



Good Practices for Food System Actors in Southern Ostrobothnia

Project report

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Introduction

This report brings together the individual reports prepared for the four pilot areas within the Ruokaprovinsi – Sustainable and Responsible Food Province project. The combined data supported the pilots by benchmarking good practices from Finland, other EU countries, and beyond.

The report begins by outlining the regional context of Southern Ostrobothnia's food system and then moves to a broader discussion on how cooperation can strengthen sustainability across the food chain. It examines the need for systemic change, stakeholder roles and interdependencies, and practical models for cooperation, including climate-change adaptation, environmental impact reduction, food waste reduction, short food supply chains, and collaborative food production. The core of the report is structured around four pilot areas: biochar in agricultural production; sustainable food processing through the utilization of side streams; responsibility in food service operations, especially waste reduction and sustainability communication; and ways of encouraging responsible consumer choices through behavior-change models and nudging. The report concludes with a summary of key takeaways and a reference section that supports the handbook's evidence base.

This report aligns with the Food Province's strategy (Välisalo et al., 2022), aiming to strengthen food sector's success by improving the broader food business environment. Sharing its mission, we view the Food Province as an innovation ecosystem built on collaboration between farm-to-table companies and RDI actors, with success grounded in responsibility, transparency, and sustainability.

While all five of the strategy's priorities support this report, the main emphasis is on the fifth—*The Accountable Food Province*—which focuses on environmentally friendly production, biodiversity, side stream use, food system resilience, and impactful sustainability work. The report also reflects *The Food Business* priority by supporting profitable, appreciated food production and visibility for small actors, and *The Food-PRO-vince* through education-driven solutions. Though the third priority, *The Food Province brand* communication, is less central here, the fourth—*The Food Province Family*—resonates strongly through our focus on active networks and informed consumers, especially in the section focusing on cooperation. The issues and solutions introduced in this report often have impact on multiple dimensions of sustainability—environmental, economic, and social—which then reflect many of the priorities presented above.

1 Regional context: Southern Ostrobothnia's food system

South Ostrobothnia (see. Figure 1: Map of South Ostrobothnia's municipalities. Source: Regional Council of South Ostrobothnia (n.d.). and its municipalities are a major food production area in Finland. In the Finnish context, food production is a significant employer in South Ostrobothnia, as the region's food companies employ the second largest number of people in the sector compared to other regions (Statistics Finland, 2024). Statistics acquired for The Food Province Strategy (Välisalo et al., 2022) show that in 2022 the food industry accounted for about one-third of all places of business, personnel and turnover in all sectors of the region.



Figure 1: Map of South Ostrobothnia's municipalities. Source: Regional Council of South Ostrobothnia (n.d.).

South Ostrobothnia has the highest share of GDP from the food sector among Finnish regions. The sector contributes nearly 15% to the region's value added and 21% to employment. Agriculture alone employs 10.3% of the population, making it the region's largest employer. Major national food processors—such as Atria, Maitosuomi Cooperative, and Juustoportti—are based in the area. The region is also a significant hub for agricultural machinery and equipment manufacturing. Agriculture and forestry play a key role in carbon sequestration (Mäkimantila et al., 2021).

The number of farms in South Ostrobothnia is declining by 150–200 annually. This is largely due to the aging farmer population—nearly half are aged 50–64, while only 15% are under 40. There are significant regional differences in farm development, even within municipalities. More developed areas with active investments in agriculture continue to strengthen. Part-time farming, alternative income sources, and subsidy policies also influence these trends. As the number of farms decreases, the average cultivated area per farm is growing. In livestock-dense areas, competition for farmland increases, raising both land purchase and rental prices. Cooperation between livestock and smaller crop farms is expected to grow, especially in feed production, manure handling, and labor sharing. Succession rates vary regionally, and structural changes are leading more farms to gradually transfer ownership. This includes growth in corporate ownership and co-ownership models. Strengthening cooperation networks can help ease the financial burden of generational changes, particularly for young farmers (Mäkimantila et al., 2021).

In 2024, South Ostrobothnia produced the most potato yield (120,4 million kg) of all the regions in Finland. Moreover, it also produced the most barley, the second most oat, and the third most peas (Statistics Finland, 2023). The same year, there were the most broilers and the second most cattle and swine in South Ostrobothnia of all Finnish regions. The concentration of animal production to the region can also be seen in the number of farms: there were the most swine and broiler farms, along with the third most of cattle farms in South Ostrobothnia (Statistics Finland, 2025).

Over half of South Ostrobothnia's farms focus on crop production. The main crops are feed barley, oats, winter and spring wheat, and various mixed crops. The cultivation area and production of oats and wheat are expected to remain stable or slightly increase—supported by rising demand for oats in the food industry and growing poultry production boosting wheat use. In contrast, barley cultivation is expected to decline due to reduced pork production. Oilseed cultivation is likely to

stay the same or decrease due to climate challenges and restrictions on plant protection products. The area of grasslands depends on CAP27 support schemes; without incentives, it is expected to shrink along with the decline in dairy and beef farms. Legume cultivation will increase due to rising demand for domestic protein and plant-based diets. Potato cultivation is expected to remain at current levels (Mäkimantila et al., 2021).

Livestock production accounts for about 70% of the total value of primary agricultural production in South Ostrobothnia—higher than the national average. While the number of dairy farms is declining, significant investments are being made, with production doubling on investing farms. As a result, the region's share of national milk production is expected to remain stable. The area is well-suited for efficient grass cultivation. (Mäkimantila et al., 2021)

In pig farming, structural changes occurred earlier, with production now concentrated near the regional center and slaughterhouse. Despite past restructuring, South Ostrobothnia is underproducing piglets. The future of production depends on consumption trends, exports, and market efficiency, as domestic demand alone cannot sustain current levels (Mäkimantila et al., 2021).

Broiler meat production is growing, with the region producing nearly 40% of Finland's total. It operates under contract farming, with expansion agreements going to current producers. Many are waiting to invest or expand, and new slaughterhouse investments support future growth. There is also some growth in sheep and goat farming, offering smaller farms alternative opportunities through specialized production (Mäkimantila et al., 2021).

Agriculture is the highest-emitting sector in South Ostrobothnia, accounting for 44.6% of total GHG emissions in 2023, compared to the national share of 22.3%. Agricultural emissions have also increased by 6.3% during the same period (SYKE, n.d.). Palomäki and colleagues (2022) explain this increase in emissions by the growth in livestock production and expanding cropland areas. Crops are mainly fertilized with synthetic fertilizers, even though the phosphorus content in manure would be sufficient to meet local crop needs. Livestock farming also relies on feed produced elsewhere, leading to an imbalance in the regional nutrient cycle. This highlights the importance of targeted mitigation in the regional food system. Furthermore, including emissions from the food industry and food services makes the food chain's total emissions even more significant.

A strong presence of SMEs and a diverse business structure are key strengths of the region. Across South Ostrobothnia, there are notable clusters of specialized industries, with industrial enterprises forming the largest share of all businesses. The economy is especially characterized by the food, machinery, and equipment industries. While industrial productivity has improved in recent years, it remains low compared to other regions. However, the value added from industrial production continues to grow. A major challenge is the renewal of the business sector, particularly as business ownership transfers are expected to accelerate in the coming years (Mäkimantila et al., 2021).

In 2023, South Ostrobothnia had 129 food manufacturing and 15 beverage manufacturing establishments. Although the number is relatively small on a national scale, the food industry plays a major role in regional employment. It generated 40% (€2.12 billion) of the total turnover of the region's industrial sector (Statistics Finland, 2024).

The Finnish Food Industries Federation's roadmap (2020) highlights the sector's relatively low direct emissions, noting that most emissions stem from primary production or energy generation, making them largely indirect. Emissions are distributed as follows: 50% from raw materials, 30% from energy production, 10% from food processing, 7% from logistics, and 3% from packaging.

In 2023, South Ostrobothnia was home to 442 food service providers, representing approximately 2.7% of all companies operating in the food service sector nationwide. This reflects the region's modest but stable share within Finland's broader food service landscape.

A total of five food companies from Alajärvi, Kauhajoki, and Seinäjoki responded to a survey for food industry actors, conducted by Mäkimantila et al. (2021). Two of the companies were moderately familiar with climate actions in the food industry. Some had set targets to reduce greenhouse gas emissions by 2035, but none were involved in climate projects. Two companies had already switched from fossil fuels to renewable energy, and one planned to do so soon. All companies had either improved or planned to improve energy efficiency. Most had taken steps to reduce production and packaging waste, as well as plastic use. Three companies were already utilizing by-products; one planned to do so in the near future. Two had participated in carbon-sequestering projects, and two more were interested. Three companies chose environmentally friendly raw materials, and two had improved or planned to improve logistics. One company offset product emissions, while four were unsure. All respondents saw financial support as very or moderately helpful for reducing emissions. Other measures included a shift to renewable energy,

organic farming, composting, bokashi, vegan products, energy recovery, and plans to strengthen circular economy practices. Three companies wanted more information on climate action.

Regional strengths

The situation picture and development needs of South Ostrobothnia's food sector has been discussed in a workshop for researchers (Talvitie, 2025). There the identified strengths were close cooperation among stakeholders along with a strong and comprehensive food sector – ranging from primary production to machinery manufacturing –, solid agricultural expertise, diverse food education, successful flagship companies, entrepreneurial spirit, and active local development.

Collaboration between stakeholders and active development is listed as one of South Ostrobothnia's strengths in the region's Regional Rural Development Plan 2023-2027¹ (Mäkimantila et al., 2021) lists. The indicated strengths include:

- Strong entrepreneurial spirit, active development orientation, and confidence in the future
- Comprehensive food chain from primary production to processing, providing significant employment
- Home to major food processing companies and technology industry players engaged in innovation
- Strong agricultural sector supported by good business networks and collaborative development actors
- Companies known for high-quality products and committed personnel
- Logistical potential supporting business operations
- Community-driven rural development and recognition of village vitality
- Clean nature, local culture, and renewable energy potential
- Diverse rural services that strengthen a sustainable food system

According to Palomäki et al. (2022), South Ostrobothnia benefits from several notable regional strengths that support its development as a leading food region. The presence of large actors capable of implementing significant emission reduction measures provides strong leverage for climate action, while the established Ruokaprovinsi brand reinforces regional identity and visibility. The region also benefits from high-quality education and a long-standing commitment to development, demonstrated through active research, development, and innovation (RDI) work. In addition, new funding opportunities available in the current EU programming period further strengthen the region's capacity to pursue strategic growth and sustainability goals.

¹ [South Ostrobothnia's Regional Rural Development Plan 2023-2027](#)

Regional challenges

Key challenges include slow adaptation to change, high investment costs, limited appeal of food careers, lack of skilled workforce, weak cooperation between primary production and processing, and low visibility of local food. Key concerns include energy use in agriculture, peatland emissions, and farmer well-being (Talvitie, 2025).

According to the region's Regional Rural Development Plan 2023–2027 (Mäkimantila et al., 2021), the weaknesses of South Ostrobothnia include the following:

- Gaps in entrepreneurial, management, marketing, and digital skills
- Limited use of expert services
- Lack of value-added and specialty food products
- Few new innovations emerging
- Farm profitability under pressure
- Insufficient adaptation to climate change and environmental challenges
- Dominance of small enterprises and lack of cooperation limiting scale and efficiency
- Shortage of long-term strategic planning
- New businesses often remain in traditional sectors
- Poor customer understanding and reliance on outdated practices
- Deficiencies in infrastructure (e.g., broadband connections)
- Regional disparities in demographics, business activity, and economic opportunities
- Weak rural accessibility
- Limited municipal and development actor resources hindering progress

According to Palomäki et al. (2022), South Ostrobothnia faces several regional weaknesses that challenge the resilience and long-term sustainability of its food system. The region is experiencing an ongoing crisis in primary production and remains heavily dependent on external production inputs, making farming both vulnerable and input-intensive. Stakeholders also perceive climate action responsibilities as unfairly distributed, adding to tensions within the sector. Micro-enterprises struggle to grow, and the broader actor landscape is fragmented, which complicates coordinated development efforts and limits the effectiveness of regional collaboration.

South Ostrobothnia's food industry's primary concerns, based on discussion material, include the importance of visibility for the climate efforts of even small food companies. Support is needed for communicating climate and sustainability actions. Respondents also emphasized the importance

of developing, utilizing, and marketing local production. Strengthening plant-based food value chains and anticipating changes in consumption habits were also noted. (Mäkimantila et al., 2021)

Regional development priorities

Central development priorities include improving overall strategic vision, enhancing skills and education, supporting small businesses in scaling and marketing, boosting local food use in public kitchens, increasing consumer understanding, and developing food tourism. More effective sustainability communication, support systems, policy consistency, and consumer engagement are needed to drive change (Talvitie, 2025).

According to Mäkimantila et al. (2021), the development priorities for the Food Province focus on both strengthening and renewing the competitiveness, profitability and skills of the regional food chain and advancing sustainability, responsibility and climate resilience. Key economic and skills-related priorities include increasing the processing level of food and developing value-added products, harnessing new technologies, digitalization, and data resources, establishing a regional “Food Table” network to enhance collaboration, managing production costs to improve profitability, and identifying current and future skills needs across the food chain. In parallel, the region aims to promote sustainability by anticipating and responding to climate change, developing solutions that improve energy and resource efficiency, supporting short supply chains, community-supported agriculture, and ecosystem services, and creating models that enable effective carbon sequestration practices.

2 Strengthening Cooperation for a Sustainable Food System

This section highlights *The Food Province Family* priority of the Food Province strategy (Välisalo et al., 2022), as we highlight the roles of active and tight networks along with diverse and conscious consumers from a regional perspective. Moreover, the section focuses on *The food business* priority through presenting numerous solutions for supporting the sales and development of local food products.

2.1 The Need for Systemic Change

Current food systems face interconnected environmental, social, and economic sustainability challenges. Environmentally, these include overuse of natural resources, water pollution (Rose, Heller, & Roberto, 2019), greenhouse gas emissions (Ahmed et al., 2025), and biodiversity loss (Buhk et al., 2017). The IPCC's Sixth Assessment Report (IPCC, 2023) confirms that greenhouse gas (GHG) emissions have intensified heatwaves, heavy rainfall, droughts, and tropical storms. Climate change is threatening food security globally. Figure 2: Climate change impacts on worldwide food security across food supply chains. Based on IPCC Sixth Assessment Report (IPCC, 2022). Figure 2 below illustrates how climate change impacts all stages across food supply chains.

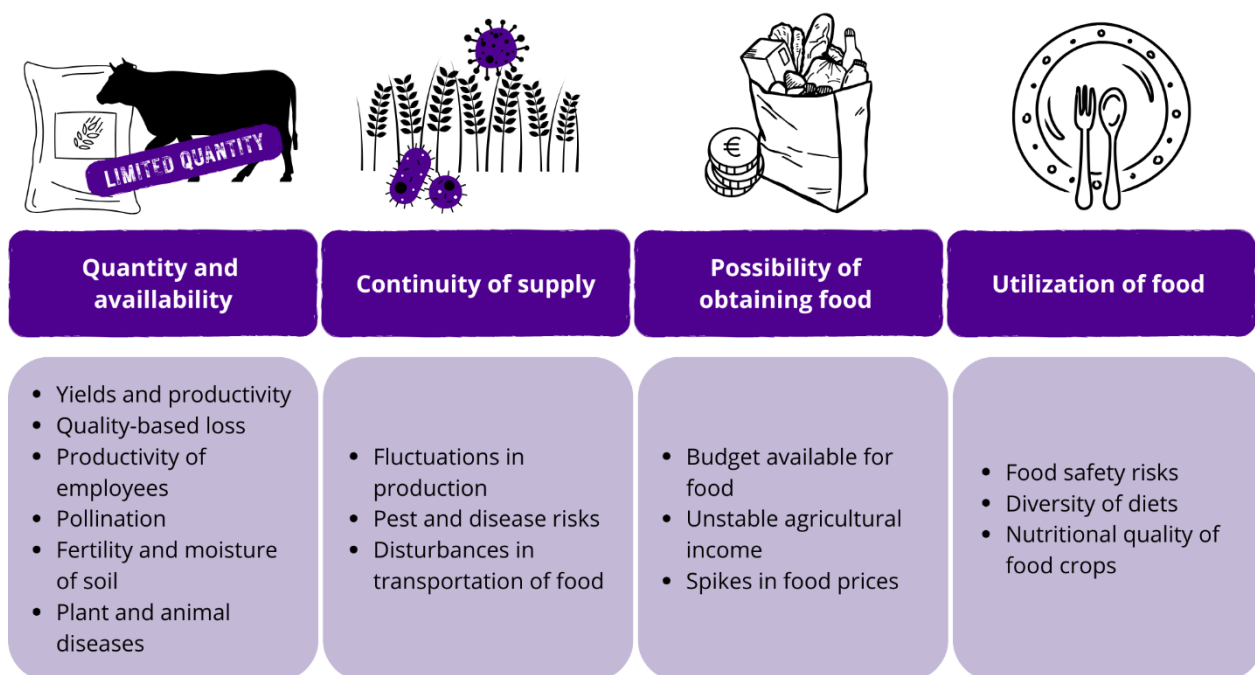


Figure 2: Climate change impacts on worldwide food security across food supply chains. Based on IPCC Sixth Assessment Report (IPCC, 2022).

In Europe, food systems are a major contributor to climate change and environmental degradation (Ludwig et al., 2022; Lehtonen & Rämö, 2023). In Finland, specific challenges such as agricultural emissions, biodiversity loss, and nutrient management issues have been particularly highlighted (Hoppe et al., 2016).

Regarding the future of Finnish food systems, South Ostrobothnia's Climate Road Map for the Food Sector (Palomäki et al., 2022) states that climate change could potentially improve the productivity of Finnish agriculture, provided that adaptation and preparedness are handled

effectively. However, agriculture and food production remain highly vulnerable to changes in climate conditions. The agricultural environment is directly influenced by factors such as a longer growing season, the fertilizing effect of increased atmospheric carbon dioxide, the emergence of new species, and ecosystem services—including interactions between pollinators and plants.

Socially, the aging of farm managers, limited youth entry, and delayed retirements are constraining farm succession (Zorn, 2025) and reducing the availability of skilled labor—a shortage exacerbated by demographic trends and competing labor demands across Europe (Gindele, Kaps, & Doluschitz, 2016). Social sustainability is also undermined by the prevalence of diets highly reliant on processed foods (Frison & Clément, 2020), and livestock products consumed in quantities exceeding dietary recommendations (Zech & Schneider, 2019). Moreover, food waste is exacerbating food insecurity and environmental harm (Alsaffar, 2016).

Economically, producers face low and unstable incomes, weak bargaining power, and limited access to resources due to market concentration (Frison & Clément, 2020) and competition from low-price products imported via global food chains (Monaco et al., 2017). Finnish farms are facing weak profitability as well, especially in grain production, though financial situations vary widely (Latvala & Niemi, 2025). Furthermore, European agriculture's reliance on imported inputs—fertilizers, fuel, and feed—means rising costs, worsened by the Russia-Ukraine conflict, are cutting farmers' profitability (Rabbi et al., 2023). Meanwhile consumers—especially low-income groups—struggle to access healthy, nutritious food, often relying on cheaper ultra-processed options. Frison & Clément (2020) describe how these inequalities experienced by both producers and consumers stem from structural imbalances in the industrial food system that concentrate economic power in a few actors. On a wider scale, global growth remains uncertain, with new U.S. tariffs risking slower growth or recession. Beyond trade risks, the war in Ukraine and potential new conflicts threaten stability (Latvala & Niemi, 2025).

Regional food systems play a significant role in addressing such various sustainability problems within food systems. Such systems can bring significant socioeconomic benefits as they can bolster local economies by increasing incomes for local producers, creating jobs, and fostering community development (Naglis-Liepa et al., 2021). Regional food systems can also emphasize environmental sustainability through sustainable agricultural practices, such as organic farming, which can reduce environmental impacts (Doernberg et al., 2016). Overall, regional food systems enhance resilience by reducing dependency on long-distance transport and external variables (Keegan et al., 2024). They also promote diversity, stability, and flexibility, which are crucial for adapting to changes and shocks (Ruhf, 2015).

To some stakeholders, such as researchers in the Sustainable food solutions (KERRU) research group, South Ostrobothnia already demonstrates strong regional cooperation across the food chain—from primary production to machinery manufacturing—and has strengths in agricultural expertise, flagship enterprises, food education, and local development (Talvitie, 2025). South Ostrobothnia has also been designated as a European Regional Innovation Valley (RIV) (Regional Council of South Ostrobothnia, 2024). This designation emphasizes the region's collaborative potential along with interregional innovation and cooperation to strengthen food system resilience and sustainability, supported by EU-level funding. Nevertheless, many sources find various weaknesses with the regional cooperation: for instance, the same KERRU research group underlined how the lack of collaboration between primary production and further processing hinders the regional food fields' growth (Talvitie, 2025). Additional areas for improvement are discussed in the following sections.

2.1.1 Cooperation for Climate-Change Adaptation

Climate change adaptation refers to the process of adjusting infrastructure, institutions, and ecosystems to reduce vulnerability to climate risks and to exploit any potential benefits. This involves a range of activities aimed at reducing vulnerability to climatic hazards, enhancing resilience, and responding to emerging opportunities (Sovacool et al., 2017).

In the context of food systems, climate-change adaptation refers to a range of strategies and measures aimed at ensuring the resilience and sustainability of food production, processing, distribution, and consumption in the face of changing climatic conditions. A comprehensive systems approach is necessary to address the complex interactions between climate change and food systems. This includes considering the entire food supply chain from production to consumption (Nissan, Simmons, & Downs, 2022). However, adaptation efforts are often hindered by behavioral, socioeconomic, policy, and structural barriers. Addressing these barriers requires coordinated efforts and institutional support (Salpina & Pagliacci, 2022).

In South Ostrobothnia, climate change poses concrete threats. Increasingly severe weather events—storms, droughts, heatwaves, freezing rain, and snow—jeopardize crops, forests, infrastructure, and water systems. These disruptions affect economic stability, public health, and essential services. While short-term weather forecasting supports preparedness, more frequent and extreme events are likely in the coming decades (Sisäinen turvallisuus, 2023). This calls for strengthened regional adaptation strategies to protect both livelihoods and ecosystems.

The region's food sector is particularly exposed. In a recent workshop (Talvitie, 2025), researchers identified limited climate adaptability as one of region's major challenges. Addressing

this vulnerability requires long-term vision, improved education and skills, and targeted support for sustainable practices. Key concerns related to climate resilience include agricultural energy use, peatland emissions, and the mental well-being of farmers. Enhanced sustainability communication, consistent policy, and stronger consumer engagement were highlighted as necessary steps forward.

Another important component of climate change adaptation in food systems is the transition toward a circular economy (CE). CE practices help reduce environmental impacts and enhance resilience by reusing raw materials and optimizing resource use—all of which reduce greenhouse gas emissions and support more efficient food systems (Rabbi & Amin, 2024; Toplicean & Datcu, 2024). These principles not only mitigate climate impacts but also strengthen adaptive capacity by promoting practices such as mixed cropping, agroforestry, and crop rotation, which reduce reliance on external inputs and create more self-sustaining food production systems (Nkansah-Dwamena, 2024).

As with other adaptation strategies, collaboration is essential for the successful implementation of CE. Transitioning to circular agriculture requires coordinated efforts among smallholder farmers, agrifood value chain actors, NGOs, and policymakers to reduce food loss and redesign agricultural systems (Nkansah-Dwamena, 2024). Similarly, with wider food systems, collaboration among various stakeholders—governments, civil society, academia, and the agri-food industry—is vital for addressing the complex challenges of transitioning to circularity (De Bernardi, Bertello, & Forliano, 2023). Effective support must also be locally tailored for recognizing regional characteristics and needs to ensure guidance and resources align with practical realities (Mäki et al., 2024).

