimate relationship that exists between humans and animals in their social and ecological contexts. Unexpected outcomes are demonstrated by effective systems approaches to public health. Comparable to "systems biology," which primarily focuses on the interactions between molecules and proteins at the subcellular level, a systemic approach to health in social-ecological systems (HSES) is an interdisciplinary and transdisciplinary investigation of intricate relationships across all domains connected to health. By anticipating the identification of novel attributes and health determinants that might emerge from a systemic perspective spanning across scales from molecules to the ecological and socio-cultural context, as well as from comparison with various disease endemicities and health systems structures, HSES goes beyond the concepts of "one health" and "eco-health (Zinsstag et al., 2011)".

4. Trends in Business Models

4.1 Business models and Animal production

An overview of the German animal production gives the following excerpt from the Thünen Institute: “In 2021, commercial meat production in Germany was a good 8.2 million tons, including offal and slaughter and by-

products. Of this, the largest share was accounted for by pig slaughtering (around 4.97 million tons), followed by poultry and cattle slaughtering. Pork production has declined for the sixth consecutive year, amounting to 146,000 tons less in 2021 than in 2020, and there is a further decline in 2022. Beef production in Germany is dominated by young bulls, cows and heifers leaving dairy or suckler cow farming. Other female cattle, steers and calves, on the other hand, account for a smaller share of beef production. For poultry slaughter, young broilers (broilers) and turkeys account for the majority of commercial slaughter. Compared to the previous year, production increased by 1.4 percent. This increase came entirely from broiler production, as turkey and other poultry production fell slightly. The production of sheep and lamb continues to play a minor role in Germany, accounting for less than 0.5 percent of the slaughter volume" (Deblitz, 2022).

The current intensive form of livestock farming is gaining in importance worldwide. However, it is confronted with growing social criticism and rejection. In northwestern European countries, there are pronounced social discussions about animal welfare and environmental protection in farm animal husbandry. Society's interest in farm animal husbandry, issues of nutrition and health, and animal welfare are long-term trends. A fundamental reorientation of the industry must follow this trend. In view of the strong structural change, the concentration-promoting effect of additional animal welfare requirements and the considerable economies of scale, there is no easy way back to small-scale agriculture. However, since the public's attitude toward large farms is in part very negative, it is precisely the larger farms and large companies in the meat industry that face the challenge of regaining trust in society. In addition to the associations, it is also these companies that have resources to expand communication. It is important to emphasize that communication alone will not be enough to win back trust and acceptance; credible changes in farm animal husbandry must also take place (Spiller et al., 2016).

4.2 Business models and Food Industry

An interesting trend has clearly emerged in the fish and seafood sector during the Corona crisis: namely, the willingness to pay higher prices for fresh products in this sector is lasting. With the availability of statistical data for the year 2020, it was possible to evaluate the changes in the German fish market (including seafood) in terms of consumer behavior and the impact on the national aquaculture sector. Because of the various restrictions, out-of-home consumption decreased significantly in 2020. This decrease was more than offset by an increase in private household purchases of farmed and wild-caught fish and seafood. As a result, sales in the 2020 exception year exceeded previous years in both quantity and value. From these data, it can be concluded that the associated supply chains and structures remained largely intact during the pandemic. While the sale of permanent preserves is likely the result of a short-term effect, the crisis has the potential to further strengthen the pre-corona trend towards high-priced, fresh products. Compared to the global aquaculture industry, the sector in Germany, as a niche market, was not able to benefit from this increased demand in the short term, but no general sales difficulties occurred. In the future, local producers could benefit from the changes in consumer behavior by increasing added value, direct sales or by expanding gastronomic offerings (Schäfer et al., 2021).

Socially, however, a negative trend can also be seen in Germany regarding the food industry. Many people distrust the food industry, accuse it of manipulation and ascribe responsibility for civilization diseases such as obesity and diabetes. In the meantime, this attitude towards "the food industry" has become common sense, especially among the socially better off, who mainly buy in organic stores and refuse sweets for their children. It is assumed that their social living situation is defined, among other things, by the discourse about the "evil" food industry and thus underlines their social distinction from the socially worse off, who are predominantly happy to be able to consume former luxury goods such as chocolate or meat despite their low income and can thus also participate in social prosperity (Endres et Klotter, 2019).

As a trend due to crises such as Corona, supply security can also be defined by the food industry. It is classified as critical infrastructure and poses risks due to its perishable products. To make matters worse, the value chain for

food products has long spanned many countries and continents, making it part of a complex global market. In this global market, companies in the food industry face growing demands from end consumers, such as sustainability. In addition, the digitalization of the economy and society acts as a catalyst that further intensifies the challenges. Increasing digital networking is creating new dependencies, for example on platform providers, and in the process is generating new expectations among end consumers, for example regarding digital services relating to food shopping. The threat of competition is no longer limited to our own industry. Online retailer Amazon, for example, is trying out a disruptive business model with its fully automated and digitized supermarket chain Amazon Go. However, companies also see digitization as an opportunity to meet the challenges with digital innovations. For example, the development and use of a novel, value-added product, service, process or business model through the integration and use of digital technologies. While retailers are trying to respond to the cross-industry threat through new digital services and business models, other players in the food industry are also looking to harness the potential of digital innovation. In this context, the industry's value chain encompasses all activities necessary to produce a food product from agriculturally sourced raw products and to distribute and deliver it via wholesale and retail outlets. For example, digital technologies have already been used for many years in food production to incrementally improve and radically redesign internal processes and workflows, for example to enable shorter lead times (Buck et al., 2023).

4.3 Business models and Veterinary Sector

One business trend concerns precision livestock farming which is intertwined with veterinary medicine. A concentration of dairy cattle farming can be observed in Germany: Since 2000, out of 142,000 farms, just under 85,000 have given up dairy farming, with the average cow herd doubling from just under 33 to 68 cows. At the same time, the total number of dairy cows in Germany fell from 4.6 to 3.9 million. Here, the share of pasture farming continues to decline and is concentrated on smaller farms. In the meantime, the image of dairy farming is not only positive: issues such as disease incidence, useful life, animal husbandry or separation of cow and calf move people and make them view dairy farming critically. There is a trend to switch to milk substitutes: Sales of plant-based milk imitations increased from 315 to 535 million euros in Germany within two years (2018 - 2020), and worldwide sales of 34.6 billion U.S. dollars are expected in 2029. In addition, animal husbandry, especially dairy farming, is mentioned as a source of greenhouse gases: Dairy farms emit greenhouse gases such as methane and nitrous oxide, and the share of dairy farming in total anthropogenic greenhouse gas emissions is estimated at about 4% in this context. Finally, the trend towards digitalization in dairy farming is unmistakable. The application of technologies collectively referred to as "precision livestock farming" goes beyond electronic herd management or automatic heat detection and will eventually lead to autonomous decision-making systems. Four parameters can therefore be defined for the dairy barn of the future, which must be met: structure, animal welfare, emissions and precision livestock farming (Kleen, 2022).

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• Portuguese trends analysis

1. Introduction into the sector structure

1.1 Animal Production

Portuguese bovine livestock, in the last 20 years, the average size of the herd per holding has more than tripled. The average number of bovines per holding has been increasing since 1999, reaching 43.8 head in 2019 (15.2 head more than in 2009 and three times more than in 1999). In 2019, 12.4 per cent of the registered holdings (around 36,000 holdings) had bovines (in 2009 there were around 50,000 holdings), totalling more than 1.5 million head of bovines, an increase of 10.6 per cent compared to 2009. The dairy bovine herd, which totalled 245,500 head, fell by 33,000 head over the last 10 years (-11.8%), 14% of farms with bovines (7 p.p. less than in 2009), and representing 15.5% of the total herd (4 p.p. less than in 2009) of the total herd (4 p.p. less than in 2009) (INE, 2021).

Average size of pig herd per holding more than doubled in ten years. In 2019, there were 2,214,000 head of pigs, which is an increase of 15.7% on the number recorded in 2009 (1,913,000 head). This result reverses the trend seen over the past decade and become closer to the number of pigs registered in 2009. This development was accompanied by a sharp increase in their average size per holding. This indicator more than doubled compared to 2009, both for the total herd and for the breeding herd, rising to 78 head for the total herd (38.2 head in 2009) and 37.8 head for breeding stock (17.7 head in 2009). The increase in the average size of the herd on the farm has further reinforced the concentration of the sector, in which a small number of pig farms own a large part of the herd. The figures for 2019 indicate that the overwhelming majority of the pig herd (87.4%, compared to 79.7% in 2009) is concentrated on holdings with 1,000 or more pigs, which represent 1.1% of holdings with pigs (0.6% in 2009) (INE, 2021).

Sheep heard remains unchanged, but average flock size increasing from 43 to 51 heads/farm. Dairy sheep have lost almost 1/3 of their numbers (32.9%) in the last ten years. In 2019 it represents 11.3% of the sheep population (16.6% in 2009) and is present on 8.2% of farms (15.4% in 2009). The average size of flocks has increased by almost 20% since 2009, from 42.9 to 51.1 head per holding. This trend was even more evident in dairy sheep, with the average size per farm increasing by 42.9%, from 46.1 to 70.2 head. There were an increase in the number of large farms with more than 500 head of cattle (+13.8%), which now account for 32.7% of the total herd (28.2% in 2009). Alongside this concentration, small producers with flocks of less than 10 sheep, whose numbers fell by 19.4% (INE, 2021).

Goat herd: decreased by 11.5%, but large herds, with more than 500 goats, increased in number (+27.6%) and in herd size (+34.4%). The goat population recorded in 2019 decreased by 11.5% and totals 372.3 thousand head (420.7 thousand head in 2009) on 22.9 thousand farms (32.5 thousand farms in 2009). The number of dairy goats fell more sharply (-26.7%), and accounted for 29.4% of the goat population (in 2009 the contribution was 35.5%), spread over 4,700 farms (11,900 in 2009). The analysis by size class shows that the decrease in both total and dairy goat numbers occurred above all on small farms (less than 10 goats), while at the same time these producers abandoned the activity (56.1% for the total herd and 46.7% for the dairy herd). It should be noted that large herds, with more than 500 goats, increased in number (+27.6%) and numbers (+34.4%). The majority of the herd is being kept in flocks between 100 and 499 head (37.6% for the total herd and 52.6% for the dairy herd), a size class that has grown in importance compared to 2009 (INE, 2021).

1.2 Food Industry

The food industry in Portugal, had a turnover in 2021 of 18131 million of € (INE data cited by FIPA), which

represents an increase of 9,61 % compared to 2020 (2020 was strongly affected by the pandemic) and 3.25% compared to 2019. In 2021 there were 11156 companies in this sector with 109519 employees, comparing with 10850 companies and 108827 employees in 2020 and 11589 companies and 118830 employees in 2019.

Despite the recovery and increase in turnover in the sector in 2021, the number of companies decreased in 2020 (pandemic) compared to 2019 and has not yet recovered in 2021, so the trend will be an increase in turnover per company and employee in 2021 compared with 2020 and 2019.

1.3 Veterinary Sector

Data obtained by the European Federation of Veterinary Surgeons (FVE) on the evolution of the number of active veterinary surgeons per 100,000 inhabitants shows that there was a large increase in Portugal between 2011 (22), 2015 (48) and 2018 (59). This growth was higher than the European average (36 and 44 in 2015 and 2018). The FVE study also shows that in 2018, Portugal is the European country with the highest percentage of veterinarians under the age of 40, at 61 per cent, compared to the European average of 41 per cent. During the period in question, there was also an increase in the percentage of female veterinarians, from 62 per cent in 2015 to almost 65 per cent in 2018, which is above the European average of 58 per cent. These figures are in line with the results of the OMV (Ordem dos Médicos Veterinários) database analysis carried out to characterise the current profession. The OMV-CIES study also analysed the 7 veterinary courses active in Portugal at the time of data collection, highlighting that only one of these courses is accredited and another is approved for accreditation by the European Association of Establishments for Veterinary Education (EAEVE). Currently, of the 7 courses, two are accredited and two are approved (EAEVE, 2023). According to the most recent data provided by the OMV (Ordem dos Médicos Veterinários), there are 6,745 veterinarians with active registration in Portugal, of whom 4,394 are female and 2,351 male.

2. Trends in sustainable production

2.1 Sustainability and Animal production

In the point 1.sector structure in the Animal production, we could see a common trend for all the sub-sectors of animal production that is the size of the farms are increasing, even if the total heard is stable or decreasing, but with an increasing production.

The Portuguese Strategic plan for CAP consider the sustainability in some of the specific objectives:

- Specific Objective 4 - Climate Change and Sustainable Energy
- Specific Objective 5 - Efficient Management of Resources
- Specific Objective 6 – Biodiversity and Landscape

In the Portuguese focus group for Animal production, had been identified as need of skills in the area of the sustainability the following:

- Feed efficiency
- Sustainable Agricultural Systems
- Waste and by-product use
- Improved animal welfare
- Characterization and management of production process flows
- Water management in livestock activity
- Rational management of natural resources

Another trend is the use of biopesticides (e.g., microbial organisms, plant-derived substances or nanoparticles of biological or mineral origin), which have a less persistent environmental impact than conventional chemical pesticides

2.2 Sustainability and Food industry

The Farm to Fork Strategy is at the heart of the European Green Deal aiming to make food systems fair, healthy and environmentally-friendly. The Farm to Fork Strategy aims to accelerate our transition to a sustainable food system that should:

- have a neutral or a positive environmental impact
- help to mitigate climate change and adapt to its impacts
- reverse the loss of biodiversity
- ensure food security, nutrition and public health, making sure that everyone has access to sufficient, safe, nutritious, sustainable food
- preserve affordability of food while generating fairer economic returns, fostering competitiveness of the EU supply sector and promoting fair trade

FIPA, the Portuguese organization of the food industry, identifies as a global vision for environmental sustainability, promoting the circular and green economy as a driver of competitiveness for the agri-food industry. In practice, they identify the following as sustainable practices:

- Energy efficiency and resource management
- Taxation and green regulation
- Deposit and refund system
- Recycling and reuse

In the Portuguese focus group for food industry, we consider the most relevant items that had been identified as need of skills in the area of the sustainability, the following:

- valorisation of industry by-products
- Processing water reuse
- Energy reuse
- Water quality for industrial use
- Efficiency Quantification Method (water, energy, GHG..)
- Compressed air (losses, dimensioning, etc...)

