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Technology strategy for food processing

in South Ostrobothnia

Food Living Labs Connecting People A76110

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Kestävää kasvua ja työtä -ohjelma

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Euroopan unioni
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Terms and Abbreviations

Big Data	Collecting, storing, and analysing large data sets.
Extrusion	The process gives the final product a chew-resistant texture and mouthfeel. The process is based on the control of pressure and temperature. Extrusion can be carried out as a wet or dry extrusion process.
Fermentation	Oxidation, an anoxic process in which microbial metabolism converts carbohydrates into compounds.
HPP-processing	In the process, the packaged product is pasteurised under high pressure and without high temperatures. In the HPP-pasteurisation process, the pressure is between 400 and 600 MPa, with an initial temperature increase of -for every 100 MPa.
IoT	The Internet of Things (IoT) refers to the interconnection of physical devices, such as sensors, with software and services via the internet.
Meat analogue	In wet extrusion, proteins are fibred or fibrillated into new proteins, and the plant proteins that undergo this process are called meat analogues. This process gives the finished product a very similar stringy texture to meat.
Living lab-activities	Living lab describes a research concept that can mean slightly different things in different contexts. The Frami Food Living Lab creates opportunities for actors in the region to develop and evolve through a network, both in terms of product development and know-how. What is important is the growing importance of cooperation between actors in the sector.

Living lab	A network approach, where RDI activities, knowledge areas and pilot environments meet. The network facilitates the flow of information, creates new models of cooperation between network actors, and enables faster access to information.
PEF-technology	A process used to destroy microbes in liquid products by passing short electrical pulses through a food placed between two electrodes.
Food Province	Term used for the food region of South Ostrobothnia. Includes the entire food chain from field to fork.
Cellular Agriculture	Protein production in closed bioreactors with the help of microbes. Bioreactor cultivation is a weather- or season-independent process.
Vertical farming	An energy-efficient farming method where plants can be provided with nutrient-rich growing conditions in a closed environment using LED lights and a closed water circulation system.
XR-technologies	Extended Reality (XR), which includes Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR).

1 Introduction

The food industry in South Ostrobothnia is part of the global technology revolution. The regional technology strategy helps food industry companies to develop their technologies in the context of the digital transformation and the green transition. In addition, the COVID-19 pandemic and the unstable global situation have put pressure on the food industry to move to new, more digital solutions. This publication looks at the current state of food industry technologies and looks ahead to the technologies of the future up to 2035.

The strategy was drawn up using a survey, expert interviews and workshops with representatives of different food industry organisations. An important element of the research was the green transition and the technological solutions and investments required. The results of the research were used to establish the technological state of the region and a technological vision. The strategy has been written by Experts R&D Alisa Ala-Huikku, Karri Kallio, Jasmine Laitila and Project Manager Merja Mäkipelkola from Seinäjoki University of Applied Sciences.

Mission. The mission of the strategy is to create a strong basis for technological development, innovation and the deployment of new technologies by exploiting national and international networking.

Vision. The vision of the technology strategy is to increase digitalisation and technological know-how for operators in the food industry in South Ostrobothnia.

Target. The long-term goal of technological development is to improve the competitiveness of companies, make manufacturing and production processes more efficient, and develop products and services that are consumer and environmentally friendly.

This strategy aims to raise awareness of new technologies among businesses and to increase the technological know-how of the province as a whole. The strategy focuses in particular on the ability of small and medium-sized enterprises (SMEs) to use new technologies to support business growth.

Activity monitoring. The achievement of the strategy's objectives is monitored by means of pre-defined indicators. The indicators will be the investment and turnover of food businesses in the region, the development of RDI activities, statistics on food applicants and the number of person-years. The guidelines and vision of the strategy will be communicated to the enterprises and the implementation of the strategy will be monitored by the implementing organisation.

Opportunities and challenges of the strategy. The strategy has the potential to bring different organisations together and develop their activities along the same lines. It is hoped that the Regional Council of South Ostrobothnia, in particular, will take account of the strategy's potential for influence as part of its activities. The success of the strategy will create prosperity and growth for businesses and operators in the region through technological development. The development of education in line with the strategy's objectives will contribute to regional technological competence. Involving research institutions in the exploitation and further use of the strategy will also create new opportunities for the region's technological development to grow. The risks and weaknesses of the strategy are particularly related to investment failures, changes in consumer behaviour, failure to adopt or evaluate technologies, the changing world situation, the green transition, the financial transformation, labour shortages and reduced market penetration and a reduction in marketing. The anticipation of risks and the capacity to change must be taken into account in the implementation of the strategy.

2 Identification of technologies

2.1 Research methods

The technology strategy was implemented using a variety of research methods, including surveys, expert interviews and workshops. These methods provided a wide range of perspectives for the development of the technology strategy and the future technology vision, as well as the opportunity to gather information from different food industry organisations. A questionnaire survey was used to identify the technology investments made by companies and the benefits and challenges they bring. The survey also identified technologies of interest to companies. Expert interviews provided a more in-depth insight, in particular on future technologies, regional development and the green transition. The workshops allowed for an active interaction between the actors of the food industry in the region, as well as providing insights for the formulation of a technology strategy.

2.1.1 Survey

An electronic survey was carried out between May and July 2022, targeting food manufacturing enterprises (Annex 3). The aim of the survey was to gather information on the technology investments made by companies and the challenges and opportunities they bring. The survey also identified technologies of interest to companies. The sample was not limited to the South Ostrobothnia region, so the survey may also include respondents from outside the region. A total of 16 responses were received.

The survey was carried out anonymously, so that only the food enterprise's sector of activity was indicated in the preliminary data. The size of the business was also included as an optional question. More than half of the respondents were SMEs and the largest sector was the beverage industry (Figure 1). A significant proportion of respondents were also from the bakery and ready meals industries.

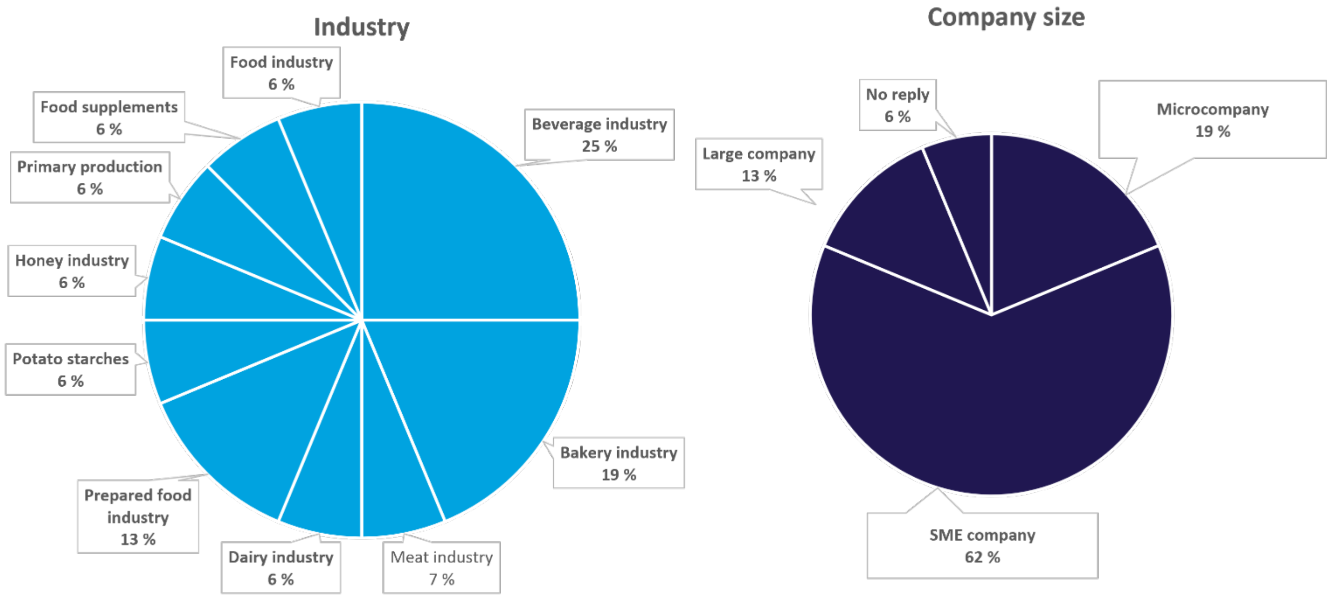

Figure1. Survey: industries and sizes of respondents.

The study shows that there are many different developments in manufacturing environments, including automation, robotics, AI applications and new packaging and manufacturing technologies. These developments have led to improvements in cost efficiency, volume, quality, hygiene and production lead time, among others. Energy efficiency has also been improved, for example through a solar power plant, and environmental sustainability has been enhanced through the introduction of biogas. Challenges to these developments have included skills requirements, space challenges and commissioning requirements. Figure 2 provides a more detailed picture of the technological developments made by companies and the benefits and challenges they have brought.

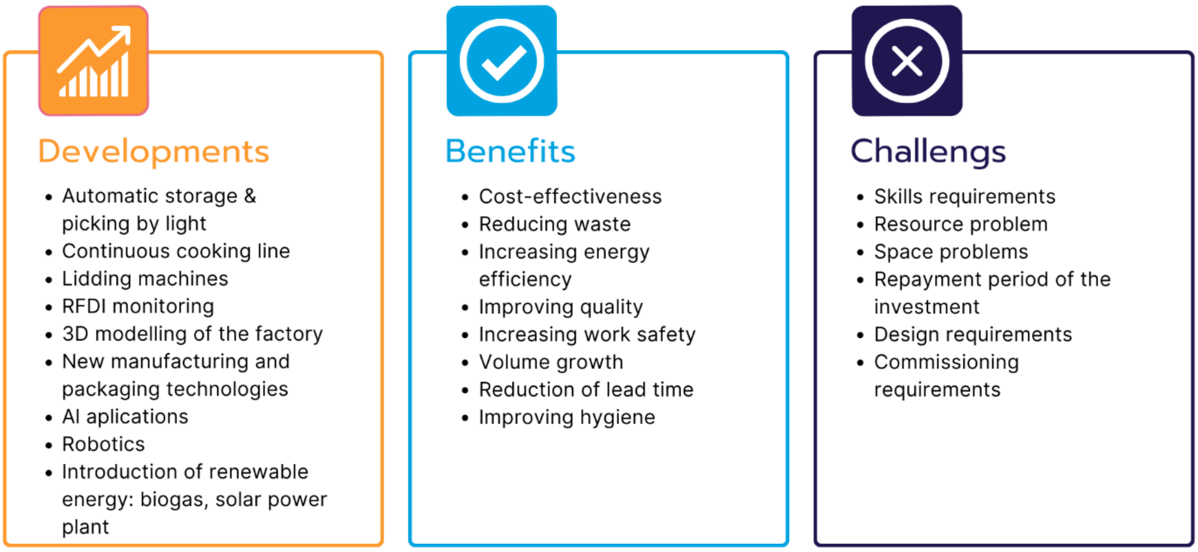

Figure 2. Survey: technological developments, their benefits and challenges.

