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Advanced Technologies for Industry – Product Watch

Sensors for farm management of livestock value chain

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Section 1

1. Background and objectives of the report

Background

The Product Watch Reports have been developed in the framework of the 'Advanced Technologies for Industry' project and serve to identify and analyse 15 promising advanced technology (AT)-based products and their value chains, with an assessment of the strengths and weaknesses of the EU positioning.

Promising AT-based products can be defined as "*enabling products for the development of goods and services enhancing their overall commercial and social value; embedded by constituent parts that are based on AR/VR, Big Data & Analytics, Blockchain, Cloud, Artificial Intelligence, the Internet of Things (IoT), Mobility, Robotics, Security & Connectivity, Nanotechnology, Micro-nanoelectronics, Industrial Biotechnology, Advanced Materials and/or Photonics; and, but not limited to, produced by Advanced Manufacturing Technologies*".

1.1 Background of this report

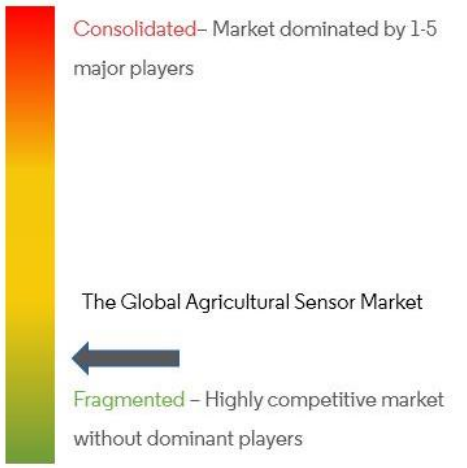
Industry currently finds itself in the fourth industrial revolution, also known as Industry 4.0, which has far reaching impacts, also affecting the agri-food value chains. The OECD defines Industry 4.0 as the use in industrial production of recent, and often interconnected, digital technologies that enable new and more efficient processes, and which in some cases yield new goods and services.[1] The transition to an Industry 4.0, includes the following main technologies: augmented and virtual reality, the Internet of Things (IoT), advanced manufacturing technology, artificial intelligence and big data analysis and cybersecurity. One of the elements of an Industry 4.0 that are particularly wide-reaching is the area of IoT which includes the use of sensors, network components and other devices to gather, collect and exchange data. Sensors can take many forms, either as stand-alone devices, as part of another object or integrated into a service to gather relevant information.

As technology is evolving, so too is the future of agriculture and food. With a growing global population, currently estimated at 7.7 billion inhabitants[2], and expected to grow to 9.7 billion in 2050, where most of the growth between today and then will take place in Asia and Africa[3], the challenge remains to deliver a sustainable food and agricultural production system.[4] Current challenges such as climate change affect the ability of food and agricultural production systems to provide food security and quality, in the face of natural hazards, such as floods and droughts, as well as pest and disease outbreaks. Furthermore, certain consumer groups (so-called 'digital natives') demand higher quality, such as organic food products and more exotic tastes.[5] There is also a need to address the enormous rate of food waste and loss, which is currently on the rise.[6] Innovative systems are highly needed, and technologies have a clear role to play to enable and ensure the transition to sustainable resource consumption across food groups, while ensuring food safety.[7]

[1] OECD(2017) The Next Production Revolution: Implications for Governments and Business
[2] Worldometer (2020, March 20) Current World Population, https://www.worldometers.info/world-population/
[3] FAO (2018) The future of food and agriculture: Alternative pathways to 2050, http://www.fao.org/3/I8429EN/i8429en.pdf
[4] FAO (2017) The future of food and agriculture: Trends and challenges, http://www.fao.org/3/a-i6583e.pdf
[5] Planet labs (2018) The Top Global Trends Driving the Fourth Agricultural Revolution, https://www.planet.com/pulse/top-global-trends-fourth-agricultural-revolution/
[6] FAO (2018) The future of food and agriculture: Alternative pathways to 2050, http://www.fao.org/3/I8429EN/i8429en.pdf
[7] FAO (2017) The future of food and agriculture: Trends and challenges, http://www.fao.org/3/a-i6583e.pdf

The fourth agricultural revolution increases the use of IoT and sensors on farms and allows farmers to make informed decisions about their crops or livestock, but also enables digitalisation and increasingly connected farms.[8] In the agri-food sector, IoT and sensors are responsible for monitoring real time parameters, setting up and being an integral part of smart systems and smart data management, enabling connectivity and information flow across value chains. Sensors are able to measure both product and process elements and can include humidity, electrochemical, mechanical, airflow, optical, pressure, water, and soil as well as temperature, antibiotic, fat, location and pH sensors, among others. The application areas are vast, covering the entire food industry from meat and fish to dairy, fruit and vegetables and bakery and can be used to manage resources such as water, measure conditions such as climate and soil, and monitor livestock, among others.[9] In 2018, the global agricultural sensor market was valued at €1.12 billion[10], with a Compound Annual Growth Rate (CGAR) of 11.04%, reaching a value of €2.34 billion by 2026.[11] The market is described to be fragmented at present, with several smaller players, and no clear market dominance, leading to considerable competition, as depicted in Figure 1.[12] Globally, North America dominates the market, whereas Asia is expected to be the highest growing market due to population growth and government support (see Figure 2).[13] Key players in the global sensor market include Robert Bosch GmbH (Germany), Texas Instruments Inc. (United States of America), Pycno Agriculture (United Kingdom), Trimble Inc. (United States of America) and CropX (United States of America/Israel), among others.[14]

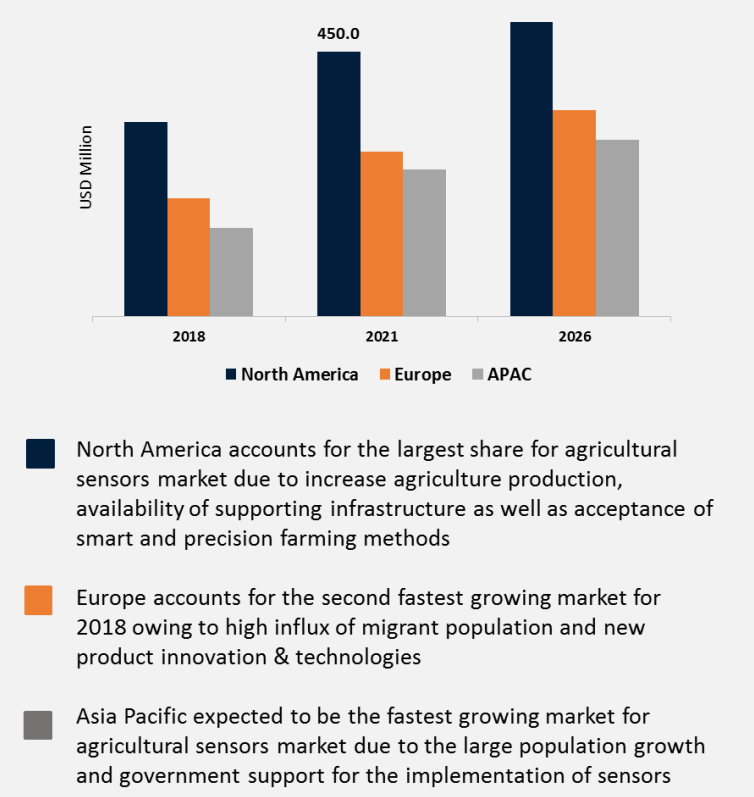
Figure 1: Market concentration for agricultural sensors