2.3 Veterinary sector

There is an increased interest in Non-Conventional Therapies (NCTs), often referred to as complementary and alternative medicines, in veterinary clinical practice.

3. Trends in digitalization

3.1 General trends

The digitalization strategy developed in the context of the Strategic Plan for CAP has 5 specific objectives:

- Promote technology transfer – advice, outreach, knowledge sharing
- Improve digital skills
- Connectivity
- Improve the context for digitalization
- Turn data into decision support decisions

3.2 Animal production

From the discussion held in the focus group, we could identify as major trends in the digitalization related with animal production:

- Data systems in Livestock systems (including the use of sensors and data analysis to monitor animal health)
- Traceability from producer to consumer
- ICT
- Remote sensing in animal production
- Smart farming practices and Precision Livestock Farming systems

In the Strategic plan for animal production Ribeiro (2019) identifies as main trends: sensors, big data and IOT.

3.3 Food industry

From the discussion held in the focus group, we could identify as major trends in the digitalization related with related with food industry:

- Intelligent transport (cold chain monitoring)
- Blockchain technology
- Mobile networks
- Digital forms
- Big Data management
- Artificial intelligence for decision making
- Automation in industry

3.4 Veterinary Sector

One main trend is the Veterinary Electronic Prescription (PEMV). Is a platform to be used by veterinarians, with the aim of issuing the prescription of medicines for animals to which they provide assistance, including the Prescription of Medicated Food for Animals. In the focus group for veterinarians, the main trends that arise from the debate where:

- Big Data
- GIS systems for animal control
- Electronic prescription
- Telemedicine

Use of augmented reality and virtual reality in veterinary medicine to improve the quality of public health and animal welfare (e.g., performing remote post-mortem meat inspections through live video-streams, or organizing digital farm tours which improve transparency in animal husbandry).

4 Trends for One-Health

4.1 One-Health and Animal production

The main trend for One-Health had been discussed in the focus groups, and some of the issues are related with the CAP strategic plan.

- The PAC strategic plan provided incentives to reduce the use of antibiotics in livestock production (from the Portuguese Strategic Plan for CAP). The issue of antimicrobial resistance is an important issue in Portugal (and in Europe), because has a strong relation with human health.
- Policy and legislation related to "one health"
- Principles of epidemiology and surveillance
- Antimicrobial resistance
- Animal health and welfare (Increasing societal pressure on animal welfare)
- Reductions of antimicrobial use

4.2 One-Health and Food industry

- Food fraud
- Food defense
- Food safety and Food security
- Nutraceuticals and health claims
- Food myths (food fads)
- System thinking and system understanding
- Management and Innovation in the use of food ingredients

4.3 One-Health and Veterinary Sector

- Antimicrobial and anti-parasitic resistance (Reductions of antimicrobial use)
- Principles of epidemiology and surveillance
- Emerging infectious diseases
- Risk management, (including crisis and risk communication)
- Knowledge of animal behaviour / Management
- Policy and legislation related to "one health"
- New treatment approaches
- Increasing societal pressure on animal welfare

5 Trends for business models

5.1 Business models and Animal production

- In the point 1. Sector structure, in the Animal production, we could see a common trend for all the sub-sectors of animal production that the size of the farms are increasing.
- There is a significant increase in the total livestock production value in the last years.
- The industry has been pressuring production to have animal welfare certifications, and the PAC strategic plan also includes measures to benefit producers who have them. The CAP strategic plan foresees support measures for cattle producers who have food efficiency measures to reduce greenhouse emissions (from the Portuguese Strategic Plan for CAP)

5.2 Business models and Food industry

- FIPA is considered an important trend for agro-food, the Dialogue and balance in the chain of agro-food value
- During the discussion on the focus groups had been identified as very important the Product and process development in Agro Industry: creativity, design thinking, critical thinking

5.3 Business models and Veterinary Sector

- In the focus group, the most important issues identified, on the business models were related with communication (with the public, customers, social media).

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• Italian trends analysis

1. Introduction

The European animal health industry is betting on digital to improve treatments and strengthen prevention. A transition that involves both the world of pets and livestock and constantly looks to the One Health approach, which inspires efforts to improve the environmental and economic sustainability of farms.

Digitalisation is influencing the animal health sector to a great extent. "Intelligent" diagnostic and monitoring tools, together with predictive or prescriptive data analysis, proactively support the choice of actions to be taken on farms and by veterinarians. Animal healthcare is currently moving into an era of “medical intelligence,” which is shifting the industry's focus from simply preventing or treating disease to effectively managing health. Digitalization is helping to increase and accelerate our knowledge of risk factors. Monitoring tools and simplification or automation of data management enable a holistic multi-actor approach to animal health.

The animal health industry has been investing in digital for some years, placing itself at the forefront of a technological and digital transformation. Breakthroughs in digital sensing tools and robotics, the use of big data, as well as genomic testing, biotechnology and advanced vaccines are now set to become essential tools for the future of both livestock farming and the veterinary profession.

In the digital space, one offering that has become more common during recent pandemic events is telemedicine. Remote appointments between vets and owners of both domestic and farm animals mean that vets are now able to diagnose illnesses and prescribe medications based on a virtual check-up. More comprehensive integrated pet health platforms are also on the rise, connecting pet owners not only to their veterinary clinic, but also to service providers such as groomers or kennels.

As already seen in the world of human health, digital has brought real-time monitoring tools for patients. The same thing is also emerging for pets or farm animals.

In fact, there are several innovative tools for owners or breeders, such as wearable devices and apps for identification and monitoring. This helps monitor the animal's behavior and assess its fitness level.

The agri-food sector in general and the livestock sector in particular are moving into an era of digitally enhanced agriculture. The valuable data generated during the various phases of animal husbandry is offering a series of changes:

- optimize animal health and welfare;
- increase the efficiency and productivity of farm management;
- reduce environmental impacts, to ensure better traceability;
- improve food safety;
- reduce the use of unnecessary interventions.

Essentially, traditional breeding strategies used by farmers, such as visual inspections, are getting a digital makeover. Technology provides a way to achieve the same goal through “smart” solutions, allowing farmers to improve their operations in terms of health and well-being.

These new capabilities give farmers better control over the “management” of animal health. The use of tools such as sound diagnostics, monitoring sensors or digital body composition analysis supports the agricultural sector's efforts to ensure responsible use of antibiotics and combat antibiotic resistance. By optimizing animal health management, these tools help farmers practice more targeted use of therapies such as antibiotic treatment. For example, on pig farms.

Noise pollution from piggeries makes it difficult for farmers to detect specific sounds that indicate health problems, such as coughing. With robust diagnostics, farmers and their veterinarians can detect problems up to two weeks earlier than conventional methods, helping to spot signs of respiratory disease early and reducing the

number of animals requiring antibiotic treatment.
With the rapid increase in global population and the increasingly crowded nature of our planet, where humans and animals live in ever closer proximity, the ability of infections to pass more frequently between species has increased. Preventive animal drugs and the widespread use and development of vaccines play an increasingly important role in preventing and controlling disease outbreaks, which can have devastating impacts on a country's economy.
region and the health of local ecosystems. Closer monitoring and surveillance of diseases at the interface between humans, animals and the surrounding environment is essential for the future control of emerging infectious diseases.
“Greater One Health” cooperation is needed to control emerging infectious diseases. This requires policies that support actions such as:

- Build effective collaboration between the human and animal health sectors;
- Improve surveillance for early detection of disease threats in humans;
- Strengthening laboratory diagnostic capabilities for new pathogens;
- Improve disease case management and infection control;
- Develop epidemic preparedness and response capabilities for emerging zoonoses.

In this report, research for the identification of the Italian trends in the sectors of **Animal Production**, **Food Industry** and **Veterinary Activities** will be held. The domains of the trends in the above sectors are:

a) Sustainable production
b) Digitalization
c) One-health
d) Business models

2. Trends in sustainable production

To ensure a resource-efficient food supply chain that integrates environmentally friendly technologies and consumer preferences, it is crucial to adopt advanced manufacturing practices, minimize waste, and enhance the utilization of raw materials. This should be achieved without compromising product quality, consumer trust, and safety standards. Additionally, there is a need to make such technologies and equipment accessible and affordable for small and medium-sized enterprises (SMEs).

The focus should be on creating nutritious and enjoyable food products that cater to dietary needs and promote consumer well-being. This requires an understanding of the interplay between diet, health, and consumer preferences, along with the development of healthier product alternatives and better nutritional information for consumers.

The transfer of advanced knowledge and skills within the food industry is vital. This includes the adoption of sustainable business models and systems that convert research findings into practical solutions for SMEs. Emphasis should be placed on efficient resource management, the implementation of advanced process control, and the preservation of nutritional value throughout the supply chain.

Prioritizing the human aspect of food production involves integrating low-cost, high-quality technologies, addressing consumer responses to price fluctuations, and enhancing the nutritional value of processed foods. Additionally, there should be a focus on sustainable transportation and logistics, the preservation of traditional food varieties, and the overall impact of food ingredients and consumption on human well-being.

2.1 Sustainability and Animal production

According to the VET provider of Confagicoltura, ENAPRA, farmers and entreprenuers in this sector are looking for ways to increase the following competences in animal production, regarding the theme of "Sustainability":

Precision agriculture tools in livestock facilities, Reduction of GHG emissions, Agenda 2030 and the sustainable development goals; Sustainability as an opportunity for growth; Integration and classification of economic, social and environmental growth objectives; Precision animal husbandry: new stimuli for competitiveness.Preservation and conservation of livestock biodiversity and genetic heritage to promote a close link between animal and territory.
Enhancement of closed-cycle farming and feed production according to the principles of the REG. EU 848/2018 on organic agriculture to guarantee the absence or drastic reduction of the use of chemical products. Propensity towards extensive forms of farming, outdoors or, if intensive, with a considerable reduction in stocking density compared to the minimum legal limits.

Recovery and valorisation of animal waste and all outputs for the production of fertilizers and renewable energy (biogas). Respect for animal welfare principles to guarantee animals optimal housing, feeding and handling conditions, which are essential for the animal's state of health and the quality of the product. Social responsibility to guarantee minimum rights to all operators.

2.2 Sustainability and Food industry

Food industry main goal, regarding sustainability, is the development and the implementation of an increasingly more efficient circular production methodology. This means a combination of more efficient machinery, less impactful packaging materials, substantial reduction of energy and water consuption, reduction – when possible – or reuse of production waste in a "circular economy" model. A more in depht analysis follows.

The food industry must consume resources within the limit proportionate to the ability of these resources to regenerate. The waste produced must not exceed the quantities that the industry can recycle or dispose of in a sustainable way. The preservation of biodiversity and the limited use of fossil fuels are also fundamental. From the point of view of the food industry, sustainable production must take into account three main aspects.

Environmental component: considering the environmental impacts of production, the depletion of resources, damage to biodiversity and so on.

Economic component: taking into account factors linked to business development such as the cost of production and food supply but also profitability and contribution to the local economy.

Social component: addressing issues related to food safety, food quality and consumer health, including consumer satisfaction but also animal welfare and the working environment of organizations operating in the food sector.

The main strategic lines of intervention on the topic of sustainability are:

the efficient use of basic inputs (primarily water and energy) through the efficiency and optimization of processes; the full exploitation of agricultural raw materials in all their components intended for human nutrition, feed and

other utility chains; the prevention of packaging waste, their eco-design, the correct management of the end-of-life of packaging; the prevention of food waste and the management of surpluses.

To understand the energy consumption of a system and intervene with an optimization perspective, the first starting point is to functionalize the data collection and analysis procedures. The problem is that in older factories, production lines still rely on electricity company meters, so it is often impossible to determine the energy consumption of individual lines and each process. This is why it is important to sensitize energy management, introducing smart metering systems at critical points, enabling dedicated data recording and processing methodologies. Most modern, connected and communicating energy meters send data to a logger (recorder) for analysis and reporting purposes. Data from probes and sensors can also be put into a system: the most advanced digital recording devices integrate mathematical functions capable of processing the information to provide the responsible technicians with indications aimed at achieving energy saving targets, reporting the situation to management. The energy consumed in a batch, for example, can be recorded and compared with monthly deadlines.

In the food industry, the equipment used in production lines is subjected to strong stress, especially in continuous processes. Thermocouples, motors and compressors can wear out over time which leads to a loss of their performance capabilities or even an interruption of operational continuity due to malfunctions and failures. For this reason, it is essential to introduce predictive maintenance, based on the use of sensors and programmed data to monitor and analyze usage dynamics over time according to certain KPIs. To this end, OEE (Overall Equipment Effectiveness) and TEEP (Total Effective Equipment Performance) are important key indicators, which help quantify the performance of an equipment or production line in terms of maximum capacity for the planned operating time. The automatic processing of various metrics (load, availability, performance, quality and so on) allow you to identify efficiency problems such as, for example, downtime linked to unplanned maintenance operations or product quality problems.

2.3 Sustainability and Veterinary activities

Recent studies have shown that perceptions of the sensitivity and suffering of farmed animals vary greatly depending on culture, country, sex and age. Most European countries today boast, in their legislation, laws against the cruelty or mistreatment of animals, and in some there has been a move towards regulation of their conditions of existence, creating duties on man in their comparisons.
Expanding the guarantees and protection for animals would also translate into raising the essential levels of health services offered to protect their health. This benefits human and environmental health.
However, the complete overcoming of anthropocentrism, which prevents us from attributing and recognizing explicit forms of juridical and legal "right" to other living beings, does not yet seem conceivable.
As we strive to develop agricultural production systems that can feed the world, we must preserve the environment and use natural resources wisely. In these circumstances, production and consumption patterns of products of animal origin must also achieve higher standards of animal welfare and aim to protect animals, environmental sustainability and health. Environmental sustainability is now a need linked to any type of company and production existing in our territory, particularly in the production chain of foods of animal origin.
The same interest is held by the issue of the protection of animal welfare, considered an essential factor in any good breeding practice and which has become, over the years, the object of attention by legislators, who have intervened several times through the issuing of legal and guidelines.
The strong human demand for products of animal origin and widely held beliefs about the legitimacy of consuming these products make complete independence from foods of animal origin unlikely in the near future.

However, even in the short term, there is room to improve the sustainability of livestock farming, in order to preserve the environment, protect biodiversity and feed the world's growing population, while also working to improve animal welfare conditions through more ethical treatment of them, for example, decreasing their negative emotional experiences and promoting positive ones. Only a trained and competent veterinary doctor can be the real driver of this change.