The survey also sought to identify technologies of interest to businesses: respondents were given a set of options for different technologies and asked to rate their interest on a scale of 1 to 5. The technologies were selected on the basis of technology trends and future technology trends. In particular, packaging technology, data-related solutions, automated quality management and robotics emerged as the most interesting technologies (Figure 3).

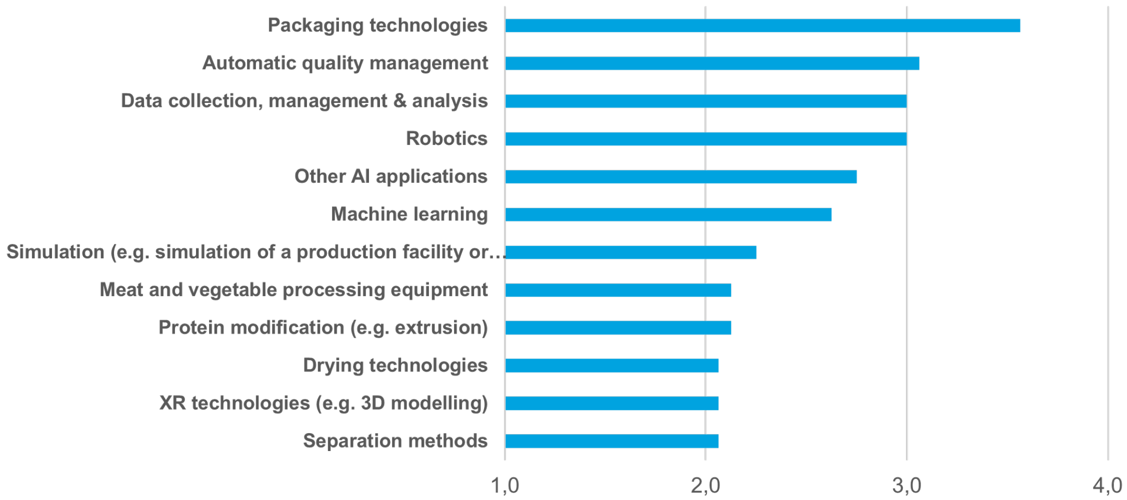

Figure 3. Survey: technologies of interest to enterprises.

Companies were asked in which area there was the greatest potential to achieve benefits in their business by upgrading their technology. According to respondents, the greatest potential is in robotics and automation. Other areas of benefit included data utilisation, equipment readiness, drying and separation technologies and data collection and reporting.

The survey aimed to identify the benefits that companies seek through technology investments and the main obstacles to their realisation. In both questions, respondents selected up to three of the pre-selected options for the benefits they sought and the main obstacles they faced. Figures 4. and 5. show the results as a percentage distribution.

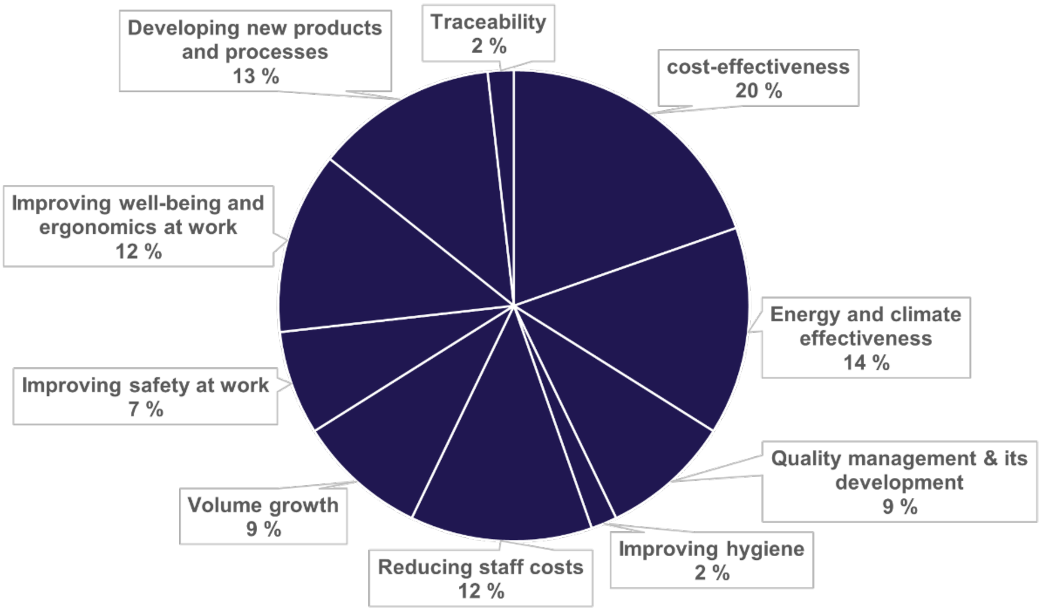

Figure 4. Survey: the benefits sought from technology investments.

Cost-effectiveness and energy and climate efficiency are seen as the main benefits. Reducing personnel costs, developing new products and processes, and improving well-being and ergonomics at work were also seen as benefits worth pursuing.

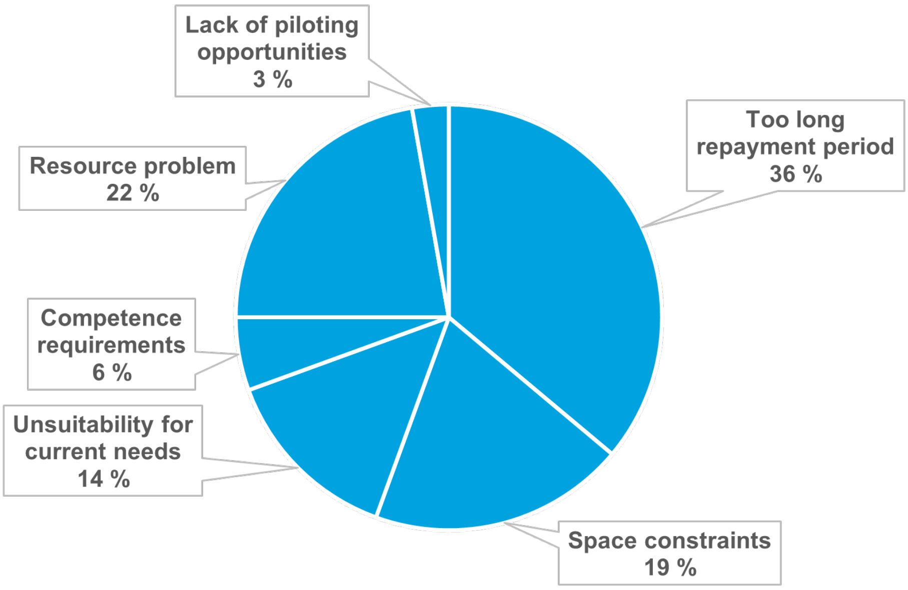

Figure 5. Survey: biggest barriers to technology investment.

The main obstacles to investing in technology were perceived as too long a payback period, lack of resources and overcrowding.

The survey was used to identify the technology investments made by companies in the food industry and the associated benefits and challenges. Respondents were drawn from a range of company sizes and from a variety of food industry sectors. The results show that the main technologies that are being implemented are packaging, automation and robotics, and data management and analysis.

2.1.2 Expert interviews

Expert interviews were carried out with business, project and education experts in the food industry to support the construction of the technology strategy. Interviews were collected not only from food industry companies but also from food industry equipment manufacturing, packaging and logistics. The interviews were carried out in the context of company meetings or alternatively as an electronic questionnaire (Annex 4). In total, interviews were collected from 16 different organisations. The interviews were conducted between October 2022 and January 2023. The distribution of respondents is shown in figure 6.

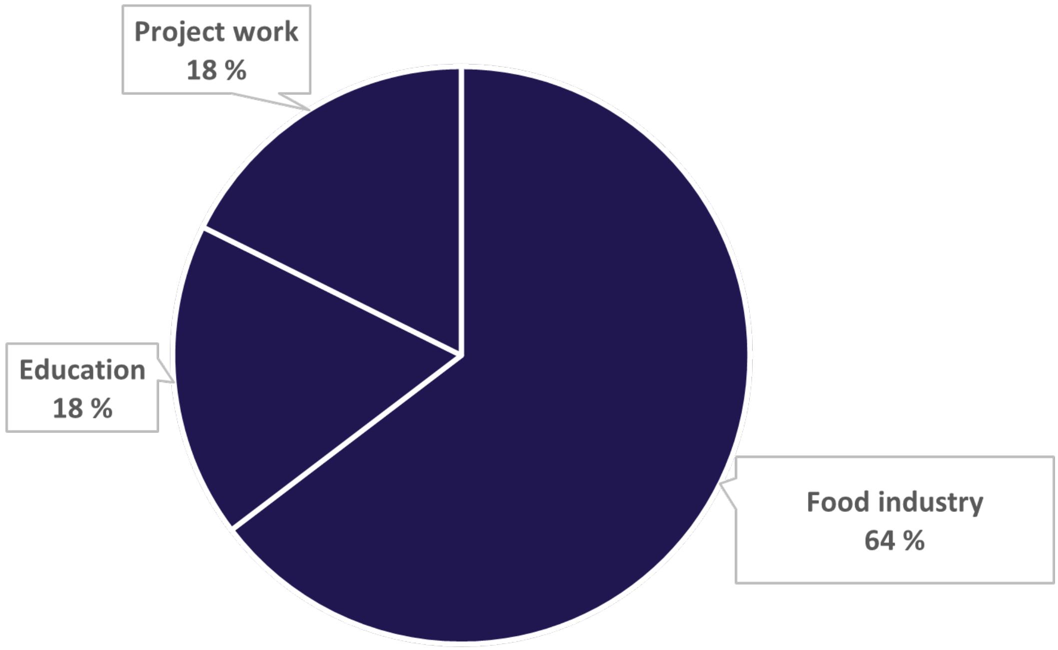

Figure 6. Expert interviews: distribution of food industry companies.