In South Ostrobothnia, several barriers challenge CE implementation, including fragmented actor networks, weak collaboration, and difficulties identifying viable business models. Flexibility and continuity in support measures also remain limited. However, the region shows significant potential: strong natural resources, growing interest in the green transition, and active efforts to build collaboration networks provide a strong foundation for advancing circular solutions that enhance both environmental sustainability and climate resilience (Mäki et al., 2024).

To address the various challenges and barriers, South Ostrobothnia's Climate Roadmap for the Food Sector² (Palomäki et al., 2022) outlines a vision for achieving a climate-resilient regional food system by 2035. The roadmap's main goals include:

- A. An active operating environment for building a climate-resilient food chain
- B. Low-carbon food chain across all stages

² [South Ostrobothnia's Climate Road Map for the Food Sector](#) (in Finnish)

- C. Adaptation and preparedness for climate change
- D. Climate-resilient consumer choices
- E. Carbon-neutral food services
- F. Carbon-neutral wholesale and retail trade
- G. Carbon-neutral food industry
- H. Carbon-negative primary production
- I. Carbon-neutral production inputs

The Roadmap also lists specific means for climate-change adaptation under goal C:

- Promote research, development, and use of knowledge related to modeling and adapting to extreme weather events.
- Explore and implement irrigation possibilities to cope with changing weather conditions.
- Support sustainable water management, such as wetland construction and drought preparedness.
- Improve soil fertility and structure to enhance resilience.

Achieving these ambitious targets requires coordinated efforts across sectors. Primary production, uniquely capable of sequestering carbon, is expected to go beyond neutrality toward carbon negativity, therefore demanding support from the entire food chain. Moreover, the need for cooperation from regional to international stages is highlighted especially for the goal A (Palomäki et al., 2022).

The strength of collective action is indeed a key driver, particularly regarding small farms' contribution to regional food and nutrition security in Europe (Arnalte-Mur et al., 2020). Smallholders' willingness and ability to cooperate influence their capacity to co-design production and participate in non-conventional value chains, especially via SFSCs. Cooperation enables both individual and collective direct selling—through farmers' markets or digital platforms—which can also support climate adaptation.

Simultaneously, the high share of total emissions attributed to agriculture was a key concern during the regional roadmap development—although it was not indicated which stakeholders shared this view. Palomäki et al. (2022) also state that stakeholders have criticized the disproportionate expectations regarding emission reductions placed on primary producers in South Ostrobothnia. According to the stakeholders, responsibility must be more equitably distributed across the food chain and among consumers. Regional climate strategies and solutions must therefore consider fairness and feasibility in assigning roles and responsibilities.

According to Palomäki et al. (2022), the most effective regional measures for preventing climate-change include promoting low-carbon production inputs, increasing soil carbon sequestration, reducing emissions, phasing out fossil fuels, minimizing food waste, and strengthening both

research and its practical application. Moreover, they emphasize how the greatest potential for emission reductions in food production lies in primary production and targeted measures on peatlands. Due to limited mineral soils, South Ostrobothnia has the second-highest share of cultivated peat soils among Finnish regions, which are estimated to account for over 60% of its agricultural emissions (Mäkimantila et al., 2021). This places the Ostrobothnian regions in a key position for reducing agricultural emissions and poses transitioning to climate-smart cultivation of peatlands as a major regional challenge. In the future, fields could sequester more carbon through carbon farming practices such as improving soil structure, using diverse crop rotations, and maintaining soil cover (Palomäki et al., 2022). For example, multi-species grasses and deep-rooted soil-improving plants are effective in storing carbon. These efforts will be critical in building a sustainable, resilient, and climate-smart food system for South Ostrobothnia.

At the national level, agriculture is a major source of GHG emissions, particularly from peatland use. Removing peatlands from production is therefore crucial for mitigation (Huan-Niemi et al., 2023). Economic tools like deforestation fees can be effective in the land use sector, though they face challenges of efficiency, legality, democracy, and legitimacy (Kärkkäinen et al., 2020). Finnish farms must also adapt through interdisciplinary cooperation between agricultural and energy policies, with potential to produce renewable energy alongside food, creating new business opportunities (Rintamäki, Rikkonen, & Tapio, 2016). Certain regions with high livestock production and peatland use—such as South Ostrobothnia—may require significant restructuring under changing diets and land use measures (Lehtonen, Huan-Niemi, & Niemi, 2022). Beyond production, dietary shifts—reducing meat and increasing plant-based foods—can substantially cut emissions (Saarinen et al., 2023).

Broadening the scale, in Northern Europe several agricultural strategies can support climate mitigation. Improving nitrogen uptake efficiency (NUpE) through plant breeding can cut GHG emissions (Johansson, Muneer, & Prade, 2023), while expanding legume cultivation improves soil health, reduces synthetic fertilizer use, and lowers emissions (Marteau-Bazouni, Jeuffroy, & Guilpart, 2024). Adjusting sowing dates and selecting suitable cultivars—especially for grain legumes—can help maintain yields under climate change (Marteau-Bazouni et al., 2024). Additionally, shifting the energy balance toward renewable sources further reduces emissions (Sokka, 2017).

As emphasized in the section above, collaboration is a central enabler of climate-change adaptation. South Ostrobothnia's Regional Rural Development Plan 2023-2027³ positions stakeholder cooperation as a regional strength and a means to foster climate resilience and

³ [South Ostrobothnia's Regional Rural Development Plan 2023-2027](#)

innovation (Mäkimantila et al., 2021). The plan outlines specific cooperation goals essential for adaptation:

- Stronger coordination among businesses, especially food producers and buyers.
- Development of networks and new business models for sustainable food and natural products.
- Cross-sector information exchange to improve decision-making and responsiveness.
- Joint planning of adaptation actions with shared responsibilities and resources.
- Participatory, needs-driven approaches involving the full food chain.
- Integration of domestic and international research into local adaptation solutions.

The plan also links cooperation directly to climate mitigation and adaptation by emphasizing closer collaboration between primary producers, small businesses, and consumers. Building a more connected and resilient food system is thus viewed as key to effective adaptation in South Ostrobothnia.

2.1.2 Cooperation for Reducing Environmental Impact

Reducing the environmental impacts of food systems requires a comprehensive and multi-layered approach that addresses the entire chain—through production, processing, distribution, and consumption. In this context, environmental impacts include greenhouse gas (GHG) emissions, land and water use, pollution, and biodiversity loss. However, assessing these impacts is complex due to variation across food production systems and the many processes involved (Benton et al., 2024).

Nationally, agriculture accounts for about 20% of Finland's GHG emissions, with livestock production and nutrient runoff posing serious environmental challenges (Lehtonen & Rämö, 2023). Though nutritionally adequate and low-emission diets are affordable, cultural preferences and norms still hinder their adoption (Irz et al., 2024). Thus, environmental solutions must also engage with food culture and consumer behavior.

In South Ostrobothnia, total GHG emissions decreased by 24% between 2005 and 2023—below the national average of 37%. Notably, agriculture remains the region's highest-emitting sector, accounting for 44.6% of total emissions in 2023, compared to the national share of 22.3% (SYKE, n.d.). This highlights the importance of targeted mitigation in the regional food system. Including emissions from the food industry and food services makes the food chain's total emissions even more significant (Palomäki et al., 2022). Food sector actors in South Ostrobothnia see that the main barrier to emission reduction is financial, based on a survey study. Respondents highlighted high costs, lack of funding and subsidies, poor investment profitability, and changes in selling

prices as key challenges. The global situation was also seen as a complicating factor. Moreover, in general, concerns were raised about the future of Finnish agricultural production. However, among farmers, 9 out of 13 believed that achieving carbon neutrality on their farms by 2035 is possible (Palomäki et al., 2022).

In South Ostrobothnia, where agriculture plays a central role in both the economy and land use, the need for systemic and locally grounded solutions is particularly pressing. Effective mitigation relies on diverse stakeholders working together, including producers, processors, retailers, policymakers, and consumers (Ciasca et al., 2025). Engaging local communities and stakeholders in decision-making processes ensures that sustainability measures are context-specific and widely accepted (Prosen, Lekše, & Ličen, 2023).

Key strategies to reduce environmental impacts in food systems include:

- Minimizing food loss and waste (FLW): Reducing waste across the food chain—especially in food services, processing, and households—can significantly lower GHG emissions, land use, and water consumption while improving resource efficiency (Cattaneo, Federighi, & Vaz, 2021).
- Promoting sustainable agriculture: As examples, organic farming practices, such as using fewer pesticides and enhancing soil health, can reduce climate impact and promote biodiversity (Krause et al., 2024). While implementing agroecological practices alongside dietary changes and waste reductions can improve sustainability (Röös et al., 2022).
- Encouraging dietary shifts: Moving toward more plant-based diets and reducing high-impact animal-sourced food consumption, such as beef, is a proven strategy for lowering food-related emissions and land pressure (Frehner et al., 2020).

Another major opportunity lies in the circular economy (CE), which emphasizes resource efficiency and regeneration. In food systems, CE strategies include reducing food waste, reusing raw materials, and shortening supply chains. These practices help cut emissions, conserve natural resources, and support ecosystem health (Rabbi & Amin, 2024; Toplicean & Datcu, 2024). As noted in South Ostrobothnia's Climate and Circular Economy Road Map, purchasing and using raw materials efficiently is essential to tackling climate change (Regional Council of South Ostrobothnia, 2022). Yet, limited collaboration among actors remains a regional challenge in implementing CE principles effectively (Mäki et al., 2024). These central aspects are covered in the potential solutions introduced below.

2.2 Stakeholder Roles and Interdependencies

Addressing the complex challenges that hinder sustainability transitions requires recognizing that actors within food systems are deeply interconnected (Kuhmonen et al., 2023). As illustrated through the issues above, the systems are intricate networks involving social, environmental, economic, and technological elements. Institutional aspects, such as the bureaucracy of EU's CAP system, play a crucial role as well in shaping agricultural practices across EU member states (Öhlund, Zurek, & Hammer, 2015). A systemic approach helps in understanding these complex interactions and addressing the multifaceted challenges they present (Pope et al., 2021). By integrating various sustainability priorities such as climate, biodiversity, and health, systemic approaches facilitate comprehensive planning and policymaking. This integration helps in identifying and addressing interconnected issues effectively (Issac, Newell, & Das, 2025).

Fanzo and colleagues (2021) highlight how actions across food system components are interconnected and lead to various outcomes, illustrated by drivers, components, and outcomes in Figure 3. The authors note that although a static framework helps visualize the system, food systems are inherently dynamic as the components are part of ongoing processes with feedback loops among them. Moreover, even though the schematic depicts a single system, food systems operate at multiple scales and interact with each other.

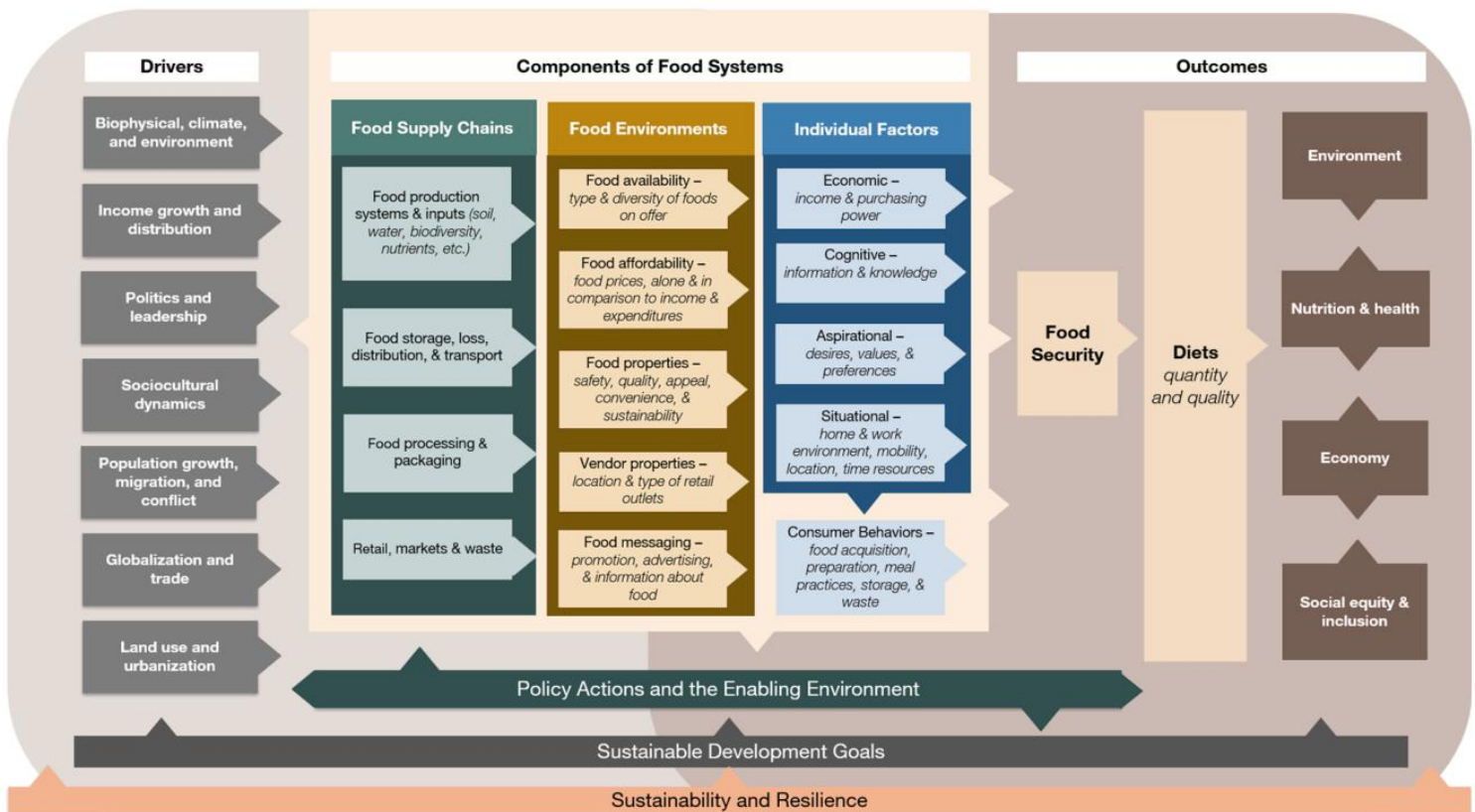


Figure 3: Food system components, drivers, and outcomes. Source: Fanzo et al. (2021)

Effective implementation of sustainable practices therefore requires multi-stakeholder collaboration (Kabato et al., 2025). Collaboration among farmers, researchers, the food industry, and livestock producers enables more diverse and sustainable farming systems (Dwivedi et al., 2017) and ensures food safety through coordinated value chain efforts (Michel et al., 2024). Shared infrastructure and digital information systems further support transparency and communication (Trienekens et al., 2012). Public-private partnerships also enable the exchange of best practices and innovations (Corigliano, Morrone, & Algieri, 2025), while short agrifood supply chains (SASCs) foster direct producer–consumer relationships, social learning, and local innovation. Volpentesta and colleagues (2013) describe SASCs as alternative networks within agriculture and the food industry, characterized by minimizing the distance between production and consumption, promoting social interaction, and enhancing innovation processes. Moreover, the authors present that learning processes develop more actively when more opportunities for collaboration arise, as innovation is seen as closely tied to social structures. Successful transformation is thus enabled by both social capital and functional knowledge networks.

Start-ups contribute to sustainable transformation as well, especially when embedded in supportive networks involving governments, investors, academia, and incubators (Ludwig et al., 2022). Specific means of enhancing collaboration include strengthening cooperation between actors, increasing transparency, improving networking within the ecosystem of actors, and learning from other countries. Overall, sustainability in food systems is best achieved through cross-sectoral cooperation that enhances innovation, learning, and systemic resilience.

In Finland, however, food system transformation is hindered by limited dialogue and narrow assessments. According to Kuhmonen and colleagues (2023), this is seen in how, for example, diverse perspectives are excluded and collective responsibility overlooked. This stems from a lack of genuine dialogue between actors and prevents common goals as some actors may feel excluded unless they align with certain viewpoints. Limited knowledge and weak cooperation thus lead to misguided expectations and hinder shared insight. This highlights the need for broad and deep understanding, required by effective collaboration in the food system.

To advance sustainability in Finnish food systems, cooperation must be strengthened across all stakeholder groups. According to Latvala et al. (2025), achieving climate and environmental sustainability requires collaboration between agriculture, consumers, policymakers, and cities. Other sources on the European level highlight producers (Saviolidis et al., 2020), distributors (Nasso et al., 2024; Saviolidis et al., 2020), retailers (Garcia et al., 2018), policy makers (Ciasca, Cito, & Lattanzio, 2025; Saviolidis et al., 2020; Zaharia et al., 2021), non-governmental organizations (NGOs)—such as advocacy groups—(Saviolidis et al., 2020), researchers

(Saviolidis et al., 2020), businesses (Makrenko, Makrenko, & Rubanov, 2023) and investors (Kirschenmann, 2022) from the private sector, as well as consumers (Zaharia et al., 2021) as key actor groups in enhancing food systems' sustainability. The responsibility of implementing sustainability measures cannot therefore rest solely on farmers but must be shared across the various stakeholders. For instance, while Latvala and colleagues (2025) highlight the roles of farmers and consumers, they also stress how cities must co-own environmental responsibility, for example through initiatives like community-supported farming.

When focusing solely on farmers, multiple factors influence farmers' readiness to adopt more sustainable production methods. Latvala et al. (2025) list support and recognition from society, along with emotional engagement and attitudes as such aspects. In addition to attitude, Sánchez Bogado et al. (2024) name access to knowledge, social capital, and perceived environmental benefits as key enablers. Financial incentives strongly influence farmers' adoption of sustainable practices as well. The EAFRD compensates farmers who voluntarily implement such measures (Biffi et al., 2021), while result-oriented incentives link rewards to environmental outcomes, improving cost-effectiveness and flexibility (Matzdorf & Lorenz, 2010). The EU's CAP provides tools and incentives to curb overuse of natural resources and boost ecosystem services, with recent reforms strengthening environmental commitments (Blasi et al., 2023). Payments for Environmental Services (PES) also promote greener practices, though low enrollment can limit effectiveness (Chabé-Ferret et al., 2023). It should be noted that according to Puupponen and colleagues (2023), Finnish food policies prioritize farmer livelihoods—along with food security—over environmental sustainability. They argue that there is a need for greater emphasis on environmental sustainability and inclusive policymaking to achieve a just transition.

Collaboration in food systems is strongly supported by effective information exchange, and Trienekens et al. (2012) emphasize that shared information systems and databases can enhance transparency, quality management, and coordination across the supply chain. This aligns with the growing focus on local and short food supply chains, where closer proximity helps make processes more visible to all stakeholders. For example, the FOX project (FOX, n.d.a) promotes healthier and more transparent regional food systems through consumer involvement and testing solutions in four European "food circles," while Maier, Klein, and Schumacher (2020) highlight that authenticity, transparency, compatible business structures, and the popularity of local foods are key success factors. At the same time, actors within innovation ecosystems often compete with one another, which can hinder cooperation. Ludwig et al. (2022) argue that ecosystem facilitators should prioritize offering honest, transparent, and supportive environments for companies, helping them navigate expectations and fostering a more collaborative and productive atmosphere.

2.3 Models and Tools for Cooperation

The following section introduces real-life examples of good practices that support both climate-change adaptation and the reduction of environmental impacts in food systems. While the first subsections focus on adaptation solutions—organized according to the cooperation goals outlined by Mäkimantila et al. (2021)—the later ones highlight approaches that lower environmental burdens through collaborative, cross-sector efforts. Taken together, these practices demonstrate how cooperation, whether through food waste reduction, short supply chains, communal food production, or farmer networks, can simultaneously strengthen resilience and promote more sustainable, locally rooted food systems.

2.3.1 Stronger coordination among businesses

Across Europe, small food businesses and producers coordinate through horizontal and vertical strategies that improve trust, reduce uncertainty, and expand market access (Hernández et al., 2021). In Norway's Hedmark region, proximity-based contracts link small horticulture and dairy farms with local buyers, often specifying delivery schedules, product grades, and seasonal volumes. Hernández and colleagues (2021) elaborate how farms diversify into SFSCs and agri-tourism, supported by public funding for training, marketing, and regulatory exemptions. Producer associations jointly invest in small-scale processing equipment and organize shared transport routes, reducing overhead costs for members.

Similarly in Latvia's Latgale and Pieriga regions, coordination revolves around dairy processing taking place on-farm to produce artisanal cheeses and yogurts (Hernández et al., 2021). Farmers pool similar products to meet larger orders and coordinate delivery timetables to reduce logistics costs while the products are marketed via farmers' markets, direct purchasing groups, online platforms, or local cooperatives, expand the products' reach. However, in Pieriga, dependence on volunteer-run markets and the decline of local shops limit long-term stability.

In West Scotland, horticultural and livestock producers form similar collective arrangements as well to supply restaurants and local events (Hernández et al., 2021). On islands such as Arran, this involves coordination by sourcing products directly from multiple small producers, agreeing on product ranges to avoid duplication, scheduling harvests to match demand, and sharing transport to lower costs. This coordination enables small farms to access regional markets more effectively. Such collaboration is exemplified by initiatives such as the Bowhouse Link platform in Fife (Scottish Government, 2022). This online platform centralizes orders from multiple local producers—including butchers, flour millers, brewers, and market gardeners—, consolidated packaging at a single hub, and organized last-mile delivery, allowing customers to buy a complete

weekly shop from local suppliers, thereby supporting small-scale producers who had lost wholesale contracts due to the pandemic.

In Italy's Lucca and Pisa, informal trust-based networks coordinate promotion of traditional and seasonal products, sometimes sharing distribution routes or processing equipment such as olive presses and refrigerated vans (Hernández et al., 2021). These businesses also engage in collective problem-solving, such as coordinating harvest times or delivery logistics, and take advantage of geographic proximity to support quick and flexible supply responses. Participation in local informal networks and community-based groups further facilitates ongoing communication and cooperation.

Cooperatives located in Portugal's Oeste and Alentejo Central, specialized in pears, wine, and olive oil, operate shared cold storage, grading, and packaging facilities. This enables continuous supply that meets the volumes, appearance, and shelf-life requirements of supermarket and export markets. (Hernández et al., 2021) Mediterranean studies confirm as well that such pooling of storage, branding, and marketing improves margins and ensures steady buyer relationships and better market access (Prosperi et al., 2024).

Vertical coordination is evident in Spain's Catalonia and Valencia regions, where citrus cooperatives are integrating their operations with European retail chains. According to Franco et al. (2023), the retailers are engaged through structured supply agreements that align production schedules and quality specifications with market demand, while also supporting the cooperative–farmer network in implementing mitigation and prevention strategies. This vertical integration strengthens resilience by enabling joint planning, coordinated investments, and rapid dissemination of innovations across the supply chain. The cooperatives are simultaneously collaborating horizontally, as they act as key intermediaries, aggregating production from members, ensuring compliance with quality and phytosanitary standards, and facilitating the adoption of climate adaptation and pest-prevention measures. The measures improved irrigation efficiency, integrated pest management, and varietal selection to cope with heat stress and disease risk.

In France too, a shift from loose, ad-hoc trading to vertical, coordinated linkages between farmers, processors, retailers, and institutional buyers can be noticed (Coyral & Batt, 2023). The vertical coordination appears as long-term, structured buyer–seller relationships across supply-chain levels, marked by clearer governance and shifts in power dynamics. While these arrangements improve stability, producers report tensions such as excessive requirements, low prices, and strict delivery schedules. In parallel, producers increasingly value buyers who offer fair prices, consistent orders, good communication, adaptability, and a strong reputation—factors that foster trust, commitment, and relationship-specific investments.