Source: Mordor Intelligence, 2020

[8] Planet labs (2018) The Top Global Trends Driving the Fourth Agricultural Revolution, https://www.planet.com/pulse/top-global-trends-fourth-agricultural-revolution/
[9] Mordor Intelligence (2020) Agricultural Sensor Market - Growth, Trends and Forecasts (2020-2025), https://www.mordorintelligence.com/industry-reports/agricultural-sensors-market
[10] All currencies are based on current exchange rate of 1€ = $US 1.08313, 26 March 2020
[11] https://www.reportsanddata.com/report-detail/agricultural-sensors-market
[12] Mordor Intelligence (2020) Agricultural Sensor Market - Growth, Trends and Forecasts (2020-2025), https://www.mordorintelligence.com/industry-reports/agricultural-sensors-market
[13] Reports and Data (2020, January) Electrochemical Sensors, Airflow Sensors, Optical Sensors, Pressure Sensors, Water Sensors, Soil Sensors, Livestock Sensors), By Application Forecasts To 2026, https://www.reportsanddata.com/report-detail/agricultural-sensors-market
[14] Research and Markets (2018) Global Agriculture Sensors Market Size, Market Share, Application Analysis, Regional Outlook, Growth Trends, Key Players, Competitive Strategies and Forecasts, 2018 To 2026, https://www.researchandmarkets.com/reports/4620288/global-agriculture-sensors-market-size-market

Figure 2: Market size for agricultural sensors, North America, Europe and Asia Pacific (APAC)



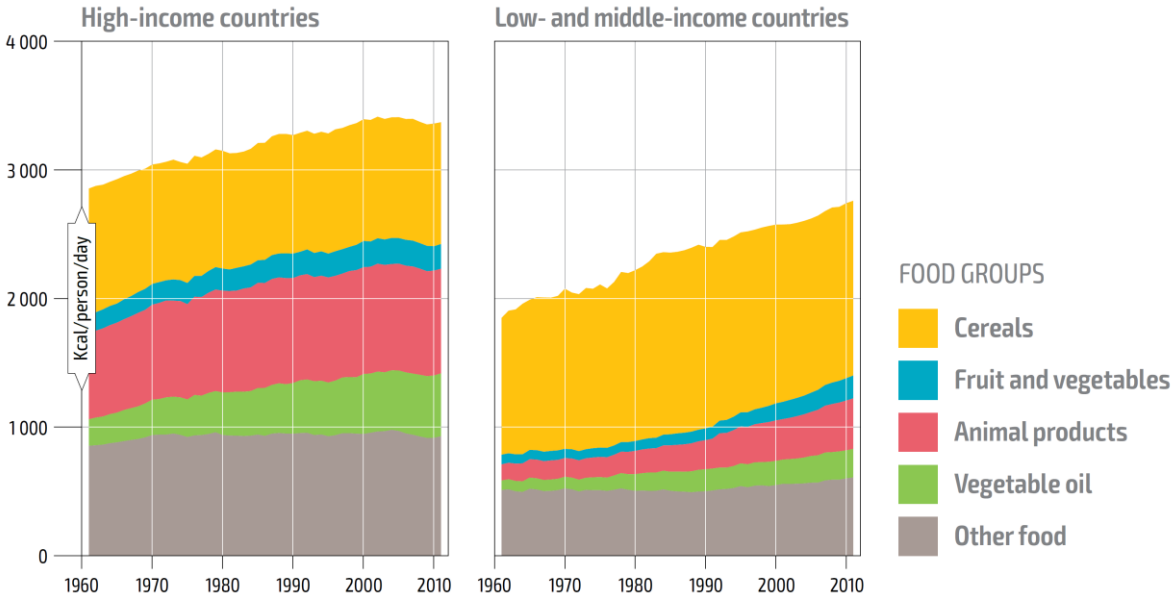
Source: Reports and Data, 2020

Zooming in, livestock application areas are becoming increasingly important, and livestock production is on the rise globally. Consumption patterns are changing, where the consumption of food by food group over the last 50 years (see Figure 3), shows that the overall consumption has increased in both high-income and low- and middle-income countries. Especially the fraction of animal products is on the rise - as countries become wealthier, the share of animal products in diets is also significantly higher.[15] This corresponds to increasing global trends in the number of livestock units per agricultural land area between 1961 and 2017 as presented in Figure 4, with increases on each continent aside from Europe during the observed time period.[16] Livestock farming can be broken down into both intensive livestock farming as well as extensive livestock farming. Intensive farming refers to farming practices that use advanced agricultural techniques to increase the overall yield, such as poultry farming. Extensive farming refers to lower intensity farming per area and typically includes large scale growing of feed, such as dairy farming. In extensive farming, animals are often kept free-range.

[15] FAO (2018) The future of food and agriculture: Alternative pathways to 2050. Rome: Food and Agriculture Organization of the United Nations, http://www.fao.org/3/I8429EN/i8429en.pdf