For the aforementioned reasons, the main focus for VET providers in the veterinary sector in Italy are:
Correct usage, storage and subministration of medications/treatments/drugs; Reproduction and selection of heads; Better conditions in livestock in general. One Health, understood as a health and environmental unit also to minimize the probability of zoonotic spillovers; Food safety, understood in the double meaning of safety and security. Farm to Fork Strategy; Animal health and welfare, two inextricable factors based on management structures from breeding to slaughter through transport that preserve the life worth living principle; Antimicrobial resistance, a threat that passes through the responsible use of antimicrobials and attention to environmental contamination.

3. Trends in digitalization

The digital transformation of Italian agriculture, which had previously fallen behind in terms of technological advancements, commenced approximately 15 years ago. Records from the Ministry of Innovation indicate a substantial investment of over 150 million euros in Agri Tech and Food Tech start-ups in 2016, positioning Italy as the third-highest investor in this sector across Europe, representing 1.8% of the global investments. This progress reflects a determined governmental commitment: the Agriculture 4.0 analysis highlighted the crucial significance of leveraging digital data within the agricultural sphere, stressing the necessity of establishing an organized approach to managing and harmonizing agricultural big data.

The ongoing digitalization of Italian Agriculture encompasses a wide array of areas, including risk management, big data analysis, predictive modeling, research and development investments, interconnectivity, decision support systems, the integration of robotics and artificial intelligence, IoT implementation on farms to facilitate herd and crop management, enhanced precision agriculture, and the effective management of satellite data. Digital technology, alongside its extensive data gathering capability, fosters enhanced collaboration and data, knowledge, and equipment sharing, while smartphone-based training, combined with decision support tools, contributes to empowering farmers intellectually. Moreover, virtual reality is increasingly assisting in the education of farmers.

The drive towards transparency in food chains is also facilitated by improved traceability, often employing blockchain technology, bringing farmers and the food industry closer to consumers and promoting more efficient information exchange. Looking ahead to 2030, the most promising areas for digital advancements include 3D printing, Artificial Intelligence, Virtual Reality/Augmented Reality, Blockchain, Advanced Automation, Data Analytics, Portable Devices for quality assurance, Internet of Things, Cloud Computing, Enterprise Resource Planning (ERP), as well as Portable Devices for production, logistics, and traceability, and Supplier Management Software.

Furthermore, the most significant operational phases identified for digitization within the agrifood chain encompass relations with public authorities, centralization bodies, and consortia, quality checks, logistics, procurement of raw materials, food traceability, commercial product enhancement, product development and innovation, as well as production.

3.1 Digitalization and Animal production

The use of digital technologies already contributes to improving various aspects of livestock management today. The research works to refine and expand the potential for using robots, sensors and artificial intelligence techniques.
The need to adopt digitalisation in precision livestock farming responds to a specific objective: to guarantee optimal health conditions for farm animals. Animal welfare responds not only to an ethical purpose, but also an economic and sustainable one in the livestock sector which in the European Union has around 9.1 million businesses with 142 million pigs, 76 million cattle and 71 million sheep and goats.

Its specific weight is notable: the livestock sector contributes substantially to the European economy, with 168 billion euros per year - 45% of total agricultural activity - and to employment, given that almost 30 million people work (ATF data).

To better manage livestock, there is increasing reference to precision animal husbandry. Defined in English as Precision Livestock Farming (PLF), it constitutes the set of technological solutions useful for livestock management. It provides useful tools for the automatic monitoring of animals to improve their production and reproduction, best protecting their lives and contributing to reducing environmental impact.

PLF solutions include both a hardware part (cameras, microphones and other sensors for livestock tracking) and software for management, observation and control.
CREA has been tackling research in Italy regarding digitalisation in precision livestock farming for some time, with various projects.
The most addressed topics are: solutions for robotic feeding; complete digitalization of all automation phases; sensors, also to control the rumination phase in particular conditions of natural thermal stress, with the possibility of detecting and improving the estrus detection system; monitoring and reduction of methane emissions; digitalisation in precision animal husbandry for not only environmental, but also social and economic sustainability of dairy cattle farming; animal protection; study of energy consumption.

3.2 Digitalization and Food industry

The pressures of global competition, the growing pressure towards a production system that is sustainable and respectful of the environment and constantly evolving consumer preferences - increasingly oriented towards the need for greater transparency and knowledge of the products - are just some of the challenges that the agri-food sector is called upon to face now and in the coming years. If correctly inserted into corporate strategies and supply chain dynamics, digital can prove to be a formidable ally in helping food processing companies to fit into such a dynamic and challenging context.

Research by the Smart AgriFood Observatory analyzed the impacts of digital on the entire supply chain. For example, with respect to the supply of raw materials, digital technologies can help strengthen ties with suppliers, promoting correct management of agricultural businesses and cultivation and breeding activities so as to obtain a better quality finished product. In the industrial phases, the application of the "Industry 4.0" paradigm allows advantages in terms of effectiveness and efficiency thanks, for example, to the use of Big Data Analytics, capable of providing indications for the optimization of processes, or of robots and co-bots, which assist operators in carrying out their tasks.

Another relevant area, in which digital is showing all its benefits, is that of traceability (linked not only to regulatory objectives, but - more generally - to the sharing and valorisation of supply chain data for the benefit of supply transparency and efficiency chain). From a mapping conducted by the Smart AgriFood Observatory, it emerges that there are more than 40 innovative solutions present on the Italian market, i.e. those solutions based on technologies capable of significantly impacting one or more phases of the traceability process, allowing, in particular, automate data collection, enable more effective sharing and enable better processing. Among these, Blockchain plays a primary role (used in 43% of solutions), but technologies related to data analysis (34% of solutions) or the Internet of Things (30% of solutions) should not be underestimated; in fact, among the examples of greatest interest, the Observatory has detected sensors applied to logistics, which allow monitoring the transport and storage conditions of the product, providing timely information so that its quality is not altered.

Despite these premises, the diffusion of digital technologies among Italian food processing companies seems limited. According to the recent Permanent Business Census conducted by ISTAT, in 2018, 10% of companies in the food industry with more than ten employees use artificial intelligence in their processes, 6% use IoT and only 3% use Big Data Analytics.

Beyond the numbers on the use of innovative technologies, what are actually the needs that today push industries in the sector to apply - or think about doing so - digital solutions to their processes? What are the benefits experienced by those who have already experimented, and what are the barriers to innovation?

To shed light on the topic, the Smart AgriFood Observatory has launched a survey aimed at all Italian food processing companies. Thoroughly understand the needs that innovation is called upon to satisfy, the barriers that to date have not allowed greater diffusion of digital among transformation companies and, above all, the benefits found by those who have begun to apply innovative solutions to their processes : these are the main questions that this survey, characterized by a strong focus on the typical productions of the Italian agri-food sector, intends to answer. Particular attention will in fact be dedicated to the specific supply chains and the differences (in terms of needs, benefits, etc.) that distinguish them.

Greater clarity on the state of digitalisation of the Italian food industry is indispensable in order to define public policies that help companies seize the opportunities offered by digital, as well as to guide technological companies in offering products that meet the needs of businesses.

3.3 Digitalization and Veterinary activities

Digitalization in veterinary, mainly insist in the monitoring of medication usage and monitoring of the overall health conditions in the livestock. The main trends are:
Virtual monitoring of the animals: in order to prevent breakout of diseases;
Big Data Analysis: these are crucial for the correct managing of increasingly big livestocks in qualitative and quantitative terms;
registration of pathologies in the facilities: for disease control;
registration of drugs usage: to avoid excessive use of the drug, also in consideration of a holistic "One Health" approach.

4. Trends in One-Health

The integrated multidisciplinary “One Health” approach represents a great opportunity to mitigate the effects of possible new pandemics. On this fundamental topic - which also plays a strategic role in the field of preventive

medicine, and the consequent savings for the national health service.
The One Health approach must be widespread in every activity, as the recent spread of the SARS-CoV-2 pandemic has taught us: working following this approach requires a broad, holistic vision of multiple disciplines that operate in an integrated manner to ensure health of people, animals and the environment.
Effective prevention, applied to food safety, guarantees the protection of human health and, at the same time, also economic savings, as demonstrated by the data published by the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) related to the main foodborne illnesses recorded in the United States in 2018.
There are 15 of the most important food-borne pathogens that cause approximately 95% or more of illnesses every year, for a total of 8,914,713 cases: every single year the cost of illnesses caused by these agents amounts to 17, 5 billion dollars. 90% of cases are attributable, in particular, to five pathogens: non-typhoid Salmonella enterica (4.1 billion dollars), Campylobacter spp. ($2.1 billion), Listeria monocytogenes ($3.1 billion), Toxoplasma gondii ($3.7 billion), and Norovirus ($2 billion). The costs are calculated considering the nature of the specific diseases, divided into acute or chronic, the amounts necessary for the consequential medical care (outpatient and hospital), deaths and lost wages.
In the European Union and in Italy there is no such refined data and above all the costs linked to food poisoning have not been estimated.
The cases notified in Europe, in the year 2021, for the 5 pathogens mentioned are equal to 196,801 (60,050 non-typhoid Salmonella enterica; 127,840 Campylobacter spp.; 2,183 Listeria monocytogenes; 133 Toxoplasma gondii; 6,545 Norovirus) and, although underestimated, represent approximately 90% of the notifications received by the Competent Authorities.
From the point of view of health policy on this front in Italy we are far behind in the application field. In addition to the almost 20 billion of the PNRR for Mission 6 (Health), there is a complementary fund (PNC) specifically dedicated to health, environment, biodiversity and climate. This plan provides for the allocation of 500 million euros with the aim of implementing integrated health-environment-climate approach programs such as the "One Health" model.
What Confagricoltura hopes for Italy is the establishment of inter-institutional/inter-sectoral/interdisciplinary regional technical tables for the sharing of data, the definition of integrated paths and procedures, based on the One Health approach.
A consolidation of the epidemiological analysis and surveillance systems of environmental risks must be achieved, also through the regional and national networks and of the digitalisation initiatives envisaged as part of the PNRR Complementary Plan.
These challenges must be addressed by public health, also on a regulatory level, with an inter- and transdisciplinary approach with the aim of improving the health of people, animals and ecosystems in general. The use of latest generation technologies, such as artificial intelligence, is useful in predicting outbreaks of vector-borne infectious diseases. In the field of food safety, the sequencing of the entire genome of pathogenic microorganisms allows us to promptly trace the sources of contamination and withdraw products from the market to safeguard public health, and reduce the number of cases of pathologies and the costs incurred.

4.1 One-Health and Animal Production

In Animal production, the holistic approach lead to several trends that require a new variety of skills:

- Build effective collaboration between the human and animal health sectors;
- Improve surveillance for early detection of disease threats in humans;
- Strengthening laboratory diagnostic capabilities for new pathogens;
- Improve disease case management and infection control;

- Develop epidemic preparedness and response capabilities for emerging zoonoses.

4.2 One-Health and Food Industry

The main trends that can be seen in Italian Food industry, based on the “One Health” approach, are as follows:

- Implementation of plant based food;
- Restoration of food variety;
- Reduction of food alteration/appetization processes through food production of ultra-processed with high caloric density, especially rich in fats and added sugars;
- Increased awareness related to food and food waste, to reduce poverty and inequality also in food supply;
- Push for regulation of the food industry and food education;
- Dissemination of the connections of the One Health approach in its function of prevention of a healthy ecosystem for food, animals and humans.

4.3 One-Health and Veterinary activities

For the Veterinary sector, the following paradigms are emerging in Italy:
One Health, understood as a health and environmental unit also to minimize the probability of zoonotic spillovers; Food safety, understood in the double meaning of safety and security. Farm to Fork Strategy needs to be implemented with this approach; Animal health and welfare are two inextricable factors based on management structures from breeding to slaughter through transport that preserve the life worth living principle; Antimicrobial resistance passes through the responsible use of antimicrobials and attention to environmental contamination.

5. Trends in business models

The structure of Italian farming exhibits considerable fragmentation. Currently, there is a noticeable shift towards the development of non-agricultural ventures that support farming activities, including tourism, renewable energy projects, agri-related services, educational initiatives, and socialization programs. These service-oriented activities geared towards the public serve both social and commercial purposes. Notably, three prominent trends are on the rise: first, the promotion of short and direct supply chains and collaborations among farms; second, the emergence of para-agricultural pursuits facilitated by farm infrastructure, production, and equipment; and third, the emphasis on local organization and skill development.

The most prevalent para-agricultural undertakings involve contract work conducted for other farms and the expansion of "farm tourism," encompassing accommodation services and leisure activities such as equestrian facilities, educational farms, and farm tours. Additionally, on-farm catering, restaurant services, and Horeca activities are gaining momentum, albeit at varying speeds depending on the region and the presence of tourist attractions. Other para-agricultural activities such as renewable energy initiatives, wood processing, forestry products, handicrafts, and the rental of buildings and facilities for pandemic-induced smart working, hosting, and garages are increasingly emerging trends.

Also, there are new trends that could take over traditional agriculture in Italy and in Europe, and can represent a threat or an opportunity.

There is synthetic meat, produced by growing animal cells in the laboratory. There are "free" foods, free of lactose or gluten, and "enriched" ones, perhaps with iron or selenium. There are food supplements. There are vegan

foods, first of all alternative milk drinks. And there are even insect flours. All together, they form the modified food category, a market that has reached 500 billion dollars worldwide and is attracting growing interest from investors. The numbers come from the Mediobanca Research Area, which not surprisingly has just dedicated a report to the so-called novel food. According to its analysts, the functional foods market will be able to count on an average annual growth rate of 6.9% which would bring the sector to 750 billion dollars in 2027. The largest category is that of foods for weight control, which is already worth 214 billion dollars, followed by supplements which are worth 140 billion globally. Baby foods reach 73 billion, while vegan specialties have a turnover of 25 billion and have the highest expected growth rate, around 9%.

Then we have alternative proteins, from the production of meat derived from legumes to steaks grown in the laboratory, up to the food use of insects and algae. According to Mediobanca, all these segments together should go from the current 2% to 11% of the overall protein market by 2035, for a global value of around 290 billion dollars. In terms of volumes, the average annual growth to 2035 would be 14%, driven mainly by plant derivatives.