The aim of the interviews was to get a more diverse view from the experts in the food industry. The interviews will focus in more detail on the future prospects for food processing technologies, the green transition and the regional development perspective. The answers given by the experts are summarised and anonymised in this section. The individual answers given by the experts are referred to by code numbering (H1-H16).

Respondents were asked how their organisation is currently taking account of technological developments. Common measures mentioned by the experts included technology investments, training, trade fairs, project work and collaboration with partners. Organisations are making investments in technology, both tangible and intangible, and are developing their production in a way in line with consumer needs. They also seek to develop the skills of their staff and exploit new technologies, for example in energy solutions. Cooperation with training organisations is also common, as is participation in projects and research.

Organisations try to keep abreast of trends in their own sector and of what other companies are doing.

Experts were asked for their views on the key new technologies in the food industry and which technologies will emerge by 2035. According to the experts, the key technologies of the future will include machine vision, collaborative robots, Big Data, other AI applications, XR technologies, increasing process optimisation, data collection and analysis, smart packaging, separation technologies for raw materials and side streams, meat substitute technologies, wood-based packaging solutions and energy-efficient processes. The consumer's role and behaviour are important at the centre of these developments. There will also be increased collaboration and information sharing between different organisations through technologies.

The interviews asked what kind of transformation around technologies will take place by 2035 and what impact they will have on development. According to the respondents, the disruption and impact is broad and varied, but a few trends can be highlighted from the responses. For example, automation, robotics, AI and machine learning will become more widespread and continue to evolve. The use of biotechnology will also expand. The circular economy of energy and materials will play an important role as fossil fuels are replaced by renewable ones and by-products are used for processing. Plant proteins and alternatives such as artificial meat will compete with the meat industry. In packaging technologies, the use of bio-based materials will become more common (H5). The rapid change and transformation of technology will bring further opportunities for companies and business.

According to experts, by 2035, multidisciplinarity and multitechnology will be particularly visible in the development and application of technologies in different sectors. For example, the food value chain will become denser and transparency will be increased through the use of process and digital technologies (H1). Storage technologies and advances in machine vision will also lead to increased operational control across sectors (H2). Smart packaging solutions and sensors will enable more accurate product tracking and quality monitoring (H5). Recycling will become easier and technology applications will be increasingly used (H7). The use of plant proteins will increase in the meat sector and robotics will become more prominent in different sectors (H9). New raw material imports from other industrial sectors could also be exploited and processed for the food industry, such as the use of wood-based raw materials in food (H12). In the future, more interdisciplinary and international cooperation between experts from different sectors will also be needed.

Supporting regional development, technological excellence and competitiveness requires, above all, skills, cooperation and networking, according to the respondents. It is important to create strong interaction between businesses, developers, administrations, educators and consumers. In particular, the role of development projects by training organisations is growing due to the lack of resources available to enterprises. The use of pilot-scale testing laboratories and de minimis projects is important to support business development. The transfer of RDI results to enterprises is also seen as important. Networking with national and international companies is also needed. Promoting a more ecological form of energy and developing energy sources as quickly as possible will support not only sustainable development but also regional development. The importance of the region's food industry needs to be recognised more widely in society.

The green transition and the pursuit of energy efficiency require a wide range of actions and investments from companies. For example, they need to introduce energy-efficient processes and equipment, renewable energy such as solar and wind power, and energy capture and storage. They also need to develop digital solutions and take energy efficiency into account in the systems they deliver to customers. It is also important to take climate awareness and carbon footprint reduction into account in brand development. Companies should also invest in financial resources and be flexible in their production processes (H3). All these measures require time, money and technological development, but they are essential for the green transition and the pursuit of energy efficiency.

Experts predict that over the next 15 years, the food system will become more responsible and sustainable, the popularity of plant-based products will grow and the use of technology will increase. Carbon neutrality and technology adoption will be key factors in reducing climate impacts. The availability and substitutability of raw materials will become more important and new substitute foods may enter the market. Raw material prices are projected to rise, which may lead to substitution of domestic production by foreign products, and therefore security of supply and maintaining self-sufficiency are important considerations.

Minimising waste and making efficient use of side streams are also seen as important objectives.

2.1.3 Workshop activities

In order to outline the strategy, an internal workshop was organised in the implementing organisation, where experts discussed how technologies have changed and what visions for the future have been outlined in other research projects. By processing the guidelines and discussion topics from this workshop, it was decided to organise a wider workshop for the business sector, with the aim of involving the region's business community in the development and implementation of the strategy.

The focus of the workshop for the business sector was to map the current situation, development targets and challenges of the food industry in South Ostrobothnia as part of the implementation of the strategy. Participants highlighted in particular the need to increase cooperation and the growth of RDI activities. In addition, the increase in training, the increasing transparency of the product chain and the increase in export growth through technologies were also highlighted. These are seen as important cornerstones that support the growth of the region and of businesses.

A third workshop for small businesses was also organised during the drafting of the strategy. The workshop aimed to identify potential opportunities for technology cooperation between RDI actors and businesses. Challenges in terms of know-how, profitability and take-up were identified as problems with the technologies. When considering cooperation models, it was noted that networking at both national and international level could be beneficial, especially in the context of deployment and skills challenges. Business-friendly funding was identified through the Highfive I3 financial instrument to support profitability and budget.

2.2 Technology trends

Climate change is a global challenge that is reflected in future technology trends in the food industry. This is also strongly reflected at the national level in the Climate and Energy Strategy published by the Finnish Ministry of Employment and the Economy (2022b), which aims for a carbon-neutral Finland in 2035. The green transition requires food industry companies to consider climate impacts from the perspective of the entire food chain. From a food processing perspective, climate-resilient and energy-efficient processes, other energy efficiency solutions, the circular economy, sustainable packaging solutions and alternative protein products are particularly relevant.

Alongside the green transition, there is also the digital-green transition, a dual transition where digital solutions support and enhance sustainable development and the green transition (Bützow et al., 2022, p. 27). The Ministry of Economic Affairs and Employment (2022a) has set Finland as an international pioneer in the dual transition by 2030 in its AI 4.0 programme, which requires the deployment of cutting-edge technologies in industry. According to the programme, the leading edge technologies identified by Finland include artificial intelligence, wireless information networks, microelectronics and photonics, and smart manufacturing. These technologies are also global trends and are part of the fourth industrial revolution. Industry 4.0 encompasses a range of digital technologies and other advanced solutions that will accelerate the rise of automation and the growth of digitalisation in industrial sectors (Hassoun, et al., 2020). These technologies include artificial intelligence, robotics, smart sensors, IoT devices, Big Data and XR technologies. These technologies bring many benefits to the food industry, such as improving quality management and product hygiene, optimising production processes and improving occupational safety.

2.3 Technology transfer

A basic understanding of chemical, microbiological and physical properties and an understanding of process technologies are required to manage food technology (Fellows, 2022). However, food processing is undergoing a transformation, with production moving in leaps and bounds towards the practices imposed by process industries. Raw materials are not moved by hand or the quality of the product is not assessed organoleptically. In the future, new innovation, efficiency and economic growth will come from development at the technological frontiers.

Innovations can be direct technology transfers, such as sensors, machine vision and filters from other industries and research. Such transfers may come from the paper or chemical industries, for example. Technology transfers can also be related to product innovation, where challenges such as raw material availability or shelf-life have been solved by licensing the know-how to manufacture the product. This patented know-how can be sold to other companies worldwide.

3 Food processing in South Ostrobothnia

South Ostrobothnia is one of Finland's leading food industry centres, with strong expertise and a long tradition in food production and processing. Known as a Food Province, South Ostrobothnia stands strongly behind competent and developing primary production. The region's food companies operate in a wide range of food processing sectors, including meat, dairy, beverage and bakery.

Food companies in South Ostrobothnia invest in research and development, new technologies and high-quality, responsible production. The region's food companies have a broad networking culture, which enables cooperation and innovation between the actors in the sector. They also have access to research and development activities provided by the region's educational organisations. The RDI activities of Seinäjoki University of Applied Sciences include continuous project cooperation with companies, public sector actors and other communities (Seinäjoen ammattikorkeakoulu, i.a.). For example, the University of Applied Sciences develops various programmes, applications and models with the help of experts in different fields, which can be used by operators in their own activities.

The region's food industry is strongly linked to the educational skills of the sector. The Sedu training centre in the region offers the possibility to study a basic food industry degree with specialisation options in food preparation or bakery confectionery (Koulutuskeskus Sedu, i.a.). It is also possible to study a vocational qualification in the food industry and a specialised vocational qualification in the food industry. At Seinäjoki University of Applied Sciences, students can study a lower degree in bio- and food engineering, which was expanded in the autumn of 2022 to become the international Agri-Food Engineering degree. It is also possible to study the Food Chain Development degree at SeAMK, which supports the skills needed for management and development tasks in the sector. Together with educational institutions, companies in the food sector in the region are able to develop know-how and innovations in the sector, thus creating a basis for long-term growth and development of the industry.

Regional food industry in figures. In 2021, there were 105 food manufacturing establishments and 15 beverage manufacturing establishments in South Ostrobothnia

(Tilastokeskus, 2023a). In 2021, there were 2 establishments in the food and drink industry in the region. Only those enterprises that declare the manufacture of equipment for the food and drink industry as their main activity have been included in the statistics. Table 1. shows the number of establishments in the food and drink manufacturing and food and drink equipment manufacturing sectors in the region in 2021. The table also shows the turnover by sector.

Table 1. Establishments and turnover in the food industry in South Ostrobothnia in 2021 (Tilastokeskus, 2023a).

2021 Industry (South Ostrobothnia)	Number of establishments	Turnover 1000 €
10 Manufacture of food products	105	1 799 854
101 Slaughtering, preserving of meat, manufacture of meat products	21	995 540*
102 Processing and preserving of fish, shellfish and molluscs	3	100
103 Processing and preserving of fruit and vegetables	14	8 647
104 Manufacture of vegetable and animal oils and fats	1	*
105 Manufacture of dairy products	7	516 111
106 Manufacture of grain mill products and starch products	8	54 803
107 Manufacture of bakery products, pasta, etc.	32	24 055
108 Manufacture of other food products	10	16 694*
109 Preparation of animal feeds	9	167 015
11 Manufacture of beverages	15	61 319
1101 Distilling and blending of alcoholic beverages; manufacture of ethanol	4	55 126
11020 Production of wine from grapes	0	-
1103 Manufacture of cider, fruit and berry wines	2	*
1104 Manufacture of other non-distilled fermented beverages	1	*
1105 Brewing beer	6	5 866
1106 Manufacture of malt	0	-
1107 Manufacture of soft drinks and bottled waters	2	*
28930 Manufacture of machinery for food, beverage and tobacco processing	2	*

*For reasons of data confidentiality, information on one or two establishments is published, only the number of is disclosed.