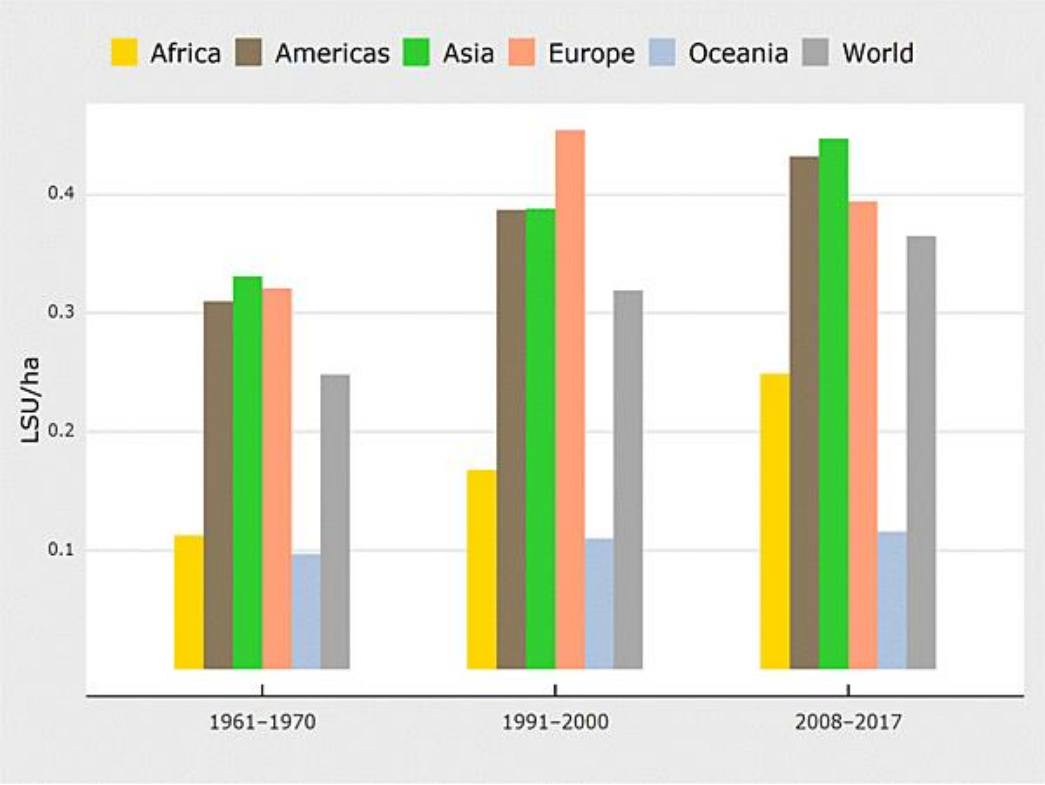
[16] FAO (2019) Environmental Statistics. Retrieved from Food and Agriculture Organization of the United Nations, http://www.fao.org/economic/ess/environment/data/livestock-patterns/en/

Figure 3: Trends in food demand by type of food group and income



Source: FAO, 2018

Figure 4: Global trends in livestock units per agricultural land area between 1961 and 2017



Source: FAO, 2019

Livestock sensors for monitoring and systems to support data collection and analysis are growing in importance as they are able to monitor animal health as well as environmental conditions. Depending on the intensive or extensive nature of the livestock farming different types of sensors and systems can be applied. For example, in extensive dairy farming, ear tags can be applied to detect increased temperature and possible diseases, thus supporting animal welfare and enabling targeted veterinary support with substantial cost savings. As a result, the livestock monitoring market is forecast to grow from €1.38 billion[17] in 2020 to €2.31 billion in 2025, with a CAGR of 10.9%, which is largely due to the adoption of IoT.[18] Building on this, Livestock Monitoring Systems, which draw upon sensors, databases, and other information sources to provide decision support systems are assessed to have a market size of €583 million in 2018. This niche market is expected to reach €1.2 billion by 2023, at a CAGR of 17.9%.[19]

Figure 5: Market development for Livestock monitoring

Source: Markets and Markets, 2020

1.2 Objectives of this report

Industry 4.0 is radically changing the way of farming in Europe. However, most farmers do not yet adopt digital technologies or only invest in proven technologies. Many farmers remain sceptical about the benefits of digital technologies due to a lack of proof of concepts that demonstrate the benefits of these technologies. In addition, customised approaches are often needed to address the specific context of various regions.

The report aims to provide an overview of relevant stakeholders to see how AT based products can help EU industry to stay ahead of global competition. The objective is to map the key players in the sensors for farm management of livestock value chain, as well as to identify their strengths and weaknesses. Analyses were based on desk-research, interviews as well as on the internal expertise of IDEA Consult on the subject.

[17] All currencies are based on current exchange rate of 1€ = $US 1.08313, 26 March 2020
[18] Markets and Markets (2020) Livestock Monitoring Market by Offering (Hardware, Software, and Services), Livestock Type (Cattle, Poultry, Swine, Equine), Application (Milk Harvesting, Feeding, Breeding, Behavior Monitoring & Control), Farm Type, Geography - Global Forecast to 2025, https://www.marketsandmarkets.com/Market-Reports/livestock-monitoring-market-72634532.html
[19] Market Data Forecast (2019) Livestock Monitoring System Market. Retrieved from Market Data Forecast, https://www.marketdataforecast.com/market-reports/livestock-monitoring-system-market

Section 2

2. Value chain analysis

The following chapter explores the specific value chain of sensors for livestock and the associated farm management system including the key actors and the current state of play of the linkages across the value chain.

2.1 Value chain structure

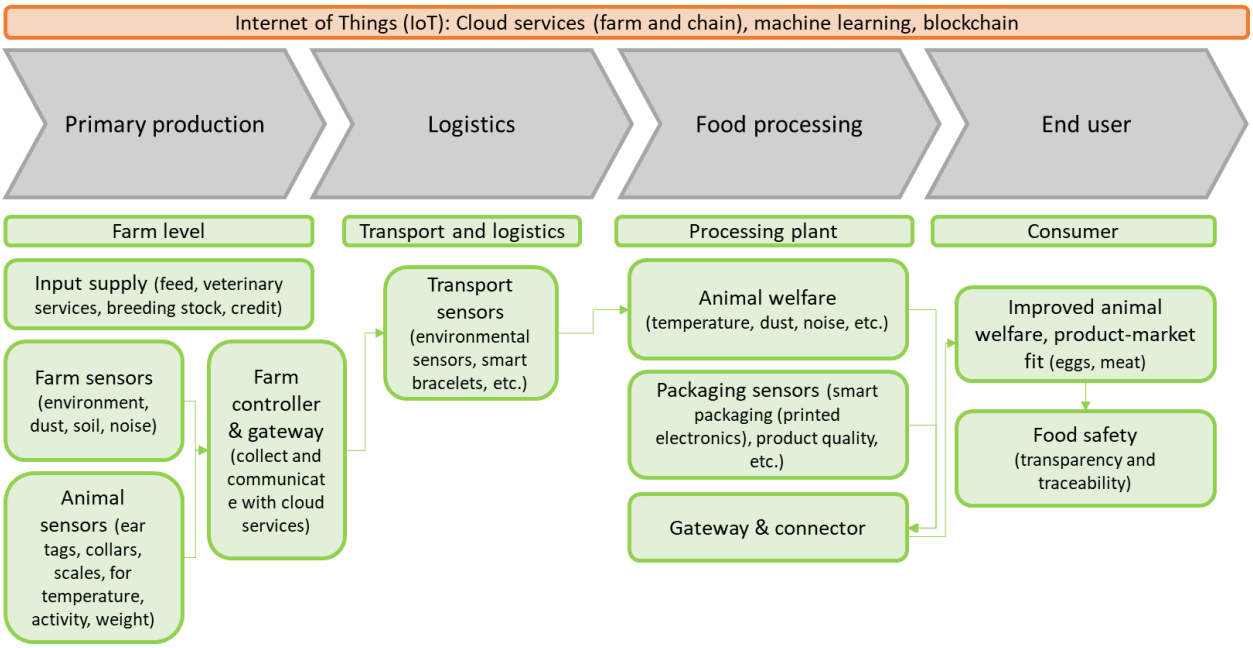
The sensors for farm management of livestock value chain, as depicted in Figure 6 consists of four main elements, namely primary production, logistics, food processing and the end user. Specifically, for each main element, a corresponding and detailed value chain segment is elaborated (in green boxes). IoT supports the entire value chain, to connect the sensors and data systems with one another. Depending on the specific type of value chain within the livestock sector (intensive vs. extensive) different sensors will be applied. For example, in poultry farms (intensive) mainly environmental and dust sensors are applied, whereas in dairy farming (extensive) animal sensors are far more common and the technologies are further developed compared to intensive farming. The value chain is elaborated to consider both types.