5.1 Business models and Animal production

The trends on business model in Italian animal production are as follows. Changes in farm structure; Multi-functional farms; Self cultivation systems for feed; Health and food consciousness of consumers; Traceability; Short food supply chains.

The common thread that we can detect when reading this list is that the creation of real, more sustainable local communities, based on concepts of circular economy, is envisaged, with a view to farming realities that are increasingly focused on self-sufficiency both in single company and in the surrounding community. This allows for greater recognition at a territorial level, which leads to greater trust on the part of the public, who feels confident in the reliability of the information, good company practices and compliance with health regulations in the company. The creation of a business model that respects these trends can ensure that agricultural companies that deal with livestock can maintain the standards that make Italy a renowned importer (think for example of cheeses or ham, whose sale in Italy is equal to 29%, while exports, which involve over 84 countries, absorb the remaining 71%).

5.2 Business models and Food industry

Investments in the alternative proteins (AP) sector are globally exploding.

In 2022 the estimated amount worldwide is 4.9 billion dollars, of which 2 billion on traditional plant-based foods (vegetable meats and milks) and the rest on new technologies such as cellular proteins grown in the laboratory or fermented. In addition to the amount, what is significant is the trend: in 2020 investments were only just over 3 billion and in 2019 around 1 billion. The sector is growing exponentially driven by new generations who are increasingly interested in their own health and that of the planet (including animals and biodiversity); but in addition to these dynamics on the consumer front there has also been a great improvement of the related products in terms of performance.

While in the past a consumption experience inferior to the reference product was accepted, new technologies and processes have brought AP products beyond an important threshold of acceptability: plant-based burgers or milks are not yet at an equal or higher level compared to animal options, but are now a more than acceptable experience in terms of flavor, texture and other factors, driven by much greater additional marketing investments than in the past in the context of worldwide sales (at around $30 billion per year) still tiny compared to traditional animal products (more than 1 trillion).

The sector has been active in Italy for a long time with traditional methods in the vegetable milk sector, but is now being enriched by the presence of innovative food-tech companies. Italy is the fourth country in Europe for

the number of start-ups in the food-tech world (even if only the tenth in related investments) so qualified companies already exist.

5.3 Business models and Veterinary activities

The Italian veterinary sector is undergoing profound changes, especially after the advent in the academic field of specific courses on the use of artificial intelligence, virtual reality, the collection and comparative analysis of the so-called Big Data and, more generally, all those forms of innovation that relate to digitalisation, specific training, holistic approaches and research.

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• Danish trend analysis

1. Introduction

In this report, research for the identification of the Danish trends in the sectors of **Animal Production**, **Food Industry** and **Veterinary Activities** will be held. The domains of the trends in the above sectors are:

- Sustainable production
- Digitalization
- One-health
- Business models

2. Trends in sustainable production

The Climate Act from June 2020 sets legally binding targets of a 70% reduction in Greenhouse Gases (GHG) emissions by 2030 (compared to 1990) and stipulates that the country must become carbon neutral by 2050 [1]. Denmark is also intensely agriculturalized and has a very large animal production sector known for its space-consuming need for feed and harmful impact on climate, biodiversity, and biogeochemical flows [2-5].

2.1 Sustainability and Animal production

The Danish agricultural area constitutes 2/3 of the total Danish territory. There are about 33,000 farms in Denmark where 2/3 are located in Jutland. One fourth (1/4) of the farms are specialized in cattle, pigs and livestock [6]. In 2022, 16,087 farms with livestock have been recorded, of which 1,677 are organic farms [7]. In May 2023, the statistical measurements showed that pigs' production is at 141 M kg per month, while cattle's production is 10,6 M kg per month [8].

Zooming in on the large Danish animal production sector and according to 2018 figures, the agricultural sector is responsible for 22% of all GHG emissions in Denmark [6], and out of these, 90% of emissions are related to animal production [9]. As a consequence, **Danish livestock production is repeatedly highlighted as central in the Green Transition** [10]. This means that stakeholders from all across the livestock sector, including industrial, political, and scientific actors, are currently engaged in intense efforts at making animal production more sustainable following the trends below:

- Investment in precision farming technology to minimize their environmental footprint and maximize their yield, e.g., Arla is exploring how to mitigate climate change through carbon sequestration, where CO_2 is removed from the atmosphere and stored in the soil.
- Exploration of new ways to reduce water and energy consumption as well as single-use plastic packaging.
- Strong focus on upgrading waste streams to valuable products. Raw material food waste that cannot be used as food is cancelled towards livestock feed, biogas production or agricultural fertilizers.
- Early implementation of new solutions. Denmark's universities have departments that are dedicated to developing knowledges and solutions for sustainable animal production. The strong interaction between universities and companies enable the testing of new products from an early stage, shortening their route to market, e.g., the farmer owned agricultural knowledge centre SEGES helps to bring the latest knowledge and technology to farmers as quickly and efficiently as possible.

- Use of alternative proteins in animal production, e.g., a new biorefining technique has unlocked the high protein (more than 40% and all the right amino acids) content of Danish clover grass and will soon make it available in feed for organic pork and poultry producers.
- Denmark's strong focus on importing raw materials for sustainable livestock, e.g., close collaboration between the Danish government and the food/agriculture sector promotes the procurement of certified sustainable soya.
- Methods to improve productivity in animal production, e.g., Danish Holstein cow produces around 10,300 litres of milk a year – more than four times the global average. Today, Danish Holsteins represent more than 70% of Denmark's dairy cow population. That makes an important difference to the farmer and the environment. Improved productivity per cow enables farmers to in- crease milk volumes without increasing the size of the herd and with no additional environmental impact [11].

2.2 Sustainability and Food industry

Explore new ways and adapting circular economy models to reduce water and energy is also a trend in Danish Food Industry, e.g., the food industry's combined efficiency improvements have reduced total energy consumption by 20% since 2006. In the same period, the renewable energy has increased more than three-fold.

Sustainable packaging/Replacement of single-use plastic packaging: Danish food companies are engaged in designing reusable, recyclable or biodegradable packaging that can both keep food fresh and safe and comply with the strict requirements for food contact materials, e.g., Arla Foods has removed a layer of material from its FSC-certified milk carton and replaced the fossil-based plastic with bio-based. The new carton has a carbon footprint that is about 20% lower. Also, at Danish Crown the 55 million meat trays sold each year to Danish consumers are now made from 80% environmentally-friendly PET plastic, which can be recycled as food packaging. The switch to PET plastic means CO_2 emissions are halved for each tray that is recycled.

Food manufacturers, retailers and technology providers have a strong focus on upgrading waste streams to valuable products.

Raw material food waste that cannot be used as food is cancelled towards livestock feed, biogas production or agricultural fertilizers, e.g., a novel initiative – Daka ReFood – has run a food waste collection service for food producers and other segments. While used cooking oil is recycled as biodiesel, all other waste is used for the production of biogas. Altogether, Daka Denmark produces 55 million litres of biodiesel a year.

Partnerships for protein innovation. E.g., a project involving several Danish companies and the Technical University of Denmark (DTU) is underway to find a profitable way to extract protein from grass and use it as a food ingredient. This transition is supported by a new partnership–Danish Protein Innovation-consisting of organizations, companies and knowledge institutions.

Denmark has a strong focus on importing raw materials for sustainable food production. Close collaboration between the Danish government and the food and agriculture sector promotes the procurement of certified sustainable and palm oil. Sustainability certification ensures production is socially fair, economically viable and environmentally sound - with no deforestation [11].

2.3 Sustainability and Veterinary activities

The Danish Veterinary and Food Administration (DVFA) strategy 2020-2023 [12] sets an ambitious direction internationally, in Denmark and for the organization internally. One of the DVFA's strategy main focus area is

sustainable food cluster. However, the road to sustainable solutions is rarely straight, and often diverges across disciplines and sectors. In collaboration with the entire food cluster, the DVFA will develop solutions that provide:

Better resource-efficiency. Danish veterinarians, through the DVFA, support companies to achieve their goals by helping clear barriers out of their way: when enterprises are to find alternative sources of feed for livestock production, when new products are to be developed and approved, when enterprises want to recycle water and other residual products and when Denmark wants to reduce food waste in agriculture, businesses and industry.

Sustainable sources of animal feed, e.g., by using alternative sources of protein such as insects, seaweed and starfish in animal feed. This often requires more flexible Regulations for food production and the many EU Regulations have moved from setting an appropriate framework to becoming a barrier. The role of the DVFA is to act as a link between industry needs, what research provides and the legal opportunities and restrictions.

Healthier food and less food waste in all phases.

Additionally, as part of the Ministry of Food, Agriculture, and Fisheries (MFAF) project "Livestock farming of the future", scientists will develop new feeding strategies to reduce methane emissions, while improving the use of energy from the feed. Methane as a greenhouse gas is 21 times more potent than CO_2 and there is therefore a significant contributor to global warming. Some of the strategies are likely to reduce the utilization of the feed or change the characteristics of the milk. Besides developing feeding strategies that reduce the emission of methane from dairy cattle, the project will therefore investigate the link between menthane production, nutrient digestibility, and milk production.

Denmark's livestock population continues to decline in 2022. In November/December 2022, Denmark reported declines in its pig population, equivalent to over one half of the EU's overall reduction. Denmark's decrease was equal to 22% of the EU's overall reduction (-1,6 million head, -12%). This decline was part of a general trend. [13]

3. Trends in digitalization

Based on the Digital Economy and Society Index (DESI) [14], basic and advanced levels of digital skills in Denmark are higher than the EU average. National Strategy for Digitalization [15] was presented by the Danish government in May 2022. As one of the most digitally advanced nations in the world, Denmark excels at seizing digital opportunities. Visions embedded in the strategy are strengthened cyber and information security; coherent service for people and businesses; more time for welfare through increased use of technology; increased growth and digital SMEs; the digital healthcare of the future; acceleration of the green transition through digital solutions; a strong, ethical, and responsible digital foundation; Denmark at the center of international digitalization; and a population ready for a digital future [16].

3.1 Digitalization and Animal production

The Danish agriculture sector has developed new tools and techniques to overcome challenges in animal production. Farmers collaborate with other professionals to maintain the pace of technological innovation. By pooling knowledge, Danish digital specialists and experts in animal production are developing sensors, artificial intelligence (AI), drones and satellite technology-and making smart data management accessible. Precision livestock farming (PLF) and site-specific input application based on GPS has been also a management tool and option for Danish farmers.

3.2 Digitalization and Food industry

In food manufacturing, demand is rising for technology that can secure food safety, quality and sustainability. Generations of innovation have driven Danish food industry to the fourth industrial revolution "Industry 4.0", where the physical and digital worlds are merging. Smart solutions for industrial automation include robots, sensors, quality analysis technology and data management systems. Automated tools improve working conditions on the factory floor and reduce the risk of contamination and human error. Additionally, digital solutions that predict the need for line maintenance is an emerging trend. Using cloud-based predictive tools, manufacturers can secure better performance and a longer lifespan for their equipment, further contributing to the sustainability of their operations [17]. Also, new enterprises are spinning up in the Danish AgriFood Tech sector, innovatively combining new technology and following a strong Danish tradition of food safety and sustainability. Some are highly consumer-oriented, such as "Simple Feast" which seeks to steer customers in the direction of more sustainable eating habits. Or the platform "Too Good to Go" which is working to reduce food waste.

3.3 Digitalization and Veterinary activities

Danish veterinarians, through the DVFA, have a long-term vision to deliver world-class digital services; a vision that extends far beyond this strategy period. The digital transformation will equip the DVFA to meet external expectations with regard to food safety, healthy food, animal health and animal welfare. The DVFA focus on efficient and responsible management of IT systems, establishing data governance and digital architecture, and setting process ownerships.

World-class digital services: Danish veterinarians consider data as resource to create cohesive services, because they work agilely and innovatively. Digitalization helps to develop control and inspection such that data will support selection for control and inspection to an even greater extent.

Transparent data: Danish veterinarians aim at making data available for both customers and employees, so that data is relevant and individually customized, e.g., for better dialogue on and outcomes from an inspection, for analysis and benchmarking, and for cohesive public services. One of the goals is the creation of a common platform, or an ecosystem, that can serve as a two-way technology solution for the veterinarians, consumers and businesses. The objective is the promotion of equal dialogue and access to keeping up to date with regulations and guidelines

Clear and concise communication with customers: there is the need costumers to meet with veterinarians who use digital technologies in core processes and disseminate proactively knowledge.

Self-serve data preparation: training in new technologies in order to improve many emergencies response task and models that combine authority data and industry data [12].

4. Trends in One-Health

One Health is a holistic approach to understanding health and is based on collaboration between different professions. The underlying basis for One Health is an understanding that the health of humans and animals and the conversation of our environment are connected. In Denmark, the officially One-Health-Institute is the Danish Statens Serum Institute (SSI). SSI collaborates with the Danish Ministry of Health, the Ministry of Environment and Food, the University of Copenhagen (KU) and DVFA for the One Health Antimicrobial Resistance (AMR) in Denmark research [18].

4.1 One-Health and Animal production

One Health is relevant with animal production, because 75% of all threats from viruses and bacteria originate

from animals. This happens due to several factors, such as change in the production systems, climate changes, demographical changes, and our growing exploitation of natural resources. Transfer of resistant genes and spreading of resistant bacteria between animals and humans and in the environment is highly important of the whole issue of antibiotic resistance. For this reason:

- Disease surveillance and control programs is implemented to improve animal health and animal welfare, and thereby support the production of safe foods, e.g., the number of imported cloven-hoofed animals has been kept as low as possible for the last years.
- Farms are imposing strict bio-security measures to prevent any spread of animal disease.
- The use of pesticides on all crops, including those grown for feed, is controlled by legislation.

4.2 One-Health and Food industry

The Danish Minister of Food, Fisheries and Equal Opportunities designated September 29th, 2020, as the first official "National Food Waste Day" aligned with the "International Day of Awareness of Food Loss and Waste" designated by the United Nations General Assembly. Food loss is much more than waste of precious food-it involves a waste of labor, natural resources, and energy.

The Danish National Food Institute monitors trends in the incidence of foodborne zoonoses. This is done in close cooperation with the authorities involved in surveillance in the farm-to-fork chain. The Zoonosis Centre at the National Food Institute gathers data on human cases of zoonotic disease as well as the occurrence oof zoonotic bacteria in food and animals.