A UK supermarket chain called Sainsbury's, in partnership with Land App and the UK Centre for Ecology & Hydrology (UKCEH), is using digital mapping technology to help UK farmers assess environmental issues across their land, identify supply chain risks, and plan climate-resilient farming practices (J Sainsbury plc, n.d.; Land App, 2023). To date, 264 farmers in Sainsbury's supply chain have used Land App to survey their farms, establishing baselines for biodiversity, habitat connectivity, and water quality, which inform land management plans such as tree planting, river protection, and pollinator-friendly areas (J Sainsbury plc, n.d.). The creation of a "digital twin" of supplier farms is told to enable precise planning and monitoring of interventions, while UKCEH's E-Planner⁴ tool identifies optimal sites for nature-positive measures, supporting informed, sustainable decisions that align food production with environmental recovery, biodiversity enhancement, and net zero goals (Land App, 2023).

2.3.2 Development of networks and new business models

Donner & de Vries (2023) introduce nine distinct types of business models contributing to sustainable food systems:

- Circular business models: Aim to minimize or eliminate resource losses by designing closed-loop systems that keep materials in use.
- Place-based social food networks: Locally embedded networks that emphasize social ties and collaborative relationships rooted in a specific territory.
- New logistics or online food distribution business models: Innovate how food is transported or sold by leveraging digital tools and logistics redesign (e.g., e-commerce platforms, last-mile solutions).
- Disruptive business models: Challenge and seek to transform existing system constraints—introducing fundamentally different approaches to production, distribution, or consumption.
- Sufficiency business models: Prioritize outcomes such as "enough" rather than excess; focus on providing adequate, healthy resource use without overconsumption.
- Inclusive business models: Embed low-income or marginalized communities directly into the value chain—benefiting both the business and social equity.
- Family business models: Businesses that are family-run and often oriented toward long-term sustainability and stewardship, rather than short-term profit.
- The focal company model: Models that position a single company at the center of coordinating broader sustainable practices across its supply chain.

⁴ [E-Planner tool](#) created by the UK Centre for Ecology & Hydrology (UKCEH).

- Regional food hubs: Facilities or platforms that aggregate, process, market, and/or distribute local or regional food, supporting collaboration and infrastructure-building

These models often emerge within Alternative Food Networks (AFNs)—socially embedded, place-based systems linking producers and consumers through SFSCs, local sourcing, and shared ethical and ecological values (Gori & Castellini, 2023; Laginová et al., 2023). AFNs enhance trust, transparency, and resilience in food systems while promoting community governance and social innovation (Belda-Miquel et al., 2021; De Bernardi et al., 2021). Many are organized as commons-oriented initiatives that enable knowledge co-production and transfer between stakeholders (De Bernardi et al., 2021). They include diverse models—such as farmers' markets, community-supported agriculture (CSA), cooperatives, and food hubs—that vary regionally but share the goal of transforming the food system through participation, transparency, and sustainability (Gori & Castellini, 2023; Laginová et al., 2023).

The Camilla Cooperative in Bologna, Italy exemplifies an AFN as a self-managed, community-based cooperative store. As presented by Sacchi et al. (2022) it operates on principles of collective action and co-production, meaning members are both owners and active participants in governance, decision-making, and day-to-day operations. The Cooperative's practical measures include:

- Direct sourcing from local and ethical producers to shorten supply chains and ensure transparency on origin, production methods, and environmental impact.
- Member work contributions—each member dedicates a set number of hours per month to store operations, reinforcing community ownership and lowering operational costs.
- Democratic governance through assemblies and working groups that decide on suppliers, pricing policies, and product selection based on sustainability and social criteria.
- Integration into wider alternative agri-food networks to exchange best practices, jointly purchase products, and support small-scale producers.
- Promotion of ecological and fair trade products, avoiding intermediaries and fostering relationships with producers aligned to cooperative values.
- Educational activities such as workshops, public events, and training sessions to strengthen consumer awareness and skills in sustainable consumption.

Through these measures, the Camilla Cooperative builds resilient supply networks, supports small-scale ethical producers, and creates a replicable model for sustainable food retail based on shared responsibility and social innovation.

In Romania, AFNs often emerge as a response to the shortcomings of mass food production and distribution, according to Florean, Crețan, and Doiciar (2024). National or regional AFN initiatives include Bio&co, Cutia Țăranului (the “Peasant’s Box”), and Cooperativa de Legume: Bio&co is a

social enterprise that combines organic vegetable production with social inclusion, employing disadvantaged people while supplying subscription-based vegetable boxes to consumers. It integrates agroecological practices and direct farm-to-consumer sales. Cutia Țăranului, again, is a national network of community-supported agriculture (CSA) schemes in which consumers subscribe to receive regular boxes of seasonal produce directly from small farmers, providing them with stable income and fostering strong producer–consumer relationships. Lastly, Cooperativa de Legume pools vegetables from multiple small farmers, enabling joint marketing, shared logistics, and better bargaining power with buyers, while promoting local, sustainable production as a producer cooperative.

Another example of direct selling is Trigo Limpio, a farmer-led initiative in northern Navarre (Spain), where five organic livestock farms collaborate to sell fresh meat and milk directly to consumers. By using native breeds and local resources, the system is resilient to climate change and market volatility, ensuring fair farmer prices, reducing intermediaries, and lowering the carbon footprint while sustaining small mountain farms and rural livelihoods (INTIA, 2023).

Portugal's Quinta do Oeste, an organic farm in the Lisbon Metropolitan Area, is highlighted by De Fátima Ferreira & Salavisa (2019) as a yet strong example of an AFN and a sustainable business model innovation. The farm's development is driven by the entrepreneur's personal commitment to sustainability and by participation in collaborative producer networks, which enable SFSCs and community-based commercialization. Through values-led leadership and localized, ecological production, Quinta do Oeste exemplifies how small-scale, networked initiatives can offer viable, scalable alternatives within broader sustainable food system transitions.

In Bulgaria, a digital AFN platform integrates a shared delivery system to cut environmental impacts and costs while improving producer–consumer connections. Developed through the INVEST Regional Living Lab with participatory stakeholder engagement, it applies the 4Cs of marketing—customer, cost, convenience, and communication—to ensure that it meets the needs of all stakeholders effectively and to support local businesses and enhance community engagement (Arabska et al., 2025).

More initiatives centered on direct selling and other forms of SFSCs are introduced in the section *Short food supply chains* as they contribute to both climate-change adaptation and the reduction of environmental impacts.

2.3.3 Cross-sector information exchange

Cross-sector information exchange plays a crucial role in enhancing decision-making and responsiveness in European food systems by integrating safety, innovation, sustainability, and

policy development into a cohesive framework. A foundational aspect of this exchange is improved risk management. The Rapid Alert System for Food and Feed (RASFF) demonstrates how timely sharing of information among EU member states can mitigate food safety threats. By enabling swift action in response to food-related risks, RASFF underscores the critical value of fast and accurate communication in protecting public health (Wollenschläger, 2019; Komínková, Vavřina, & Polák, 2020).

Building on this need for timely data, digitalization offers powerful tools to strengthen food system responsiveness. The development of Common European Data Spaces for the agri-food sector enables structured and secure data sharing that supports both the digital and green transitions. With access to real-time and comprehensive data, decision-making improves across all levels—from farms to public institutions (Brunori et al., 2025). Moreover, the integration of advanced technologies such as Internet of Things (IoT), AI, and big data enhances transparency and coordination across supply chains, allowing stakeholders to better manage complexity and adapt to changing conditions (Gaspar, Soares, & Caldeira, 2021). In the food sector information systems are indeed strong support tools for decision-making (Poturo et al., 2012).

As food systems become more data-driven, sustainability and consumer trust emerge as essential dimensions of information exchange. Transparency tools that track the environmental, social, and economic impact of food products can rebuild consumer confidence and align practices with sustainability goals. Enhancing existing systems to reflect Triple-P transparency—Planet, People, and Profit—supports informed choices and more responsible production and consumption patterns (Wognum et al., 2011).

Technology alone, however, is not enough. Durrant et al. (2021) emphasize that secure, equitable, and scalable data sharing must also rely on governance models like Data Trusts—neutral frameworks that manage shared data on behalf of multiple stakeholders. These Trusts set clear rules for data access and use, ensuring accountability and transparency. In the agri-food context, Data Trusts could facilitate innovation, improve supply chain efficiency, and enable better decisions through aggregated insights. They also unlock the full potential of machine learning models, which can analyze large, diverse datasets to forecast yields, detect diseases, optimize resources, and support smart supply chains.

One practical example of such information sharing is the Food Sharing Compass platform, offering a structured means for policy makers, researchers, Food Sharing Initiatives (FSIs), citizens, and food supply actors to share and access information that enhances adaptive capacity (CULTIVATE, n.d.a). The platform features five integrated tools that facilitate data collection, sustainability assessment, policy support, citizen engagement, and knowledge transfer (CULTIVATE, n.d.b):

1. The Food Sharing Calculator helps assess the environmental and social impacts of FSIs, supporting data-driven decisions for resource allocation and policy development.
2. The SHARECITY200 Database enhances the mapping and monitoring of FSIs, enabling a clearer understanding of local practices and their contributions to food security and climate resilience.
3. The Menu of Good Governance provides guidance for aligning local policies with the needs of FSIs.
4. The Library of Citizen Engagement strengthens participatory approaches.
5. The Community of Practice Amplification Programme fosters cross-sector learning and replication of effective practices across European cities.

The tools are now being replicated in six European cities from Dublin to Athens, meaning the final results will be released later on after refining and validating the tools (CULTIVATE, n.d.b).

Food4CE provides a similar solution for information sharing within European food systems. The project has established a network of local and transnational Innovation Hubs to foster collaboration and knowledge transfer between stakeholders in the agri-food and logistics sectors (Interreg Central Europe, n.d.a). These hubs support Short Food Supply Chains (SFSCs) and AFNs by enabling the uptake of innovative technologies and sharing of best practices across Europe. Each Innovation Hub addresses specific local challenges while contributing to a shared transnational goal of climate-resilient, efficient, and sustainable food systems (Interreg Central Europe, n.d.b):

- The ORBITaLA Innovation Hub in Slovenia tackles digitalization and logistics challenges for AFNs by offering tailored workshops, co-creation sessions, and advisory services.
- The Austrian Future Food Connective Innovation Hub strengthens stakeholder collaboration and problem-solving as a platform offering cross-border exchange of best practices, tailored solutions, networking activities, and personalized support.
- The Localog Innovation Hub conducts a needs analysis of AFNs along with workshops on solutions and technological innovations and develops regional, national, and European policy recommendations (ITL, 2024) while generating a collaborative regional action plan for resilient food systems.
- The FOOD4Health Innovation Hub Budapest connects regional and national stakeholders, coordinates data and communication across case studies and hub managers, exchanges best practices within the European community, and organizes workshops to disseminate results and drive innovation (Sustainable Food System Innovation Platform, n.d.a).

- The PULS Innovation Hub strengthens SFSCs by creating business plans, analyzing profitability, guiding sustainable production shifts, and optimizing production intensity, as well as evaluating and cutting logistics costs.

Tying all these regional efforts together, the Transnational Innovation Hub serves as a central platform for cross-border cooperation, sharing experiences, and collectively addressing challenges. It promotes mutual support and a broader perspective for innovation in AFNs and SFSCs, aligning local actions with regional and international climate adaptation goals (Interreg Central Europe, n.d.b).

Food4CE has also created the Knowledge Transfer Platform⁵, which offers a range of tools and resources to support learning and collaboration. The platform features an interactive map highlighting AFNs and related actors—such as producers, logistics providers, and online platforms—showcasing their work in advanced logistics, digitalization, local focus, sustainability, and transparency. As a part of the platform, a comprehensive knowledge base wiki offers access to project results, logistics solutions, policy insights, and educational tools like courses and quizzes. By encouraging users to share their own experiences and insights, the platform promotes cross-sector learning and supports the development of more resilient, efficient, and climate-adaptive local food systems (Interreg Central Europe, n.d.c).

Moreover, the Matchmaking Platform under the FOOD4CE project is a web-based tool designed to connect stakeholders across the food supply chain by aligning their logistics needs—from farmers to AFNs, logistics providers, and customers. Developed with stakeholder input and expert knowledge, it will support more efficient, collaborative, and resilient AFNs in participating regions once launched (Interreg Central Europe, n.d.b).

The Foodtech Living Labs Platform⁶ offers another practical tool for enhancing decision-making and responsiveness in Europe's foodtech sector through cross-sector collaboration and knowledge exchange. It connects national and regional Food Systems Living Labs (FS-Labs)—real-world environments where diverse stakeholders co-create solutions to food system challenges such as sustainability, food security, and digital innovation. This way the platform shares best practices, scales successful models, and enables cross-border partnerships (FOODPathS, n.d.).

In Finland, a distinctly regional network is being created in the Urban&Local – Future Food Ecosystem project (Forum Virium, n.d.) to foster collaboration between cities, businesses, food actors, and research institutes to strengthen local food systems in Uusimaa. The project develops test platforms and innovative solutions to support sustainable production, distribution, and

⁵ The [Knowledge Transfer Platform](#) created in the Food4CE project.

⁶ [Foodtech Living Labs Platform](#) created in the FOODPathS project.

consumption of local food. By promoting short, transparent food chains and urban farming, the project enhances climate resilience, economic growth, and social sustainability. Aligned with Helsinki's strategy for sustainable innovation, Urban&Local helps position the city as a leader in clean, local food while supporting the visibility of the female-led food and restaurant sector.

2.3.4 Joint planning of adaptation actions

In their study of 52 European food system partnerships, de Vries et al. (2024) found that various forms of inclusive, co-creative partnerships work together to advance sustainability. They highlight how successful co-creation requires joint planning of adaptation actions built on shared responsibilities and pooled resources. These inclusive partnerships, especially those including innovative private actors, smallholders, and academic partners, thrive when all stakeholders co-define objectives, coordinate activities, and efficiently use resources across varying scales and timeframes. Public and civil society actors are found to play vital roles as initiators and enablers, organizing interactions and creating “snowball effects” that amplify impact.

Co-planning is similarly emphasized by Simón-Rojo et al. (2023) in their analysis of the Urban Master Plan of the Metropolitan Area of Barcelona and the Biodistricts Plan in Andalusia as practical models. Both models integrate ecological, economic, and social dimensions to support sustainable food systems by protecting peri-urban agricultural land, promoting agroecological practices, and reinforcing local economies. They operationalize climate resilience by prioritizing sustainable soil and water management, reducing emissions, and fostering adaptive food production systems. Importantly, these plans create green jobs and strengthen urban–rural linkages through SFSCs and support for small-scale producers. What makes these models especially effective is their use of innovative governance mechanisms that enable collective action. In Barcelona, participatory planning tools bring together diverse stakeholders to shape food-related decisions, while in Andalusia, multi-actor platforms facilitate coordination between public institutions, farmers, and civil society. These governance structures distribute responsibilities and pool resources, allowing for co-creation and implementation of agroecological initiatives.

De Toni et al. (2021) illustrate how Italy's Inner Peripheries—areas that face marginalization despite not being geographically remote—demonstrate the value of joint planning with shared responsibilities and resources. These territories leverage collaborative governance structures to revitalize local food economies by aligning development strategies with place-based needs. The authors show how partnerships among municipalities, local producers, civil society, and institutional actors enable integrated planning that supports agroecological practices, short food supply chains, and landscape preservation. By pooling resources and fostering cross-sector

collaboration, Inner Peripheries implement context-sensitive food system strategies that address economic vulnerability, demographic decline, and environmental challenges. These joint efforts promote local employment, strengthen territorial identity, and enhance resilience to climate change.

2.3.5 Participatory, needs-driven approaches involving the full food chain

Trento's Urban Food Strategy exemplifies a needs-driven approach by engaging a wide range of stakeholders across the entire food chain through transdisciplinary action research. Giovanni and Forno (2023) elaborate how the strategy was developed within a lab-like initiative that prioritized co-creation, inclusivity, and responsiveness to local needs. It brought together municipalities, civil society organizations, researchers, and businesses in a collaborative process to identify food-related challenges and co-develop context-specific solutions. This model enabled shared ownership of outcomes and fostered mutual learning, ultimately reinforcing the integration of sustainability goals and local values into urban food governance.

Another Trento-based good practice is Nutrire Trento. The initiative fosters Civic Food Networks (CFNs) that actively involve actors across the entire food chain—producers, consumers, institutions, and researchers. Rooted in transdisciplinary action research, the initiative engages citizens in co-designing solutions to local food system challenges, prioritizing democratic governance, transparency, and shared responsibility. By embedding food into broader urban policy and empowering local stakeholders, Nutrire Trento strengthens social ties and builds collective capacity for more sustainable and resilient food systems (Giovanni & Forno, 2023).

In Swedish context, Sellberg and colleagues (2020) demonstrate a practical bottom-up approach using participatory narrative scenario methodology, where regional actors in Stockholm collaboratively developed detailed future scenarios for sustainable and resilient food systems. This method engaged diverse local stakeholders—farmers, businesses, policymakers, and civil society—as well in workshops to share knowledge, identify challenges, and co-design actionable strategies. Through this hands-on, inclusive process, local initiatives were empowered to expand their regional niches and align their efforts with global sustainable diet goals, making the approach a concrete tool for guiding coordinated, place-based food system adaptations.

Participatory Guarantee Systems (PGSs) are AFNs that embed democratic participation in local food chains, involving stakeholders—including consumers—in organic verification to build trust and direct producer–consumer relationships (Kaufmann et al., 2023). By engaging local actors in certification, PGSs tailor standards to community needs (Ninnin & Lemeilleur, 2024), aiming to

raise consumer awareness and participation despite current low involvement (Kaufmann et al., 2023), while empowering producers and promoting community self-management (Cuéllar-Padilla et al., 2022). As a European example, Nature & Progrès (N&P) in France reflects a specific, polycentric governance structure tailored to the local institutional context, granting producers significant rights in certification and involving stakeholders in decision-making. This participatory, collectively managed approach bridges the gap between organic labels and their users, enhancing both legitimacy and effectiveness (Ninnin & Lemeilleur, 2024).

2.3.6 Integration of domestic and international research into local adaptation solutions

Several international proposals, such as the Milan Urban Food Policy Pact, the C40 initiative, and the EU's "Farm to Fork" strategy, promote sustainable food systems. Local plans like the Urban Master Plan of the Metropolitan Area of Barcelona and the Biodistricts Plan in Andalusia have incorporated these frameworks, focusing on ecological, economic, and social dimensions to foster agroecological systems (Simón-Rojo et al., 2023).

Simón-Rojo et al. (2023) explain that in the Urban Master Plan, these global proposals inform zoning and land-use protections for peri-urban agriculture, integration of food system considerations into urban design, and measures to strengthen SFSCs. Such measures include:

- Protecting and prioritizing peri-urban agricultural land from urban sprawl so it can be used for local food production.
- Facilitating direct sales points (e.g., farmers' markets, municipal markets, on-farm shops) to connect producers and consumers without intermediaries.
- Improving local food logistics by creating collection and distribution hubs dedicated to small-scale producers.
- Promoting public procurement from local producers for schools, hospitals, and other institutions, ensuring steady demand for nearby farms.
- Supporting processing facilities (e.g., small dairies, packing plants) near production areas so value can be added locally before food enters the market.
- Enhancing producer–consumer networks through education, promotion of community-supported agriculture, and local branding schemes.

This aligns with "Farm to Fork" priorities on reducing food miles and supporting local production, while following the Milan Pact's emphasis on urban governance for sustainable food systems.

Similarly, in the Biodistricts Plan in Andalusia, the influence of these international initiatives is reflected in the promotion of territorially based governance models that unite farmers, local authorities, and consumers to develop agroecological practices (Simón-Rojo et al., 2023). The practices comprise:

- Creating territorial governance bodies that bring together farmers, local administrations, consumers, and other stakeholders to coordinate production, marketing, and policy support.
- Facilitating direct marketing channels such as farmers' markets, farm shops, and consumer cooperatives.
- Encouraging public procurement of local organic products for schools, hospitals, and other public services.
- Developing local processing and packaging facilities so that added value stays in the territory.
- Supporting training and advisory services for farmers on agroecological practices and marketing strategies.
- Promoting territorial branding and certification schemes that identify products from the biodistrict and communicate their environmental and social value to consumers.

The plan takes on "Farm to Fork" goals of boosting organic production and applies C40's climate-oriented metrics to ensure food strategies contribute to emission reductions. In both cases, the authors highlight that these frameworks provide shared targets and methodologies, which are adapted to local contexts to foster resilient, agroecological food systems (Simón-Rojo et al., 2023).

As another example, according to Mikelsone and Cīrule (2024), the Cities2030 project supports the transformation of city-region food systems in line with the EU's Food2030 policy and the European Green Deal. Cities2030 applies a design thinking approach that places co-creation and stakeholder engagement at the center of planning and implementation. In this project the practical measures include:

- Establishing multi-actor food system living labs where policymakers, farmers, businesses, researchers, and citizens collaborate on designing and testing sustainable food solutions.
- Using co-creation workshops to jointly identify challenges, set priorities, and develop interventions tailored to local contexts.
- Developing and piloting an impact assessment tool to measure progress toward sustainability, resilience, and health objectives across the food system.
- Facilitating cross-sector partnerships to integrate agriculture, health, education, and environment into cohesive food strategies.

- Promoting knowledge exchange and capacity building through training sessions, peer learning, and dissemination of best practices.
- Implementing pilot actions—such as local procurement programs, food waste reduction initiatives, and support for short supply chains—tested within the living labs before broader rollout.

These measures enable stakeholders to co-design actionable strategies, ensure that policies reflect local realities, and link city-region food systems to EU sustainability goals.

Numerous projects such as “Food systems in European Cities – FoodE” support the development of local and regional food systems through pilot case studies in various EU cities. Righini and colleagues (2022) present practical actions across these pilots to include:

- Urban and peri-urban food production initiatives such as community gardens, rooftop farms, and aquaponics systems to increase local supply.
- Short supply chain models like farmers’ markets, food box schemes, and direct partnerships between producers and consumers.
- Public procurement of local foods for schools, hospitals, and municipal facilities to ensure steady demand.
- Educational and engagement activities (e.g., workshops, cooking classes, farm visits) to raise awareness and strengthen community involvement in food system decisions.
- ICT tools and platforms for coordinating supply, demand, and logistics among local producers, retailers, and consumers.
- Circular economy actions like composting schemes and food waste reduction programs to close resource loops within the city-region.

These initiatives are co-designed with citizens and stakeholders, demonstrating innovative solutions in market and social contexts. The measures are tailored to the specific social, economic, and environmental contexts of each city, but all aim to foster community-driven, resilient urban food systems that align with broader sustainability goals.

Similarly, various other initiatives introduced in this report exemplify more of such locally adaptable measures created as parts of European-wide projects. For instance, a number of the initiatives are part of the COACH project supporting collaborative agri-food initiatives rooted in local food systems by connecting farmers, consumers, local authorities, and other stakeholders. Overall, COACH has gathered 34 exemplary initiatives – called beacons – from 16 European countries. These beacons demonstrate diverse, inclusive approaches to improving farmer incomes and roles in food systems and are featured in a Living Library⁷ on the project’s

⁷ [Living Library](#) of Collaborative Short Food Supply Chains created in the COACH project.

Collaboration, Learning and Information Platform (CLIP). (COACH Project, n.d.a) Hence, the project fosters innovation through knowledge sharing and coordinated strategies. The project website provides many other materials too, including a learning module on costs and benefits and alternative grain networks (COACH Project, n.d.b).

Similarly, SMARTCHAIN-project has introduced a variety of innovations into the food chain. It is a large-scale EU project that operated in nine countries, with two pilot projects launched in each. The goal of the initiative was to accelerate the transition to collaborative SFSCs by implementing innovative practical solutions and robust business models. (Sustainable Food System Innovation Platform, n.d.b) Some of the relevant pilot projects presented in the sections below have been operating under SMARTCHAIN as well.

2.3.7 Food waste reduction

The Finnish food system created 607 million kilos of food waste in 2022. Figure 4 shows how this total amount of food waste was generated by the distinct stages in the food system – by primary production, food industry, retail and wholesale of food, restaurants and food services, and households (Luke, 2025).