The combined turnover of food and beverage manufacturing in South Ostrobothnia accounted for 16% of the total turnover of food and beverage manufacturing in Finland in 2021 (Tilastokeskus, 2023a). The turnover of the food industry in the region has increased by 102% between 2002 and 2021 (Figure 7). The number of establishments has decreased by 12%, but the number of employees has increased by 31% (Tilastokeskus, 2023b). The graph shows the figures up to 2007 according to the old classification of establishments (TOL15, manufacture of food products and beverages), after which the establishment classifications of manufacture of food products (TOL10) and manufacture of beverages (TOL11) have been added together.

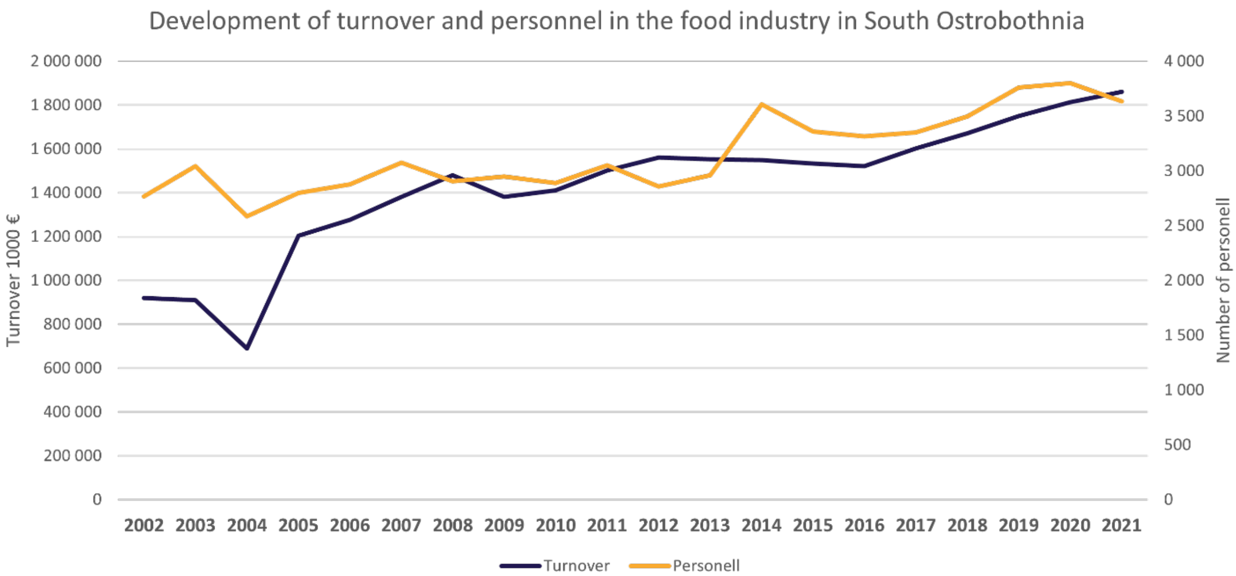

Figure 7. Development of turnover and number of employees in food and beverage manufacturing in South Ostrobothnia 2002-2021 (Tilastokeskus, 2023b).

The common enterprise size distribution for food and beverage manufacturing in South Ostrobothnia is presented in Figure 7. The enterprise size distribution was formed according to the size class of personnel as defined by Statistics Finland (i.a.-a, i.a.-b) and does not take into account the annual turnover or balance sheet of enterprises. It is therefore indicative and does not give a fully true picture of the size distribution of enterprises in the food industry in the region. According to this graph, 70% of the enterprises in South Ostrobothnia are micro enterprises with less than 10 employees. The graph shows that the majority of enterprises in the food industry are SMEs.

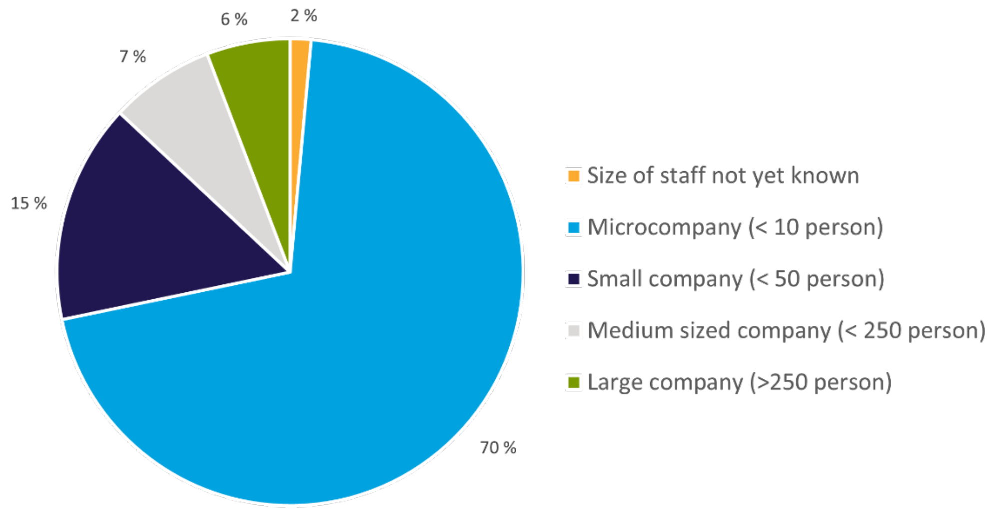

Figure 8. Size distribution of food and beverage manufacturing enterprises in South Ostrobothnia by size class of personnel (Tilastokeskus, 2023c, i.a.-a, i.a.-b).

Definition the current state of technology. The current state of the art of the region's food processing technologies is illustrated by a technology pyramid (Figure 9). The technology pyramid is based on the research data collected for the strategy and the technology discussions held in the workshops, where the current state of the region's food industry was discussed together. The organisations involved in the discussions came from different categories of the industry, providing a wide range of views on different aspects of the pyramid. The statistical data presented above were also used to define the current situation. The technology pyramid identifies the technological spearheads, key and enabling technologies in the region.

Spearheads. The spearheads of the technology pyramid reflect the international and national expertise in food processing in the region. The spearheads were defined as responsible animal production, food education, the regional development of Living Lab activities and a high level of product development expertise of the operators. This competence is continuously being developed further by the training actors in the region. The region's education is also of international importance due to the high level of international interest and the number of applicants for the Agri-food Engineering programme.

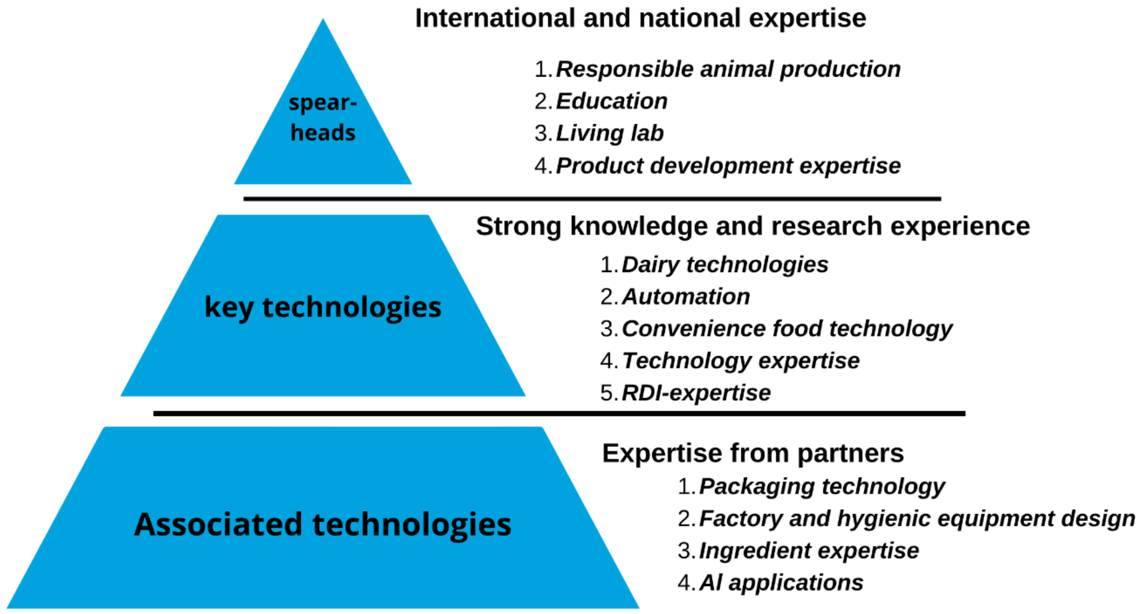

Figure 9. The technology pyramid of the food industry in South Ostrobothnia.

Key technologies. The key technologies in the technology pyramid describe a subsector of the food industry in the region with strong know-how and research experience. The key technologies were defined as dairy and convenience food technology, automation, technological know-how and RDI activities. South Ostrobothnia has some of the largest dairy operators in Finland, which, together with educational expertise, make dairy technologies a regionally significant factor. The identification of automation and convenience food technologies is explained by the strong knowledge base of companies in the region, as well as a bold approach to technology investment and deployment. The identification of technological know-how as a key technology is explained by the product development skills and willingness to develop of food technology manufacturers in the region. RDI activities were identified as key technologies because of their continuous growth and the extent of networks, and they support the technological development and upgrading of skills in South Ostrobothnia.

Associated technologies. The associated technologies in the technology pyramid describe the know-how that can be obtained from partners. The associated technologies were defined as packaging technology, factory design and hygienic equipment design. In addition, they include ingredient know-how and AI applications (such as modelling, consumer research and AI development). These enabling technologies were identified on the basis of the perceived lack of a sufficient knowledge base within the company. In such cases, it is easier to buy expertise from partners than to go deeper into the subject.