4.3 One-Health and Veterinary activities

A European One Health Action Plan against AMR [19] is defined as a joint effort of various disciplines to provide solutions for human, animal, and environmental health. Denmark's National One Health Strategy (2017) [20] identifies five goals aimed at reducing the use of antibiotics and preventing resistance in relation to humans and animals:

a) a prudent use of antibiotics to reduce the incident of resistance. The main goals are: (1) the reduction of 2% per year (2019-2022) in the use of antibiotics for pigs, and maintain or reduce the use of antibiotics for other livestock species, and (2) the maintenance of the low use of antibiotics that are critically important for treating humans.

b) greater efforts to prevent infections and to facilitate antibiotic alternatives. The objectives are: (1) the maintenance or if possible, the reduction of low incidence of resistance in food, with an emphasis on critically important resistance, by enhanced focus on biosecurity and hygiene in production animals and food production as well as on animal health, and (2) the limitation of the spread of livestock-associated methicillin-resistant staphylococcus aureus (MRSA) from pig herds and in the community.

c) enhance knowledge to improve targeted measures. Veterinarians aim at ensuring that monitoring of resistance bacteria in food production is broad and comprehensive, so that is possible to: follow and catch trends, compare results with monitoring of resistant bacteria in humans, take relevant measures to follow up on monitoring results, to use the best, most up-to-date methods to reduce the use of antibiotics and to increase the knowledge of methods to reduce the use of antibiotics.

d) information and guidance on resistance and transmission. The main goal is to create awareness

and share new knowledge on resistance and transmission pathways.

e) a strong international cooperation to minimize the development of antibiotic resistance. Danish veterinarians want to share their experience and ensure Danish influence and impact on EU legislation and Codex Alimentarius documents. They also aim to ensure that EU legislation is implemented in a timely manner.

The DVFA's second Action Plan [20] for antibiotic resistance in production animals and food for 2021 to 2023 follows the above five goals of the Danish One Health Strategy (2017).

- Some other Danish and international One Health research projects and networks are:
- ADONIS: assessing determinants of the non-decreasing incidence of Salmonella [22].
- BeOne: a solution for cross sectoral collaboration on outbreak detection [23].
- Campylobacter transmission in boiler chickens investigated by genome sequencing.

Some of the Danish One Health preparedness and surveillance activities are:

- DANMAP: collaboration for the surveillance of antibiotic consumption and occurrence of antibiotic resistant bacteria in animals, food and humans. DANMAP plays an important role as the basis for the development of national guidelines and risk management of AMR and is also referred to as one of the major One Health initiatives in Denmark and internationally [24].
- Surveillance of influenza virus (in swine, birds and humans, including detection of notifiable influenza virus in both animals and humans).
- Surveillance of ornithosis and avian chlamydiosis etc.
- Cross disciplinary collaboration on foodborne outbreaks. [25]

5. Trends in business models

The life science industry in Denmark has evolved into one of the strongest clusters in Europe, and investment in Danish biotechnology is number two in the region. The Danish government has been supporting the agriculture sector with a number of policies, trying to stabilize the output and seeking ways to ensure the sector is growing healthily and sustainably. There is also broad political consensus for land, labour and tax reform to help the sector reach its potential.

5.1 Business models and Animal production

Danish producers export meat and meat products to 140 countries around the world and observing high standards remains crucial to maintaining their market position. The achievement of high standards is paramount throughout the whole production chain, on the farm, during transport and finally at the abattoir [26]. The country makes efforts to integrate new agricultural technologies to improve the sector's efficiency and increase productivity. Livestock plays a key role in National and Global food supply and the requested significant reductions in emissions can be obtained by reducing the footprint per kg of product. This will make Danish livestock production more competitive on an international market, and potentially create more jobs in the sector. These jobs and revenue will not only be generated within the primary production and downstream industries, such as dairy and meat processing companies, but also in industries involved in the development of the new technologies. This could be, for example, breeding companies, feed suppliers, and companies providing feed additives and precision livestock farming tools [27]. A 2018 study from Statistics

Denmark shows that 27% of skilled farmers in Denmark use RTK- GPS-systems.

5.2 Business models and Food industry

Plant based food production is an important part of the Danish food production. Many start-ups and established food companies are already developing a wide range of plant-based food products. Substantial investments in research, innovation and implementation will make it possible to exploit the full growth potential of the plant-based food value chain and bring Denmark in a position to achieve a global market share of plant-based food between 1% and 3% coupled with the creation of between 9,000 and 27,000 new jobs.

Biotechnology-based food production and alternative protein sources will support the transition towards a more sustainable food production in Denmark and internationally. Biorefinery, novel microorganisms and animal cell-based alternatives are projected to reach 10-20% of the global protein consumption by 2035. Functional food ingredients, cultures and additives are part of this value pool [27].

5.3 Business models and Veterinary activities

Danish veterinarians aim at anchoring innovation. Innovation is to predict opportunities and barriers, and in this context, research plays an important role. Therefore, the certainty that research is an element in providing the necessary academic weight to remove barriers to innovation. The approach to innovation is drawn on inspiration from Design Thinking, test and define methods for competence development. Danish veterinary sector wants to focus on how collaboration with stakeholders can be further developed in the overall portfolio of tasks. Therefore, test methods to involve stakeholders in connection with new or changed legislation will be tested. At the same time digital innovation will be also applied to provide targeted and relevant knowledge for the individual enterprise or farm. The objective is the maintenance and the development of high quality, better control, and inspection.

In Denmark, the continued focus on reduction in antimicrobial usage and the sustained efforts to ensure competitiveness of the pig sector have provided Danish pig herd veterinarians with unique expertise in preventive medicine. Veterinarians collaborate on structural changes, and agricultural, economic, and financial matters, resulting in a holistic view of the farm and visions of the future [28].

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• Dutch Trends analysis

1. Introduction

The Netherlands has a strong agri- and food sector and is the second largest exporter of agricultural products in the world (>90 billion euros in 2020) at this moment. Most important sub-sectors for export are: floriculture, dairy, eggs, meat (chicken, pork), and vegetables. Although, also other products like fish, fruits deliver important income flows. The number of farms in the Netherlands is decreasing rather quickly. 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; 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; Agrimatie, 2020). So, in general less farms, and bigger farms instead.

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*[1]	10.444	4.144

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

1.1 Food Industry general information

The food industry in general is increasingly an instable sector; raising inflation, higher company costs, fluctuating availability of materials, and changing consumer preferences (Aptean, 2023) make it more challenging to run a business in the food industry than ever before. According to Aptean the biggest challenges are: higher operational costs, changing consumer preferences, sustainability and climate change, growing inflation / material prices. Nevertheless, most companies expect more income in 2024 (Aptean, 2023).

1.2 Animal production general information

Of organic livestock, laying hens are the biggest livestock producers, but the number of organic laying hens reduced with 13% in 2023 (partly due to bird flu resulting in clearances and lock-in, due to which eggs of these laying hen farms couldn't be sold as organic). Numbers of organic goats (-9%) and sheep (-4%) also reduced, but broilers (+16%), pork (+2%), and cattle (+4%) increased in 2023.

1.3 Veterinary sector general information

The veterinarian is a profession that requires knowledge from the Master's Veterinary Medicine (*Diergeneeskunde*) to practice it. It includes veterinarians who work in a veterinary practice, supervising veterinarians for the Dutch Food and Consumer Product Autority (NVWA), veterinary researchers from the Faculty of Veterinary Medicine and other veterinarians, who for example work as policy officers at the Dutch government or in the pharmaceutical industry (SEO, 2022).
For this sector the following trends are relevant:

- During COVID-19 the pet population increased, there were less staff available and less people per time unit could be helped due to restrictive measures. Work pressure reduced after the pandemic https://www.digiredo.nl/is-er-werkelijk-een-tekort-aan-dierenartsen. This, among other reasons, makes that the veterinary care develops rapidly due to increasing number of pets, innovation, collaborations and sustainability. https://www.rabobank.nl/kennis/dierenartsen?query=&tab=knowledge&page-number=1&page-size=6&type=text. And because of these reasons a reorientation in the veterinary

industry is expected; government (Ministerie van Landbouw) requires the sector to find a branch organization and build a quality system. This is due the following reasons: livestock decreases 10-40% (due to nitrogen crisis and subsequent purchase schemes) the upcoming years. However, revenue regarding pet animals will increase slightly (since the start of the COVID-19 pandemic / 2020-2021 the number of households with a pet animal increased with nearly 2%; 150.000 households, in total there are 21.75 million pet animals in the Netherlands, of which 1.8 million dogs (18% of households), 3.2 million cats (25% of households) and 12 million fish (4% of households). And in addition, pets receive increasingly improved care and expenses of veterinarian medicine increased from 250 million in 2010 to 340 million in 2017 https://www.rabobank.nl/kennis/s011370623-herorientatie-in-dierenartsbranche-verwacht

2. Trends in sustainability

2.1 Sustainability and Food industry

According to Aptean (2023), within food industry is becoming more sustainable a trend. This is often motivated by societal pressure, and commercial reasons (e.g., more efficiency or competitiveness). With regard to sustainability, the following trends can be identified in the food industry:

- Protein transition
  - Alternative protein sources: we are in the midst of what we call the protein transition. In general a consumers' diet changes bit by bit from more meat protein, to more plant-based or alternative sources of protein. That makes within the food sector that there are higher investments in milk alternatives (Aptean, 2023) or other novel foods are created: e.g., new taste with the use of AI, or using AI to find bioactive peptides to support conditions such as diabetes and to support animal and plant health (Aptean, 2023).
  - Less animal products, more plant-based is a trend, including switching from animal protein to plant-based protein (Berkhout et al., 2023). In 2019-2021, 43% plant-based protein and 57% animal protein was consumed in an average Dutch diet (RIVM, 2023 in Berkhout et al., 2023), target is 50:50 in 2023 (LNV, 2022 in Berkhout et al., 2023), this will be monitored with the Eiwitmonitor from 2023 (Berkhout et al., 2023).
- Biodiversity loss
  - Compared to other European countries, the Netherlands have little habitat types and species with a favorable conservation status, but relatively many habitat types and species with a (moderately) unfavorable conservation status show an improvement (CLO 1483). The next report (period 2019-2024) is planned for 2025. The objectives of the Habitats Directive have not yet been achieved in the Netherlands. The Dutch report to the European Commission contains many pressure factors that contribute to the decline of the species and habitat types. The most negative effects are caused by water management for agriculture (desiccation due to the extraction of groundwater and lowering the water level) and the excessive use of fertilizers in agriculture, among other things to nitrogen deposition.
- Consumer expectations (climate friendly products, e.g. palm oil free, rainforest initiatives, CO2-neutral)
  - Use of BI-tools and AI-technology planned to adapt to changing consumer expectations, e.g., becoming more sustainable (Aptean, 2023) and more driven by health claims.
  - Convenience increasingly important for consumers in product decisions. This includes mental convenience as too many options result in decision fatigue (two trends: more concepts with limited product options like discountsupermarkets and "flitsbezorgers", and helping consumers to make healthy and sustainable food choices, e.g., Nutri-Score and apps). Marketing the product (how convenient, sustainable, contributing to health is it, etc.) is becoming more important than its content (Evmi, 2023)

  - Consumers are willing to pay for convenience. Two trends: 1) “gemak in een pak” pre-cut vegetables, readymade meals. 2) convenience order; takeout, restaurants in supermarket which prepares and service products from the supermarket (Evmi, 2023)
  - Ecolabeling as a response to the increasing demands of the consumer, are increasingly developed and put in place.
- Increasing energy efficiency/circular production
  - Digitalisation improves operational efficiency (Aptean, 2023)
  - Initiatives to improve water and general efficiency (Aptean, 2023)
  - Natural gas is not renewable, and the rise of cogeneration lead to the increasing use of natural gas in 2006-2010, with only a slight reduction in 2021 compared to 1995 (Berkhout et al., 2023)
- Decreasing environmental pollution
  - Emissions from greenhouse gases, nitrogen, phosphorus and particulate matter from agriculture decreased compared to 1995, but decreases of GhG and nitrogen were small in the past years, but: production volume increased with 21% since 1995 (Berkhout et al., 2023)
  - GhG emissions 17% lower for agriculture since 1995, but reduction happened in 1995-2002, which means no reduction since 2002, governmental policy is to reduce emission with 30% between 2021-2030 (Berkhout et al., 2023)
  - Particular matter emissions reduced with 53% since 1995 -> good for health (Berkhout et al., 2023)
  - Phosphorus surplus per hectare is relatively big for EU countries, density of the livestock is biggest in NL, leading to surplus in phosphorus and nitrogen, harming the environment (Berkhout et al., 2023)
  - NL is responsible for 88% of all ammonia emissions in air (Emissieregistratie.nl) and for 46% of the total nitrogen deposition in Natura 2000 areas. Policy is to reduce emission with 41% by 2030 compared to 2019 (LNV, 2023c) (Berkhout et al., 2023). Emission of ammonia reduced with 70% in agriculture due to banning of widely spreading manure above ground, reductions in livestock, nitrogen-reducing measures, increase of low-emission stables, using less manure due to export, less nitrogen levels in cattle feed, etc
- Nearshoring: regional production in combination with urban agriculture (vertical farms)
  - Vertical agriculture (Aptean, 2023)
- Organic standards
  - Number of certified organic farms (including livestock but also vegetables/fruits) increased with 1% in 2023, number of not-certified and certified companies in transition reduced, many companies transition phased, the volume of organic produce grows faster than the growth of certified organic businesses, size of organic farms with cultivated land increased by 7% from 42 to over 44 ha, (CBS, 2023a in Berkhout et al., 2023)
- Reduced use of pesticides
  - Decreased 14% since 1995 while production volume increased with 21% since 1995 (Berkhout et al., 2023)
  - Pesticides contaminate surface water, but environmental impact reduced stronger than active use, which indicates that used products are becoming less polluting (Berkhout et al., 2023)
- Production improvements
  - Sustainable investments = investments in sustainable production systems, increased with 9% for agriculture and horticulture and fishery since 2020, with a total part of 27%, mostly due to policy measures like “Energie-investeringsaftrek” (EIA) (Berkhout et al., 2023)
- Waste management
  - Single use deposit return system; Plastictoeslag since july 2023 Vanaf 1 juli betaalt u extra voor wegwerpbekers en -bakjes met plastic | Nieuwsbericht | Rijksoverheid.nl
  - Plastic reduction: deposit system since march 2023 Statiegeld Nederland - Statiegeldflesjes, lever ze in!
  - Initiatives that change food waste into consumed products, e.g., Kromkrommer (Aptean, 2023)

- Reducing amount of plastic in bottles (Aptean, 2023)
- Food waste = removing food and unedible parts of food from the food chain (including composting, anaerobic digestion, bioenergy production, cogeneration, incineration, disposal to sewer and landfill) (Delegated decision - 2019/1597 - EN - EUR-Lex (europa.eu)). Lowering food waste is necessary for circular food system, (Berkhout et al., 2023). Globally, 1/3rd of produced food doesn't reach consumers, in the Netherlands this is estimated to be 1/4th (Soethoudt en van der Burgh, 2017 in Berkhout et al., 2023). Food waste extends beyond food loss, because every factors contributing to production of food are also lost, e.g., land, water, labour, seeds, fertilizer, food security (Berkhout et al., 2023). Food waste contributes to climate change, with estimated contribution of 8% to GhG emissions (FAO, 2019 in Berkhout et al., 2023). NL food waste in 2020 161kg per person (Soethoudt & Vollebregt, 2023 in Berkhout et al., 2023). NL 5th EU place of most food waste, but also 2nd agrifood exporter, which means a relatively high loss during production, which is included (Berkhout et al., 2023). Different policy measures to tackle food waste are present, ranging from food safety and hygiene policy (such as donation of food, animal feed), to fisheries policy (think of bycatch), financial policy (tax cuts) or energy policy (e.g. incentives for anaerobic fermentation/biogas plants). An evaluation by Vittuari et al. (2015) has fifty-two identified legislative acts with food waste implications covered by EU law and policy (Berkhout et al., 2023). Target is to reduce food waste with 50% by 2023 compared to 2015 (Berkhout et al., 2023).