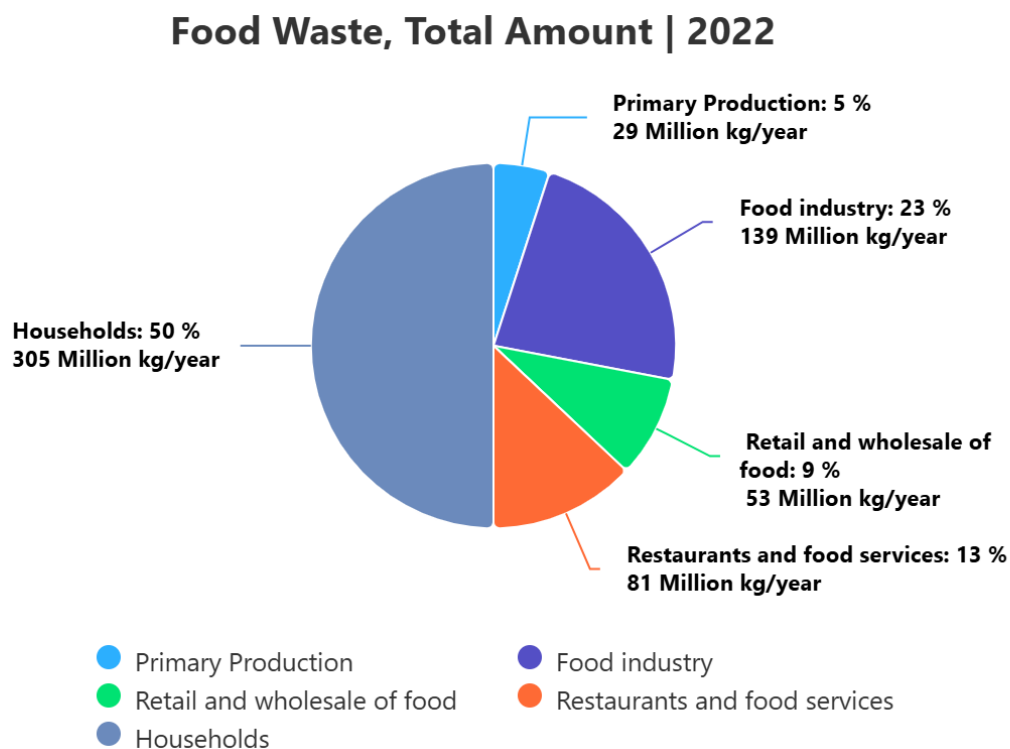


Figure 4: Food waste generated by distinct actor groups in food systems in Finland in 2022. Source: Luke (2025)

Reducing food waste can significantly improve the profitability of the agri-bioeconomy—encompassing agriculture and the food processing industry. According to Friman and Hyytiä (2022), in South Ostrobothnia, cutting food waste by half in food services and the food industry could boost regional GDP, increase employment, and raise household incomes. Achieving this equitably requires coordinated, cross-sectoral efforts to ensure that no segment of the food chain is disproportionately burdened with the costs. Less waste means producing more with fewer resources, making the system both more efficient and sustainable.

Beyond economic gains and the reduction of environmental impact, minimizing food waste is also one of the most effective measures for creating a climate-resilient regional food system, as Palomäki et al. (2022) state. Cooperation plays a central role in achieving these outcomes. A study by Aschemann-Witzel et al. (2017) found that all stakeholders involved in consumer-related food waste reduction initiatives viewed collaboration as essential to their success—both in

2.3.7.1 Consumers

Looking first at the Finnish solutions, Hävikkihyppy (Food waste jump) (Kuluttajaliitto, n.d.a) is a national project bringing together businesses, organizations, and consumers to develop practical solutions and raise awareness regarding household food waste. The project's key activities include creating a situation picture of the current context, involving ecosystem mapping to identify impactful actors; an innovation challenge competition for businesses to find new consumer-focused waste reduction tools; advocacy work and dialogue; as well as communication and raising awareness, highlighted by a nationwide Food Waste Week. The project promotes dialogue, supports new business opportunities, and encourages lasting behavioural change through shared knowledge and cooperation.

The full ecosystem mapping (Kuluttajaliitto, n.d.b) can be found from the Hävikkihyppy project page⁸. It highlights products, services, and other solutions, both Finnish and international, for reducing households' food waste. The map shows how different food chain actors' solutions affect consumer food waste and highlights where most current solutions are focused.

Any business could apply to the innovation challenge competition at the start of 2025. The challenge brought together six distinct solutions or tools⁹ which are currently being piloted—financial pilot support is also distributed among these participants on the basis of actual costs. Code Ananas and Satokausi (“Season”) were crowned as the winning solutions. Code Ananas is an AI-based mobile application for consumers that helps households reduce food waste. The app

⁸ [Hävikkihyppy ecosystem map](#) (in Finnish).

⁹ [Introductions on the participants of the innovation challenge competition by Hävikkihyppy](#) (in Finnish).

identifies ingredients found at home, suggests recipes based on them, and creates a shopping list based on actual consumption. The Satokausi solution is a household marketplace in the Satokausi® app, where consumers can sell and buy surplus ingredients (Kuluttajaliitto, n.d.c).

The other solutions are CoReorient, which, like Satokausi, encourages consumers to share their unused spices and dry goods among other food items with their neighbours through a food cabinet located in their stairwell. Secondly, WasteNoMOre is another mobile app. A consumer uses it to scan a purchase receipt and reports food waste, providing item-specific data on the amount and causes of waste. The data collected also benefits stakeholders in the retail, research, and public sectors. The two last solutions are based on training consumers on food waste matters: Kauppavalmennus educates consumers, helping them to identify and track their food waste in general. Ekokumppanit, on another hand, targets young people who are moving to live by themselves. In their self-directed online training program, participants learn and practice new skills over 12 weeks to build routines. Ekokumppanit are also looking to integrate the training into sustainability studies at upper secondary education institutions (Kuluttajaliitto, n.d.c). The solutions are not yet available to the public, as they are in the piloting phase.

Moving on to international solutions, a Danish nudging solution in the fish and meat sector is also based on training consumers. Zero Waste Cooking has offered cooking classes to students and lunch customers. These sessions focused on practical strategies to reduce canteen food waste and were praised for fostering community and delivering actionable tips for everyday waste reduction (FOODRUS, n.d.a).

The utilization of mobile apps can as well be found within international initiatives. One notable example is the Regusto app. Regusto10 enables consumers to purchase surplus meals from nearby partner restaurants at reduced prices, directly preventing food waste at the consumption stage. The meals are packed in eco-friendly bags, adding convenience while supporting sustainability goals. Its impact is measurable: participating restaurants saw a 9% reduction in food waste, and 73% of users reported no food waste after using the service—demonstrating strong potential for behaviour change through digital solutions (LOWINFOOD, n.d.a).

Another mobile-based initiative is the Cook app, developed in the Slovakian bread value chain. The app promotes meal recipes built around sustainable and local ingredients with a strong emphasis on maximizing food use, especially of bread. The same recipes are also available in a Zero Waste CookBook called “*Second Life for Bread. Delicious ways to prevent bread waste in households*”¹¹. It features 35 traditional and modern-day recipes – from starters to main dishes

¹⁰ [Regusto platform](#) for information on how it works and how institutions and companies can utilize it.

¹¹ A Zero Waste CookBook for bread: [Second Life for Bread. Delicious ways to prevent bread waste in households](#)

and desserts—co-developed through public surveys. The CookBook also includes nutritional information and tips for minimizing bread waste (FOODRUS, n.d.b).

2.3.7.2 Food services

A wide range of practical solutions to reduce food waste in food services emphasize cooperation as their foundation—between staff, customers, educators, technology developers, and broader food system stakeholders. These initiatives combine training, digital tools, and shared practices to tackle food waste collectively.

The PAJATSO project in Finland highlights collaboration in professional settings by creating a training material package for food service workers¹². The material—covering waste terminology, measurement, donation practices, and behavioural insights among other aspects—was developed in dialogue with sector professionals. A supporting PAJATSO podcast series¹³ encourages continuous learning and collective engagement in food waste prevention (Luke, n.d.).

Technological tools have also enhanced cooperation in kitchens. Mitakus, AI-powered forecasting software helps chefs and planners reduce surplus by generating accurate demand predictions and menu suggestions. Its success in Germany and Sweden stems from ongoing cooperation between developers and kitchen users who refine the tool with real-world feedback (LOWINFOOD, n.d.b). Likewise, KITRO's automated food waste management system enables collaborative decision-making in canteens, hotels, and restaurants by providing teams with shared, data-driven insights into what food is being wasted and why. KITRO has been implemented in Germany, Switzerland, and Greece (LOWINFOOD, n.d.b).

In school settings, Matomatic's plate waste tracker¹⁴ strengthens cooperation between pupils and kitchen staff. Implemented in Sweden, Germany, and Austria, the tool uses smart scales to give children feedback on their plate waste while allowing them to inform staff why they didn't finish their food. This fosters two-way communication and shared responsibility for food waste reduction (LOWINFOOD, n.d.b).

The “educational meals” approach in Sweden and Austria is built entirely on cooperation as well. Teachers, pupils, and kitchen staff co-create learning environments around mealtimes. In Sweden, food waste education is integrated into the curriculum, with classroom lessons tied directly to shared meals. In Austria, collaborative workshops bring together students, educators,

¹² [PAJATSO training material package](#) (in Finnish)

¹³ [PAJATSO podcast series](#) (in Finnish, no subtitles available)

¹⁴ [More information on Matomatic's products](#), including the plate waste tracker (in Swedish only)

chefs, and researchers to explore causes of food waste and create low-waste meals, ending with shared reflections and dining (LOWINFOOD, n.d.b).

In schools as well as in other industrial kitchens, The FoodOp platform¹⁵, implemented in Denmark, supports kitchen staff in tracking guest preferences and food waste using weight sensors and analytics. This data becomes a shared resource, enabling kitchen teams to improve both meal quality and sustainability outcomes collaboratively. Similarly, the Chef's Course in the Danish fish and meat value chain provides hands-on training for chefs and kitchen teams to reduce food waste and meat consumption. The course fosters a shared understanding and skills within the kitchen team for more sustainable practices (FOODRUS, n.d.a).

Beyond individual kitchens, Matvett in Norway demonstrates how sector-wide cooperation can drive systemic change. Involving food services, researchers, and public authorities, Matvett developed zero-waste guidelines for food trade fairs¹⁶ through co-design with stakeholders. The model stresses clear communication, shared goals, and collective tools for sustainable event planning (Matvett, n.d.).

More solutions will become available in the future as another Finnish project, HävikkiHUB, (XAMK, n.d.) continues this cooperative approach by fostering dialogue and joint learning between food service providers, their customers, and key stakeholders in co-development workshops. Its main output, a freely accessible online training package, aims to enhance shared knowledge and practical skills in food waste management. The package will be released further along the project's progress in the next few years.

2.3.7.3 Processing and retail

Efforts to reduce food waste in the processing and retail sectors increasingly rely on cooperation between actors along the value chain. Collaborative models were piloted in the Italian bakery sector to tackle surplus bread, in northern Lazio. 12 small bakeries participated in structured dialogues and surplus tracking using diaries, resulting in a joint roadmap, "Una mano contro lo spreco" ("A hand against waste"). The roadmap outlines five shared actions: measuring surplus, improving order planning, increasing consumer awareness, organizing donations, and promoting municipal-level collaboration. This model has been shared more broadly, including in Finland through the Finnish Bakery Federation (LOWINFOOD, n.d.c).

In the fish and vegetable sectors, Leroma, a digital B2B marketplace, connects producers with manufacturers and retailers to redistribute surplus or cosmetically imperfect raw materials.

¹⁵ [FoodOp's website](#) for further information on their services.

¹⁶ [Guidelines for a sustainable Food trade fair by Matvett](#) (in English).

Originally developed for the fish sector and extended to vegetables, the platform opens alternative channels for local and global trade, reducing loss through real-time collaboration between buyers and sellers (LOWINFOOD, n.d.d; n.d.e). Leroma is already working in 88 countries worldwide¹⁷ (Leroma, n.d.).

Also addressing food loss at the processing stage, the FOX “Food Processing in a Box” project uses mobile, low-impact container-based units to process surplus fruits and vegetables close to the source and communities. Tested across four European “food circles,” FOX relies on cooperation between farmers, consumers, and researchers while it promotes healthier, more transparent food systems. (FOX, n.d.a) In the Netherlands, for example, the project transforms green pea and carrot pomace side streams into ingredients using sustainable technologies like High Pressure Processing and Pulsed Electric Fields (FOX, n.d.a; n.d.b). Likewise, Biofruits SA, a Swiss SME under the SMARTCHAIN initiative, aggregates organic fruits from seven Valais-based producers (Biofruits, n.d.) and produces juices and nectars from fruits that do not meet retail appearance standards. It also provides custom processing services for local farmers, exemplifying how cooperative processing infrastructure can reduce food loss while supporting regional supply chains. (Sustainable Food System Innovation Platform, n.d.c)

Imperfect or surplus produce is utilized by ConServe, a solidarity-based food processing initiative, as well. In Tuscany, ConServe processes such local farm produce into preserved foods. The initiative operates through informal but effective partnerships between farmers, cooperatives, and social organizations. It also engages and supports disadvantaged workers, aiming to scale production while maintaining its ethical, community-oriented mission. (COACH Project, n.d.c)

Retail solutions also reflect cooperative strategies. In Denmark’s fish and meat value chains, Employee Food Waste Shops have been introduced, allowing staff to purchase short-shelf-life products at a fixed, reduced price via a mobile app. These shops operate within existing storage areas and require no additional logistics or payment infrastructure. The model depends on active staff participation and strong organizational support, offering a simple yet effective way to reduce food waste internally. (FOODRUS, n.d.a)

2.3.7.4 Primary production

As in other stages of food value chains, in primary production innovative solutions are increasingly focused on reducing food waste through cooperation. The SISTERS initiative supports fruit and vegetable producers in marketing imperfect or surplus produce through direct sales. Its digital

¹⁷ [Leroma’s website for further information on the company](#) and [their platform for finding raw materials](#).

platform, the Regioneo app¹⁸, allows farmers to bypass traditional retail channels by connecting directly with consumers, thereby creating shorter, more transparent supply chains. This enables the sale of fresh products that would otherwise be rejected due to cosmetic standards. The application is in use in France and Italy (SISTERS, n.d.a; SISTERS, n.d.b).

Similarly, the Unverschwendet initiative in Austria fosters partnerships between primary producers and food businesses, such as restaurants and processors. Surplus or unharvested fruits and vegetables are transformed into marketable products like chutneys, chips, and syrups. The initiative is supported by BOKU University, which provides a sustainability assessment tool to help determine which surplus products can be viably recovered and repurposed (LOWINFOOD, n.d.e).

Following the same principle, Fruta Feia (“Ugly fruit”) is a self-sustaining initiative that reduces food waste by creating an alternative market for misshapen or oversized fruits and vegetables typically rejected by retail due to cosmetic standards. Working directly with local farmers, the initiative purchases these products weekly and sells them in affordable consumer baskets at designated delivery points throughout Portugal. This practical model educates consumers, supports local producers with fair prices, and prevents edible produce from going to waste—demonstrating a scalable solution to market inefficiency and food loss (Mendes, Anjos, & Almeida, 2022a).

2.3.7.5 Throughout the value chain

FoodLoops is a Baltic Sea Region project that addresses food waste holistically by connecting stakeholders across the food value chain—from schools and caterers to farmers and circular economy experts. A key practical solution developed by the project is a manual on local cooperation for circular bio-waste¹⁹, which compiles effective strategies from real-world case studies. The manual highlights how schools, caterers, farmers, and circular economy experts can collaborate to reduce food waste—particularly in schools, which generate significant amounts of waste. (Interreg Baltic Sea Region, n.d.)






Examples include partnerships where schools and farmers jointly manage composting on school grounds or return food waste to farms for reuse, turning waste into valuable resources. This tool promotes improved food waste separation and strengthens local cooperation across the food value chain. (Pepper & Hafiz, n.d.) The whole summary of solutions is illustrated on the Table 1

¹⁸ [Further information on](#) and links for downloading the Regione app.

¹⁹ [Manual on Local cooperation for circular bio-waste in schools and beyond.](#)

below. FoodLoops demonstrates how cross-sector collaboration can enable circular solutions, reduce waste, and foster environmental awareness throughout the entire food system.

Table 1 Summary of solutions from the FoodLoops project. Adapted from Pepper & Hafiz (n.d.).

Stage of value chain	Key actors	Cooperation areas
Production 	<ul style="list-style-type: none"> Local farmers Schools (administrators, teachers) Catering companies 	<ul style="list-style-type: none"> Field trips with pupils to local farms, teaching about origins of food Local farmers support schools in setup of own fruit and vegetable garden
Distribution 	<ul style="list-style-type: none"> Schools (administrators, procurement officers) Catering companies Suppliers Local farms Municipalities (legal departments) 	<ul style="list-style-type: none"> Procurement of organic food from local farms Collaboration on contract terms regarding procurement sources (schools/ caterers/ suppliers) Legal support from municipalities to meal procurement officers to enforce and challenge contract terms
Processing 	<ul style="list-style-type: none"> Schools (administrators, pupils, kitchen staff, cooks, parents) Municipalities 	<ul style="list-style-type: none"> Improving cafeteria atmosphere through re-design, better acoustics and queuing arrangements Involve pupils and parents in menu planning and naming of dishes Educational activities for sustainable consumption practices Collaboration between schools and municipalities to improve organisation of school meals to prevent food waste
Consumption 	<ul style="list-style-type: none"> Schools (administrators, pupils, kitchen staff, cooks, parents) Municipalities 	<ul style="list-style-type: none"> Improving cafeteria atmosphere through re-design, better acoustics and queuing arrangements Involve pupils and parents in menu planning and naming of dishes Educational activities for sustainable consumption practices Collaboration between schools and municipalities to improve organisation of school meals to prevent food waste
Valorisation 	<ul style="list-style-type: none"> Schools Farmers Regulatory bodies 	<ul style="list-style-type: none"> Reuse food leftovers for next-day meals or food sharing, ensure regulations allow this Collaborations between schools and farmers to set up compost on school grounds or return food waste to farmers

2.3.8 Farmers' collaboration

Collaboration among farmers in the form of creating new partnerships and diversifying agricultural enterprises is emerging as a promising avenue for reducing the environmental impacts and overall enhancing the sustainability of food systems. Workshop insights by Latvala et al. (2025) emphasize how new business structures and cooperative models not only promote environmental goals but also attract and support farmers—especially younger generations—through shared responsibility and well-being.

Several grain production value chains demonstrate the power of farmer cooperation. In Germany, Maier, Klein, and Schumacher (2020) analysed local barley–malt–beer chains that prioritize sourcing and distribution within the shortest distances possible. These models reduce reliance on intermediaries and benefit from strong cooperation across the value chain, helping to build transparency, authenticity, and sustainability. While specific ecological benefits such as water protection were difficult to verify, the breweries involved showed a strong awareness of their dependence on the natural environment. Similarly, Sacchi et al. (2019) found that in Tuscany wheat producers collaborate with millers, bakers, and universities to cultivate ancient varieties and create local bread value chains rooted in agroecological methods and joint value creation.

Another leading example is Granennetwerk Pajottenland, Belgium's Cereal Collective involving 10–15 farmers working with brewery Brouwerij 3 Fonteinen. This long-term, trust-based partnership emphasizes agroecological practices, participatory crop selection, and fair compensation—farmers are paid both per hectare and per ton to share risks and guarantee income even during poor harvests (COACH Project, n.d.d; 3 Fonteinen, 2023). The brewery further supports the system by paying over triple the market rate and investing in shared infrastructure, such as grain silos and sorting equipment, demonstrating how fair pricing and collaboration can reshape food value chains²⁰ (3 Fonteinen, 2023).

Moving away from grain production, Germany's Rheinische Ackerbohne e.V. organizes fava bean producers—mainly farmers but also involving agricultural trading companies—to ensure consistent supply for feed manufacturers and increase the crop's visibility. The beans offer agronomic benefits like improved soil health and biodiversity, while also supporting the development of new value chains and economic opportunities for stakeholders. Though challenges in market development remain, such initiatives highlight the importance of collective action to drive systemic change (Stute et al., 2020).

²⁰ Further information on [3 Fonteinen's website](#).

Focusing more on circular practices and value creation, a Swiss initiative gathers farmers and processors to collaborate for turning apple press residues into vinegar. The vinegar can be used as a detergent and plant growth promoter, while the remaining biomass can be further processed through biodigestion. These practices strengthen the local circular economy and offer farmers additional income streams. Innovations like biochar made from apricot pits further support environmental goals in drought-prone areas (FAIRCHAIN, n.d.).

Some solutions can be found within meat and dairy production too. Emphasizing meat production, De la Terre à l'Assiette supports organic meat producers through collective processing and selling of products in France. This initiative therefore links farmers more closely with consumers and public food procurement along with promoting organic farming, territorial food planning, and farmer control (COACH Project, n.d.e).

Finally, Belgian Fairecoop is a farmer-led dairy cooperative designed to ensure fair income for local producers while reducing environmental impact through sustainable practices and shorter value chains. Unlike traditional cooperatives often controlled by non-farmers, Fairecoop is managed by farmers who process their milk into dairy products sold under the Fairebel brand in regular retail stores. Members receive a premium of €0.10 per liter of milk sold, and some consumers also support the initiative by purchasing shares. By strengthening farmer collaboration and connecting directly with consumers, Fairecoop offers a scalable and replicable model for fairer, more sustainable food systems (van den Bossche et al., 2022).

2.3.9 Short food supply chains

Short food supply chains (SFSCs) can significantly reduce the environmental impacts of food systems by addressing multiple critical factors. By shortening the physical distance between producers and consumers, SFSCs help lower transportation-related emissions and energy consumption (Majewski et al., 2020). Their emphasis on local production and consumption also reduces food loss across the supply chain, contributing to notable environmental benefits (Voge et al., 2023). In addition, SFSCs strengthen local economies and support small-scale producers, encouraging more sustainable land use and farming practices tailored to local environmental conditions (Çalik, 2019). However, the environmental benefits of SFSCs can vary depending on the context and the structure of the supply chain. Therefore, assessing their sustainability requires careful consideration of regional factors and how each SFSC is organized (Malak-Rawlikowska et al., 2019). Paciarotti and Torregiani (2018) report that at least in Italian context there is strong interest for participating in cooperatives from both producers' and restaurant operators' sides to improve local food logistics.

The initiatives introduced below offer practical, cooperative solutions that directly link producers and consumers. By removing intermediaries, reducing transport distances, minimizing food loss, and encouraging fair compensation, these models address environmental, economic, and social sustainability in an integrated way. They highlight the power of local cooperation and demonstrate replicable strategies for building resilient, low-impact food systems.

In Finland, REKO exemplifies a cost effective, self-organized system connecting producers and consumers through closed Facebook groups. Producers post their offerings, and consumers order by commenting. Weekly or biweekly pickups at designated spots minimize transport and consolidate distribution, reducing emissions and food miles. At the pickup locations all orders from various producers are collected in one visit. The system is free and low-barrier, relying on producers for all logistics, payment arrangements, and legal compliance. (Snellman, 2021) According to Grönqvist (2024), REKO has proven to be an economically important sales channel for small producers, particularly in urban areas where consumer demand is stronger. It enables farmers to bypass intermediaries, sell flexible quantities, and offer niche or organic products directly to a loyal customer base, ensuring fresher food and fair prices. REKO also promotes transparency and trust through direct interactions between producers and consumers, enhancing producer visibility and appreciation. Moreover, the use of existing digital tools like Facebook ensures accessibility, while the system fosters community ownership and peer support (Grönqvist, 2024).

Another Finnish solution with a similar idea, Uudenmaan Ruoka, operates as a regional food hub. Through an online platform²¹, consumers can order local and seasonal products from multiple producers and collect them from central pickup points in the capital region. The system provides small farms with market access and predictable income, especially through consumer contracts that secure prepayments for seasonal goods. This shortens supply chains, reduces waste, and supports sustainable local food systems (Gillon, 2022). While some other Finnish food hubs like Southwest Finland and Pohjois-Savon ruoka in North Savo have ceased operations, the Uudenmaan model demonstrates how shared logistics, cooperation among producers, and digital infrastructure can reduce the environmental impact of food systems. Information is not provided on the reasons behind the success of Uudenmaan Ruoka nor the ending of the other food hubs.