The primary production segment at the farm level includes various sensors and technologies to support the collection of farm data such as environmental sensors capturing the conditions of the farm (environment, dust, soil) as well as animal sensors in the form of ear tags, collars, scales, among others to determine, temperature, weight, movement of the animals to ensure their overall health and well-being. In addition, the farm level includes the input supply for the functioning of the farm itself, depending on the specific livestock concerned and includes the feed supply, breeding stock, veterinary services as well as financial resources to purchase infrastructure among other material resources. A farm controller and gateway are responsible for collecting all farm data and serves as an interface to the farmer and can transfer the data to the next value chain segment.

The logistics segment consists of sensors in transport that should help to ensure that transport is safe. Transport sensors include environmental sensors, but also smart bracelets for those handling animals, among others. Currently, transport sensors are applied for livestock transport. Broiler transport systems for closed compartment transport are being developed for the poultry sector. In short chains, logistics segments are minimised with processing plants at primary production sites and proximity to markets and end users[20].

[20] Transport and logistics also take place between food processing and the end user. As the focus of this report is on farm management of the livestock value chain, this step is not explicitly mentioned in Figure 6.

Figure 6: Sensors for farm management of livestock value chain



Source: IDEA Consult based on IOF 2019a; IOF 2019b; Ovo-vision 2016

Food processing takes places in specific forms depending on the livestock in question. Where dairy and egg production are concerned, the orientation is towards milk and eggs, however for beef, chicken or other meats, sensors are targeted towards the animal's physical properties and surroundings at the slaughterhouse. Sensors in the specific environments monitor temperature, noise, dust, among others depending on the specific requirements. Furthermore, food processing also considers the packaging of food. Various packaging sensors exist to capture information about product quality, such as sealing of the packaging, as well as temperature. The decreasing cost of sensors also enables smart packaging, where sensors are included in the product packaging through, for example, printed electronics. These types of sensors can determine the temperature of a product throughout its lifetime and give a signal of product quality if the product has been heated, thus compromising its food safety. However, this type of sensor is still faced with challenges, as it tends to encourage food waste, since consumers are hesitant to buy products that are close to their expiry dates, but that are safe to consume.

The end user of the value chain is dependent on the specific product. Through closer monitoring along the value chain, animal welfare, but also product-market fit and quality, are improved. In addition, information on food safety in the form of transparency and traceability are provided to the end user. End-users are becoming increasingly interesting in animal welfare and food safety issues. Currently QR-codes are applied to allow consumers to obtain more information about the whole value chain. In the coming years this trend is expected to continue, demanding more specific information on animal level, for example information on where a calf is bred and what medications it has received throughout its lifetime will be desired.

Along the entire value chain Internet of Things (IoT) including **cloud services, machine learning and blockchain technologies** connect the sensors and data systems with one another. Sensor data that is collected throughout the value chain, including tracking and tracing, enables transparency and traceability. This can result in labelling and increased pricing and earnings for all stakeholders in the value chain, including the initial farmers and data collectors. Traceability is becoming more and more important, also using track and trace as a quality guarantee. Challenges remain to make use of the data across the whole production system and make it feasible for the farmer and consumer to access this information. This information can also be used to interface

with government about the fulfilment and monitoring of regulatory requirements. Farmers, however, remain sensitive to the use of this data.

2.2 Key actors in the value chain

A series of key actors are essential in the realisation of the value chain. The following list contains the main stakeholders (non-exhaustive) for this value chain. These include:

- Farms
- Intermediaries and cooperatives
- Veterinarians
- Sensor manufacturers
- IoT service providers
- Logistics companies
- Processing plants
- Retailers
- End users

Farms. Farms and farmers are a central element of the primary production and are key stakeholders due to their importance in raising the livestock. Farms have the possibility to implement sensors that depict the first phase of the value chain and thus capture valuable information about animal health and environmental conditions that can be used to improve the well-being of animals and also reduce the environmental impact of farming. Farmers are also data collectors and should recognise the importance and value of the data that is collected on the farm. Potential value for the data from farmers should be capitalised upon to the extent possible.

Intermediaries and cooperatives. Local intermediaries are organisations that have a good relationship with farmers, and act as gate keepers for the introduction of new technologies in the farming ecosystem. Intermediaries can include innovation intermediaries as well as cooperative that have the trust of the farmers. In the case of regional innovation intermediaries, this can include organisations such as Bretagne Développement Innovation (BDI)[21] - Brittany's regional innovation and economic development agency, which can disseminate technologies to farms, and can also be a key stakeholder for promoting technologies from abroad where relevant. In addition, depending on sector and specific national context, farms are often members of first- and second-degree cooperatives. First degree cooperatives are understood to be linked directly with the farms, whereas second degree cooperatives bring several cooperatives together. While in most cases farmers make the final decision on what technologies to implement on their farm, cooperatives do play a vital role in making recommendations to their farmers on what techniques to take up. For example, Arla is a cooperative that represents all dairy farmers in Sweden. While Arla does not impose decisions on the farms, it does have an influential role on the use of equipment and standards. Hence, cooperatives can also be key in deciding whether and which sensors are taken up at farms.

Veterinarians. Especially for the monitoring of animal health, veterinarians are key for temperature monitoring, bacteria detection and executing tests to determine the need for medications and antibiotics. Veterinarians are also responsible for administering and prescribing the medications for farms. Depending on the national context, veterinarians are the only means by which medications can be obtained, thus represent an important actor in the animal welfare aspect of the value chain. When considering the use of artificial intelligence sensors such as those that can detect bacteria, veterinarians are also key in training the AI to detect certain diseases. It is therefore important that veterinarians are involved in the uptake of sensors at farms and even considered in the business model of the technological solution.

Sensor manufacturers. These are companies that are focussed on the production of various types of livestock sensors, both environmental and animal based, but also transport, processing and packaging sensors. In Table 1, a non-exhaustive list of sensor manufacturers specifically

[21] See: https://www.bdi.fr/en/home/

related to the livestock sector are presented. The list was compiled based on a series of sources combined with input from expert interviewees.

IoT service providers. IoT service providers in the livestock value chain provide cloud, dashboard, and other data management and interpretation solutions to help farmers and other stakeholders in the value chain to obtain, track and manage the system as a whole. Table 2 includes a non-exhaustive list of companies that provide data platform services, including the services that enable the sharing of data with different actors in the field and along the value chain.