2.2 Sustainability and Animal production

With regard to animal production, is was recently revealed that lifestock lives 4 months longer on average in 2022 (5.01 years) compared to 3 years before. https://www.veearts.nl/20230705/in-drie-jaar-tijd-leeftijd-veestapel-met-vier-maanden-verlengd/.
Other trends that are worth mentioning are:

- Animal welfare and organic standards are becoming increasingly important. Animal welfare mainly due to pressure from consumers and NGOs. Organic standards are an outflow from this and also related to the trend of more certification.
- Biodiversity (loss measures)- there are more and more measure to prevent biodiversity loss. With regard to the animal production sector this means that paddocks should be more diverse and farmers should offer more possibility to let other plants grow in addition to their gras.
- Closed-cycle farming is an upcoming trend to use and re-use everything again.
- Environmental pollution – the trend is that we are aiming for a reduction of GhG emissions
- Livestock population – the trends is that our livestock population should be more diverse.
- Organic production – farmers are more and more stimulated to produce organically. There are really strong and promising examples in the Netherlands, but only holds of a small percentage of all farmers.
- Soy and animal feed production – the production of animal feed should not go at the cost of biodiversity or should not destroy forest in other countries. Investigations are taking place to balance out the environmental costs and monetary costs for animal feed (Nutricontrol.nl).

2.3 Sustainability and Veterinary activities

- Organizations KNMvD, Covetrus, Evidensia, AniCura, Aeres opleiding and Yuverta opleiding started the foundation De Groene Veterinair in autumn 2023 to come to an approach regarding sustainability in the veterinarian sector. Their goal is to make rapid changes through collaboration, offering a knowledge platform for veterinarian practices in The Netherlands and improve sustainability in practices. Themes are: (reducing) waste, communication, energy usage, finances, medication (e.g., effects of production on environment), "meten is weten", https://www.knmvd.nl/dossier/duurzame-diergeneeskunde/ , Degroeneveterinair

3. Trends in Digitalization

3.1 Digitalization and Food production

- 3D-printing
- Digital transition
  - Digital transformation impacts organization context and revenue (Aptean, 2023)
  - Automation secures supply, reduces risks for growth (Aptean, 2023)
  - Advanced stages of digital transformation in many organisations (Aptean, 2023)
  - Supports updating personnel base: which tasks will be automated, which skills need to be updated, what expectations employees have regarding work place and tools -> outdated/isolated technology needs to be replaced to become datadriven (Aptean, 2023)
  - Many organizations are digitizing their business operations (Evmi, 2023)
- New technologies
  - Automation, cloud adoption crucial to stimulate market conditions (Aptean, 2023)
  - Digitalisation used to solve supply chain issues such as visability (Aptean, 2023)
  - product lifecycle management (PML), enterprise resource planning (ERP) software,
  - Most popular: technologies for managing client relationships, production activities, supply chain. In 2024: efficiency; simpler cashflow and data streams, online pay platforms, EDI- and BI-software investments, cost optimalisation in niche targets such as shipment and transport management and employment challenges (Aptean, 2023)
  - 1/3d of the sector in the Benelux already implements/uses AI (Aptean, 2023)
- Packaging as communication tool
- Smart materials
- Traceability
  - Request for visibility of data accepts BI and AI (Aptean, 2023)

3.2 Digitalization and Animal production

- APPs and educational programs
- Farm presentations (social media)
- Realtime experiences on the farm
- Smart farming
- Work enhancements (milking robotics, animal sensors, stall ventilation, feeding and water systems)

3.3 Digitalization and veterinary sector

- Use of BoviLab to do blood analyses with cattle, https://www.veearts.nl/20230905/sneller-en-beter-advies-met-apparaat-voor-bloedanalyse/
- Dashboard digiRedo for cattle veterinarians to examine performance of their practice and improve work happiness https://www.veearts.nl/20230823/dashboard-geeft-inzicht-in-prestaties-van-rundveepraktijk/ , https://www.digiredo.nl/grip-op-je-praktijk-1/dashboard-grip-op-je-praktijk/
- Increasing use of technology for diagnosis and treatment, animals get scans in more early stages of life (in 2016 8% of animals was <1 year old, in 2019 14%).
- 2023 Trends veterinarian practices: more use of advanced diagnostic techniques (e.g., echography, MRI-scans, CT-scans, blood tests) to diagnose more accurately and make more effective treatment plans, the role of technology increases and makes care more efficiently + enhances communication with owners (electric patient files, making appointments online, telemedicine-consults, digital imaging, monitoring systems) https://www.marktdata.nl/nieuws/Ontwikkelingen-en-trends-dierenartspraktijken

4. Trends in One-Health

4.1 One Health and Food production

- Control and safety of nutritional supplements
- Disease prevention
  - Healthy foods increasingly recognized as contributors to health, to reduce medical expenses (Evmi, 2023)
- Ethical consumerism (e.g., fair trade)
- Food safety and product transparency
  - Transparant label products: Nutri-Score Voedselkeuzelogo Nutri-Score | Voeding | Rijksoverheid.nl
  - Transparency; consumers need to see how sustainable and healthy producers products are. This is becoming a trend, as suppliers from retail get asked about this (Evmi, 2023)
  - Price/quality balance (Evmi, 2023)
  - Food safety (Evmi, 2023)
- Mindful eating, healthy lifestyle
- Organic standards
- Policy
- Production improvements

4.2 One Health and Animal production

- Animal welfare – organic standards
- Antibiotics and germ resistance (animal/human)
  - "One Health policy. Antibiotic policy in the Netherlands has become part of the One Health approach. Together with professionals. The ministries of Health, Welfare and Sport, LNV and IenW are taking action in healthcare, livestock farming, food and the environment. The integrated One Health approach includes careful use of antibiotics, better monitoring and surveillance, research towards new resources and alternatives, infection prevention and communication. One is currently being worked on National action plan to write down the current policy in a plan according to the One Health approach." (Berkhout et al., 2023)
  - Antibiotic usage monitored by Autoriteit Diergeneesmiddelen (SDa), sales of veterinary medicine and resistance development published in yearly Nethmap-MARAN-rapportage https://swab.nl/nl/exec/file/download/197 , together with Stichting Werkgroep Antibioticabeleid (SWAB) and Centrum Infectieziektenbestrijding (CIb), sales reduced with 22.9% in 2022 compared to 2021 (77.4% between 2009 and 2022, despite livestock numbers being relatively stable), usage with 12.8% in 2022 compared to 2021 (Berkhout et al., 2023)
  - New benchmarksystem for vets since 2021 Veterinaire Benchmark Indicator
  - NL has less problems of infection outbreaks caused by resistant bacteria (in animals, food or the environment; One Health), because antibiotics are only prescribed when necessary, resistance and usage are monitored to take preventive measures timely. Intestinal bacteria became less resistant in the past 10 years in livestock (Nethmap, 2022). (Berkhout et al., 2023)
- Cultural landscape
- Environmental pollution
- Farm to fork
- Foodborne zoonoses
- Medical health
- Monitoring
- Skills needs
- Pesticides

4.3 One-Health and Veterinary activities

- Animal health and welfare important themes in Dutch livestock farming, factsheet about neglect in 2022 https://www.vertrouwensloketwelzijnlandbouwhuisdieren.nl/uitgelicht/vertrouwensloket-meer-dan-ooit-nodig-dierverwaarlozing-vaak-laatste-signaal/
- KNMvD requests Dutch politics to pay attention to accessible veterinarian health care, and to look at problems regarding human, animal and environmental health from the One Health perspective https://www.veearts.nl/20230901/knmvd-doet-aanbevelingen-aan-politieke-partijen/ , "KNMvD-aan-politiek.-7-aanbevelingen-voor-de-diergeneeskundige-zorg-DEF.pdf"
- SDa started development independent monitoring and benchmark system for care of young animals to improve animal health and welfare, https://www.veearts.nl/20230111/ontwikkeling-monitorings-en-benchmarksystematiek-zorg-jonge-dieren-begonnen/ , https://www.autoriteitdiergeneesmiddelen.nl/nl/zorg-jonge-dieren/algemeen-zorg-jonge-dieren
- Use of antibiotics in most farm animal sectors reduced in 2022 to 3.2 DDDA for dairy cattle, 0.4 DDDA for remaining cattle, 5.8 DDDA pig sector, 5.8 DDDA broiler sector, 6,4 DDDA rearing broiler farms, no antibiotics in most laying hen rearing farms except for some high dosage users (> 20 DDDA), turkeys 9.2 DDDA, but increased in calf sector (with 5.6% to 16.2 DDDA) and incomplete data about goats, in 2024 further policy regarding sector specific reduction targets will be made https://www.veearts.nl/20230828/adema-waardeert-inzet-en-aanpak-reductie-antibioticagebruik/ , https://www.veearts.nl/20230626/antibioticagebruik-in-meeste-sectoren-verder-gedaald/ , https://www.veearts.nl/20230626/antibioticagebruik-in-meeste-sectoren-verder-gedaald/ , "def-sda-rapport-met-brief---het-gebruik-van-antibiotica-bij-landbouwhuisdieren-in-2022.pdf", "33621324.Kamerbrief Stand van zaken veterinair antibioticumbeleid 2023 .pdf"
- In comparison to other European countries the Netherlands has quite a low use of veterinary medication (+- 6% of total European use, food safety demands and public opinion make use of medication happen more consciously and lower dosages) https://www.rabobank.nl/kennis/s011142757-positieve-verwachtingen-voor-de-dierenartsbranche
- 2023: increasing specialization (e.g., cardiology, dermatology), importance of preventive health care increases to maintain animal health and target diseases from early onset (e.g., regularly checkups, vaccinations, parasite prevention, dental care, food recommendations), focus on importance of animal welfare increases (besides medical care, behavioral care, nutrition, movement and stress reduction) https://www.marktdata.nl/nieuws/Ontwikkelingen-en-trends-dierenartspraktijken
- Welfare. Wet Dieren was revised in 2019 (revisions active since 2023). Now, it's not allowed to harm the welfare or health of an animal with the purpose of holding and housing it a certain way. The underlying rationale was to adjust the way of livestock farming to lifestock, instead of the other way around. With this revision, it is also not allowed anymore to keep animals in a housing system that prevents them permanently from expressing their natural behaviours. But how can these open norms be interpreted? What is natural behaviour and what not? And what if natural behaviour may harm the or another animal? These open norms may lead to uncertainty for sector parties and enforcing institutions licg.nl - Wijziging Wet Dieren: wat betekent dat voor huisdieren? , https://www.berenschot.nl/nieuws/2020-november-uitkomsten-evaluatie-wet-dieren , Plenaire verslagen | Tweede Kamer der Staten-Generaal , wetten.nl - Regeling - Wet dieren - BWBR0030250 (overheid.nl)
- Focus is more on preventative healthcare and advice (in contrast to food, medicine and curative treatment) https://www.rabobank.nl/kennis/s011142757-positieve-verwachtingen-voor-de-dierenartsbranche

5. Business models

5.1 Business Models and Food Production

- AKIS (Agricultural Knowledge and Information System)

- Aquaculture
  - Hydroponic fishing (Aptean, 2023)
  - Aquaculture businesses no not growing (Berkhout et al., 2023)
- Business structure
- E-commerce systems, automatic supermarkets
  - Food delivery, including meals (e.g., meal boxes, dark kitchens: restaurants that offer delivery only) and groceries; many businesses focus on (only) e-commerce, food service gained popularity during/after covid-19 (Berkhout et al., 2023)
- Education
  - / employment. Covid-19 forced many professionals to retire, with a lack of skills and knowledge and re- / upskilling personnel as a result, but young employees have different expectations (e.g., digital skills highly important) (Aptean, 2023)
- Food cooperatives, direct sales
- Food sharing and SoLaWis
- Inter-farm cooperations (machinery rings)
- New food products/concepts produced (by startups)
- Organic production as business model
- Relationship
  - Initiative to share knowledge and experience of companies in the field of meat and convenience food service and retail (Aptean, 2023)
- Short supply chain
  - Price inflations are paid by consumer, especially in long chains (Aptean, 2023)
- Supply security
  - Consumer starts to trust supply chain (Aptean, 2023)
  - Automation is crucial (Aptean, 2023)
  - Supply chain resilience is top priority (with use of technology and improving relationship management with suppliers), e.g., due to disruptions such as labour shortage, skills deficiencies, geopolitical conflicts, extreme weather conditions that affect Mondial supply stream (Aptean, 2023)
- Sales
  - Although inflation and ingredient costs reduce, many organisations maintain record prices to protect margins (Aptean, 2023)
  - Higher revenue in 2023, important role for technology in this, e.g., product lifecycle management (PML) or enterprise resource planning (ERP) software (Aptean, 2023)
  - Retail 71%, foodservice 29% of all food expenses in 2022 (Berkhout et al., 2023)