4 Creating a partnership

Building regional cooperation is an essential part of the technology strategy for the food industry in South Ostrobothnia. The aim is to create strong partnerships and networks between food organisations in the region, both nationally and internationally. Through cooperation, it will be possible to increase the exchange of information, create collaborative projects and improve the competitiveness of the sector together. Through cooperation, businesses in the region can build on each other's strengths and develop new innovations and solutions. It will also help to develop food processing in the region in a more sustainable and responsible way.

4.1 The emergence of the Living lab

Building the Living Lab research concept relies heavily on the food industry in our region. The network also includes equipment manufacturers, the beverage industry and other food-related activities such as logistics and packaging design. The network's integration and activities can be broken down into three different priorities, as shown in Figure 10; knowledge transfer and know-how, RDI activities, and cooperation between companies and research institutes at both national and international level. The Food Network's activities will culminate in the development of actors, research and training in line with regional needs. In practice, this means the introduction of a low-threshold Living Lab testing environment at national and international level, increasing the importance of cooperation and networks, and responding to the needs of the region in terms of capacity building and training.

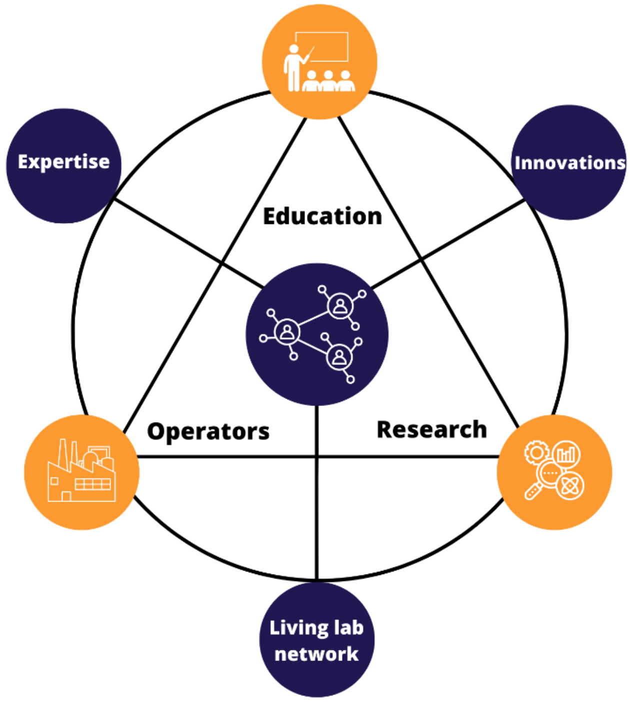

Figure 10. Description of the Living lab network.

4.2 Frami Food Living lab-concept

Living lab activities can be divided into four categories; user-led, supplier-led, user-led and enabler-led (Leminen et al., 2012). The Frami Food Living lab network, built within the Food Living Labs connecting people project, is enabler-led, as it aims to develop the area in the long term. It is important to increase cooperation between actors in the region and to raise awareness of the scope of the Frami Food Living Lab services and how they can be used.

The three main organisations of the Frami Food Living lab service in South Ostrobothnia are Seinäjoki University of Applied Sciences SeAMK, Sedu Seinäjoki Törnäväntie and the contract manufacturer Foodwest Oy. These operators invite businesses in the region to their premises to use the services and solve challenges together with industry experts.

The Frami Food Living lab development path is usually business-driven, which can start, for example, with the development of a new product for which the company does not have the equipment or know-how. Consultations with an RDI expert from SeAMK will identify where and how the product can be produced: at Sedu with meat and bakery equipment, at SeAMK on a laboratory or pilot scale, or in pilot and production scale at Foodwest. The Frami Food Living lab is also the ideal place to organise consumer research. After a successful product, the company can make an equipment investment in its own production line or start a subcontracting partnership with the contract manufacturer Foodwest Oy.

4.3 International networks

The networks are particularly targeted at groups that identify and develop food technologies or influence future trends. South Ostrobothnia plays an active role as a developer and contributor in the Smart Sensors 4 Agri-Food and ERIAFF networks. These networks contribute to both technology development and European-wide innovation programmes. However, the development work is not finished; the networks must be further strengthened and new partners must be found, especially those who can renew the economy. In the course of the strategy work, similar countries have been identified at international level, where technological development is seen as a key to future development activities. It is therefore important to build strong partnerships and cooperation with food technology developers across Europe.

5 Technology vision 2035

The Technology Vision forecasts the technological future of the food industry in South Ostrobothnia until 2035. Technologies are highlighted thematically, measures are defined to develop technological competence and regional activities, and the opportunities and challenges brought by technologies are considered from a regional perspective. The technology vision and its themes are presented in visual form in Annex 1. The implementation of the strategy will shape the requirements and future applications of technologies in food processing in South Ostrobothnia in 2035.

5.1 Themes

The Technology Vision 2035 themes were developed on the basis of future technology trends and research data. There were similarities in the data, so the themes were grouped under four different headings: digitalisation, sustainable & responsible production, packaging technology and alternative proteins. These themes contain the key technologies that will be used to build future business development.

Technologies are presented in each theme from the perspective of the food industry, with a special focus on how food businesses in South Ostrobothnia can use technologies in their own operations. At the end of the themes, the risks and opportunities associated with the technologies are discussed using a SWOT analysis. The analysis takes into account the internal strengths and weaknesses of South Ostrobothnia, as well as the external opportunities and threats on a Finnish scale. The implementation of each theme requires companies to take the steps shown in Figure 11.

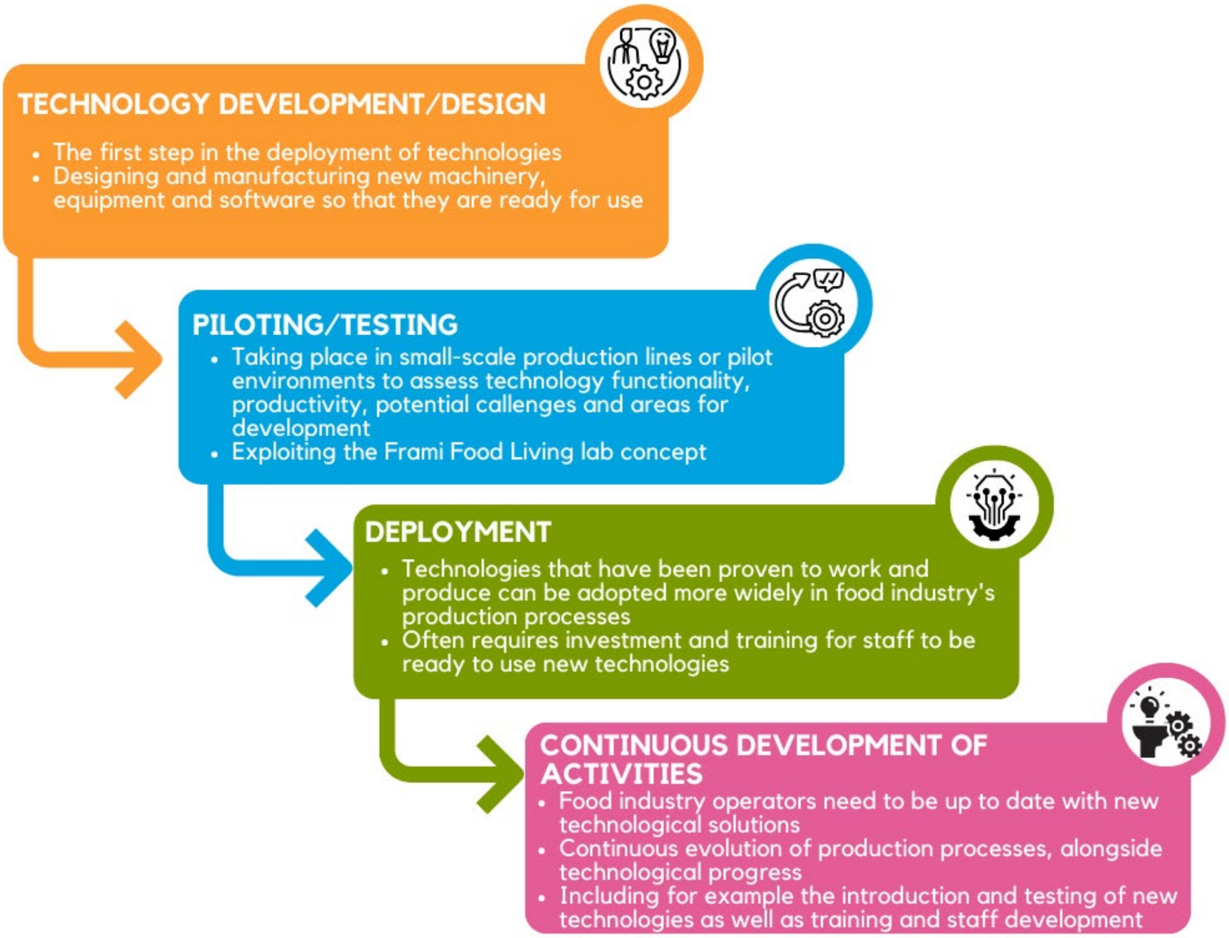

Figure11. The stages of technology deployment.

5.1.1 Digitalisation

The food industry in South Ostrobothnia is known for its high-quality and high-value products, and digitalisation can be an important factor in maintaining and developing this reputation. Food businesses in the region can take advantage of the many opportunities offered by digitalisation and automation, such as robotics, AI and other smart technologies enabled by Industry 4.0. In the future, these technologies will play an increasingly important role as the industry moves towards more automated and intelligent solutions.

The food industry in South Ostrobothnia consists mainly of SMEs. Intelligent technologies could be used in SMEs in the region, for example: collaborative robots can be used to replace manual processing steps in production that require precise and fast handling. These include dosing, sorting and packaging tasks. Collaborative robotics can therefore be a useful solution, especially for SMEs that do not have the resources to invest in large and expensive robotics systems. Collaborative robots can work together with workers, allowing for a more efficient and flexible production process (Grobbelaar et al., 2021). Collaborative robots are also easier to deploy compared to large industrial robots and are easily adaptable to changing needs or processes. If combined with machine vision, robotics can, for example, identify and separate different products, speeding up product sorting and packaging processes and reducing the risk of quality defects (Suomen robotiikkayhdistys, i.a.). Smart sensors and IoT devices enable production monitoring and optimisation in real time, allowing for example the optimisation of materials and resources (Hassoun, et al., 2020). In addition to optimising production, AI can be used to analyse and utilise the collected production data for production quality assurance and predictive maintenance (Vermesan, 2021, p. 253). Intelligent technologies can also be used in the food supply chain. According to the Finnish Food and Drink Industries' Federation (2018), digitalisation has fostered the emergence of logistics services that make use of traceability technologies such as blockchain technologies, intelligent inventory management systems and IoT solutions.