Many more similar grassroots initiatives can be found across Europe highlighting practical ways of reconnecting consumers with producers. In Navarra, Spain, Landare is a consumer-run non-profit association that provides a direct sales model between organic farmers and 4,000 members. By sourcing locally and operating on a cost-covering margin of 10–20%, Landare ensures

²¹ [Uudenmaan Ruoka online platform](#) for browsing products and participating local producers and placing an order.

transparency, fair pricing, and access to healthy food. Farm visits deepen consumer understanding of ecological practices and reinforce trust (INTIA, 2022).

In Belgium, a single farmer called Steven has developed a closed-loop local sales platform using vending machines to sell his and neighboring farmers' products. He also invests in processing facilities, logistics, and diverse sales channels (Stoeva et al., 2024) while collaborating with a local miller and baker to create value-added goods. Direct customer interaction—on-site and via active social media—builds loyalty, provides feedback channels, and ensures fairer prices. (Moretti & Avermaete, 2022) Furthermore, restaurants, among other agri-food sector actors, can strengthen their position in the food supply chain by gaining access to fresh, organic products and having greater influence over supply dynamics (Stoeva et al., 2024). This accessible model can be adapted throughout the EU (Moretti & Avermaete, 2022).

An array of other initiatives collects multiple farmers' products for direct selling as well. A rural complex "From the farm" in Bulgaria combines a pasture-fed animal farm, farm shop, bakery, and restaurant—all supplied by local producers. Situated in a depopulated village, it revitalizes the local economy through agri-food tourism, supports traceable food systems, and fosters producer collaboration. This integrated approach has strong potential for replication in other rural areas seeking sustainable local development (Stoeva, 2023).

Marketplaces and food hubs also rely on consumers being able to buy products directly from producers. Farmers' Market Varna supports small local producers in Bulgaria by organizing a farmers' market that fosters direct, face-to-face connections with consumers, while producers set their own prices. Beyond commercial exchange, it promotes sustainable agriculture education and food waste prevention—an effective, replicable model for regional food systems. (Stoeva, 2022a) Likewise, in Denmark, GRØNT MARKED organizes monthly farmers' markets in three locations in Copenhagen, allowing only small-scale producers. Moreover, the producers must meet strict sustainability criteria—regarding local production, biodiversity, and soil conservation—whereas each stall must be manned by someone directly involved in production. This way farmers sell their own products directly, ensuring transparency and reducing environmental impact while raising consumer awareness of sustainable agriculture (Prag, 2023).

The Āgenskalns Food Hub in Riga, Latvia, transforms a historic market into a multifunctional food hub with a market, co-creation kitchen, catering services, and educational programs. Up to 70 local producers benefit from this public-private-people partnership, which promotes sustainable consumption and strengthens community ties (Šūmane, 2022).

Some grocery stores or chains collect numerous producers' produce into one place as well. In France, Couleurs Paysannes is a farmer-run grocery chain with three stores selling cheese, meat and fresh produce along with other products. There producers get to set the prices and sell directly

while they also work in the store (Sustainable Food System Innovation Platform, n.d.d). Similarly, Gaia, located in Greece, comprises of two grocery stores selling local farmers' products and house-branded orange juice and olive oil, as well as baked goods. The cooperative also hosts social and cultural events and has created an informal group of producers exporting avocados, oranges, and grapefruits (Gaia, n.d.).

Diverse digital tools are also being utilized in making direct purchases of local products more accessible for consumers. In Germany, the *Einkaufen auf dem Bauernhof* initiative connects consumers with local farm shops through an online platform²² listing the shops' contact details, product offerings, and events. The initiative also forms a network that supports direct marketers with federal-level marketing. (*Einkaufen auf dem Bauernhof*, n.d.) Similarly, producers participating in the *Zala-völgyi Nyitott Porták* ("Open Doors in the Zala Valley") initiative are responsible for regularly announcing open farm days and events, which are then published on the project's website²³ for consumers' easy access. The project is a Hungarian collaboration of farmers, local producers, and rural tourism service providers. (*Nyitott Porta*, n.d.) *Pick-me-up Stavanger* in Norway uses digital platforms to connect consumers with local food via new, organized consumer-friendly marketplaces and pick-up points. By engaging stakeholders across the value chain—from digital solution developers to local producers—, it supports small-scale farmers and improves access to sustainable food (COACH Project, n.d.f).

Accessibility of local, sustainable food is further enhanced with initiatives offering convenient forms of food delivery. The Portuguese PROVE initiative is based on a farmer-led box scheme, as it supports clusters of 3–5 peri-urban farmers in delivering weekly produce boxes directly to consumers. The model enables fair prices, strengthens consumer ties, and lowers environmental impact through local distribution. PROVE also provides farmers with training along with legal and fiscal support, making it a scalable model for empowering small producers. (Mendes, Anjos, & Almeida, 2022b) A Hungarian pilot, *Foodhub.hu*²⁴, sells fresh food online with home delivery services and offers a weekly "cash and carry" pickup service for restaurants. It also partners with schools and farms through its "Grow and Harvest Your Own Potatoes" program, donates leftovers to the Hungarian Food Bank to reduce food waste, and operates the Urban Food Café and co-working space, welcoming producers and other stakeholders. Moreover, it takes part in Hungary's annual farm open day, when hundreds of farms open to the public on the first weekend of June (*Foodhub.hu*, n.d.).

²² [Einkaufen auf dem Bauernhof online platform](#) for finding local farms and farmer's markets.

²³ [List of actors participating in the open farm days](#), as part of the *Zala-völgyi Nyitott Porták* (in Hungarian).

²⁴ [Further information on Foodhub.hu's website](#), on subjects such as the farmers, chefs, and events connected to the initiative.

Some initiatives, on the other hand, are focused on providing local ingredients to food services. In the Netherlands, local2local²⁵ supplies locally produced food for the hospitality and healthcare sectors (local2local, n.d.b). It collaborates with a range of producers—from artisanal cheese makers to organic fruit and vegetable growers—and it uses optimized logistics (within 150 km). Moreover, local2local minimizes plastic use and promotes biodiversity and soil health. It also partners with educational institutions to raise awareness of sustainable food systems. (local2local, n.d.a; local2local, n.d.b) A Bulgarian initiative called Good for You, Good for the Farm connects local farmers and businesses—more precisely 250 employees with 50 producers—through a farmer-led online platform, enabling direct ordering to companies such as food services. The platform is complemented by a farm shop and pop-up markets in corporate backyards. In all the purchase situations farmers set their own prices while the system enhances income stability and rural-urban connections. Good for You, Good for the Farm is found to be among the highly replicable initiatives for regions seeking to reduce food waste and improve local food systems (Stoeva, 2022b).

In a similar vein, farm-to-restaurant collaborations in the city-region of Groningen, the Netherlands, demonstrate how direct relationships between primary producers and food services can reinforce local food systems. Restaurants and farmers build trust-based partnerships grounded in shared values, such as promoting regional products and sustaining local traditions. These relationships not only provide restaurants with access to fresh, high-quality ingredients but also enhance visibility and branding for producers. However, the case study highlights a lack of coordination between municipal actors and restaurants, suggesting that food hubs—if supported by local governments—could bridge gaps, streamline logistics, and amplify cooperation. Such hubs are most effective when they reflect local identity, foster reciprocal partnerships, and reduce the coordination burden for both producers and food services. (Smaal, 2022) These findings are supported by a case study by Ganesh (2024)—although conducted in Toronto, Canada—which emphasizes that farm-to-table partnerships improve ingredient quality, restaurant transparency, and income stability for farmers, along with environmental benefits following from reduced food miles and support for sustainable farming practices. It also underlines the importance of supportive policies, flexible menus, and digital tools to overcome logistical challenges and seasonal variability.

Also focused on bringing primary producers closer to food services, the Copenhagen Potato Tender is making public food procurement more accessible to small-scale farmers. At the core of the initiative is designing simplified, flexible tenders—starting with potatoes. Through market dialogue, kitchen needs assessments, and smaller contract lots, the process enables broader

²⁵ Further information for stakeholders in catering, healthcare, and education on [local2local's website](#) (in Dutch).

participation. The city fosters collaboration among officials, kitchen staff, and suppliers, and integrates educational elements like school farm visits (COACH Project, n.d.g).

A Slovenian initiative has taken a different approach than the initiatives introduced above. The Taste Laško²⁶ has created a regional brand that connects farms, food producers, and local businesses through SFSCs. With the help of local partners, the brand facilitates direct distribution, organizes events, and promotes certified local products through retail outlets and social media. This approach increases visibility and sales of local food in restaurants, households, and institutions, while supporting farmers economically (Dergan, Ivanovska, & Debeljak, 2022). Moreover, restaurants and tourism businesses benefited from fresh, high-quality products, a stronger local image, and competitive differentiation (Stoeva et al., 2024). The model is scalable and replicable, fostering sustainable rural development through branding, cooperation, and knowledge sharing (Dergan, Ivanovska, & Debeljak, 2022).

On a broader scale, EU-wide initiatives like agroBRIDGES and COCOREADO support farmers in developing and scaling SFSCs through sets of digital tools. The agroBRIDGES Toolbox (n.d.)²⁷ is a set of multilingual digital tools designed to help farmers and food producers, along with other stakeholders, to develop and manage SFSCs. These tools support local food systems by offering resources for business planning, collaboration, and communication. Key tools include the Decision Support Tool (DST), which offers tailored SFSC business model and sales channel recommendations based on farm-specific data—along with impact assessments. Another, differing tool is the #WeNeedLocalFood Campaign, which provides step-by-step guidance for promoting local food through effective social media content.

A similar toolkit was developed in the COCOREADO project, which empowers young “ambassadors” across Europe to act as key players in innovation, public procurement, and sustainable food systems by co-creating locally adapted solutions (COCOREADO, n.d.a). The project’s Food System Innovator Toolkit²⁸ itself provides step-by-step guidance on building networks, communicating change, engaging with policy, and developing business ideas. Co-created with the ambassadors and validated by European partners, the toolkit supports practical implementation. Overall, COCOREADO’s initiatives include innovative public procurement models and youth-led SFSC pilots, strengthening the role of farmers at the heart of sustainable food systems (COCOREADO, n.d.b).

Together, these initiatives show that SFSCs, when based on cooperation, digital innovation, and community engagement, can provide scalable and sustainable alternatives to centralized food

²⁶ [Further information on where to buy the Taste Laško products.](#)

²⁷ [The agroBRIDGES Toolbox](#)

²⁸ [COCOREADO Food System Innovator Toolkit](#)

systems. They not only lower environmental impact but also empower small-scale farmers, create local economic value, and strengthen the social fabric of rural and urban communities alike. Their diversity in structure and scale—from vending machines to online hubs and collective brands—demonstrates high adaptability and replicability for other regions seeking sustainable food system transitions.

2.3.10 Communal food production

Communal food production, centred on local and small-scale agriculture, offers practical solutions for reducing the environmental impact of food systems. By minimizing transportation, these localized systems lower emissions and energy use. Ecological farming practices commonly used in small-scale production further reduce greenhouse gas emissions and other environmental harms. In addition to environmental benefits, local food systems bolster regional economies by creating jobs, supporting farmers, and fostering more meaningful, resilient work within communities (Norberg-Hodge, 2021).

Across Europe, a growing number of communal food production initiatives showcase how cooperative approaches—especially models like community-supported agriculture (CSA)—can effectively connect producers and consumers. These initiatives promote sustainable, transparent food systems that not only lessen environmental impacts but also empower local economies and reinforce the central role of farmers. CSAs can also reduce food loss and waste by creating direct connections between producers and consumers, which helps in better matching supply with demand and reducing the need for aesthetic standards that often lead to waste. This direct connection can also lead to lower food loss and waste during production, distribution, and consumption stages (Voge et al., 2023).

One such example on comprehensive, localized food systems built on cooperation is the Palopuro Agroecological Symbiosis (AES), a collaborative network located in Hyvinkää, Finland. An agroecological symbiosis in this context refers to

“a mode of operation in which primary food production (farms and gardens), food processing companies, food retailers, and consumers function as a symbiotic food system. Agroecological symbiosis is local as nutrient recycling and the use of produced bioenergy are possible for all its participants.” (Helenius et al., 2017a, p. 17)

Palopuro therefore creates a nutrient- and energy-self-sufficient, community-based food system. At its core is the organic Knehtilä Farm²⁹ while the network also integrates organic farming, energy production, and food processing through local cooperation between farms, food producers, energy providers, and hospitality services (Koppelmäki et al., 2017b). The collaboration not only

²⁹ [Further information on Knehtilä Farm on their website](#) (In Finnish).

lowers the system's environmental footprint by recycling nutrients and producing biogas locally but also boosts rural development and food culture (Koppelmäki et al., 2017a). Compared to conventional farming, Palopuro's AES demonstrates positive or very positive environmental impacts on the cultivation ecosystem (Helenius et al., 2017b), although efficiency per unit of food or energy depends on eco-efficiency. By enabling farmers to focus on biomass production and involving other actors in energy handling, the model provides a realistic and scalable pathway toward low-carbon food systems (Helenius & Koppelmäki, 2017).

Similarly, CSA-based models enable cooperation between producers and consumers through advance purchase agreements. All Finnish CSA farms and communities are listed and mapped³⁰ by KUMAKKA and Kumppanuusmaatalous ry, a project and an organization focused on CSA, respectively. (Kumppanuusmaatalous, n.d.a). Currently, 25 actors are listed, 11 of which are located in the Uusimaa region (Kumppanuusmaatalous, n.d.b).

While no CSA actors are to be found in South Ostrobothnia, an example from Northern Ostrobothnia is Keskkikoski Farm³¹ in Siikajoki. Keskkikoski Farm offers pre-paid vegetable shares, providing ecological produce via direct sales. Their marketing also relies solely on the direct sales. (Keskkikosken tila, n.d.a) In practice, consumers pre-purchase a share of the farm's harvest in spring and receive their portion every two weeks, either via farm pickup or delivery. In addition to fresh produce, they get newsletters, recipes, priority access to other products, and the opportunity to attend the annual Kekri Festival featuring a farm-to-table dinner. Shareholders may also help with farm work if they choose. In return, the producer commits to growing agreed-upon crops, distributing shares to designated locations, and keeping participants updated on farm activities (Keskkikosken tila, n.d.b).

Råbäck Gård³², an apple orchard, uses a similar approach where customers buy an annual share of a tree and receive its entire harvest, either by collecting it or harvesting themselves. This builds financial stability for the farmer while it enables better planning and strengthens the connection between producer and consumer. The system also promotes local, transparent food production with opportunities for customer participation and co-development. (Råbäck Gård, n.d.) According to Koivisto, Sevón, and Niemi (2023) the model is easily replicable for various crops and regions and demonstrates how farmers can create resilient, sustainable businesses through direct engagement with local demand.

Internationally, Arvaia³³, a CSA cooperative in Bologna, Italy, produces organic food according to sustainable and fair-trade practices. It fosters a participatory farming model where members co-

³⁰ [Map and list of Finnish CSA farms](#) (in Finnish)

³¹ [Keskkikoski Farm's website](#) for information on their products and their take on CSA (in Finnish).

³² [Råbäck Gård's website](#) for information on available trees and varieties (in Finnish or Swedish).

³³ [Arvaia's website](#) for further information on their operations (in Italian).

fund and co-decide on agricultural operations. (Arvaia, n.d.a) Members pay an annual fee based on projected cultivation costs and receive a weekly share of 6–7 kg of organic vegetables, picked up at designated locations. Participation in cooperative work—such as field tasks, event planning, or communication—is encouraged. (Arvaia, n.d.b) Arvaia currently has 300 members and grows 50 different varieties of vegetables, fruits, and grains on 47 hectares. (Arvaia, n.d.c) The cooperative’s emphasis on shared risk, fair compensation, and democratic decision-making exemplifies a socially and ecologically grounded food system (Arvaia, n.d.a).

In Germany, Netzwerk Solidarische Landwirtschaft represents solidarity farming models as farms’ operating costs are being funded by household subscriptions rather than product prices. This way it reinforces long-term personal relationships and shared responsibility between producers and consumers. This network thus prioritizes transparency, mutual support, and community governance. (Solidarische Landwirtschaft, n.d.a) Furthermore, it supports the movement by providing networking, training, and research, among other services, and by representing solidarity farms nationally and internationally (Solidarische Landwirtschaft, n.d.b). A map of farms, initiatives, and other relevant places is available on their website³⁴, making them more accessible to consumers.

The Spanish initiative Tierra-Papel-Tijera (TPT)³⁵ expands on CSA principles by mutualizing production between three cooperative farms and 50 subscribing households. Members receive fixed weekly baskets of organic, seasonal vegetables and legumes. (Tierrapapeltijera, n.d.) The model supports biodiversity, reduces plastic use, and balances farm work with family life through shared labor and crop planning. Farmers use local varieties and low-impact techniques, demonstrating how agroecological farming can be adapted to small-scale, community-based systems. (COACH Project, n.d.h)

In the UK, Tamar Grow Local³⁶ runs a diverse mix of community-led initiatives including cooperative orchards, allotments, food hubs, and school garden programs. The organization supports both commercial and amateur growers by improving land access, offering business support, and coordinating markets. It builds food sovereignty through education and cooperative governance, enabling people to produce and consume more locally grown food. (Tamar Grow Local, n.d.)

Lastly, in Serbia, the Udruženje (“Association”) of fruit and vegetable processors supports small and medium-sized enterprises by strengthening cooperative marketing and production. The initiative improves logistics, develops an export network, and provides member training, alongside

³⁴ [Map of solidarity farming actors](#) provided by Netzwerk Solidarische Landwirtschaft (in German).

³⁵ [TPT’s website](#) for further information on their products and operations (in Spanish),

³⁶ [Tamar Grow Local’s website](#) for further information on their current projects, community, as well as events.

operating a dedicated help desk at the local Chamber of Commerce. They provide a list of all member companies on their website³⁷. These efforts enhance producers' competitiveness and negotiating power, while also enabling the creation of localized supply chains that help reduce environmental impact (Udruženje kompanija za preradu voća i povrća Kraljevo, n.d.).

3 Pilot 1: Biochar in Agricultural Production

Biochar has gained growing attention as a multifunctional tool for improving soil health, enhancing nutrient use efficiency, and supporting climate-smart agriculture. As interest in circular bioeconomy solutions increases, understanding what biochar is, how it is produced, and why it is used has become increasingly important. The following section provides an overview of the fundamental characteristics of biochar, outlining its key properties, agricultural applications, and the reasons behind its rising relevance in sustainable food and farming systems.

3.1 What is Biochar and Why Use It?

Biochar is a carbon-rich material produced through the pyrolysis of biomass in an oxygen-limited environment (Torabian et al., 2021). As a stable material it can persist in soils for long periods (Torabian et al., 2021) and its high internal porosity and surface area enhance its ability to retain moisture and nutrients (Mulinari et al., 2021). The properties of biochar can vary significantly depending on the type of feedstock used and the conditions of the pyrolysis process, such as temperature and residence time (Murtaza et al., 2021).

Biochar offers versatile benefits in agriculture by improving both sustainability and farm efficiency. When applied to soil, it strengthens structure, enhances water retention, and binds nutrients, which reduces leaching and can increase yields (Lehmann & Joseph, 2015). In manure and slurry management, biochar helps control odors and capture nutrients, supporting closed-loop nutrient cycles (Bioenergia ry, 2022). Used as a feed additive for ruminants, it can aid digestion, cut methane emissions, and ultimately return to fields via manure, further enriching soils (Hagemann et al., 2019). Thanks to its porous structure, biochar is also suitable for greenhouse substrates and landscaping applications that benefit from active microbial processes (Ippolito et al., 2020). Importantly, in every application biochar acts as a long-term carbon sink, as the carbon stabilized during pyrolysis can remain in soil for hundreds or even thousands of years (Muhonen, 2024).

³⁷ [Website of Udruženje kompanija za preradu voća i povrća Kraljevo](#) listing member companies (in Serbian)

On the other hand, field trials conducted in the Swedish Rest till Bäst project (Rest till Bäst, n.d.) showed that small amounts of various biochar products had no significant positive or negative impact on the yield or quality of beets, potatoes, or cereals. However, when biochar was applied at a 25% volume ratio in greenhouse experiments, it increased the nutrient content in maize and beet plants. Specifically, potassium levels rose, while magnesium and calcium concentrations decreased.

Biochar's use in orchards or other perennial horticulture systems has also shown limited benefits—although based on limited research. In young apple orchards, biochar had no significant effects on yield, fruit quality, photosynthesis, nutrient content, or water use, though trunk growth was higher in some years (Eyles et al., 2015). Similarly, biochar did not reduce nutrient leaching, and in some cases increased potassium and phosphate losses (Hardie et al., 2015).

In greenhouse studies, results have been more positive, like above. Biochar improved soil pH along with nutrient, organic carbon, nitrogen, and phosphorus levels, leading to notable yield increases—up to 79% for beans—within six months of application (Jing et al., 2018). Yield effects varied depending on feedstock, pyrolysis temperature, and biochar chemistry, with manure-based biochars and low-temperature pyrolysis showing the best results. Mixing biochar with pig manure further enhanced soil organic matter and reduced early nutrient losses, though overall crop biomass and nutrient uptake did not differ significantly (Banik et al., 2021a).

The properties and impacts of biochar in soil depend strongly on feedstock and pyrolysis conditions. Higher pyrolysis temperatures increase stability and nutrient retention, while chemical or biological post-treatments can enhance performance as a fertilizer supplement (Sánchez-Monedero et al., 2019). Feedstock origin matters: animal-waste biochars tend to be nutrient-rich, whereas plant-based biochars are more effective for carbon sequestration and reducing greenhouse gas emissions (Ahsan et al., 2022; Cely et al., 2015). Reviews highlight biochar's role as a carrier for microbial inoculants, supporting nitrogen fixation and nutrient uptake due to its porous structure and interaction with soil microbes (Bhattacharyya et al., 2024; Schmidt et al., 2021). It also improves soil properties such as porosity, pH, conductivity, and nutrient levels.

Results, however, vary by context. A Finnish field study found no significant reduction in N₂O emissions during a dry test period, but across three sites biochar increased yields and improved nitrogen use efficiency over seven years, while lowering CH₄ and N₂O emissions relative to crop output. Effects were strongest in clay-rich, carbon-poor soils (Kalu et al., 2022).

3.2 Distinct raw materials as biochar feedstocks

The properties and applications of biochar are largely determined by the feedstock used. In Finland, production is mostly wood-based, utilizing stemwood, demolition timber, surplus wood, and forestry residues. Agricultural by-products such as grain waste and straw also offer untapped potential. Internationally, feedstock selection reflects regional resource availability. In Asia and Africa, maize, cotton, and rice straw are common; in China, pine dominates; while in Brazil, coffee husks and poultry manure are key raw materials (Mykkänen, 2025). Thus, raw material selection is often locally optimized based on regional agriculture and forestry structures.

In Finland and as a part of the Sustainable and Responsible Food Province project short-rotation coppices such as willow have been explored to expand biochar production, particularly on former peat production areas. Willow grows quickly, produces abundant biomass, and thrives on wet, low-value soils, making it a promising option that does not compete with food production. Biochar made from willow is uniform, highly porous, low in heavy metals, and has excellent water retention capacity, making it suitable for soil improvement in green spaces and tree root zones.

Many farms already have the necessary machinery and infrastructure for handling willow or similar biomass, linking agriculture and forestry practices. Establishing willow plantations on decommissioned peatlands could provide new uses for these areas and modest additional income, though significant investments in land preparation and harvesting equipment are needed. Moreover, former peatlands and underperforming fields can be used to avoid competition with food production. Profitability still requires large-scale cultivation—several hundred hectares—and further development of biochar markets to support wider adoption.