5.2 Business models and Animal production

- 24/7, direct selling points
- Farm structure
- Meat production trends
- New technologies
- Strengthening of the farmer-consumer relationship
- Tourism as a business model for farmers

5.3 Business models and veterinary activities

- Collaboration and multidisciplinary care increases (veterinarian practices work together with other specialists and disciplines like behavioral professionals or physical therapists to treat animals more holistically) https://www.marktdata.nl/nieuws/Ontwikkelingen-en-trends-dierenartspraktijken

- In 2020 +- 118 million farm animals (102 chickens, 12 pigs, 3.8 million cattle, pets most revenue (60%), second cattle (20%), third pigs (9%), yearly veterinarian costs on average €140 per cat, €160 per dog https://www.rabobank.nl/kennis/s011142757-positieve-verwachtingen-voor-de-dierenartsbranche
- Number of veterinarian practices with one or more branches: 2400 (60% pet oriented, >20% mixed and +- 5% horses). There is also upscaling: bigger practices differentiate tasks, working times, etc.
- Chain formation happens: smaller practices collaborate more often, which makes it possible to offer specialized knowledge (e.g., DierenDokters). https://www.rabobank.nl/kennis/s011142757-positieve-verwachtingen-voor-de-dierenartsbranche
- Foreign parties also enter the Dutch market. 20-25% of the market are chains. Chains occur due to feminization of the profession and a declining aspiration of young veterinarians to own a practice https://www.rabobank.nl/kennis/s011142757-positieve-verwachtingen-voor-de-dierenartsbranche
- 2021 trends: bigger chains (e.g., Evidensia, Anicura, CVS) grow but less takeover than previous years, covid-19 -> increase of cat and dog pet animals -> overflow of veterinarian practices; higher prices caused by chains + more veterinarian hospitals lead to increased costs of medical healthcare in practices, more pet insurances, more independently practicing veterinarians, https://www.raadgevers.nl/blog/trends-in-veterinair-nederland-voorjaar-2021/
- 3742 (veterinary service main activity) + 638 (veterinary service sub activity) registered (KvK) businesses in NL currently, growth compared to previous years (21.1% from 2017 – 2022), most businesses in Noord-Brabant (631, 16.9%), smallest number in Flevoland (72), industry revenue increased with 22.4% between 2018-2020 (65% between 2010-2020) https://www.marktdata.nl/nieuws/Sterke-groei-veterinaire-sector#:~:text=Het%20aantal%20bedrijven%20met%20als,3.350%20in%20het%20jaar%202022.
- General branch info and numbers veterinary service: 2835 companies Q4 2022, 6.70% sales growth 2022, -40% consumer and –2.2% producer trust M8 2023 Branchedashboard veterinaire dienstverlening (firmfocus.biz)
- A structural shortage of veterinarians is expected if the demand for veterinary care from the market continues to grow, especially in pet practice. This shortage could increase to as many as 2,000 FTEs by 2040. To enhance the supply of veterinarians, important policy choices are needed that increase the inflow of veterinarians and reduce the outflow https://www.digiredo.nl/is-er-werkelijk-een-tekort-aan-dierenartsen/
- Specific demand and supply of veterinarians is unclear (currently, no central organisation keeps track). Rough estimates of core statistics of the labor market for veterinarians are based on data from the Veterinary Pension Fund Foundation (SPD), Veterinary Medicine Register, NVWA, Koninklijke Nederlandse Maatschappij voor Diergeneeskunde (KNMvD) – the professional organization for Dutch veterinarians, previous SEO publications Studie & Werk (SEO, 2016; 2020) and recent web search of the SEO) (SEO, 2022):
  - Approximately 6000 veterinarians currently work in the Netherlands
    - Of which 75% in a veterinarian practice (of which 80% working with pets, 20% with horses and almost half works with at least one type of farm animals (due to overlap this exceeds 100%)
    - Approximately 1500 veterinarians don't work in a veterinarian practice
    - Approximately 600 veterinarians work for NVWA
  - 75% of the veterinarians work at least 4 days a week. Women more often work parttime than men.
  - Approximately 1000 veterinarians switched to a non-veterinarian profession that does not match the training of Veterinarian Medicine (approximately 15% of all veterinarians)
- Labor market flow changes due to influx of Utrecht University and Ghent University graduates, immigration from other European countries and outflow (i.e., those leaving the vet job market) of veterinarians and retirement. Other sources of influx (reskilling at later age) and outflow (work disability or death) may influence the change mildly (SEO, 2022).
  - Influx past years: 380 veterinarians per year:
    - 160 from Utrecht University but expected to increase to 230 from 2025 due to 'zij-instroom'/study transfer

- 60 from Ghent University (+- 33%, whereas almost 0% 30 years ago) and expected to decline from 2025 as places will decrease and admission tests will be required
- 160 from immigration
- Of which an increasingly large number is female (currently +- 80%, which was almost 0% 40 years ago)
- Differentiation of pet animals increasingly popular (from +- 33% 40 years ago to 66% today)
- Also inflow from husbandry -> indicates flexibility between specializations

- Outflow: uncertain, premature outflow from veterinarian practices +- 120 vets per year (of which a large amount switches to another veterinarian job), +- 100 vets per year retire
  - Outflow from practice often to other veterinarian professions (governmental, private: consultancy firms or pharmaceutical, education)
  - Reasons for outflow of practices are: high workload (workload and work stress are mentioned by 50% of the switching veterinarians, highest for veterinarians working in practices, research and education, for female veterinarians twice as much the reason to stop working in a veterinarian practice, workload and stress mostly caused by understaffing and demanding customers, other reasons are: poor collaboration, job insecurity and lack of flexibility), work/private life balance, employment conditions, growth opportunities, insufficient perceived support from the employer (+- 30%)
  - 30% of outflowing veterinarians leave because of reasons related to the content of the job (which may be positive, such as wanting to learn something new)
- Although these numbers suggest that the influx > outflow, this is uncertain because outflow numbers outside of veterinarian practices are unknown
- Male veterinarians working in a practice have a higher salary than female veterinarians working in practice. This can be partly explained by men working more hours and being older on average, but despite correcting for these factors there is still a difference
- It is unsure whether there is a shortage of veterinarians that is higher than for other professions, the first half of 2022 there was a general labor market tightness including veterinarians
  - Scarcity of veterinarians increased more strongly in the past decade than other professions, indicated by starting salaries and job opportunities that increased harder in the period of 2009-2020 than those of other professions
  - Increasing scarcity of veterinarians may jeopardize public interests such as animal welfare, animal health, food safety, public health and the environment -> limiting scarcity (for which workload and work stress seem important signals) is important
  - For pets, the NVWA and the provinces of Zuid-Holland and Noord-Brabant, the absolute number of job vacancies was high in 2022
- Starting veterinarians often get paid relatively good compared to other, university educated, starters and search time for a job short, but after 10 years of work experience veterinarians' rewards are small compared with other professions
- The SEO conducted a scenario-analysis including for possible scenarios until 2040 that have specific policy implications. To indicate which scenario is more likely, core statistics of the labor market of veterinarians should be mapped out more precisely, as well as monitor the development of the healthcare demand and to analyze which determinants of the care demand are most important

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• Appendix 2 - Country scenarios

• Local route for sustainability country differences

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
Sustainability						
Consumers are focused on ethically produced products	Consumers are reducing meat consumption	Precision agriculture tools and integration of systems is being implemented	Resource efficiency	Livestock farmers are focused on collecting and disposing waste properly.	Food markets, cooperatives and short food supply chains are the renewed trends	Consumers are focused on ethically sourced products
Waste is intended to be reduced by e.g. direct sales, farm markets	Establishing community-supported agriculture	Recovery and valorisation of animal waste and all outputs for the production of fertilizers; renewable energy is the norm.	Agenda-setting consumers are demanding healthy, safe, and sustainable food.	Food industry is focused on "green solutions" for the recycling of products and materials for reuse purposes	National livestock production is sufficient so, imported meat will be reduced.	Short supply chains and direct sales contribute to waste reduction
High diversity of plants and animals enable a highly diversified nutrition of consumers.	Improving husbandry conditions	Increasing respect for animal welfare principles	The Danish Veterinary and Food Administration (DVFA), supports companies to achieve their goals	Anaerobic digestion as a waste management method	A major development in Portugal of protein production from insects.	Local production and distribution
Veterinarians are personally involved in the wellbeing of animals and have close contact to farmers.		Reduction of waste			Veterinary services are provided by local co-operatives or other local organizations	Medical solutions options are recycled and/or re-used
		Farm management becomes more efficient, reducing the economic and health impact resulting from drug abuse.			Anaerobic digestion to transform livestock effluent into biomethane.	
Digitalization						
Consumers want convenience through digitalization from their local food producers and markets	Technical applications connect consumers with nearby farmers	Precision agriculture tools in livestock facilities are implemented to improve the quality of management.	Fostering connections between producers and consumers, promoting sustainability, and enhancing the local food economy.	The digital transformation of Greek companies has been raised as a prerequisite for growth and maintaining their competitiveness.	Communication of (sustainability oriented) practices on a local scale.	Technology is used to support communication of (sustainability oriented) practices on a local scale
Sustainability	Consumers	Precision	Digital	Veterinarians are	Remote sensing	Sustainability

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
drives digital entrepreneurship on a local, small scale.	and producers work with personalized recipe suggestions based on seasonal, local ingredients	animal health systems are used and field operation management systems lead to a large amount of data	marketplaces and distribution platforms connect consumers with local farmers	aware of the legislation and know-how of operation of automated machinery while digital analysis of some external features	technology	drives digital entrepreneurship on a local, small scale.
Animal welfare, disease and medication are precisely monitored by veterinarians.	Technical devices enable animal owners to directly contact veterinarians		Develop guidelines, and regulations for the digital Danish veterinary practice.	Basic knowledge on digital tools is constantly improving in the livestock sector	Telemedicine	Rising pet adoption and increased health monitoring and management result in less availability of veterinarians.
One-Health						
Consumers are concerned about mindful eating, healthy lifestyle, ethically produced food and a circular, transparent food supply chain.	Establishing community-run "health hubs" can provide integrated healthcare services	Build effective collaboration between the human and animal health sectors	Transparent communication and consumer engagement build trust and confidence in the safety, integrity, and sustainability of Danish food products.	Transparent, short supply chain and organic-extensive livestock farming is promoted, by following traceability and avoiding the production of unsafe products for humans.	Consumers become more concerned with the spread of pathogens, motivating local businesses	Ethical consumerism drives innovation in food options which improve the balance between environmental, animal and human health.
Local production drives businesses and economy to invest in short supply chains and circular economy.	Focus on organic farming and transparent supply chains	One Health, understood as a health and environmental unit also to minimize the probability of zoonotic spillovers.	Minimize disease transmission and promote public health	There is a local demand for safe products	Biosecurity	Consumers become more concerned with the spread of pathogens, motivating local businesses to take more prevention and control measures
Overall monitoring of pathogens is taking place	Community health days		A national One-Health coordination mechanism			The public demands animal health and welfare improvements beyond regulations.
Veterinarians are more concerned about diseases prevention						
Business models						
Livestock numbers decrease and there is also less concentration of livestock.	Zero-waste culinary incubators	The connection with the consumer base is strengthened by providing feedback and information.	Collaborative initiatives involve farmers, producers, distributors, retailers, and other stakeholders	Local animal production and food industry companies,	Close collaboration between the food industry and livestock farms provides sustainable, local-to-local and traditional	Close collaboration between the food industry and livestock farms provides sustainable, local-to-local and artisanal

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
					products.	produce.
Close collaboration of veterinarians, farmers, and meat producers	The demand of meat continues to decrease	Circularity is key: the structure of the farm must change in a more independent way.	Danish farmers recognize the importance of integrating One-Health principles into animal production business models to promote sustainable practices	New entrepreneurship steps in the food industry are mostly made by young people, on a local scale, promoting organic and new products.	Food industry and animal production business models focus on consumers' preference for a sustainable diet.	Food industry and animal production business models focus on consumers' preference for a sustainable diet.
Veterinarians use the concept of joint practices	Animal medical care centers	An ever-increasing number of breeders participate in training and educational events, becoming specialized personnel.	Danish veterinary practices offer preventive health programs and wellness services	Skilled and experienced professionals help their colleagues and partners to advance their knowledge.	Small and family-owned farms, focusing on ecological production, win back business terrain.	Livestock numbers decrease and there is also less concentration of livestock.
					The veterinary shift towards companion animals continues and also on wild life.	For veterinarians more options for health care and wellbeing arise, with a focus on preventive and holistic care.
					Cooperatives and farmer associations have locally veterinary services	Collaboration between veterinary specialists, disciplines and practices aims to provide holistic treatment

- Route continued for sustainability country differences

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
Sustainability						
Governmental policy supports (1) the increasing percentage of plant-based food in human and animal diets and (2) consumer education towards a more sustainable diet	Government regulations in Germany become stricter	A significative reduction of GHG emissions, along with the preservation and conservation of livestock biodiversity and genetic heritage to promote a close link between animal and territory.	Danish national government continues to support organic food production via public procurement.	Governmental policy supports livestock waste reduction and proper collection.	EU directives and national policies invest in more balanced diets, with more vegetables	Governmental policy supports the increasing percentage of plant-based food in human and animal diets.