Smart technologies enable companies to collect and analyse data to improve their business. For example, smart sensors can collect information on the temperature, moisture and other properties of raw materials and products. Data from sensors can be used to improve product quality, for example (Hassoun, et al., 2020). Big Data analytics can be used to process large amounts of data. In the food industry, it can be used to monitor product quality, improve operational efficiency, analyse customer sentiment and personalise products (Sadiku, et al., 2020). Big data analytics can be applied from food production to customer service and can be used by all affiliated groups to optimise their operations.

Food businesses can also use digital solutions to help them design, deploy and develop technology. These solutions include product or production process modelling and simulation tools and XR technologies. XR technologies can be used in the food industry, for example in the deployment of equipment and production processes. Virtual reality (VR) can be used to create virtual environments in which production processes can be designed, tested and optimised (Jackson, 2020). Augmented reality (AR), on the other hand, allows virtual elements to be placed in a real environment, such as virtual models of equipment in a real production environment. Augmented Reality can be used, for example, for equipment and machinery maintenance and staff training. These tools have been complemented by a more multidimensional digital twin combining intelligent technologies. A digital twin is a virtual model of a product, a piece of equipment, a production process or an entire factory. It can be used to perform analysis and apply strategies (Bottani et al., 2020). The digital twin is based on many Industry 4.0 technologies such as IoT devices, cloud computing and Big Data analytics. The digital twin can use AI, machine learning and analytics applications, which are used together with production data to create digital simulation models. The data is updated in real time as production changes. In the food industry, the digital twin can be used to deploy physical equipment or production processes, optimise production and occupational safety, and perform predictive maintenance, for example.

Digitalisation can also minimise the environmental impact of production, which will help companies in the digital-green transition. Intelligent systems can monitor production side streams and resource consumption, helping companies to optimise the circular economy and energy efficiency of production (Hassoun, et al., 2020). Production deviations and energy efficiency can be controlled according to process requirements by using machine vision, pattern recognition methods and sensors to measure parameters (Vermesan, 2021, pp. 255-256). AI-based prediction, alerting and energy management tools can be used to minimise environmental impacts. These predictive machine learning algorithms can help manufacturing plants identify problems early, reducing potential downtime.

Based on the research that has been done, it can be concluded that companies in the food industry in the region have already taken steps to develop automation and digitalisation, but in the future its importance will only increase. The use of digitalisation will help companies to develop new products, improve production processes and increase cost efficiency, among other things.

A SWOT analysis was created for the digitalisation theme (Figure 12). The growth of digitalisation and automation in South Ostrobothnia is supported by the region's strong research and technological expertise. The region has a wide range of offerings in the field of related technologies for the food industry, which are also provided to food businesses in the form of digital solutions and automation by companies in the technology industry, for example. The testing and development of technologies is supported by training and Living Lab activities in the region. The Frami Food Living Lab concept allows not only new products to be tested, but also technologies to be tested on a pilot scale. The concept enables, for example, the use of SeAMK's robotics laboratory or the XR laboratory for testing smart technologies.

The majority of food industry operators in South Ostrobothnia are SMEs, and therefore the limited resources and lack of expertise of the companies can be considered a weakness in the use of digitalisation. Problems may also arise in terms of scalability and investment costs. Many firms may have a large number of old production lines or equipment that are challenging to adapt to new technologies. Lack of data or inaccuracies in data can also limit the exploitation of digitalisation. Smart technologies are also often associated with preconceptions, often due to a lack of foresight or knowledge. This can lead to a lack of confidence to invest in new technologies. It would therefore be useful to make use of cooperation between companies and other organisations, particularly during the technology development phase, in order to minimise the weaknesses described above.

Above all, digitalisation can help companies grow their business and competitiveness, and new technological solutions can enable the development of new products and services. The technologies brought about by digitalisation also require new types of skills that can create new types of jobs in the future. Increased digitalisation can also, if successful, enable transparency through the food chain to the consumer.

As a result of the development of digitalisation, cyber and information security threats are becoming more common. Minimising these threats also requires training employees in information security. In addition, the increase in automation and digitalisation will lead to a reduction in manual tasks, which will mean a reduction in the manual workforce. On the other hand, digital solutions also create a skills shortage, as new technologies raise the level of demands and require staff to adapt to new skills. Overall, staying competitive and distinctive requires staying on the cutting edge of the rapidly changing digital landscape.

Figure12. SWOT analysis: digitalisation.

5.1.2 Sustainable & responsible manufacturing

Direct greenhouse gas emissions from food production are moderate, as the larger emissions are mainly indirectly caused by raw material production, logistics and energy production (Food Association, 2020). The Finnish Food and Drink Industries' Federation's (ETL) vision for 2035 is to reduce emissions from the food industry by 75% from current levels. The vision is strongly influenced by the Government Programme Carbon Neutral Finland 2035. To achieve this goal, food companies will have to increase energy efficiency, purchase energy with lower emissions, invest in energy-efficient processes, adopt new technological solutions, reduce emissions from packaging materials and use side streams from production. These measures will require a lot of cooperation between food businesses, primary producers and logistics. Once the target is achieved, Finnish food production will be sustainable and responsible.

As a result of the green transition, the food industry needs to adopt energy-efficient processes to save water, energy, raw materials and other resources. One example of such a process is the HPP process, or high-pressure pasteurisation (Food Safety, 2015). In this pasteurisation process, no energy is used to heat the product, as in normal pasteurisation. Other processes include PEF technology, which uses electrical pulses, and US technology, which uses sound waves (Hassoun, A. et al., 2020). Vertical farming is also the farming method of the future, with half the energy requirements compared to conventional greenhouse farming (Porvali et al., 2021).

To promote the circular economy, companies should take into account and make use of waste heat, side streams and wastes from production and processes (ETL, i.a). This can also be referred to as material efficiency. Proper recycling of plastics and other wastes and their possible further processing supports the green transition. Water use, amount of wastewater and possible reuse should be identified at different stages of the food process. Industrial side streams should be recycled, for example by processing them into new products or producing biogas from them. Side streams and wastes can also be used in cellular agriculture in bioreactors to feed protein-producing microbes. (Penttilä, 2021).

The transformation of South Ostrobothnia towards sustainable & responsible production is not straightforward. Therefore, a SWOT risk analysis was conducted for the theme, which is presented in Figure 13. The strengths of the theme are in particular the carbon and climate targets of large companies for 2035, which will lead food processes in a more sustainable direction. The targets emphasise the circular economy and the adoption of sustainable energy. The targets will serve as a guide for SMEs, which will be eligible for development grants to develop their activities towards a green and digital dual transition. A weakness within the region is the unwillingness to change, which can lead to a lack of new technologies and energy-efficient processes. This reluctance to change is influenced by the economic situation, the difficulty of implementing investments, the attitude of employees towards innovation and the lack of other resources.

The implementation of the theme and the green transition will create new jobs and skills in South Ostrobothnia, as the introduction of energy-efficient processes requires new technological know-how. Increased energy self-sufficiency and the introduction of energy-efficient processes will reduce production costs. However, threats to the realisation of the potential are a lack of skills, which may lead to a skills shortage in the region, partial non-achievement of the carbon neutrality targets, lack of cooperation, and possible water quality and distribution problems.

Figure 13. SWOT analysis: sustainable and responsible manufacturing.

5.1.3 Packaging technology

As a result of the green transition and the carbon neutrality objective, the food industry will have to move to more environmentally friendly recyclable food packaging. The European Commission's target is that by 2030 all packaging materials used in Europe will be reusable or economically recyclable (EU, 2022). More environmentally friendly packaging materials include wood-based solutions. Wood cellulose can be used to make biocomposite films, fibres to replace disposable containers and bottles for liquid products (EUON, i.a.).

The implementation of smart and active packaging technologies is an effective way to reduce waste, extend shelf-life, increase product traceability, and improve product quality and freshness, for example through an on-package indicator of freshness and spoilage (Drago et al., 2020). Active packaging aims to change the condition of the packaged food, for example by adding a moisture remover to the package. Changes in the colour of an indicator added to an intelligent package indicate changes in the pH, temperature or enzymes of the food inside the package. Indicators can also be used to verify the cold chain of a food product, thus increasing product traceability and transparency of the production chain. Smart packaging can also contain digital information about the product, for example in the form of a QR code or other digital identifier, which allows consumers to view the cold chain of the product and its journey from factory to retail, for example. The QR code can also include information on the sustainability of the raw materials and production used in the product.

The Green Transition has a strong impact on the implementation of the packaging technology theme in South Ostrobothnia. The region's adaptation to future challenges and opportunities is discussed in Figure 14. In the context of the climate goals of large companies, the transformation of packaging solutions to more environmentally friendly alternatives is also putting pressure on SMEs to develop packaging. In the South Ostrobothnia region, SMEs can outsource packaging development and research to different actors, so they do not need to use their own human resources for development and research. Through new packaging forms and materials and smart packaging, a company's brand can be made stronger and more distinctive. The mention of a more environmentally friendly packaging solution and easily recyclable material on the packaging will attract consumer interest and the design will differentiate the packaging on retail shelves.

Developing wood-based packaging materials in Finland will boost the economy and boost exports. For example, wood-based bioplastics can be used to replace traditional plastic film in food packaging. The addition of integrated indicators to packaging will strongly correlate the amount of waste caused by temperature variations, for example in logistics, which in turn will reduce costs. Logistics and production are also made more efficient by packaging designs that reduce the amount of packaging material. This allows more packaging to fit into a smaller space, enabling logistics to transport larger quantities at a time. Indicators also improve food safety and shelf life by allowing the cold chain of transport to be verified. The introduction of new packaging solutions in South Ostrobothnia requires extensive know-how, which is why the knowledge requirements can be classified as a threat to the realisation of the vision. Packaging legislation will have to adapt in parallel with the new packaging solutions in order to classify packaging materials as food-safe, which in turn will require a number of studies to be carried out. The influence of consumers on the adoption of new packaging solutions by companies is significant. Consumers are becoming increasingly environmentally aware, which influences their purchasing behaviour. This puts pressure on companies to change towards greener packaging solutions.

Figure 14. SWOT analysis: packaging technology.