Logistics companies. Logistics companies are responsible for the transport between the primary production and the processing and end user. Sensors are applied to track the conditions of transport and ensure animal health and welfare.

Processing plants. Processing plants are responsible for the preparation of the food product, whether it is a dairy product, or the preparation and packing of meat. This step can also include slaughterhouses, which can also be equipped with environmental sensors. Packaging sensors are important to track the product quality and food safety. Low cost sensors can be applied also directly to product packaging to detect temperature development during the package lifetime to ensure food safety to the end user.

Retailers. Retailers play an important role in deciding which products to place in stores in order to reach the end user. This includes products that are supported by sensors in their production but also products that include sensors or so-called 'digitally assisted products'. If retailers do not decide to give shelf space to digitally assisted products, the end users have little opportunity to show their preferences.

End users. End users are consumers of the end good, whether it is dairy, poultry, beef or other animal product. End users are increasingly interested in information about the value chain and the food they are consuming.

Table 1: Sensor manufacturers for livestock

Sensor manufacturer	Sensor type(s)	Country	Website
Afimilk	Heat, calving, health	Israel	https://www.afimilk.com/cow-monitoring/
Agricam	Temperature, bacteria, thermal, BHB ketone	Sweden	https://www.agricam.se/sensorer?lang=en
AGRIsales	Temperature, pregnancy detectors	United States of America	https://www.agrisales-inc.com/
Antelliq (distributor)	Heat, calving, health, particles	France	https://www.antelliq.com/allflex-livestock-management
Bosch	Scales for weighing cattle, transponders	Germany	https://www.bosch.com/stories/smart-agriculture/
Copeeks	Livestock: CO_2, NH_3, humidity, animal behaviour	France	https://copeeks.fr/en/home/
CowManager	Ear sensor (fertility, health, nutrition and location tracking)	The Netherlands	https://www.cowmanager.com/en-us/

Sensor manufacturer	Sensor type(s)	Country	Website
Dairymaster	Heat, calving, health, cell count, temperature	Ireland	https://www.dairymaster.com/
Delaval	Cell count, health	Denmark	https://www.delaval.com/da/
Digitanimal	Animal tracking	Spain	https://digitanimal.com/
Dräger	Ammonia	United Kingdom	https://www.draeger.com/en_uk/Home
Draminski	Medical, health, ultrasound, pregnancy detectors	Poland	https://www.draminski.com/
EMS	Temperature, climate, humidity	The Netherlands	https://www.macview.eu/en/
Exafan	Temperature, climate, humidity	Spain	http://www.exafan.com/paginas/productos/subgrupo/12
Fancom	Particles, optical, distance	The Netherlands	https://www.fancom.com/
Farmtech Solutions	Ultrasound scanners, ovulation and pregnancy detectors	Canada	https://www.farmtechsolutions.com/
Gallagher	Weight, light, health	New Zealand	https://am.gallagher.com/au
GEA	Cell count, health	Germany	https://www.gea.com/en/applications/dairy_farming/index.jsp
GPS Tracker Shop	Trackers	United States of America	https://gpstrackershop.com/
Herdsy	Tracking systems	Ireland + UK	https://herdsy.com/herdsy-next-generation-livestock-technology/
Heritage Animal Health (distributor)	Health, breeding, tag trackers,	United States of America	https://heritageanimalhealth.com/317-livestock
Icerobotics	Fertility, lameness, health	United Kingdom	https://www.icerobotics.com/
Impact Vision	Optical	Sweden	https://www.impactvi.com/
Innoscentia	Biochemical	Sweden	https://www.innoscentia.com/technology/
John Deere	Temperature, manure nutrient levels	United States of America	https://www.deere.com/en/electronic-solutions/sensors/
Luda Farm	Security, motion detection	Sweden	https://www.luda.farm/
MicrochipID	Trackers	United States of America	https://www.microchipidsystems.com/your-work/livestock/
Nedap	Health, livestock management, identification, recording	The Netherlands	https://www.nedap-livestockmanagement.com/
Qcsupply (distributor)	Temperature, moisture, pressure, feed	United States of America	https://www.qcsupply.com/

Sensor manufacturer	Sensor type(s)	Country	Website
QuantifieAG	Health	United States of America	https://quantifiedag.com/
Sensefarm	Temperature, moisture, humidity, climate	Sweden	https://www.sensefarm.com/
Sensephone	Monitoring systems	United States of America	https://www.sensaphone.com/industries/livestock
SKOV	Particles, climate control, humidity, optical	Denmark	https://www.skov.com/EN
Sol-Chip	Temperature, lights, climate, humidity, health	Israel	http://sol-chip.com/
Soundtalks	Animal health monitoring	Belgium	https://soundtalks.com/products
Väderstad	Optical	Sweden	https://www.vaderstad.com/en/
Vaisala	CO_2, dew point, humidity, H_2, H_2O_2, CH_4, temperature	Finland	https://www.vaisala.com/en
VFA-Solutions (ASPRA line)	Indoor air quality, temperature, CO_2 concentration, relative humidity, sound, light intensity, particulate matter, air flow	The Netherlands	https://www.vfa-solutions.com/en/products/accessories/sensoren/
Winsen	Temperature, humidity, ammonia, CO_2, H_2S	China	https://www.winsen-sensor.com/application/husbandry-solution.html

Source: compiled by IDEA Consult based on data from Wageningen Research & University, 2018, MarketsandMarkets 2020, Mordor Intelligence 2019, Reports and Data 2020, Market Data Forecast 2019, Smart Farming (n.d.), Internet of Food & Farm 2019a and b, and Market Watch 2019

Table 2: IoT service providers for livestock sensors and farm management

Company	Country	Website
Biosens	Serbia	https://biosens.rs/?page_id=10936&lang=en
BMP Innovation	Sweden	https://www.bmpinnovation.se/
Bosch	Germany	https://blog.bosch-si.com/agriculture/connected-agriculture-beefed-up-networking-in-brazil/
Cainthus	Ireland	https://www.cainthus.com/
Connectera	The Netherlands	https://www.connecterra.io/about/
COPEEKS	France	https://copeeks.fr/en/home/
CowManager	The Netherlands	https://www.cowmanager.com/en-us/
CSEM	Switzerland	https://www.csem.ch/Food
Dol SENSORS	The Netherlands	https://www.dol-sensors.com/products/dol-53/
ENGS Systems	Israel	http://www.engs-dairy.com/
Fullwood Packo	United Kingdom	https://fullwoodpacko.com/