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
Circularity a continuing work in progress.	To foster trust into the food system, "food passports" are implemented	The growth opportunities of the farm are increasing, as are the opportunities for employing specialized personnel, with better feedback from the market and the consumers	The Danish government-controlled animal welfare label is a strong parameter	Industry promotes sharing economy and the CE strategy is considered as environmental responsibility	Raw materials and packaging are recycled more, and food waste is reduced	Raw materials and packaging are recycled more, and food waste reduced
Livestock production systems with free-range (indoor) options for animals are common	Precision livestock farming will help make husbandry economically more efficient	In more stable scenarios, the selection of animals on the farm will be better, and will reward the healthiest ones.	The use of antibiotics in Danish dairy, poultry and pork production is among the lowest in Europe.	Developments are forcing the otherwise non-accepting farmers to adopt new technologies and precision livestock farming systems.	Consumers and the market continue to demand that producers show concern for animal welfare in their production process.	Emission quota are established, with most reductions accounted for in the animal production sector
In the veterinary sector circular product design (medical devices), waste prevention, reuse and refurbishment of resources is pushed by increased regulations.	Telemedicine in VET practices will be fostered helping medical diagnosis become more convenient for pet owners.	The use of the drug will be proportionally reduced and the quality of breeding will be improved.			Focus is lowering the use of ray materials	
		The paths towards organic products are growing, which affects increasingly larger slices of the market.				Veterinary professionals collaborate for circularity of the sector following increased regulation.
Digitalization						
Precision agriculture is used in many subsectors to optimize use of resources in particular, large farms	AI tools help businesses adapt to changing market demands while minimizing waste and emissions.	The use of technology reduces the burden of work in some sectors of the farm, creating different jobs that require adequate training.	The digitalization standard scenarios implemented in the Danish food industry are enhancing efficiency, sustainability, and transparency	Precision livestock farming technologies	The widespread use of automation technology supports food supply chain resilience following disruptions	The widespread use of automation technology supports food supply chain resilience following disruptions
Environmental initiatives and strategic business goals	Smart farming monitors eating behavior of animals helping	The study of Big Data makes animal and livestock	The Danish government provides financial	Food companies consist of employees who are up-to-date	Environmental initiatives and strategic business goals	Environmental initiatives and strategic business goals

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
are more often connected to invest in digital technologies	to optimize feed input	management more organised.	incentives and support for farmers to adopt digital technologies	and familiar with digital tools and new technology.	are more often connected to invest in digital technologies which support sustainable growth.	are more often connected to invest in digital technologies which support sustainable growth.
A strict EU+ animal welfare policy has been implemented for slaughterhouses	VETs can directly access farm animal data bases to check the health status of individual animals	Digital skills, information management on the farm, traceability and field operations are honed.	Digitalization facilitates enhanced epidemiological surveillance	Training sessions and initiatives are developed to help veterinarians to better adopt and use the increasing digital systems.	Information and data control systems in intensive animal production are very important for reasons of production efficiency and animal health and welfare	As policy regarding animal health and welfare is becoming more strict, the animal production sector is using digital technologies (PLF) to allow for better adaptation of the environment to animal needs and improved health management.
				The use of precision digital tools to the animal production sector are essential for better monitoring of animal living conditions	Electronic prescription is mandatory to respond to the new legal requirements and to control the use of antimicrobials	Increasing digital systems are implemented to improve quality assurance.
One-Health						
Consumer health maintains to be a prioritized focus for the quality management in food industry	One-Health remains an academic project with little impact on the everyday life and awareness of the population.	Strengthening laboratory diagnostic capabilities for new pathogens	Denmark promotes sustainable food production systems that prioritize environmental stewardship, animal welfare and social responsibility.	Governmental bodies and policy makers promote public awareness regarding food loss, animal health-welfare and environment protection.	Food security - with the meaning of access to food for all, but also access to balanced diets.	Policy improves professional and public awareness of the role of food in human, animal and environmental health.
Production, processing and import and export regulations become more strict	One-Health will increasingly be acknowledged as an interdisciplinary and holistic approach,	Improve disease case management and infection control.	Denmark upholds ethical considerations	New policy drives livestock and food industry businesses to get familiar with legislation related to one-health	Food safety - Prevention and control measures are strict.	Pathogens are closely monitored by the government to reduce spread of infectious disease between humans, animals and the

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
						environment.
The increase of alternative protein intake is promoted	The use of antibiotics is being increasingly regulated	It has been prevented antimicrobial resistance, a threat that passes through the responsible use of antimicrobials and attention to environmental contamination.	Interdisciplinary training opportunities foster collaboration, communication and teamwork among professionals from diverse backgrounds,		Veterinary medication usage is strictly monitored.	Veterinary medication usage is strictly monitored.
Chemical pesticides are reduced		Increased awareness related to food and food waste, to reduce poverty and inequality also in food supply;				
Sales of antibiotics is reduced		Push for regulation of the food industry and food education.				
Business models						
Various small businesses/start-ups were founded producing new food products	Economic actors in the food sector agree with politics to pass a law that prohibits food waste and make it easier for companies to donate leftover food	Multi-functional farms are starting to develop both as individual farms and cooperatives.	Diversification	Driving collaboration between different sectors, affects the final products quality and transparency.	Safety and quality are key issues in food chain management, driving collaboration between businesses.	Safety and quality are key issues in food chain management, driving collaboration between businesses.
Vegan alternatives are produced	Industry goes for plant-based meat alternatives and they foster the strategy of premium meat and dumb cheap meat	Self cultivation for feed, implementation of renewable energy sources, integration of precision agriculture systems in livestock facilities is ongoing.	Danish animal producers prioritize animal welfare and transparency	New business models, support by governmental funding is mainly adopted by young people that have been taken educational marketing sessions.	Policy initiatives support trend of "healthifying" consumer diets.	Policy initiatives support trend of "healthifying" consumer diets.
Farms aim to improve production efficiency while meeting increasing political demands regarding animal health and food	Veterinary practices with only one or two VETs are bought up by large, specialized investment funds	Specialized personnel acquire/improve their technical and digital skills: the transition to the use of virtual realities and artificial intelligence in	Danish veterinary sector wants to focus on how collaboration with stakeholders can be further developed in the overall	Associations are developed in order to bring together various stakeholders from the veterinary and animal production	Number of livestock farms decrease, but size and production increase.	Numbers of livestock farms decrease, but size and production increase. F

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
safety		the company is refined.	portfolio of tasks.	sector.		
Collaboration between veterinarians and veterinary disciplines is mainly driven by policy measures					Sustainability measures force further reduction of livestock imports.	Sustainability measures force further reduction of livestock (concentration).
The shortage of veterinarians is counteracted by making the job more attractive to young people					Collaboration between veterinarians and veterinary disciplines is mainly driven by policy measures	Collaboration between veterinarians and veterinary disciplines is mainly driven by policy measures

- Tech route for sustainability country differences

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
Sustainability						
Sustainability is reached by an innovation supported circularity system	Introducing a mobile app that utilizes augmented reality to educate consumers about sustainable food choices	"Enhancement of closed-cycle farming and feed production according to the principles of the REG. EU 848/2018 on organic agriculture to guarantee the absence or drastic reduction of the use of chemical products.	One of the biggest environmental challenges is waste from single-use plastic packaging.	Livestock units value waste management for the protection of the area and are supported through technological tools	Consumers prefer sustainable diets, specific to their needs. Food demand is more diverse, according to own's needs, from DNA analysis.	Consumers value convenient and personalized diets, which are supported through technological innovation.
Reduction of meat is achieved by fostering cell culture meat and 3D printed food	Implement "green corridors" in urban areas of Germany, where abandoned spaces are transformed into community gardens	Propensity towards extensive forms of farming, outdoors or, if intensive, with a considerable reduction in stocking density compared to the minimum legal limits.	A new briefing technique can unlock the high protein content of Danish clover grass	Leading Greek companies are switching to a CE model by adopting or developing specific CE procedures and technologies available	Production, processing and distribution innovations support circularity. E.g., improved energy efficiency and (biodegradable) packaging innovations reduce waste.	Production, processing and distribution innovations support circularity.
Emission reduction is achieved by widespread use of technology	Computer-monitored aquaculture will help to further scale this form of production,	Complete reduction of waste.	The implementation of precision livestock farming	Precision livestock farming technology supports emission	Online food shopping.	Precision livestock farming technology supports emission

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
				reduction and waste management in the livestock sector		reduction
Reduced number of livestock farms, those existing are getting larger and more efficient– supported by technologies	VET telemedicine apps reduce the need to drive to veterinary practices yourself and thus help to avoid unnecessary journeys	In high tech paths, the aid of computerization and robotization of procedures will lead to the elimination of the risk of overdose, abuse and improper use of the drug, in a more sophisticated analysis and anticipation of the needs of the breeding, in a better quality in terms of health and efficiency in leaders and management.			The use of precision livestock farming (PLF) will make it possible to minimize the environmental and climatic impacts of this activity, while keeping production adequate for consumption.	The veterinary sector invests in technology solutions that lower the use of raw materials in medicinal packaging.
Veterinarians use diverse technical tools to obtain animal health and welfare					The veterinary sector invests in technology solutions that lower the use of raw materials in medicinal packaging.	
Digitalization						
Purchasing and communication is completely relocated online	Utilize blockchain technology to enhance transparency and traceability in the food chain	SMART FARMS are developing and cooperation between farmers and customers/food industry is strengthening.	Food industry invests in digitalization to meet the changing demands of consumers and improve efficiency in the production process.	Extensive farming encourages engagement in new technologies to remain competitive and optimize their production.	Data-driven business intelligence, sensors and robotics become common and resources are more optimally utilized.	Data-driven business intelligence, sensors and robotics become common and resources are more optimally utilized.
Consumers want to track their health, nutrition and ecological influence	AI-supported camera systems track farm animals in real time and automatically detect changes in behavior that could indicate health problems.	Traceability is complete, allowing the prevention of serious pathologies on the individual animal and on the various animals, as well as on the staff who manage them. The use of robots and	Relevant digital technologies include invasive as well as remote sensors for livestock monitoring	Pioneering digital technologies, are becoming increasingly important to businesses.	Digitalisation follows the aim to support competitive business growth on a large (global) scale. Improving efficiency of production is a catalyst.	Digitalisation follows the aim to support competitive business growth on a large (global) scale. Improving efficiency of production is a catalyst.

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
		drones is widely implemented and determines scrupulous, efficient and effective factor management.				
AI technologies are widely used in quality assurance and monitoring of animal health.	Develop a virtual reality training program for veterinarians and animal health professionals, allowing them to simulate various scenarios		Predictive analytics and modeling tools help veterinarians and public health officials anticipate disease spread	New digital tools enable more efficient diagnosis of animal health issues.	PLF is implemented widespread. It supports circularity through enabling optimal production efficiency, lowering feed loss and (animal) waste as a result	PLF is implemented widespread. It supports circularity through enabling optimal production efficiency, lowering food loss and (animal) waste as a result.
Digitalisation enables more efficient use of medication/ resources				The use of digital tools and platforms is implemented widespread, supporting the animal production sector activities	Digitalization enables the use of large amount of information (Big data).	Digitalisation enables more efficient use of medication / resources, reducing waste, improved communication with clients (including telemedicine) and increasing collaboration between veterinarian stakeholders.
One-Health						
Huge AI based databases are involved to enable government control	Develop AI-powered diagnostic tools that analyze environmental data, animal health records, and human health indicators to identify potential disease outbreaks	Develop epidemic preparedness and response capabilities for emerging zoonoses.	Smart Food Safety Systems (e.g. blockchain) and Nutritional Labeling are Public Health initiatives to provide consumers with clear and accurate information about nutritional content and health benefits	Large-scale traceability tools are used across the value chain by the businesses to improve their global competitiveness regarding the production of ethic products.	Global competitiveness drives businesses to become more driven by environmental and animal health, through technology	Global competitiveness drives businesses become more respective of environmental and animal health.
Consumers are concerned about a healthy and sustainable diet. Personalised diets are	Developing wearable health monitoring devices for livestock that continuously track vital signs	Animal health and welfare, are considered two inextricable factors based on management structures from	By harnessing innovative technologies, Denmark improves animal welfare, enhance	Livestock and food industry businesses implement digital innovations which help to	Businesses implement digital innovations which help to prevent, detect and control	Businesses implement digital innovations which help to prevent, detect and control

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
achieved by e.g. microbiome and DNA testing.	and behavior.	breeding to slaughter through transport that preserve the life worth living principle.	environmental sustainability and safeguard public health.	prevent, detect, and control animals' health and the safety of the final food products.	pathogens and secure (safety of) the food supply chain.	pathogens and secure (safety of) the food supply chain. Examples are PLF and closed systems.
Food safety and mitigation of pathogens is an important topic	Develop wearable health monitoring devices for pets and farm animals,	"Reduction of food alteration /appetization processes through food production ultra-processed with high caloric density, especially rich in fats and added sugars."	Denmark institutes technological mechanisms for continuous monitoring, evaluation and adaptation of One-Health initiatives in the veterinary sector.		Increasing use of advanced diagnostic techniques support early diagnosis, effective and efficient treatment (less required use of antibiotics).	Increasing use of advanced diagnostic techniques support early diagnosis, effective and efficient treatment (less required use of antibiotics)
Digital solutions are used to monitor the health of livestock						
Business models						
Large food supply chains collaborate and cooperate on an international scale. Safety assurance and traceability systems are essential.	Establish a digital platform that connects farmers with surplus produce to food banks and charities in need,	Multi-functional "green" farms have being optimized.	Denmark's food businesses leverage digitalization and e-commerce platforms to enhance customer engagement, streamline operations, and reach new markets.	Large food supply chains collaborate and cooperate on an international scale. Safety assurance and traceability systems are essential.	Large food supply chains collaborate and cooperate on an international scale.	Large food supply chains collaborate and cooperate on an international scale. Safety assurance and traceability systems are essential.
E-Commerce and Online Marketing is the most important tool.	Launching a decentralized food delivery platform that utilizes blockchain technology to connect local producers directly with consumers.	Safety and quality must be assured by managing the food chains properly and efficiently.	Danish animal producers adopt precision livestock farming technologies to optimize animal health, welfare, and productivity.	New marketing trends, using tailor made products and online shopping are developed, establishing new profitable and popular business models.	E-commerce is a profitable and popular business model	Marketing is focused on convenience and personalization.
Livestock farms decrease, but the remaining get larger	Augmented reality will make it possible for consumers to virtually visit the place of origin of animal produce,	The exploitation of the skills achieved expands in the holistic perspective of one-health: innovative exchanges, more aware forms of	The objective is the maintenance and the development of high quality, better control, and inspection.	Information and Communication Technology supports collaboration between veterinarians and livestock professionals.	Intensive livestock farming is still widely implemented to meet the demands.	Livestock numbers decrease, but concentration continues. Small and family farms pave way for corporate farms and chains.

Austria	Germany	Italy	Denmark	Greece	Portugal	The Netherlands
		management, new value chains are created.				
New and more specific job profiles are defined for the veterinary sector,	Digital literacy in the veterinarian sector should be prevented,				The increasing concentration of livestock farming supports data driven business intelligence.	The increasing concentration of livestock farming supports data driven business intelligence. Farmers become more knowledgeable in the field of digitalisation to remain competitive.
					High level of specialization, it is a new trend. Linked with the emerging technologies for veterinary.	Information and Communication Technology supports collaboration between veterinarian

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