5.1.4 Alternative proteins

The use and processing of alternative proteins in the food industry will increase by 2035. The development of new protein sources will be consumer-driven, as consumers demand increasingly transparent production. The journey of food from field to table must be more clearly presented to consumers, for example through smart packaging. Meat analogues, which imitate the texture and taste of meat as consumers perceive it, are being made from plant proteins (Jan van der Goot et al., 2023, pp.445-450). The preparation of meat analogues also supports the green transition, as the processing of products generally requires less raw materials, energy and water. Extrusion processes, and in particular wet extrusion, are the plant protein shaping processes of the future, giving plant products a meat fibre structure through pressure and heat. The texture of the final product can be made to be similar to beef or chicken, for example. In wet extrusion, proteins are combined with other ingredients such as fat and carbohydrates.

The production and product development of meat and milk analogues must take consumer behaviour into consideration (Poinski, 2022). Prices of plant-based protein products need to decrease to increase consumer interest and consumption. According to Poinski (2021), analogues should be produced using raw materials familiar to consumers, such as soy, wheat, and for example coconut oil as a starch protein. The composition of the product should also be pleasing to the consumer and mimic the composition of meat. It is estimated that by 2035, 11 % of all proteins consumed will be plant-based.

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Meat analogues are produced using a wide range of meat processing equipment, mixers, vacuum injectors and packaging equipment (Betz, 2020). Plant-based products substituting minced meat products are based on a vegetable protein-based starting product similar to minced meat, often texturised in an extruder. The starter is mixed with plant lipid and the mixture can be extruded through a shaper's vacuum pump to form steaks, rounds, sticks and nuggets.

Future alternative proteins will use fermentation processes to produce products that resemble animal proteins (Bijl & Keppler, 2023 pp. 273-281). In fermentation tanks, yeast, mould or bacteria or other micro-organisms can be used to produce protein proteins such as egg white. The protein production process developed by VTT (2020) uses *Trichoderma reesei* fungus, which offers a safe and more environmentally friendly alternative for protein production. Protein production results in 75% less greenhouse emissions and no risk of salmonella.

Looking at the SWOT analysis of alternative proteins in Figure 15, the number of meat and dairy companies can be considered a strength of South Ostrobothnia. For example, the meat industry is well suited for the production of plant protein products alongside meat products and the dairy industry can be used for the processing of plant-based products. The region therefore needs specialists in the meat and dairy sectors, as well as in other alternative proteins. The region's strength is the extensive training in protein and meat skills offered by the Seinäjoki University of Applied Sciences. Courses in protein expertise have been added to the bio- and food technology studies, as well as a specialisation in meat technology, where the use of meat equipment is studied in depth. The weakness of South Ostrobothnia in increasing the use of alternative plant proteins is the reluctance or lack of courage to switch to plant-based protein applications. This is also influenced by the investments that companies are likely to have to make when introducing alternative protein applications. Investments may include the purchase of new equipment and the expansion of production facilities, for example for an extruder.

Figure 15. SWOT analysis: alternative proteins.

The adaptation to the alternative proteins theme will give South Ostrobothnia and the whole country the opportunity to increase the demand for domestic plant proteins nationally, as well as internationally for exports. In particular, the demand for plant proteins will increase with the green transition, as consumers become more aware of what is environmentally sustainable. This will also drive companies to develop their products more consumer oriented. However, the issue may be threatened by the availability of raw materials, as in times of global crises and pandemics, availability problems increase. The introduction of new technologies and processes also requires strong skills, which could be a challenge in the future. The expected consumer uptake of alternative proteins may also be the opposite of what is expected, which may be due to the price of the products if the price decrease is not as expected.

5.2 Regional development roadmap

The roadmap for food sector development in South Ostrobothnia (Annex 2) is based on the research material for the strategy. The roadmap brings together RDI actors, companies and international networks in the food sector. The map aims to predict development milestones over the next 15 years. The vision is based on current visions for the future of regional development, organisations and networks. At the same time, the milestones presented in the roadmap will help businesses in the region to adapt to the vision of the future of food technology 2035 presented above.

The roadmap is divided into five different sections: RDI activities, company-specific measures, food technology development, inter-organisational measures, development of Living Lab platforms and future perspectives for international networks.

RDI-activities. In the future, RDI activities in South Ostrobothnia will develop into a nationally and internationally significant centre of food expertise. International RDI activities will grow through new networks, training activities and partners. Strategic and targeted RDI co-operation with key partners at national level will be pursued with determination. Strong domestic networks will help to raise the level of RDI activities, food technology and education in South Ostrobothnia to a more comprehensive and effective level. This is a strong continuation of the current situation, where networks have been successful in bringing European-wide Horizon project implementations (Highfive I3 and SRIA) to the South Ostrobothnia region. As a result of the expansion of the networks, South Ostrobothnia is expected to significantly raise its competence profile as a project actor on a European scale in the future.

Company specific measures. Company-specific measures in the region include increasing product development expertise and making new equipment investments that serve the growth and future prospects of companies. The digital twin shift is seen as an important driver for the future, helping the industry to meet the government's Carbon Neutral Finland 2035 target. In addition, new innovations, funding frameworks and willingness to develop will help companies' research and development activities to grow in the future.

Technological developments. A new I3 financial instrument to support business investment will help companies in the region to identify new technologies, learn about new technologies and invest. I3 is a business-friendly technology development funding instrument that can be used to support a company's efforts to adopt new technologies, for example. The importance of this is particularly highlighted in the region of South Ostrobothnia through its expertise in protein processing. The region has strong meat know-how, which can also be applied to the processing of alternative proteins. Targeting the use of meat equipment to plant proteins will diversify the use and scope of existing equipment. There will also be a strong industry-wide trend towards a more transparent food chain using these technologies.

Measures between organisations. Product testing, the introduction of new technologies, the growth of product development and development activities at regional level create a permanent and long-term cooperation between organisations. The increase in the value added of the raw materials and products produced in the region, as a result of the rise in the skills profile, is seen as important for increasing exports in the future. At national level, the market is highly competitive. High growth is difficult to achieve in a small country, so the pursuit of growth usually requires opening up exports and internationalising the company and establishing a foothold in the target country. Between organisations, the pursuit of increased exports can be facilitated through cooperation and a willingness to change. At regional level, the increase in product development expertise increases the added value of products and therefore the profitability of the business.

Living lab. An emerging and internationally active Living Lab network facilitates the flow of information and networking between actors. The views expressed by representatives of the organisations interviewed highlighted in particular the need for future investment and business growth. The regional challenges in South Ostrobothnia are related to the geographical location, the lack of a start-up culture, the scarcity of technology players, especially equipment manufacturers, and the lack of higher education. Living lab activities will be developed regionally in the future, but also internationally in cooperation with other actors. The use of pilot platforms and the possibilities for product testing are seen as important for the development and competitiveness of the region. The functioning of low-threshold testing environments and cooperation between RDI actors in support of the Living Lab are seen as areas that will raise the region's profile in terms of knowledge and networking.

International networks. For international activities, two approaches have been chosen based on the interviews. The first is networks focused on technology development and built around business clusters. The most important of these is the Smart Sensors 4 Agrifood network, which combines business clusters, technology development and the search for business funding. Another part of the networks is to seek leverage on European Union programmes and funding. These include ERIAFF (The Network of European Regions for Innovation in Agriculture, Food and Forestry) and SFSP (Sustainable Food Systems Partnership), which can contribute to the overall development of a sustainable food system. In the future, network cooperation should be extended towards cutting-edge research to ensure the long-term competitiveness of South Ostrobothnia. The European Federation of Food Science and Technology (EFFoST), a network of leading food scientists, has been identified as one such network to support development. The ISEKI Food association is a network of food science institutions, educators and businesses.

6 Summary and conclusion

The changing food chain and the global technology revolution will shape the needs and starting points of the food industry now and in the future. The digital dual shift and the technological solutions it brings are part of a more sustainable future and the ability of the food chain to innovate. The regional strategy looked at the current state of food processing technologies and envisioned the evolution of activities up to 2035. The strategy was compiled through a survey, expert interviews, workshops and statistics. The strategy also drew on future technology trends and scientific articles.

Building cooperation plays a key role in the technology strategy for the food industry in South Ostrobothnia. The region aims to create strong partnerships and networks between food organisations, also on an international scale. The aim is to increase the exchange of information, create cooperation projects and jointly improve the competitiveness of the sector. The Frami Food Living lab, built during the project, will help to achieve these objectives. The cluster of companies gathered will be used to increase cooperation between companies, the flow of information, and also cooperation between companies and educational institutions. The Frami Food Living lab will also connect companies in the region to the international Smart Sensors 4 Agrifood network, which includes living lab operators from all over Europe. Cooperation between food businesses in the region can also improve the competitiveness of food processing in the region as a whole and enable new markets to be found internationally. However, it is also important to put responsibility and sustainability at the heart of the cooperation.

Technology Vision 2035 is an important part of the technology strategy for the food industry in South Ostrobothnia. The vision foresees future technological trends and plans milestones for the development of the region's technological expertise and operations. The technology vision addresses different technology themes, such as digitalisation, sustainable & responsible production, packaging technology and alternative proteins. The themes take into account the use and transformation of technologies in the region's food processing. The vision also sets out measures to ensure the future sustainability of technological skills and development. Important elements include the development of training, support for research and development, and the introduction of innovation and new technologies. Food legislation needs to keep up with future research and development in order to introduce new technologies and packaging materials and to produce new types of food and protein sources for consumers.

In summary, the technology strategy for the food industry in South Ostrobothnia is a comprehensive and forward-looking package that takes into account the region's strengths and challenges in the use and development of technologies. The strategy aims to promote the competitiveness and sustainable development of food processing in the region through co-operation and technologies.

After the completion of the strategy, the measures include the implementation and dissemination of the strategy to the actors in our region, such as the Union of South Ostrobothnia. The strategy would enable funding to be channelled more effectively to the introduction of new technologies, investments and skills development. The strategy will be brought to the attention of food businesses in the region and its implementation will be monitored by the implementing organisation through pre-defined indicators. The aim is to update the region's technology strategy after 2035.