Company	Country	Website
Hokofarm-Group	The Netherlands	https://hokofarmgroup.com/
Infovet	India	http://www.infovet.in/index.php
Lely	The Netherlands	https://www.lely.com/be/nl/
Motorleaf	Canada	https://www.motorleaf.com/
Nedap	The Netherlands	https://www.nedap-livestockmanagement.com/
Sensowave	Spain	https://sensowave.es/en/
Slimme Stal	The Netherlands	https://slimmestal.nl/
Smart Stable	The Netherlands	https://slimmestal.nl/
Sol-Chip	Israel	http://sol-chip.com/
Stalmeesters	The Netherlands	https://stalmeesters.nl/
Sum-It	United Kingdom	https://www.sum-itsoftware.co.uk/
Valley Agriculture Software	United States of America	https://web.vas.com/

Source: compiled by IDEA Consult based on data from Wageningen Research & University, 2018, MarketsandMarkets 2020, Mordor Intelligence 2019, Reports and Data 2020, Market Data Forecast 2019, Smart Farming (n.d.), Internet of Food & Farm 2019a and b and, Market Watch 2019

2.3 Linkages along the value chain

At present, data sharing across the farm management of livestock value chain is limited. Only where farms implement precision farming or some sensors or IoT system is this feasible, however not all value chain segments are digitalised and thus data sharing is poor.[22] Sensors and data, as well as improved interoperability and platforms can enable this further. As farms integrate sensors and generate data, it becomes apparent that there is a need for seamless interoperability among the various emerging data platforms, based on standard interfaces, to avoid lock-in situations and to enable the collection of all information along the value chain and make it visible. Currently various companies are working on separate parts of the value chain; however, it would be desired to have all information centralised in one data platform. For example, Stalmeesters provide sensors, that they purchase from a certain producer, but they also make their system available for sensors from other companies. This approach can start at farm level and be expanded. In addition, there is also a need for a data broker. A data broker is a stakeholder that can safeguard information along the value chain, collecting it and permitting use and access to certain parts of the data to certain stakeholders in a secure manner. For example, Kiwa acts as a broker in the data collection on manure processing.[23]

Some large companies use sensors technology for their own purpose, but they have such an amount of data that it would be advisable to see if the use of their data could be expanded. For example, the global market leader of egg selecting machines has data on one billion eggs per day being processed by its machines. Currently, the data is only used by the company. However, it could be interesting to revisit ways to work with large companies to have access to the results of the data from the sensors in their machines through a bottom up approach. This can be complemented by policy making to enable this possibility through requirements to large companies.

[22] IOF (2019a) *DECISION-MAKING OPTIMISATION IN BEEF SUPPLY CHAIN*, https://www.iof2020.eu/trials/meat/iot-and-blockchain-for-beef-supply-chain.
[23] Kiwa (n.d.) Kiwa Data Solution, https://www.kiwa.com/nl/nl/markten/management-systemen/data-solutions/

Section 3

3. Analysis of EU competitive positioning

An indication of the EU competitive positioning can be outlined according to the strengths and opportunities as well as the risks and challenges faced. Figure 7 depicts an overview of these key strengths, opportunities, challenges and risks for the sensors for farm management of livestock value chain.

Figure 7: Strengths, opportunities, challenges and risks for the sensors for livestock value chain

Source: IDEA Consult

3.1 Strengths

Leading in precision livestock farming. Thanks to a strong industry and a strong agricultural policy, the EU agricultural and food related industry creates regular work for over 20 million people, with up to 44 million jobs.[24] The EU is a leading producer and exporter of agricultural products. This can be attributed to the varied climate and soil conditions, in combination with the strong technical and industrial skills of the farmers and supporting stakeholders, such as innovation intermediaries. These strengths enable further innovation and the optimisation of the livestock sector, adopting new technologies such as sensors and farm management tools.

Building on the agricultural industry, EU livestock farming has become specialised in precision livestock farming. Precision livestock farming includes milk harvesting, feeding management, as well as livestock monitoring and management, which includes hardware, software and services. The EU continues to be a market leader in this specific segment of precision farming technologies. Sensors for livestock make up a part of this segment. By strengthening Europe's position in the livestock sensor market, the position as leader in precision livestock farming would be further reinforced.

Improved decision making. The sheer availability of data for farmers, but also for other stakeholders in the value chain enables decision making based on results. The elevated temperature of a cow, measured in real time, or the increased levels of dust in a farm can allow the farmer to take action, to engage a veterinarian to administer antibiotics or take other appropriate measures to limit disease spread in a targeted fashion, or take other measures to reduce activity that stirs up dust. Through information flow across the value chain, improved

[24] European Union (2019). Agriculture. https://europa.eu/european-union/topics/agriculture_en

decision making can take place at many aspects of the value chain. Real time monitoring can also reduce administrative burdens on farms and the whole value chain by using the data to forego completion of administrative forms and provide transparent information to government.

Product quality and traceability. Through available sensors product quality can be improved and controlled at various value chain segments. At the farm, farmers can monitor animal growth and condition and optimise wellbeing, which could result in an increase of the average weight of a flock of chickens of 10%. Many developments in the livestock sectors are focussing on combinations of blockchain and other digital technologies to enable data collection and interpretation for traceability. Blockchain, for example, allows data to be collected at each segment and securely stores it in an unchangeable format. Furthermore, a decrease in the use of antibiotics due to available sensor data about animal temperature, as well as the need for fewer medical treatments means that animal welfare increases, which also has a positive outcome on product quality. In the processing value chain segments, sensors technologies are used to check the quality of the sealing of the packaging to ensure that is it properly closed. Food packaging sensors, which are enabled by low cost sensors, allow to track properties of the package throughout its lifespan. For example, packaging equipped with a temperature sensor can signal whether its product quality has been compromised (e.g. by changing colour if it has been warmed above a certain temperature) and thus ensure that food safety regulations are met.

3.2 Opportunities

Production efficiency. According to the Food and Agriculture Organisation (FAO), one third of all food produced is lost or wasted[25]. This also includes the death of animals due to illness as well as products that are rejected for quality purposes. Precision farming and the application of sensors allows to track the specific animal health and wellbeing for livestock production. This enables the timely and targeted use of antibiotics and helps to minimise animal stress in transport which can also lead to animal death. For example, a project on Poultry Chain Management anticipates feed waste reduction of 10% through optimised monitoring of poultry growth at farm level.[26] Furthermore, optimised slaughtering could also lead to a better product-market fit, reducing food waste.

Acceptance of livestock farming. Through sensor data available at farm level, a farmer can provide data to help improve the acceptance of the farming activities. Data can also contribute to the so-called 'licence to produce' which can secure social acceptance for this kind of production in the future. For example, using sensors, records of emissions are taken, new techniques and management approaches can be applied to further reduce emission which will in turn have a positive impact on the local area. Through providing the information to neighbours of a farm, who in general express an opposition to having a farm in the area ('not in my backyard')[27], social acceptance of this kind of production can be improved, and the overall acceptability in society can increase. An increased acceptance in line with reduced emissions can also mean that animal production can be located closer to urban areas, allowing short chain production ambitions to be reached. Short chains also enable reduced transport which in turn lead to fewer emissions and a lower impact of the livestock value chain.