Most biochar feedstock comes from forests and forest industry side streams, but agriculture offers diverse options too. Farm by-products such as grain drying waste or digestate from biogas plants could be used, though quantities on individual farms are typically small. According to interviews, digestate is usually applied directly as fertilizer, and grain drying waste volumes are limited. Also based on an interview, the efficiency of biochar production depends on the yield of final product relative to feedstock, where wood-based materials often perform better. Direct use of farm residues as fertilizer or for energy may be more practical unless feedstock volumes can be increased through cooperation between farms, as indicated by an interview. For example, pelletized straw and grain husks show potential if pooled at larger scale.

Various other agricultural and industrial side streams have been studied as feedstocks for biochar production as well. In a Finnish study, Elo, Nummela, and Kymäläinen (2021) compared garden waste, demolition wood, and digestates derived from sewage sludge and biowaste. Their study showed that sludge-based materials have lower carbon and dry matter content than wood-based ones, resulting in higher energy demand for drying. Sludge-based biochars also had the lowest nitrogen yields, though their carbon and energy content can be improved by adding wood chips.

On international level, Sánchez-Monedero et al. (2019), in the FERTIPLUS project, found that biochar from animal manure contains the highest nutrient levels (N, P, K), followed by sewage sludge, while biowaste had the lowest. Biochar additions increased soil organic carbon and raised soil pH in acidic soils. Although biochar alone had minimal fertilization effects, biochar-compost mixtures significantly improved soil fertility by enhancing nutrient cycling, element availability, and microbial activity. Utilizing another input material, the EU-funded REFERTIL project developed bone-based ABC biochar with a high phosphorus content (30% P_2O_5), which can be used as an organic fertilizer. A plant-based biochar was also developed with high carbon content but low nutrient availability, limiting its economic value (REFERTIL, n.d.).

Similarly, Wang et al. (2012) demonstrated that biochars derived from nutrient-rich biomasses such as manure or sewage sludge can function as effective phosphorus fertilizers. Over six crop cycles, such biochars performed comparably to conventional phosphate fertilizers in enhancing shoot yield. Focusing on manure-based biochars, Cely et al. (2015) evaluated different feedstocks, including cattle manure, poultry litter, and pig slurry. Poultry litter showed the highest potential for increasing yields, particularly in nutrient-poor soils. The highest biochar yields were obtained from pig slurry (due to high ash content) and poultry litter (due to efficient carbonization at lower temperatures). Pyrolysis also reduced mobile forms of zinc and copper, lowering groundwater contamination risks compared to raw material application.

According to Glaser et al. (2019), combining biogas digestate with biochar increased maize yield more effectively than biochar alone. Similarly, Greenberg et al. (2019) found that digestate alone reduced rye biomass compared to mineral fertilizers, while biochar alone had no effect. However, applying 40 Mg/ha of biochar enhanced carbon mineralization during incubation and resulted in increased soil organic carbon (SOC) than digestate alone. This dosage had no effect on crop biomass but highlighted challenges in measuring SOC sequestration at low application rates.

Lastly, Muhonen (2024) emphasizes that the key factor affecting biogas digestate suitability for pyrolysis is moisture content. He studied four pyrolysis systems from different manufacturers and of these, three required a separate dryer to reduce the moisture content before pyrolysis.

3.3 Pyrolysis process and the needed equipment

The intended use of biochar plays a crucial role in determining both the choice of feedstock and the configuration of pyrolysis conditions, such as temperature and process type (Riikonen, 2019). By tailoring these factors, the properties of biochar can be adjusted to suit specific agricultural or environmental applications.

Among the key production parameters, pyrolysis temperature has a significant impact on both the stability and nutrient content of the final product. Higher temperatures yield biochar that is more chemically stable and resistant to decomposition, while lower temperatures help retain more nutrients from the original biomass (Bioenergia ry, 2022a). Muhonen (2024) notes that biochar produced at temperatures above 500 °C may have half-lives exceeding 1,000 years, highlighting its potential as a long-term carbon storage solution.

It's important to note that, as Elo et al. (2021) emphasize, biochar is not a uniform product but a diverse category of materials whose properties depend heavily on the feedstock and production method. Ippolito et al. (2020) examined the combined effects of pyrolysis temperature, feedstock type, and pyrolysis method on the physicochemical characteristics of biochar. Their findings indicate that higher pyrolysis temperatures increase both total carbon content and specific surface area (SSA), which can enhance soil water retention and nutrient holding capacity. Wood-based biochars generally exhibit the highest SSA, and when produced under optimal conditions, can significantly improve soil physical properties. While temperature influences the structural stability of biochar, the nutrient availability—such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and copper (Cu)—is primarily determined by the composition of the feedstock. Ippolito et al. suggest that nutrient release potential can be anticipated based on the raw material's total ash and nutrient content.

Biochar production is typically small-scale and best suited to batch-operated slow pyrolysis units at the farm scale. This means biomass is processed in discrete loads. The appropriate unit size for farms is usually around 10 cubic meters. Another interviewee notes how multiple units can be installed alongside a single boiler—for instance, three separate pyrolysis chambers can form an efficient, farm-optimized production line. However, decentralized production remains a bottleneck

in scaling biochar use. Reliable and cost-effective pyrolysis systems suitable for on-farm applications are still lacking on the market.

Machinery used for applying biochar was mentioned in only a few studies or projects. In the Rest till Bäst project (Rest till Bäst, n.d.), both a precision spreadertypically used for solid manure—and a disc harrow were employed. The precision spreader distributed the biochar on the soil surface, while the disc harrow incorporated it into the soil.

According to International Biochar Initiative's (IBI) guidelines (Major, 2010), biochar can be applied using a range of conventional agricultural machinery already in use for other soil amendments. In field cropping systems, biochar is often broadcast with lime spreaders, solid manure spreaders, or broadcast seeders, and then incorporated into the soil using equipment such as disc harrows, chisels, rotary hoes, animal draft plows, or hand hoes—depending on the scale of farming. Banding is another option, where biochar is placed in narrow strips in the soil with minimal surface disturbance, using standard banding equipment or simple hand hoes for small-scale operations. Biochar can also be mixed with other solid amendments such as compost, manure, or lime and spread with existing manure or compost applicators, reducing field operations. When combined with liquid manures, biochar can be applied as a slurry using conventional liquid manure application systems, which also helps minimize dust losses. In horticulture and landscaping, biochar may be incorporated into new topsoil or mixed with substrates like sand and compost before application. For tree crops, biochar is often broadcast and incorporated over planting areas or applied in localized zones such as planting holes, trenches, or mulched areas around the drip line. These approaches demonstrate that biochar can be integrated efficiently into existing farm and landscaping practices without requiring specialized machinery.

3.4 Key Benefits and Limitations

3.4.1 Profitability of biochar production

The profitability of biochar production and use is highly case-specific and remains uncertain (Campion et al., 2023). It is influenced by factors such as location, feedstock availability, production scale, pyrolysis conditions, biochar market price, crop type, and whether externalities such as carbon sequestration are monetized. Among these, the most critical factors are the selling price of biochar and the purchase price of feedstock (Campion et al., 2023). In Finland, on-farm biochar production can be viable if closely tied to heat generation and if the pyrolysis unit operates near maximum capacity (Juva, 2023). For instance, on a crop farm practicing energy

entrepreneurship, investment in biochar production was found profitable with a 40% subsidy—even without selling biochar. Without subsidy, profitability would require biochar sales at about €100/t. By contrast, on a livestock farm producing biochar for internal use, the system was not profitable even with subsidies. Only under scenarios where carbon credit prices exceeded €200 (or nearly €400 without subsidies) and/or biochar sales achieved margins of around €350/t would the system become attractive. Carbon credits refer to financial instruments representing certified reductions in GHG emissions (Salma, Fryda, & Djelal, 2024). Additionally, the number of operating hours of the pyrolysis unit was found to strongly affect the payback period and overall feasibility (Juva, 2023).

At a broader level, the economics of pyrolysis–biochar systems depend on feedstock costs, pyrolysis efficiency, and the market value of carbon offsets. Systems using waste biomass streams—such as garden waste that would otherwise incur disposal costs—present the strongest opportunities for profitability (Roberts et al., 2009). Transport distance of biomass feedstocks is also a major barrier, as it raises costs significantly.

On-farm studies emphasize that capturing and utilizing the large amounts of heat generated during pyrolysis is crucial for economic viability (Heinrich et al., 2023). Heat can replace fossil fuel use, thereby stabilizing energy costs in farming operations. Moreover, applying biochar to fields can reduce reliance on mineral fertilizers by improving soil quality, offering additional savings. Nonetheless, high upfront investments and 20-year depreciation times pose challenges, and profitability is generally achieved only if the farm was already purchasing biochar and transitions to self-production.

In Sweden, simulation models of farm-scale pyrolysis systems highlight the importance of correct system sizing. An oversized unit was found to demand excessive operator time, emit higher levels of air pollutants, and perform poorly economically. Climate change, by altering heating demand, further constrained the biochar production potential of the system. Thus, optimal matching of pyrolysis unit size to the farm's heat demand was identified as a key factor for both environmental and financial sustainability (Azzi, Karlton & Sundberg, 2021).

Overall, several factors support the production and use of biochar on Finnish farms. Suitable biomass feedstocks are often available within a reasonable transport distance, and links between agriculture and forestry provide opportunities to utilize wood biomass from thinnings and other forest management practices. Existing farm infrastructure, logistics, and machinery can be used for collecting, transporting, and, if needed, drying biomass in storage facilities. However, profitability also depends on marketing and sales capabilities, as a functioning market requires strong networks, sales expertise, and a product that meets customer needs.

Carbon credits and condensates can serve as potential revenue streams from biochar production (Heinrich et al., 2023). Carbon credits have the potential to significantly improve the profitability of biochar, and Heinrich et al. (2023) identify them as a positive factor in the future, particularly as demand and credit prices increase. However, they emphasize Hansen-Connell et al.'s (2022) point that despite access to voluntary carbon markets, high initial investments, information barriers, and environmental and economic uncertainties may discourage small-scale producers. Thus, carbon credits are not yet a readily accessible income stream for farm-level biochar producers.

In Finland, puro.earth plays a central role as an intermediary between producers and buyers. According to puro.earth (2024), producers must comply with specific methods and standards to qualify as carbon credit suppliers. These requirements include using sustainable biomass feedstocks and ensuring that the biochar functions as a long-term carbon sink, for example, through soil amendment. Additional criteria apply to the production facility and the calculation methodology used to quantify CO₂ removal. Currently, only one Finnish biochar producer holds a recognized CO₂ Removal Certificate (CORC) through puro.earth: Carbofex Nokia 1 (puro.earth, n.d.).

According to Laine (2015), pyrolysis distillates—also called wood distillate, wood vinegar or pyroligneous acid—can substitute synthetic pesticides and be applied as soil amendments, fuels, surface treatment agents, and even in the food industry. A Finnish techno-economic study (Fagernäs et al., 2014) further suggests that processes combining soil improvement and charcoal production with the use of tars and gases for energy, and distillates for crop protection and odor control, can significantly enhance profitability. However, Fagernäs and colleagues stress that underdeveloped markets for pure distillates and soil-improving biochar remain a major risk factor. Overall, most research on this subject is relatively recent, and markets for pyrolysis distillates are still in an emerging phase.

However, pyrolysis distillates generated during the pyrolysis process can be collected using equipment such as SoilCare Oy's Amacee 800 and Amacee 1700 systems. The Amacee 800 produces approximately 30–80 liters of distillates and tar per batch, depending on the biomass used, while the Amacee 1700 yields 800–1000 liters of distillates per batch (SoilCare, n.d.a; SoilCare, n.d.b). SoilCare also purchases surplus distillates produced at these biochar facilities for its own use.

Research on pyrolysis distillates highlights a wide range of potential applications in agriculture, though effectiveness varies depending on crop, target species, and dosage. Firstly, studies show promising results for pyrolysis distillates as natural herbicides. Hagner et al. (2020a, 2020b) demonstrated that hardwood-based distillates inhibited the germination of giant hogweed

(*Heracleum mantegazzianum*) seeds at >20% concentrations, and that mulching with distillate-enriched peat suppressed weed growth both in greenhouse and field trials. Aguirre et al. (2020a, 2020b) found that distillates reduced weed biomass by over 70% in nitrogen-rich plant communities and performed as effectively as synthetic herbicides in growth chamber experiments. However, results are not universally positive: Hyvönen et al. (2023) reported weak effects of distillate-based mulches compared with plastic films and glyphosate, while Hagner, Ruuttunen & Hyvönen (2024) showed poor efficacy against monocot weeds such as *Elymus repens* at practical application rates.

Pyrolysis distillates exhibit antifungal and biocontrol properties as well. Mmojieje and Hornung (2015) found them effective against certain plant pathogens and pests. Giannini et al. (2023) showed that pine-based distillates inhibited growth of *Fusarium culmorum* by up to 70%. Other trials demonstrated suppression of specific pathogens (Darwesh & Elshahawy, 2023). Multiple studies confirm antifungal effects against *Botrytis cinerea* (Pertile & Frac, 2023) and *Fusarium proliferatum* (Kara et al., 2024), suggesting potential as cost-effective, eco-friendly alternatives to synthetic fungicides. Additional research shows larvicidal, mold-inhibiting, and wood-preserving properties (Akkuş, Akçay & Yalçın, 2022; Yıldızlı et al., 2024), with antimicrobial activity reported against *Salmonella*, *Listeria*, and yeast (Riekkinen et al., 2022).

Other reported effects include crop protection from environmental stress. Bianchi et al. (2024) and Vannini et al. (2022) found that treatments reduced ozone-induced damage, preserving photosynthetic function and enhancing antioxidant production. Furthermore, Celletti et al. (2023) reported that pyrolysis distillates mitigated negative effects of biodegradable plastics on basil growth by reducing oxidative stress.

Research on the use of pyrolysis distillates for enhancing crop growth indicates promising but species-specific effects: Carril et al. (2024) reported a 25% increase in legumes' pod production, especially during early seed development. Fedeli et al. (2023a) found foliar application improved chickpea seed size and weight. Carril et al. (2023) showed significant gains in biomass, pods, and seeds mainly for lentils, while Becagli et al. (2023) found field beans responded with higher leaf and pod nitrogen and phosphorus contents under field conditions, although growth responses varied. All treatments delayed senescence.

For leafy vegetables, such as lettuce, several studies highlight improved growth and stress tolerance. Ghorbani et al. (2024) observed enhanced biomass, protein, and antioxidant activity under drought conditions. Fedeli et al. (2022) and Vannini et al. (2021) reported increases in biomass, chlorophyll, starch, and sugar contents, with co-application of lecithin amplifying growth responses by ~50%. Seed pre-treatment with low concentrations of distillate also improved germination in lettuce, chickpeas, and basil (Maresca et al., 2024).

Moreover, distillate application benefited sunflower and maize growth and yields (Darwesh & Elshahawy, 2023), while tomato seed priming improved germination, seedling growth, and tolerance to aluminum-induced oxidative stress (Ofoe et al., 2022). Pine-based distillates stimulated milk thistle germination and seedling growth more than twofold (Giannini et al., 2023). Lastly, for Chinese cabbage, combined application of pyrolysis distillate and biochar enhanced both growth and quality (He et al., 2025).

Research on pyrolysis distillates and soil shows largely positive effects at low concentrations, though impacts vary with dosage and application method. Koç et al. (2019) found no negative impacts on soil microbes when pyrolysis distillate was used as a biopesticide; at 3% concentration it even increased bacterial populations and β -glucosidase enzyme activity. Similarly, Cardelli et al. (2020) observed no adverse effects up to 1% concentration, with positive trends in microbial activity, though higher doses reduced soil quality and enzyme function. Sivarami, Mukunthan & Megharaj (2024) concluded that low concentrations may enhance soil fertility by supporting earthworm activity. In addition, Becagli et al. (2023) reported that irrigation with pyrolysis distillates raised dissolved organic carbon, microbial biomass, soil nitrate, and available phosphorus.

When used in combination with biochar, He et al. (2025) found this to result in increased soil pH, electrical conductivity, and dissolved organic carbon more than either input alone, improving soil properties and photosynthesis. Similarly, Becagli et al. (2022) found that combined use enhanced organic carbon content in microbial biomass, stressing that correct dosages promote microbial activity and overall soil biological quality. Moreover, Hagner et al. (2021) studied combining manure with pyrolysis distillate, by acidifying cattle slurry with the distillate. The treatment had no negative effect on soil nematodes, and although crop yield, seed germination, and microbial activity were temporarily reduced after application, the effects were short-lived. Importantly, the treated slurry significantly reduced ammonia nitrogen ($\text{NH}_3\text{-N}$) emissions.

Further research indicates that pyrolysis distillates can enhance the nutritional quality of a variety of crops. For fruits, Fedeli et al. (2024a) found that pyrolysis distillate improved apples' nutritional parameters, including phenols, flavonoids, tannins, antioxidant capacity, sugars, pectin, amino acids, and mineral content. In tomatoes, Fedeli et al. (2023b) reported higher nutritional values and extracts with antioxidant and anti-inflammatory effects, while Agosti et al. (2024) showed that combined use of biochar and pyrolysis distillate increased antioxidant activity and phenolic content, especially in soilless systems where coconut peat was partially replaced by biochar and pyrolysis distillate was applied as a biostimulant. For onions, Zhang et al. (2023) observed enhanced antioxidant and enzyme-inhibiting properties.

In potatoes, pyrolysis distillate significantly increased total carbohydrates, starch, and soluble sugars, though it reduced copper and phosphorus contents (Fedeli et al., 2023c). For chickpeas,

lentils, and beans, pyrolysis distillate treatments were linked to higher protein content, polyphenols, starch, and antioxidant capacity, alongside greater concentrations of health-relevant minerals such as iron, calcium, magnesium, and potassium (Carril et al., 2023; Fedeli et al., 2023a, 2024a). Nearly all essential free amino acids were also increased. In chickpea flour biscuits, made from distillate-treated crops, Fedeli et al. (2024a) found higher peptide content, pointing to potential for nutritionally enriched baked products. Lastly, Fedeli et al. (2024b) demonstrated that in the mushroom *Pleurotus tuber-regium*, pyrolysis distillate raised phenol, vitamin C, and soluble protein levels while lowering glycogen content.

In addition to agricultural uses, pyrolysis distillates have been studied in other applications as well. Väisänen et al. (2016) investigated their use as additives in commercial wood–plastic composites. Results showed that pyrolysis distillates reduced water absorption in some samples and improved the processability of composite granules. More recently, Filippelli et al. (2024) explored potential applications in human and veterinary medicine. Their findings indicate that pyrolysis distillates exhibit both anti-inflammatory and antioxidant effects across different cell types, suggesting potential for dermatological uses.

3.4.2 Regulations and certification regarding biochar

The use of biochar in fertilizer products is regulated both at the EU and national level. At the EU level, Regulation (EU) 2019/1009 recognizes pyrolysis and gasification materials (i.e., biochar) as approved components in EU fertilizer products, provided they meet strict safety and environmental requirements. The regulation also sets maximum limits for harmful substances such as polycyclic aromatic hydrocarbons (PAHs) (EUR-Lex, 2022; Finlex, 2022a; Bioenergia ry, 2022b).

In Finland, fertilizer products must comply with the national Fertilizer Act (711/2022)—regulating the production, marketing, and use of fertilizers—, which is supervised by the Finnish Food Authority (Ruokavirasto). The authority maintains a list of approved ingredients, with pyrolysis biochar classified under ingredient category 9 (Ruokavirasto, 2022). Furthermore, the Ministry of Agriculture and Forestry Decree 964/2023 supplements the Act by defining product quality standards, ingredient categories, and processing requirements, while also setting rules for the use of fertilizers and manure as well as product-specific labeling obligations (Ruokavirasto, 2023). Overall, biochar must be safe for humans, animals, and plants, as well as environmentally friendly (Bioenergia ry, 2022b).

To ensure the sustainability and quality of biochar production, several international certification systems have been developed. One of the most prominent is the European Biochar Certificate

(EBC), which categorizes biochar into six classes based on its intended use. Each case requires specific certification parameters that must be clearly defined. For example, the EBC-Agro class, designed specifically for agricultural applications, sets strict limit values to prevent soil and water contamination. The EBC system outlines stringent requirements regarding the origin of raw materials, production processes, end-product quality, and usage. It promotes circular economy principles, environmental safety, and climate benefits. Certified biochar can also be recognized as a carbon sink under this system (International Biochar Initiative, 2024).

The certification process requires production facilities to ensure full traceability of raw materials and production steps through proper documentation. Additionally, facilities must undergo annual audits by an independent third party. Producers are also required to report greenhouse gas emissions and any measurable carbon sequestration effects (International Biochar Initiative, 2024).

Other certification systems are also in use. For instance, the International Biochar Initiative (IBI) offers its own quality standard, which is based on applicable U.S. and international guidelines. The IBI standard emphasizes the technical characteristics and safety of biochar, particularly in agricultural use (International Biochar Initiative, 2024).

Certification has become increasingly important, especially in contexts where biochar is used within voluntary carbon markets or public support schemes. Without certified quality, demonstrating the climate benefits or ensuring environmental safety of biochar can be challenging. As such, certification serves as a tool for building trust and managing risks—for authorities, producers, and end-users alike.

This section highlights *The Accountable Food Province* priority of the Food Province strategy (Välisalo et al., 2022) as biochar has high potential for enhancing sustainability—environmental, social and economic—of farming. In addition, *The Food Business* priority is emphasized through the possible improvement of primary production's profitability from a regional perspective.

3.5 Manure-Enriched Biochar (MEB) Practices

The practice of inoculating biochar with manure has been the subject of growing scientific interest, with several studies highlighting its potential benefits for nutrient management and soil health. Sarkhot, Berhe, and Ghezzehei (2013) investigated the efficiency of biochar in absorbing ammonium and phosphate from dairy manure effluent. Their findings suggest that biochar can effectively capture excess nitrogen and phosphorus, making it a useful tool for nutrient recovery. In a related study, the same researchers (Sarkhot, Berhe & Ghezzehei, 2012) demonstrated that

applying biochar inoculated with dairy manure can enhance the retention of carbon and nitrogen in soil, offering potential environmental benefits.

Pandit et al. (2024) explored the impact of biochar inoculated with cattle urine on maize cultivation in low-fertility soils. Their study found that when urine-inoculated biochar was applied to soil—alongside additional manure—it significantly improved soil pH, organic carbon content, and levels of key nutrients (N, P, and K), compared to the control. Notably, total nitrogen, available phosphorus, and potassium were all significantly higher with urine-inoculated biochar than with treatments using biochar or biochar combined with manure alone. This treatment also led to the highest NPK uptake in plants and improved the partial factor productivity of nitrogen and phosphorus. Most strikingly, the use of urine-inoculated biochar resulted in a 62% increase in maize yield compared to the control.

Similarly, Banik et al. (2021b) examined the effects of swine manure–inoculated biochar on nutrient dynamics and carbon retention in a Mollisol typical of the U.S. Midwest. They tested biochars produced from three different feedstocks: neutral pH red oak (RO), highly alkaline autothermal corn silage (HAP), and slightly acidic iron-treated autothermal corn silage (HAPE). The study found that combining biochar with manure stabilized both carbon and nutrients from the manure. When applied to soil, this inoculated biochar improved soil quality and nutrient availability more effectively than manure alone.

Finally, Seyedsadri et al. (2022) reported that manure-treated biochar enhanced nutrient retention in the soil. Their research also concluded that biochar—either alone or following composting or manure treatment—can improve water retention in low-organic-matter soils, while also maintaining or enhancing the soil's capacity to retain nutrients.

Preliminary interest for utilizing MEB has been found among Finnish nurseries. As part of the *Sustainable and Responsible Food Province* project, Tampere University conducted a survey targeting nurseries about the current and potential use of MEB. A total of 25 nurseries, mostly located in Western Finland, were contacted. Although the response rate was limited, the four nurseries that provided answers expressed a clear interest in MEB. They identified several potential benefits, including improved plant growth, enhanced soil fertility, reduced fertilizer use, and better water retention. Concerns about cost and the need for further support—such as technical training, financial assistance, and supply chain development—were also noted. Most respondents were open to testing MEB and expressed interest in participating in research or pilot projects. These findings suggest that, while the adoption of MEB is still in its early stages, there is promising interest among nurseries, provided that practical and economic barriers can be addressed through targeted support and further development.