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APPENDECES

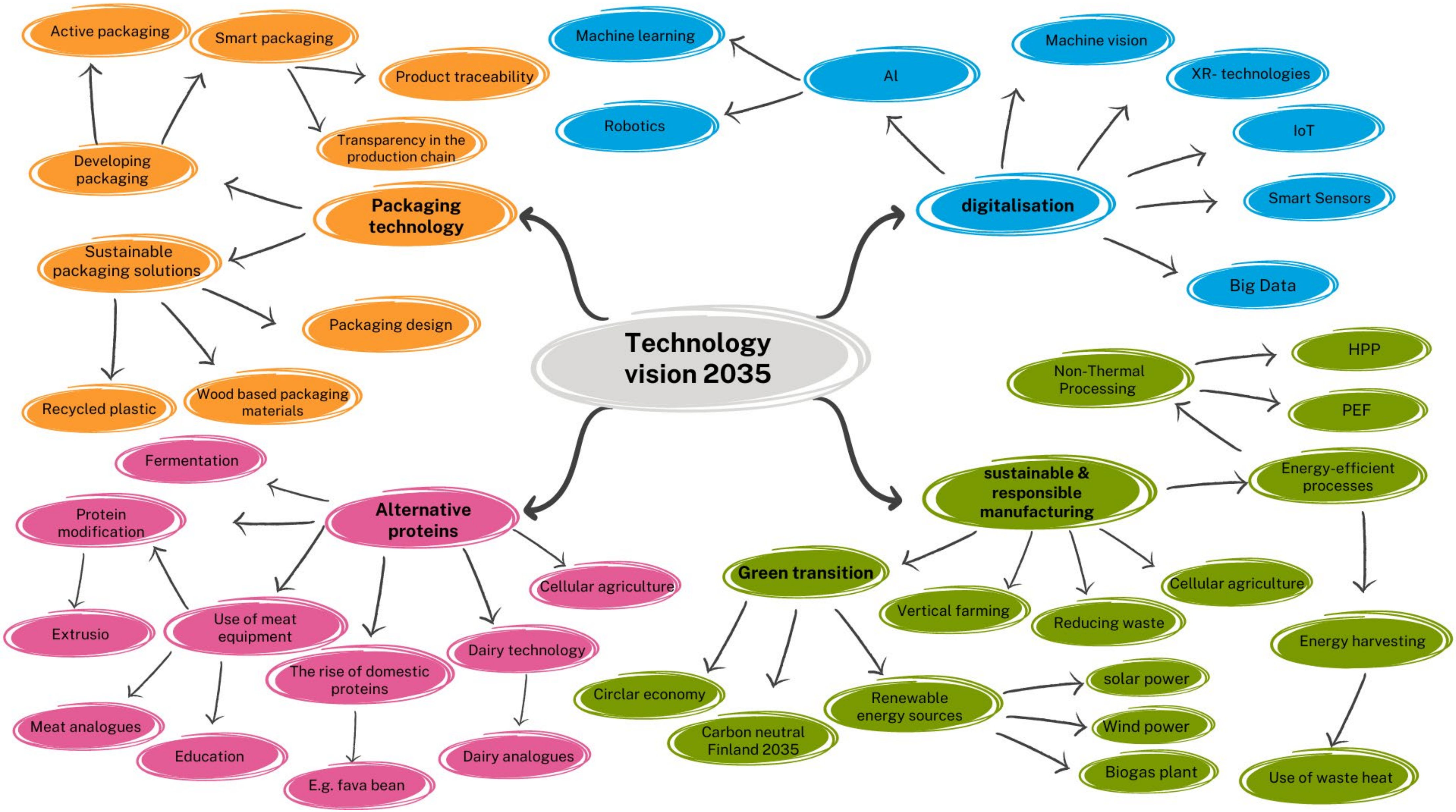
Appendix 1. Technology Vision 2035.

Appendix 2. Regional food sector development roadmap for South Ostrobothnia 2023–2035.

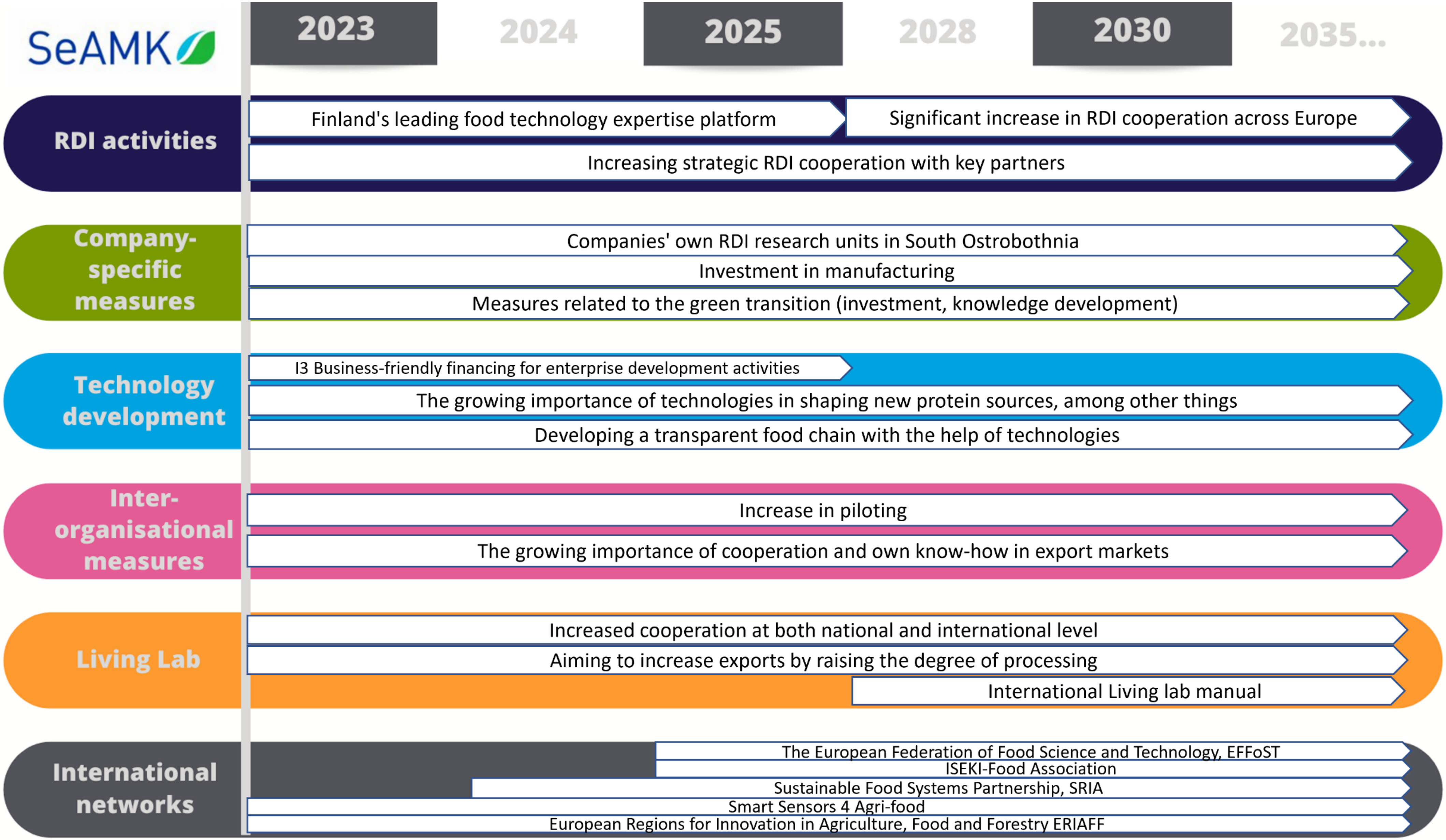
Appendix 3. Mapping of technologies in the food industry in South Ostrobothnia – Electronic survey questionnaire (Forms)

Appendix 4. Questions of the expert interview on the survey of technologies in the food industry in the South Ostrobothnia region

Appendix 1. Technology Vision 2035.



Appendix 2. Regional food sector development roadmap for South Ostrobothnia 2023-2035.



Appendix 3. Survey of food industry technologies in the South Ostrobothnia region - Electronic survey questionnaire (Forms)

1. Sector of your food business

   - Meat industry
   - Dairy industry
   - Beverage industry
   - Bakery industry
   - Equipment manufacturing
2. Other, what?
3. Size of your company?
   - Large enterprise
   - Small and medium- sized enterprises
   - Micro-enterprise
4. What technological developments have taken place in your production environment in recent years? For example, new manufacturing and packaging technologies, AI applications, 3D models/digital twins..
5. What are the benefits of new technologies? For example, improved safety/quality/hygiene at the workplace, cost-effectiveness, reduced emissions...
6. What challenges have technologies brought? For example skills, resource constraints or failed investment..
7. Is your company interested in the following technologies (rate your interest on a scale of 1 to 5, where 1=no interest and 5=very much interest)
   - Machine learning
   - Robotics
   - Automatic quality management
   - Other AI applications
   - Separation methods
   - Protein modification (e.g. extrusion)
   - Meat and vegetable process equipment

- XR technologies (e.g. 3D modelling)
- Data collection, management & analysis
- Simulation (e.g. simulation of a production space or device)
- Drying technologies
- Packaging technologies

8. Please mention any other technologies of your interest to your company:
9. In wich area is there the greatest potential to achieve benefits in your company by raising the level of technology (e.g. machine vision, robotics or automation)?
10. What are the specific benefits your company would like to achieve with new technologies? Select up to three options
    - Reducing staff costs
    - Volume growth
    - Improving safety at work
    - Improving well-being and ergonomics at work
    - Quality management and its development
    - Improving hygiene
    - Traceability
    - Energy and climate efficiency
    - Cost-efficiency
    - Developing new product and processes
11. What are the biggest barriers to technology investment in your company? Select up to three options
    - Too long a repayment period
    - Unsuitability for current needs
    - Competence requirements
    - Lack of resources
    - The region lacks a successful forerunner
    - Lack of piloting opportunities
    - Other, what? Answer the following question
12. Other obstacle, what?

Appendix 4. Questions of the expert interview on the survey of technologies in the food industry in the South Ostrobothnia region

1. Which organisation do you represent?

2. How is your organisation currently addressing technological developments? (investments, training, project work, etc..)

3. What do you think are the most important new technologies in the food industry and which technologies will emerge by 2035? (Technology Vision 2035)

4. What kind of transformation will take place around technologies by 2035 and what impact will they have on development?

5. How will interdisciplinarity (multi-technology) be reflected by 2035?

6. How do you think the food system will change in the next 15 years?

7. What are the most important issues to support regional development, technological excellence and competitiveness? How could regional development be supported?

8. How will the future availability of raw materials shape the needs of the food industry?

9. What does the green transition and the energy efficiency drive require from a company?