Improved earnings and addressing labour shortages. Through the data collected, farmers can identify new earning potential. Data is not only valuable for the insights it gives, but the data can also serve as a concrete opportunity for a farmer to increase their efficiency, but also to obtain a direct financial benefit. While it depends on the specific type of sensor, the cost trend shows that sensors for livestock farming are becoming cheaper. Further improvements in price are expected, which support the possibility for further uptake. In order to take advantage of the opportunity, farmers, but also other intermediaries, need to rethink how they can organise business models as a data provider as well as the provider of livestock and other animal products. A possible solution could be in the form of an agricultural data market mechanism, building on blockchain technology.

[25] Planet labs (2018) The Top Global Trends Driving the Fourth Agricultural Revolution. https://www.planet.com/pulse/top-global-trends-fourth-agricultural-revolution/
[26] IoF 2019 Poultry Chain Management, https://www.iof2020.eu/trials/meat/poultry-chain-management
[27] Refers to the fact that people do not want to have something near their own house

In addition, the agricultural sector, and especially the livestock value chain, is affected by an undersupply of labour. Sensors can support the farmer in allowing for closer monitoring of animals as well as their environments in order to ease this burden. Furthermore, through applying digital solutions, a new type of labour force may be attracted to the livestock sector.

3.3 Risks

Robustness and quality of sensors. A challenge remains to detect and distinguish high quality sensors from low quality sensors. Sensors from the United States of America and Japan are reputed to be of the highest quality and are considered the most durable. This is due to the fact that, while considerable types of sensors already exist on the market, not all sensors are fit for purpose, e.g. some dust sensors are subject to clogging, as the very dust they are trying to measure infiltrates the sensor causing it to malfunction. The regional deal[28] 'Regio Deal Foodvalley' in the Netherlands for example, is exploring to import sensors, among others, from the United States of America and Japan.

It is important that sensor technologies applied in livestock farms are suitable for an application area. The agriculture sector is a tough world for sensors, they break easily due to their exposure to high concentrations of ammonia and fine dust. Using sensor technology - especially as part of IoT - has to be accompanied by a lot of guarantees, e.g. to protect against false positives or other potentially incorrect results. Outbreak management can be accompanied by very drastic measures such as lockdown, culling of animals etc. In addition, the economic and psychological damage can be enormous. Hence it is important that sensors are able to guarantee results and are coupled with other measurements to verify their outcomes and limit risks from false information. Current European sensors that are on the market should have the possibility to further develop to the level of robustness required for their use and implementation in order to facilitate their uptake. Demonstration of the technologies is key for these types of improvement, and hence increased support could be offered to support technology demonstration for sensors for agri-food, specifically livestock.

Data sharing. Stakeholders in the sensors for farm management of livestock value chain are known to be averse to sharing data for fear that it will be used to penalise farmers rather than improve their business model. In that regard farmers may be averse to the implementation of sensors and reluctant to understand the benefits of sensors and the data they can provide. This is especially a risk for farmers that are not well connected to intermediaries such as the Poultry Expertise Center who can support the uptake of technologies. In addition, companies in the value chain need to ensure that reliable and trustworthy data are collected, also in view of the inherent threat of cybersecurity. Considerations on how to maintain secure data flows should be implemented together with sensors, systems and dashboard in order to ensure the best possible protection against cyberattacks.

3.4 Challenges

Market size in the United States of America versus Europe. Market data show that while the landscape is fragmented, it is nevertheless dominated by companies from the United States of America. This is likely due to harmonised legislation in a larger area, which enables the uptake of new technologies to an equally larger market. At the same time, this enables investment and it becomes more attractive for risk capital. By comparison, the European landscape is fragmented with legislation that is not harmonised across Member States, acting as a barrier to the uptake of technological solutions. Furthermore, the largest growth of the market is expected in Asia where population growth will be highest. In order to strengthen the EU position, existing technology providers should be supported in their efforts to promote the uptake of technologies, and farmers, as well as other stakeholders in the value chain, should be encouraged to take up these technological solutions.

[28] Boer aand het roer (n.d.) Regio Deal Foodvalley, http://www.boeraanhetroer.nl/

Cost aversion and implementing cost for the farmer. While temperature sensors are common and not expensive, other sensors still have a high cost, especially those that are considered as new for the livestock sector. Farmers' willingness to invest resources (financial, time) in the setup of the technological solutions remains limited. For example, an integrated sensor solution, with a whole kit and a smart phone app at a cost of €5,000 is judged to be too expensive according to the farmer. While the solutions aim to support the farmers, the companies selling the solution are likely to struggle to make a profit for a technology that will benefit the farm, farmer, animal and consumer.

Framework conditions. The legislative context within a country has the power to enable a certain technological solution to be implemented, and equally a slightly different setting can hamper uptake. For example, the role of the veterinarian in the prescription of medication for cattle on a dairy farm differs within the EU, with varying degrees of trust and reliance on the veterinarian to support the use of medication. Certain sensors allow for the detection of bacteria and infections and can carry this out faster than a veterinarian relying on artificial intelligence. However, given the legislative framework and the relationship with the veterinarian, such solutions are challenged in their ability to enter certain markets, or to sell to the farmer directly without involving the veterinarian in the business model design. The use of sensors for real time monitoring, for example in combination with smartphones depends on the availability and stability of the communication network. In rural areas in many European countries there is still room for improvement in the coverage and stability of communication networks.

In France, for example, prescriptions and refills may only be issued by a veterinarian while in Sweden prescriptions are issued by the veterinarian, however refills of the same prescription can be issued by the pharmacy without a renewal from the veterinarian as long as the farmer can prove that the animals in question were still in need of the medication. The business model for a technological solution such as Bacticam from Agricam[29] in Sweden support the farmer in proving that the bacteria are present. In France however, the same legislative framework does not apply, preventing the farmer to go directly to the pharmacy. In France, the farmer still needs to pass by a veterinarian and get his approval for the prescription, although by applying Bacticam, the farmer knows that he needs a prescription. Consequently, the business model for commercialising Bacticam in France, is rather targeted towards the veterinarian (instead of the farmer), who can speed up the testing time (5 days to 24 hours) and is required to visit the farms less frequently. This is also in an interplay with the size and closeness of farms, where more remote and rural communities do not have the same access to veterinarians as more densely populated regions. These challenges appear in all domains and need to be addressed in order to facilitate the expansion of technologies into new markets. Intermediaries play an important role here, especially through cross-regional platforms such as the Thematic Smart Specialisation Platform. The High-Tech Farming partnership for example aims to create an ecosystem for testing, disseminating and commercialising European technological solutions and to connect regional platforms consisting of regional authorities, demonstration farms, and technology providers.