In addition to the regulation on biochar presented in previous sections, some supplementary regulations must be taken into account regarding the production and use of MEB. According to §4 of the Finnish Fertiliser Product Act (Finlex, 2022b), a fertiliser product includes fertilisers, liming materials, soil improvers, growing media, biostimulants, and their mixtures. A fertiliser is a substance intended to promote plant growth or improve crop quality, primarily through nutrients. A soil improver is defined as a substance aimed at maintaining or enhancing the physical, chemical, or biological properties of soil. A fertiliser product mixture is composed of two or more fertiliser products, each meeting the requirements of its respective category.

Based on these definitions, manure-enriched biochar can be interpreted as a fertiliser product mixture. Manure is clearly classified as a fertiliser, while biochar is typically categorised as a soil improver (e.g., Heinrich et al., 2023; Farooq et al., 2024; Seyedsadr et al., 2022). For instance, Ndoung, de Figueiredo & Ramos (2021) note that biochar used alone can lack nutrients, prompting the development of biochar-based fertilisers enriched with manure to enhance soil fertility. Thus, while biochar alone functions as a soil improver, it becomes a fertiliser only when combined with nutrient-rich materials like manure.

In the list of permissible fertiliser ingredients, mentioned above, manure belongs to ingredient class 5: animal by-products (Ruokavirasto, 2024). Acceptable forms include untreated manure (as per Regulation (EC) No 1069/2009, Article 9(a)), unmineralised guano, gut contents, and frass, provided they are processed in accordance with Regulation (EU) No 142/2011. Manure must originate from livestock farms, slaughterhouses, or insect farms and is classified as an animal by-product of category 2. For regulatory purposes, manure includes the excrement and/or urine of livestock animals (excluding farmed fish), with or without bedding material.

Biochar, on the other hand, is listed under ingredient class 9: pyrolysis carbon. Acceptable feedstocks include solid biofuels and wastewater sludge. Biofuels must fall within categories A or B of the SFS-EN ISO 17225-1:2021 standard, including wood, plant, fruit, and aquatic biomass or their blends. Permitted sludge sources include municipal treatment plants, septic tanks, dry toilets, and farm-level wastewater systems (Ruokavirasto, 2024). Importantly, manure is not included as an approved feedstock for pyrolysis biochar, meaning biochar must be made from other materials. Therefore, MEB production must occur by combining manure with biochar after the pyrolysis process.

The Fertiliser Product Decree (Decree 964/2023), issued by the Ministry of Agriculture and Forestry, elaborates on product class requirements. Annex I details the specifications for fertilisers and soil improvers. For all fertilisers, micronutrients can only be declared if they meet minimum thresholds. The decree outlines specific criteria for organic fertilisers, organomineral fertilisers, and inorganic fertilisers, each with its own subcategories.

Organic fertilisers and soil improvers — the most relevant classes for MEB — share several requirements. Both must not exceed set maximum levels for heavy metals and pathogens. Organic fertilisers must contain biological-origin nutrients and organic carbon. Solid organic soil improvers must contain at least 15% dry matter and 7.5% organic carbon by mass, while liquid versions must contain at least 2% organic carbon or 0.2% total macronutrients (Decree 964/2023).

These regulations do not prohibit the production of MEB, as long as all components meet their respective regulatory criteria and are processed accordingly. Biochar cannot be made from manure, but manure can be legally combined with biochar post-pyrolysis to form a fertiliser product mixture, provided all safety, quality, and compositional requirements are met.

4 Pilot 2: Sustainable Practices in Food Processing – Utilization of side streams

The Finnish Food Industries Federation's roadmap (2020) emphasizes that more efficient use of by-products from food and beverage manufacturing would further lower emissions and support energy efficiency. Moreover, the roadmap lists the following key strategies for reducing emissions in the sector:

- Improving energy efficiency
- Switching to low-emission energy sources
- Reducing emissions from raw materials
- Minimizing packaging-related emissions

Side streams in food processing are valuable resources that can be harnessed to create higher added value products. Below you can find some relevant information and good practices related to side streams from different sectors.

The practices introduced below reflect well *The Accountable Food Province* priority of the Food Province strategy (Välisalo et al., 2022) as the utilization of side streams generated by the food chain is listed as one of the key activities for enhancing the responsibility of the Food Province. Furthermore, the measures for reaching such responsibility include identifying the sources of side streams; making them easy to find and utilise; training companies to develop business activities

based on side stream products; and developing nutrient self-sufficiency. Many of these measures are included in the good practices below.

4.1 Milk whey side streams

Recent research has increasingly highlighted the untapped potential of dairy side streams as valuable resources for developing new food, biochemical, and biotechnological applications. Instead of being treated as waste, these nutrient-rich by-products are now being explored as substrates for microbial cultivation, functional ingredient production, and innovative processing technologies. The following studies illustrate the breadth of possibilities emerging from whey valorization and demonstrate how circular approaches can enhance sustainability across the food system.

Scotto di Uccio et al. (2023) tested a food-grade mixed culture of bacteria and yeasts under different operational conditions for the treatment and the valorization of cheese whey permeate (CWP), the residue of whey protein recovery, into microbial protein (MP). Their preliminary estimate indicated that 2–11% of the future MP-based food production could be satisfied by only valorizing lactose-rich dairy residues such as CWP.

Filla et al. (2021) demonstrated that whey protein pectin complexes can be applied to replace fat in food products, e.g., pudding and yogurt, contributing to creaminess while adding a source of protein and fiber. They aimed at improving a production process of the complexes using a scraped-surface heat exchanger (SSHE), which could be utilized on a larger scale.

Bansfield et al. (2023) tested the metabolic activity and possible growth of seven fungi and three yeasts in five different food production waste streams. They found that cheese whey was the most promising waste stream for yeast/fungal growth. Interestingly, pellet inhibition resulted in increased metabolic activity of cells in the confectionary bakery waste stream with agar but decreased metabolic activity in whey with agar. The best-growing species, *Geotrichum candidum*, has potential commercial value as a producer of enzymes, biochemicals, and lipids, and could provide added value while improving the circularity of water and nutrients in food production.

Lagoa-Costa et al. (2023) explored cheese whey as a feasible substrate for the selection of a mixed culture highly enriched in polyhydroxyalkanoate (PHA)-storing bacteria. PHA is considered a cost-effective alternative to conventional plastics. In conclusion, cheese whey can be considered a good feedstock to efficiently select a mixed culture with high potential to accumulate PHA and a good way to give this by-product added value.

Rantamäki et al. (2019) developed novel compositions of edible protein coatings based on the immunoglobulin (Ig) fraction from bovine milk. Biologically active Igs can be successfully incorporated in and released from milk protein-based edible films. Nisin, commonly used for food protection, was used as a model of an antimicrobial peptide. Nisin retained its activity better in film containing Ig-enriched whey. Incorporating Ig-enriched whey into films enhanced adhesion and tensile strength of the films. The Ig-enriched whey also affected strongly on the appearance of films based on commercial whey protein concentrate in a dose-dependent way by making the films more smooth, transparent, and clear which are all favored properties in most food and pharmaceutical applications.

Raak et al. (2023) combined sunflower seed press cake and cheese whey to obtain matrices containing valuable proteins, structuring polysaccharides, as well as lactose and minerals facilitating fermentation with three different co-cultures of lactic acid bacteria and yeasts. Their research demonstrates the potential of fermentation as a means to stabilize side stream blends while only minimally affecting their physical appearance.

Poladyan et al. (2023) studied cheese (sweet) whey (SW) and curd (acid) whey (AW), with pre-treatment (filtration, dilution, and pH adjustment) and with and without the use of β -glucosidase, as sources for cultivating heterotrophic *Escherichia coli* and chemolithoautotroph *Ralstonia eutropha*. The results open new avenues for effective whey treatment using thermostable β -glucosidase and confirm whey as an economically viable commodity for biomass and biocatalyst production.

Reitmaier & Kulozik (2022) applied ultrafiltration permeate obtained from acid whey (AWP) as a diafiltration (DF) medium during skim milk microfiltration. Heating induced controlled spontaneous formation of gels with concentration- and pH-dependent firmness. AWP, a rather problematic dairy side stream, could thus be utilized for the production of calcium-rich acidic casein gels providing sensory characteristics of cultured dairy products.

Shen et al. (2019) demonstrated an efficient process for producing ethanol from delactosed whey permeate (DWP), a side stream of whey processing, based on *C. glutamicum*. The results obtained clearly show a great potential for this newly developed platform for producing value-added chemicals from dairy waste.

The studies discussed above highlight the potential of food production waste streams, particularly cheese whey, for various applications. These include the production of enzymes, biochemicals, lipids, microbial protein, biomass, biocatalysts, polyhydroxyalkanoate, calcium-rich acidic casein gels, whey protein pectin complexes, edible protein coatings, and ethanol. These findings open new avenues for the valorization of these waste streams, contributing to the circularity of water and nutrients in food production and providing added value to these by-products.

Three good practices can be found regarding milk whey side streams. The first one is a project called AgriChemWhey. The objective is to build a sustainable industrial-scale bio-refinery that converts dairy by-products (whey permeate and delactosed whey permeate) into lactic acid. The produced lactic acid will be used to manufacture biodegradable plastics, bio-based fertilizers, and minerals. For instance, the plastic derived from lactic acid could be used for packaging dairy products produced by farms, while the bio-based fertilizer could support mushroom cultivation. This project aims to enhance resource efficiency by reducing food waste, creating more products from milk, and integrating food and non-food material production. The AgriChemWhey project is a collaborative effort involving 11 partners from 5 EU countries and it aims to replicate its model across other European regions. (AgriChemWhey, n.d.)

As a part of another project INGREEN, sustainable biotechnological processes were developed to create new products for food, feed, pharma, and cosmetics sectors. The goal was to utilize whey, along with other materials like wheat and rye brans, and paper milling wastewater, to innovate and produce functional ingredients efficiently. The project aimed to develop tailor-made processes for producing biomasses from whey with different compositional features. These biomasses served as microbial adjuncts to create innovative cheese prototypes with reduced ripening time. Safe microorganisms, including validated wild strains of *Yarrowia lipolytica*, were used to produce starters, co-starters, or adjuncts directly in food. This approach enhanced sensory features, functionality, and sustainability by reducing ripening times. INGREEN also concentrated lactose from whey using Nanofiltration technology. The concentrated lactose was then converted into valuable products such as Galactooligosaccharides (GOS) and Lactobionic acid (LBA). (INGREEN, n.d.)

The INGREEN researchers developed multiple potential products: Using safe microorganisms and enzymes they created innovative Caciotta cheese with an accelerated ripening time compared to traditional Caciotta cheese. By incorporating *Y. lipolytica* biomasses, this cheese has a stronger and unique taste and smell. Importantly, it does not contain the preservative natamycin and boasts a longer shelf life. Other products were an intimate cleanser containing GOS and LBA and a vaginal gel enriched the same ingredients. The cosmetic gel exhibits good antimicrobial and anti-biofilm properties against pathogens responsible for vaginal diseases. These innovations demonstrate the project's commitment to utilizing whey by-products effectively and creating valuable products for various applications. (INGREEN, n.d.)

The third project is MilkStreamValue, initiated by Arla Foods Ingredients (AFI) and the University of Copenhagen. AFI is one of the world's leading producers of whey-based ingredients for pediatric, sports and medical nutrition, health foods and everyday foods, such as bakery and dairy products. The objective was to develop new methods for analysing and quantifying small components in milk and whey products. This included identifying all the components that make up the non-protein nitrogen fraction in lactose. (AFI, 2020)

4.2 Distillery side streams

Distillers' grains, also known as draff or spent grain, are by-products of ethanol production from various cereals such as wheat, rye, triticale, and barley. These grains have been the subject of numerous studies due to their potential nutritional value and applications in food production.

Mustafa et al. (2000) aimed to determine the nutrient degradability of thin stillages and distillers' grains produced from these cereals. They found that the ruminal degradability of dry matter was highest for rye distillers' grains and lowest for barley distillers' grains. Crude protein in barley distillers' grains had lower ruminal degradability compared to that in wheat and rye distillers' grains. For neutral detergent fiber, ruminal degradability was highest in rye distillers' grains, intermediate in wheat and triticale distillers' grains, and lowest in barley distillers' grains. The study concluded that thin stillage and distillers' grains from barley had a lower nutritive value for ruminants compared to those from wheat, rye, and triticale.

In a separate study, Świątkiewicz & Koreleski (2007a) examined the effect of different dietary levels of maize- and rye distillers dried grains with solubles (mDDGS and rDDGS, respectively) on nutrient digestibility and balance of nitrogen, calcium, phosphorus, and zinc in laying hens. They found that a 15 or 20% inclusion of mDDGS or rDDGS had a positive effect on phosphorus balance, but negatively affected organic matter and crude fat digestibility and the dietary metabolizable energy level. Addition of feed enzymes increased nutrient utilization in diets containing 20% DDGS. Świątkiewicz & Koreleski (2007b) researched also the effect of a decreased level of fodder phosphate in hens' diet containing distillers dried grains – with the same solubles as in their other study – on laying performance, eggshell quality and mechanical parameters of tibia and humerus. They found that diets with 20% rDDGS resulted in worsening laying rate and feed conversion, but a decrease of fodder phosphate levels in diets containing DDGS had no negative influence on performance, thickness, density and strength of eggshells and strength, elasticity and stiffness of the tibia and humerus.

Regarding the use for human food, Brochetti & Penfield (1989) studied the sensory characteristics of bakery products containing distillers' dried grain (DDG) from corn, barley, and rye. Total dietary fiber (51.22%) and protein (26.59%) were found to be the principal constituents of the DDG. Compared with all-purpose flour, the DDG was more acidic, absorbed more water and oil, and was darker in color. Consumer panels evaluated the acceptability and intensities of sensory characteristics of corn muffins, hush puppies, spiced doughnuts, and molasses-raisin cookies containing 10, 20, and 30% DDG (flour-weight basis). They found that as the replacement level of DDG increased, the appearance, flavor, and texture of the products were adversely affected; however, acceptable products were prepared with either 10 or 20% DDG.

Chetrariu & Dabija (2021) studied two extraction methods to extract antioxidant phenolic compounds from spent grain generated in malt whisky production: the ultrasound-assisted method (US) and the Ultra-Turrax method (high stirring rate) (UT). The spent grain extracts were analyzed for their total phenol content (TPC), total flavonoid content (TFC), and antioxidant activity was measured. Both methods were found to be efficient for recovering the abovementioned value-added compounds. In a more general context, Chetrariu & Dabija (2023) mentioned that spent grain is nutritionally rich, composed of fibers—mainly hemicellulose, cellulose, and lignin—proteins, lipids, vitamins, and minerals, and must be managed properly due to its high moisture, high protein and high fiber content and susceptibility to microbial contamination. They stress the need for suitable, cost-effective, and environmentally friendly valorization method of processing it. The authors also mentioned that spent grain is possible to be used as a raw material, due to its nutritional values, in the production of many food products, such as bakery products, pasta, cookies, muffins, wafers, snacks, yogurt or plant-based yogurt alternatives, frankfurter sausages or fruit beverages.

In conclusion, distillers' grains present a significant potential for nutritional and sensory applications in food production, although their characteristics can vary depending on the type of cereal used in their production. Further research is needed to optimize their use and manage their potential drawbacks.

One relevant project as a good practice can be found regarding distillery side streams, the SYMBIOMA project. The SYMBIOMA Technology Innovation Platform (TIP) supports business development by helping valorize food industry waste biomass and improve resource efficiency. Acting as a collaborative network of research organizations promotes knowledge exchange and service development to foster circular economy models in remote EU regions. Backed by the SYMBIOMA project and the Interreg Northern Periphery and Arctic Programme, the platform offers open-access services and webinars on circular economy topics, including distilling side streams, to drive economic and environmental sustainability. (SYMBIOMA, n.d.a)

4.3 Potato side streams

Potato peels can serve as a natural food preservative due to their high levels of phenolic compounds, offering a potential alternative to synthetic antioxidants and antimicrobials (Gebrechistos & Chen, 2018). Although potato peel extracts typically require higher application levels than synthetic antioxidants, studies have shown promising results: Rehman et al. (2024) found potato peel extract performed nearly as well as synthetic antioxidants BHA and BHT, a finding supported by Samarin et al. (2012) and Saeed et al. (2022), who also reported comparable antioxidant activity to BHA and BHT across various concentrations. While TBHQ remains the most effective synthetic antioxidant, potato peel extract can be safely used in oils, fats, and other food products to reduce lipid oxidation. Additionally, Sepelev and Galoburda (2015) demonstrated that, unlike artificial preservatives, potato peel waste extracts are non-mutagenic and non-carcinogenic.

Beyond preservation, potato peel waste shows value in other applications. It can be used as a substrate for microbial growth in solid-state fermentation (SSF) (Khanal et al., 2023) and, due to its high starch content, supports enzyme production (Kot et al., 2020). Sepelev et al. (2020) also developed food-grade antioxidant capsules from potato peel that effectively inhibited lipid oxidation in ground pork under accelerated storage conditions, highlighting its potential for industrial-scale processing. Finally, Jeddou et al. (2017) found that adding potato peel powder to cake recipes improves protein and dietary fibre content, with cakes containing up to 5% potato peel powder maintaining acceptable quality and favourable dough rheology. According to the study of Gebrechistos et al. (2020), caffeic, chlorogenic, and neochlorogenic acids are the main chemical compounds found in potato peel extract and responsible for its antimicrobial property. Potato peel extract has antibacterial as well as antioxidant properties and incorporating it with potato starch produces an active film which can be used as an alternative technology for active food packaging. A bioplastic composite (for a biofilm) can be produced from potato peels alone, but it requires added starch, glycerol, and fibre to withstand larger loads (Brandt, 2022).

Potato peel has various interesting pharmacological compounds such as glycoalkaloid which could be used as a precursor for steroid hormone (Schieber & Saldaña, 2009). Due to the steroidal alkaloids, potato peel waste can be used to make substances with apoptotic, chemo preventive, and anti-inflammatory effects (Khanal et al., 2023).

Potato peel is a prominent food waste that could be used as an alternative animal feed due to natural sources of energy and fibre with low levels of protein (Ncobela et al., 2017). Potato waste feeding has antimicrobial activity by reducing coliform bacteria and improved performance of

weanling pigs (Jin et al., 2014). The produced wastes from potato and vegetable peeling processes are suitable feed for domestic animals. This requires that the livestock farm is located near the peeling facility. Using the peel mass as feed is proposed to be the primary utilization target. Lehto et al. (2007) performed a shelf test and as a result peel mass can be stored in tight tanks to reduce lactic fermentation.

Potato peel waste can be used to produce biogas through anaerobic digestion. For example, Kryvoruchko et al. (2009) compared digesting potato pulp, potato skin pulp, and potato fruit water, of which the pulp generated the most methane. Potato peel waste has yielded aromatic chemicals, which can further be converted into biofuels (Liang & McDonald, 2014).

Potato peels have been used to make biofertilizers, as the peels contain large levels of proteins and carbohydrates which soil bacteria can break down to increase the nitrogen content of manure (Priyanga et al., 2016).

Biosorbents based on potato peels can be utilized in treating contaminated sources such as metals, pigments, colours, bio composites, and packaging materials in addition to being utilized as dietary fibre or medications (Elgarahy et al., 2023). In the study of Nathan et al. (2021), potato peels were immobilized to create biosorbent beads for the biosorption of heavy metals to initially neutralize the pH and to maintain low ion concentrations for drinking water.

The research by Attia et al. (2020) highlights the potential of potato peel extract as an eco-friendly corrosion inhibitor for carbon steel in formation water. Increasing potato peels extract concentration improved the inhibition efficiency, reaching up to 92.27% at 25°C for a 2.5% (v/v) concentration. The inhibition efficiency also increased as the temperature decreased.

The SYMBIOMA project introduced above in relation to distillery side streams is also a good practice regarding potato side streams: the TIP platform offers publicly available services and a series of circular economy webinar recordings on the topic of potato side streams too. (SYMBIOMA, n.d.b)

In addition to potato peels, the sludge generated in the process of peeling potatoes has some potential applications. As a good practice already in use in South Ostrobothnia, Suupohjan Perunalaakso Oy uses potato peeling sludge to produce biogas.

The sludge has also been studied as a part of the Sustainable and Responsible Food Province project. Ruhberg (2025) investigated the effects of potato cell sap on bread roll dough properties, moisture content, water activity, nutritional composition, staling, and sensory evaluation. The differences between control samples and those with higher cell sap concentrations indicate significant and noticeable effects, as the sap shows promise in improving the structural and sensory qualities of bread rolls and enhancing their micronutrient content. However, limitations

include possible measurement errors and a small sensory panel, affecting statistical reliability. Further research is needed on microbiological stability, cost-effectiveness, and environmental impact to fully assess its potential in baking applications.

4.4 Meat processing: pig and bovine blood

Bovine and pig blood have been incorporated into a variety of food products such as chocolate, cookies, sausages, drinks, gummies, and extruded items, due to their content of heme iron, bioactive proteins, and peptides. While microbial risks exist, slaughterhouses manage blood residues effectively (Chiroque et al., 2023). Using pig blood as a side stream of meat production has been studied as a way to address malnutrition and iron deficiency. For example, González-Rosendo (2010) found that chocolate-filled cookies made with pig blood, providing 10.3 mg of iron, increased adolescents' hemoglobin levels by 16% after seven weeks of consumption. Similarly, Fernández-Michel et al. (2006) showed that pancakes with 8% dehydrated serum doubled their protein content to 12% compared to controls.

Similarly, Benitez et al. (2008) demonstrated that biscuits containing 35 g/100 g blood plasma reached a protein content of 5.22%, helping to meet daily protein requirements for school-age children (about 50 g per day). According to Barboza et al. (2005), adding 40 g/100 g blood plasma to a cachapa-type corn pancake increased its protein content by 82.77% (from 3.54% to 6.47%), without affecting sensory qualities, and provided essential amino acids with a protein efficiency index of 2.64.

Méndez & Pérez (2011) reported that chocolate enriched with 5.7% dehydrated heme iron contained 8.2 ± 0.34 mg/100 g heme iron and showed a 72% increase in protein content (from 7.25% to 12.47%) with acceptable color changes. Tirado et al. (2015) developed a rice-based beverage with 29% blood plasma, achieving a protein content of $2.47 \pm 0.31\%$. Arias et al. (2018) found that milk fortified with hydrolyzed heme iron (56.92 mg/kg) provided 7.4% protein, with a 250 g serving meeting the daily iron requirements for children aged 1–3 years. In addition to pig blood, bovine blood has also been utilized in food production. For example, Andango et al. (2015) made a porridge from blood flour made from whole blood, resulting in an iron content of 121.0 ± 5.6 mg/ and protein content of 8 g/DM. Galarza & Cairo (2013) created an extruded product with 10% blood flour from whole blood, which had a protein content of 12.47 g/100g and iron content of 31.87 mg/100g. The consumption of these formulations could prevent iron deficiency anemia.

Furthermore, the European Food Safety Authority (EFSA) in 2015 stated that thrombin (food enzyme) from cattle and pig's blood does not give rise to safety concerns under the intended conditions of use, making it fit for human consumption and use in food production. This opens up

possibilities for the utilization of slaughterhouse blood side stream in general. For instance, the cellular fraction of blood can be used as a color enhancer for sausages, and better flavor can be obtained if hemoglobin is removed and used to replace fat in meat products (Viana, Silva, Delvivo, Bizzotto & Silvestre, 2005). However, applications are limited due to hemoglobin's dark color and sensory effects. Hygiene considerations remain crucial (Ofori & Hsieh, 2014). Thrombin and fibrinogen (marketed as Fibrimex®) serve as binders in meat processing. They enhance meat texture, hardness, and springiness, contributing to restructured meat products (Toldrá et al., 2016).