[29] Agricam (n.d.) Sensors, https://www.agricam.se/sensorer?lang=en

Section 4

4. Conclusions & outlook

4.1 Conclusions

Improving uptake of R&D. Many Horizon 2020 and other Framework Programme projects have addressed the topic of sensors for agri-food. Examples are: IOF2020: Internet of Things in agri-food[30], SMARTAGRIHUBS: digital innovation hubs in agriculture[31], ATLAS: Agricultural Interoperability and Analysis System[32], and DEMETER: Building an Interoperable, Data-Driven, Innovative and Sustainable European Agri-food Sector[33], among others. Under Horizon Europe, Intervention Areas will address specifically 'agriculture, forestry and rural areas' with a focus on digitalisation and participatory approaches as possible relevant opportunities to support further digitalisation and work in the area of sensors for agri-food. It is important to improve the uptake of the research results and support research projects and the resulting technological solutions in their implementation in the market, bridging the valley of death. Focussing on the application of these solutions should be more dominant than research. Spreading of use should be encouraged so that systems can become cheaper and more available to farms. In addition, there is a need for projects that can bridge or meet the challenge of market expansion across differing national framework conditions (legislative, role of veterinarian). It is very costly to redesign a business model that works in one legislative context to another legislative context, and companies are reluctant to bear these costs associated to legislative and cultural barriers. Although the benefit for society is clear, the financial benefit for the technology provider is not easy to demonstrate. As a result, many SMEs are reluctant to demonstrate their technology in another national context. Hence, there is a need for public support to support this type activity to encourage the uptake of technological solutions in this field. Cross-regional platforms are an opportunity to facilitate the uptake of technological solutions that have a clear benefit to society.

Support for digitalisation of the agri-food sector. Some technological solutions are available now, but farmers miss a clear signal on how to and what to digitalise. Targeted support for farmers to digitalise, but also for other value chain stakeholders to implement sensors would be needed. Field advisors (such as agronomists), who have the role to support the farmers, similarly lack the relevant skills to advise and support them. Educational programmes are lagging in this respect, leading to agronomists and other field advisors that are insufficiently tech-savvy to support farmers in the digital transition. In addition, incentives to connect data across the value chain would complement this digitalisation. Incentives could be specifically targeted towards large players that collect, manage and interpret large quantities of data for their own use. Ways for small and medium-size enterprises to work with large companies to have broader access to the results of the data from the sensors in their machines could be encouraged by policy making, for example through requirements towards large companies to take on a kind of mentoring or coaching role.

Targeted legislation. European policies on mandatory reduction of food waste to make the EU a global leader in food waste reduction across the value chain would be an enabling factor to the use of sensors in the livestock value chain. In addition, harmonisation of rules in agriculture across Member States to enable technologies also to cross European borders would be welcome. In the area of fine dust reduction, there are certain laws and regulations focussed on certain techniques to reduce fine dust. With real time sensors, real emissions of a farm can be made visible. In this way the techniques that the farm has implemented, but also the management of the farms in connection with the local environmental conditions can relate to the farm's actual measurable

[30] https://www.iof2020.eu/
[31] https://smartagrihubs.eu/
[32] https://www.atlas-h2020.eu/
[33] https://h2020-demeter.eu/

impact for its environment. Farms are positive about the possibilities, but also sceptical about granting governments access to data because they are afraid it will be misused.

4.2 Outlook

The sensors for farm management of livestock value chain present many great opportunities for farmers as well as end users. With the increasing importance of animal products in global diets, and the growing concern over climate change and food waste and losses, increasing the resources efficiency of the sector is vital. Sensor technologies can address points that are at the top current policy priorities.

4.3 COVID-19 – impact on the agri-food sector

During the current and ongoing COVID-19 crisis, the agri-food sector has been designated as a vital sector. This means that the sector must be continuously operational throughout the crisis period. The implications are that employees must continue to be actively working, and seeing the nature of the sector, work at home is not considered feasible. Three key principles are essential in this period:

1. The safety of employees and the non-spread of the virus are paramount. A strong focus is placed on the importance of ensuring employees remain in good health and do not contract the virus.
2. Food security and safety is and remains guaranteed. The sector continues to operate to ensure that food is provided continuously, while at the same time ensures that food safety should be guaranteed.
3. Interregional trading activities are continued. It is important that exporting/importing activities can continue in order to ensure that countries with low self-sufficient percentage of food generation can still obtain food. On the other hand, countries with a high self-sufficient percentage can maintain their export and thus sustain their business.

Availability of foreign workers. At the time of harvest, but also in other periods, as well in agriculture as in livestock keeping, farmers have to rely on the efforts of foreign workers to support their activities. Due to travel restrictions as well as lockdown in their home countries, many foreign workers are not able to support the sector as needed. Thus, countries that apparently are self-sufficient struggle to secure their food production due to the lack of available foreign workers. Workers have been flown from Romania to select European countries such as Germany and the United Kingdom to address harvest needs this spring.[34]

Livestock interaction. Livestock keeping means intensive interaction between humans and animals. Various research institutes worldwide are investigating whether COVID-19 can also infect animal species. Out of precaution, keepers from livestock are recommended to avoid contacts with their animals. Initial results show that at least pigs and chickens cannot be infected. There are no indications that livestock is a source of infection for humans.

Learning from previous outbreaks in the livestock sector. Outbreaks of the highly pathogenic H5N8 bird flu and African Swine Fever continue to occur in Eastern Europe. Farmer organisations therefore continue to appeal to be alert and keep a close eye on the biosecurity at farms and companies. After the large contamination of Avian Influenza in 2003, certain countries established effective outbreak management policies (such as the Netherlands). Early warning systems combined with a hutch duty have prevented large sources of infection with far-reaching consequences. For other sectors, similar protocols have been successfully developed. The use of sensors combined with apps to improve the early warning system and large hygiene prescriptions in all parts of Europe, as well as measures to reduce emissions, are recommended to improve outbreak management in livestock.

[34] https://www.theguardian.com/world/2020/apr/15/romanian-fruit-pickers-flown-uk-crisis-farming-sector-coronavirus

Value chain outlook. For the time being, certain value chain segments are only experiencing a limited impact from the COVID-19 crisis. For example, feed suppliers report that COVID-19 has a limited direct influence on the production chain and raw materials are still available. However, there are issues in the sales market due to transport restrictions, border controls and the closure of restaurants and the catering sector. The limited supply of supermarkets jeopardises sales and risks reduced output over the long term, leading to potentially increasing costs. This combination of increasing costs and decreasing sales will ultimately lead to economic damage for all parties along the value chain. In the long term, this could lead in some places to restrictions on production that endanger food availability.

Section 5

5. Annexes

5.1 List of interviewees

Interviewee	Company	Country
Jos Berkvens	Regio Foodvalley	The Netherlands
Anne-Jo Smits	Poultry Expertise Centre	The Netherlands
Marijke Everts	VanDrie Group	The Netherlands
Thomas Högman	Region Östergötland	Sweden

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. It will provide policymakers, industry representatives and academia with

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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