Cow blood is a byproduct of meat processing. Blood meal powder demonstrates considerable potential as a soil fertilizer. The study by Gholami et al. (2023) revealed that the application of blood meal powder significantly enhanced the levels of carbon (C), nitrogen (N), phosphorus (P), and zinc (Zn) in the soil compared to control samples. Furthermore, the abundance of culturable microorganisms and dehydrogenase activity saw notable increases in the amended soil. However, other soil enzyme activities remained unaffected, and there was no observed increase in basal respiration.

The study of Momtaz et al. (2021), conducted in India, evaluated the efficacy of blood meal as a bio-rationale amendment in the production and sustained yield of onions. The results indicated that blood meal is a viable alternative to growth hormone treatments, which are often expensive, and to urea, which can adversely affect soil health. The findings support the use of blood meal as a cost-effective and environmentally friendly option for agricultural purposes.

The study by Erwiha et al. (2020) investigated ammonia (NH₃) volatilization from various organic fertilizers, including feather meal, blood meal, fish emulsion, and cyano-fertilizer. The impact of fertilizer type, application method, and rate on NH₃ emissions was measured over two years. In the first year, blood meal applied at a single rate and feather meal at both rates exhibited the highest NH₃ fluxes. In the second year, surface-banded applications of blood meal and feather meal resulted in the highest NH₃ emissions, indicating the significance of application methods on NH₃ volatilization.

Blood and its derivatives have diverse applications across multiple industries. Blood can be processed into blood powder or separated into plasma and red blood cells, which can then be further refined into plasma protein, globin protein, or bioactive components. Blood proteins possess excellent nutritional and functional properties, containing all essential amino acids. Plasma is particularly processed into protein products for the sports nutrition market, with immunoglobulins known to reduce cholesterol levels. In the food industry, plasma concentrate has shown a positive influence on the sensory and technological qualities of cold cuts, making it a suitable replacement for red meat or added proteins like soy without compromising quality.

Additionally, blood fractions are utilized as binding agents in the paper, plywood, glue, and plastic industries, and in the animal feed industry as dried blood meal, plasma meal, or albumin (Pihlanto et al., 2012).

The reviewed studies collectively highlight the versatile applications and benefits of blood meal and blood-derived products. Blood meal enhances soil fertility and crop yield while offering a sustainable alternative to conventional fertilizers. Blood derivatives serve significant roles in both food and non-food industries, demonstrating the potential for comprehensive utilization of blood byproducts. In conclusion, the use of pig and bovine blood in food production presents a promising avenue for enhancing the nutritional value of food products, particularly in addressing malnutrition and iron deficiency. However, more research is needed to explore the potential of these side streams in different food contexts and their acceptability among consumers.

The presented data is a general overview of the topic, and the choice of techniques and practices depends on the specific raw material and intended product. Collaborating with experts and discussing options will help determine the best approach.

4.5 Fish sector

Various good practices in relation to utilization of side streams can be found also within the fish sector. The introduced projects below represent a commitment to sustainable practices and the circular economy in the European fish sector. They showcase innovative approaches to utilizing sidestreams, contributing to waste reduction and the creation of new, valuable products.

Firstly, a Finnish startup Hailia has developed technology to transform discarded fish into new food products, such as chunks, bites, strips, and patties, utilizing sidestreams from responsible fishing partners. In early 2023, Hailia Small Fish Products, crafted from Baltic herring, made their debut in the Finnish food service market. Shortly after their launch, they received the prestigious title of Seafood Innovation of the Year in Finland. Their recognition stemmed from their versatility, user-friendly nature, cost-effectiveness, and flavor. (Hailia, n.d.)

A wider-scale SEA2LAND project, funded by the EU's Horizon 2020 program, aims to address challenges in food production, climate change, and waste reuse. It promotes the production of large-scale fertilizers in the EU using local raw materials to reduce soil nutrient imbalances. The project focuses on developing demonstration pilots for Bio-Based Fertilizers (BBFs) across Europe's fisheries sector, with the goal of boosting local growth. It involves implementing nine technologies in seven cases, producing BBFs from seafood processing and aquaculture by-products. The project also assesses its environmental and social impacts and aims to partially

replace imported nutrients for agriculture in Europe. The project takes into consideration various stakeholders significant from the point of view of fish side streams: fish and aquaculture industry, agricultural producers, fertilizer producers and sellers, academia and research focused on nutrient recycling, business and financial advisors, policy makers and authorities, along with public entities and the general public. (SEA2LAND, n.d.)

Another EU-project, the WaSeaBi project, funded by the EU's Horizon 2020 BBI JU initiative, aims to address the issue of underutilized seafood side-streams, which are often treated as waste despite their potential value. These side-streams contain valuable components like protein, fatty acids, and minerals. The project focuses on developing innovative technologies to efficiently extract these components and turn them into marketable products such as protein-based food ingredients and mineral supplements. The project began with an analysis of the seafood industry to identify barriers to efficient utilization, including technological limitations and market constraints. Laboratory-scale technologies were tested to extract valuable components, and decision-making tools were developed to guide the valorization process, considering technical, legal, economic, and environmental factors. Life cycle assessment highlighted the importance of reducing chemical usage and improving energy efficiency to minimize environmental impact. Overall, the WaSeaBi project represents a promising approach to sustainable and economically beneficial utilization of seafood side-streams, contributing to waste reduction and environmental conservation while creating high-value products. (WaSeaBi, n.d.)

Finally, the EcoeFISHent project aims to create a replicable and sustainable cluster to valorize fishing and fish industry side streams through circular value chains (CVCs). These CVCs will connect blue and green economies, integrating human activities with marine ecosystems. The project focuses on obtaining bio-actives, galantine, and other products from fish-processing side streams for food supplements, skin care, and packaging. Additionally, it aims to convert other side streams into soil fertilizers, biodiesel, and chitin for cosmetics. EcoeFISHent develops interconnected CVCs across various industries, promoting a climate-neutral and circular approach while reconciling economic activities with environmental limits. Each CVC fosters links within different industrial domains and seeks synergies with stakeholders interested in deriving value from fishing and fish industry side streams. (EcoeFISHent, n.d.)

5 Pilot 3: Responsibility in Food Services' Operations

A survey study targeting food service actors in South Ostrobothnia showed that four out of six companies felt they knew the sector's climate actions moderately well, two had limited knowledge. Four aimed to reduce greenhouse gas emissions by 2035. None participated in climate projects. All currently use or plan to use more environmentally friendly materials or ingredients. Five already work to reduce food waste. Two are improving resource efficiency now, and three plan to soon. Two have switched to renewable energy, with two more planning to within five years. Two have optimized logistics and embraced circular economy practices; one more plans to do so. Only one showed interest in carbon capture projects. Five viewed subsidies as a major or moderate aid for emission reduction, and three valued training as moderately helpful. (Palomäki et al., 2022)

On national scale, most of of restaurants' emissions (93%) come from electricity and heating in owned and leased buildings. Switching to low-emission fuels is expected to cut emissions by 77% by 2035 without extra measures, shifting fuel's share to 18% of restaurant emissions. However, they emphasize that even if a company's direct carbon footprint is small, it can still influence emissions indirectly through its supply chains and by offering low-emission or carbon-neutral products or services. (Descombes, Saario, & Heikinheimo, 2020)

As in the sections above, here the presented solutions reflect the Food Province strategy's (Välisalo et al., 2022) priorities as well. Many of the introduced solutions for improving food services' responsibility are based on educating food field professionals, representing the priority of *The Food-PRO-vince*. Another particularly relevant priority for food services is The Food Province family, as we highlight the roles of active and tight networks along with diverse and conscious consumers.

5.1 Reducing Waste in Kitchens and Dining

A review article (Lefadola, Viljoen, & du Rand, 2018) outlines various strategies to prevent food waste in food service operations. These include flexible pre-booking systems, accurate portion ordering, effective communication between all relevant stakeholders, automated forecasting tools, long-term analysis of meal data, and advanced demand planning software.

Pre-booking systems are highlighted in other studies too as a common theme: Marais and colleagues (2017) suggest that giving students the option to cancel meals up to 24 hours in advance, instead of the current 48-hour fixed system, could increase flexibility and help better

align food preparation with actual demand. Similarly, Painter et al. (2016) found that meal bookings made 48 hours in advance can help reduce food waste by enabling more accurate demand predictions and note that raising awareness about food waste's environmental and economic impact can further support reduction efforts. Papargyropoulou et al. (2016) also emphasize the role of pre-booking in minimizing overproduction. Lastly, in Swedish schools' context, Marthinsen et al. (2012) describe structured systems where ordering and cancellation must be done in advance, and where failure to comply can result in penalties, highlighting the role of accountability in waste reduction.

Other research has focused on the long-term analysis of meals. Betz and colleagues (2015) advocate for the use of long-term sales data to optimize meal planning based on patterns such as weekdays, seasonal changes, holidays, and events, helping to align supply more closely with actual demand. Similarly, GreenHealthcare (n.d.) recommends tracking unserved food over a full menu cycle to spot trends and refine estimates.

5.1.1 Demand planning software (machine learning & AI)

Various studies suggest that AI solutions, especially those based on machine learning, seem promising in predicting the demand for food services. However, according to Rodrigues et al. (2024), the development of such forecasting models for minimizing food waste is still emerging.

Rodrigues and colleagues (2024) developed four machine learning models³⁸ for food catering services to forecast their demand accurately in the short future (next-day forecasts). The models were tested on data from three food catering services (FCSs): two student canteens and a company canteen. The data used and variables connected to it varied between the FCSs. However, common variables were the dish; the day, week, and month; a holiday and the days before or after a holiday; along with temperature, precipitation and other weather conditions. Based on the results, forecasting models utilizing the random forest algorithm and long short-term memory neural networks delivered the most accurate predictions. These models enabled a 14%-52% reduction in wasted meals. Additionally, utilizing these forecasts allowed food catering services to decrease unmet demand by 3%-16% compared to the baseline models.

³⁸ Two of the models were casual models - one based on a random forest algorithm and the other based on the light gradient-boosting machine (LightGBM) algorithm – and two were time series models - one based on a long short-term memory (LSTM) neural network and the other based on a transformer neural network. The authors also created baseline models that mimicked how managers currently do their demand forecasts.

In the context of subsidy-based university dining where students reserve their meals, Faezirad et al. (2021) present a new model for reducing food waste³⁹. Over the course of a year, food waste was reduced by 79.66%. This reduction was achieved primarily by decreasing the number of uneaten meals, directly lowering the volume of food discarded.

Arunraj and Ahrens (2015) looked at improving the predictability of daily banana sales in a German grocery store. They tested several forecasting methods, including three advanced versions of a common statistical model (ARIMA) and one based on artificial intelligence. Two of their models—SARIMA-MLR and SARIMA-QR—performed better than the others in predicting future sales. The SARIMA-MLR model excels in generating precise point forecasts, while SARIMA-QR offers enhanced prediction intervals and provides deeper insights into the influence of demand factors across different quantiles. The researchers also gave advice on choosing the right forecasting method based on the kind of data available, how much sales vary, and how precise the predictions need to be. These results and instructions can thus also be utilized in food services' demand planning.

Some EU projects concentrate on such order system accuracy or demand forecasting. Binspector leverages advanced technology to monitor and document potential food waste automatically. By integrating a smart camera, a smart scale, and AI-powered image recognition, it provides actionable insights to enhance operational efficiency. Additionally, it can pre-fill restaurant ordering systems, streamlining inventory management and reducing waste. (European Commission, 2024) The project has ended, and the system can now be found by the name Orbi (Orbisk, n.d.).

Under another project, LOWINFOOD, software called Mitakus has been generated, as mentioned already in relation to food waste reduction. Mitakus “provides a web-based software that generates precise forecasts and menu recommendations with the help of AI algorithms based on internal and external factors, such as the weather, holidays, vacations, events and dietary restrictions and preferences.” (LOWINFOOD, n.d.b)

Various other similar practices or programs provide demand forecasting software too. Such Finnish demand forecasting programs include JAMIX kitchen system and Pinja. The JAMIX system is presented as a comprehensive information management system, which can control recipes, menus, and inventory, among other things. It can also be integrated into other systems to predict the number of diners. On the JAMIX website, the number of diners is told to be affected by the history of diners in numbers, seasonal trends, weather conditions, campaigns, local events,

³⁹ The model consists of a two-step estimation using a machine learning model based on artificial neural networks (ANNs) to ensure significant accuracy of demand prediction. First, the definite demand component is estimated and then, in the post-processing step, the uncertain demand component is estimated using error analysis.

and holidays. (JAMIX, 2024) However, it is unclear whether these variables are included in the kitchen system software. Pinja's APS (Advanced Planning and Scheduling) system, iPES, is a production planning tool that can adjust to rapid changes in production orders and create an optimized plan according to production requirements. (Pinja, n.d.) To note, the system is used in food industry, not in food service.

Even more such systems have been developed within Europe. Apibase originates from Belgium and is a food and beverage management platform for multi-site operations. It uses historical sales data, current inventory levels, and information on menu items to generate accurate forecasts. Factors such as weather conditions or local events can be adjusted manually in the software. This digital service is used by for example Sodexo (Apibase, n.d.a). In addition, they have a more specific Central Kitchen Management Software for efficient linking of central kitchens and local restaurants (Apibase, n.d.b).

The same ideas are utilized in Tenzo, a UK-based software. It also integrates historical data with weather, events, holidays, and other trends to generate an accurate prediction of demand. Tenzo's forecasting solution combines machine learning with a mobile app for restaurant managers. They present their own case studies with the software users, for example a restaurant chain called Nando's. (Tenzo, n.d.)

German Delicious Data uses AI through a machine learning system to enhance production and workforce planning with forecast horizons of up to six weeks. The software allows adjusting item-level forecasts to minimize sellouts and optimize cost of sales. According to the website, the software integrates data from cash registers or inventory management systems in any format, automatically enriching it with weather and calendar insights, leading to improvements of 40% on average in planning accuracy. Furthermore, Delicious Data dashboard is told to visualize forecasts alongside critical KPIs and reports for actionable insights. (Delicious Data, n.d.a) Specifically for food services, Delicious Data states that their software reduces overproduction, produces fewer sellouts, and enables the food service to have more time for the guests by reducing surplus processing workload (Delicious Data, n.d.b).

Outside of EU, Switzerland-based Prognolite utilizes AI to forecast turnover and the number of guests for restaurants. The software analyses historical points of sale (POS), portfolio management services (PMS), and front office data along with timely weather, vacation, and holiday information. It also focuses on resource planning, sales forecasts and cost analysis, automation and efficiency, as well as employee productivity (Mirus, n.d.).

5.2 Communication with Diners

In the quest for sustainability, food services play a pivotal role in influencing consumer choices. While labeling has been a primary tool for communicating sustainability attributes, it is not the only method available. This chapter explores various strategies beyond labeling that food services can employ to promote more sustainable food choices. By examining current practices, challenges, and regulatory initiatives, the chapter is an overview of how food services can effectively encourage consumers to make environmentally friendly decisions. It is important to start this overview by sieving through the regulations on sustainability communication.

1.1.1. EU regulations and initiatives on sustainability communication

The European Commission has several initiatives for regulating communication with customers about sustainability. These initiatives apply also to communication done by food services.

A notable initiative is the European Commission's Sustainable Food Systems Framework Initiative (European Commission, n.d.). It proposes a legislative framework for sustainable food systems (FSFS), and it is one of the flagship initiatives of the wider Farm to Fork Strategy. The initiative aims to accelerate and facilitate the transition to sustainable food systems. Its core objectives include promoting policy coherence at both the EU and national levels, integrating sustainability into all food-related policies, and strengthening the resilience of food systems. The initiative was planned to be adopted by the Commission by the end of 2023, but the adoption has not been executed yet.

The FSFS is related to the SAM Report (Scientific Advice Mechanism (SAM), 2020), which states that information-based initiatives should be included in the policy mix, even though they alone would not be enough to change behavior. The same conclusion applies to education and communication initiatives, such as awareness campaigns, as they are necessary but not sufficient to achieve the desired changes.

Another European Commission's initiative is a part of the Sustainable Food System Framework initiative: the Sustainability Labelling Framework (Regulation 1169/2011). The objective of this framework is to empower consumers to make informed and sustainable food choices. It will regulate the provision of consumer information regarding the sustainability of food products. In conjunction with other relevant labeling initiatives, such as front-of-pack nutrition labeling, animal welfare labeling, and 'green claims,' it will address consumer information related to the nutritional, climate, environmental, and social aspects of food products.

The abovementioned EU Green Claims Directive (European Commission, 2023) covers the substantiation and communication of voluntary environmental claims. The requirements on the substantiation of environmental claims are as follows. The claims

- i) rely on recognized scientific evidence and state of the art technical knowledge;
- ii) demonstrate the significance of impacts, aspects and performance from a life-cycle perspective;
- iii) take into account all significant aspects and impacts to assess the performance;
- iv) demonstrate whether the claim is accurate for the whole product or only for parts of it (for the whole life cycle or only for certain stages, for all the trader's activities or only a part of them);
- v) demonstrate that the claim is not equivalent to requirements imposed by law;
- vi) provide information on whether the product performs environmentally significantly better than what is common practice;
- vii) identify whether a positive achievement leads to significant worsening of another impact;
- viii) require greenhouse gas offsets to be reported in a transparent manner;
- ix) include accurate primary or secondary information.

Moreover, article 4 of the directive sets out further requirements for comparative claims. Lastly, there are also more specific requirements on the communication of environmental claims, such as that all claims shall only cover environmental impacts, aspects or performance that are assessed in accordance with the substantiation requirements laid down in the directive proposal and are identified as significant for the respective product or trader. (European Commission, 2023, p. 18-20)

One of the first deliverables of the EU Farm to Fork Strategy and an essential part of its action plan is the EU Code of Conduct on Responsible Food Business and Marketing Practices (European Commission, 2021). The code outlines common goals and suggested actions that actors 'between the farm and the fork,' such as food manufacturers, food service operators, and retailers, can voluntarily align with, commit to, and support to facilitate the transition towards sustainable food systems. The code's first aspirational objective is stated as Healthy, balanced and sustainable diets for all European consumers. The aspirational targets under this objective are i) Improved food consumption patterns in the EU; and ii) A food environment that makes it easier to choose healthy and sustainable diets. Furthermore, there are target-specific indicative actions of which many are relevant for sustainability communication. The actions for the first target are:

- 1) Encouraging increased consumption of fruits and vegetables, wholegrain cereals, fiber, nuts and pulses, including locally produced varieties (e.g. by increasing the availability and/or access);
- 2) Providing/promoting more sustainably produced food products/meals:
- 3) Improving, where feasible, the nutritional composition and environmental footprint of food products/meals;
- 4) Reviewing and/or offering a range of appropriate portion and serving sizes aimed at sustainable food consumption;
- 5) Promoting consumer awareness of healthy, balanced and sustainable diets, including sustainable food consumption, as part of healthy and sustainable lifestyles (European Commission, 2021, p. 10–12).

For the second target, the actions are

- 1) Providing transparent, voluntary product information to consumers;
- 2) Applying responsible food marketing and advertising practices, e.g. by adhering to self- and co-regulatory initiatives and standards;
- 3) Promoting healthy and sustainable food service practices;
- 4) Integrating sustainable practices and health in the workplace;
- 5) Supporting local actions to enhance the availability of/access to healthy and sustainable diets for all. (European Commission, 2021, p. 12)

European Economic and Social Committee (EESC) has also released multiple opinions on sustainability communication related to food. Firstly, EESC has provided recommendations for establishing a sustainable food labeling framework (European Economic and Social Committee (EESC), 2022). More specifically, they recommend a labeling framework that is transparent, based on science and as simple and pragmatic as possible, both helping economic operators to assess and improve the sustainability of products and providing useful information to help consumers make informed choices. According to the EESC, a sustainable food labeling framework must start with a clear definition or methodology that equally addresses all three pillars of sustainability (environmental, social, and economic), encompassing the entire food value chain from production to consumption. In the specific comments, EESC states that sustainability claims should be based on principles of reliability, transparency, relevance, accessibility, and clarity, following UN guidelines for providing product sustainability information. The certification system must also ensure that the structural background is considered to avoid penalizing small entities such as farmers, SMEs, farm gate sales, and weekly markets.

EESC suggests focusing on specific aspects of sustainability, such as animal welfare or social and environmental criteria, instead of a fully defined and rated sustainability framework. However,

the term "sustainable" should only be used within a comprehensive rating system. Simultaneously, EESC notes that existing EU quality schemes, such as organic farming and geographical indications, already contribute to greater sustainability in the food system and should be recognized. The existing rules should thus undergo a sustainability check and be supplemented with adequate sustainability provisions if needed. Overall, EESC believes that labeling systems using a rating scale, such as a traffic light system, can help consumers make informed choices and encourage companies to improve their processes along the food chain.

EESC recommends a voluntary approach initially – with a future evaluation to determine if mandatory labeling is necessary. Sustainability labels or claims not meeting these conditions should be prohibited. In the opinion paper's general comments, EESC states that an EU-wide sustainable food labeling framework should accommodate national and regional systems, but definitions and evaluation rules must be harmonized across the EU. Lastly, EESC concludes by emphasizing the importance of education in providing a basic understanding of sustainability aspects related to food. Awareness-raising campaigns and measures to support the affordability of sustainable food products can promote the transition towards more sustainable food systems.

Secondly, EESC has an opinion paper on Promoting healthy and sustainable diets in the EU (European Economic and Social Committee (EESC), 2018). In this paper, EESC recommends providing New Sustainable Dietary Guidelines that would also help create clearer direction for farms, processors, retailers and foodservice. Simultaneously, the agri-food system would benefit from a new "framework" to produce, process, distribute and sell healthier and more sustainable food with a fairer price. EESC emphasizes that a common European food labeling approach, aligned with the Sustainable Dietary Guidelines, would enhance transparency and deter the use of unhealthy and unsustainable raw materials, such as trans fats, palm oil, and excess sugars. Importantly, expanding food labeling to include environmental and social aspects would benefit consumers by guiding their choices toward healthier and more sustainable options.

Thirdly, in EESC opinion paper on Digitalization and Sustainability (European Economic and Social Committee (EESC), 2020), EESC urges on developing a new smart sustainable system on sustainable food labelling. The system would provide comprehensive information about products to promote sustainable consumer choices and lead to healthier diets. The suggested labeling could cover information about production, environmental effects, composition, use, repairability, and usability of any given product.

The Global Reporting Initiative (GRI) also has topic-specific disclosures on marketing and labeling (Global Reporting Initiative (GRI), 2016). Disclosure 417-1 states that the reporting organization is required to report the following on its product and service information and labeling (p. 8):

- 1) Whether each of the following types of information is required by the organization's procedures for product and service information and labeling:
 - a. The sourcing of components of the product or service;
 - b. Content, particularly with regard to substances that might produce an environmental or social impact;
 - c. Safe use of the product or service;
 - d. Disposal of the product and environmental or social impacts;
 - e. Other (explain).
- 2) Percentage of significant product or service categories covered by and assessed for compliance with such procedures.

GRI states the following as background for the requirements: Customers and end users require accessible and sufficient information about the positive and negative environmental and social impacts of products and services. The information may include details on the safe use and disposal of a product, as well as the sourcing of its components. Providing this information is told to enable customers to make informed purchasing decisions. Furthermore, disclosure 417-2 requires reporting incidents of non-compliance concerning product and service information and labeling, and disclosure 417-3 incidents of non-compliance concerning marketing communications.

5.2.1 Projects on developing sustainability communication towards consumers

Various Finnish projects have been focusing on developing food services' communication on sustainability or corporate social responsibility (CSR) towards diners.

Ce4Re project (Matkailun kehittämiskeskus, n.d.) focuses on the development of joint circular solutions in the central Baltic restaurant sector. The project lists offerings to actors in the restaurant industry and one of these offerings is developing consumer communication. More specifically, the project helps actors to discover how to increase consumers' awareness of the sustainable development and circular economy measures a restaurant takes. The material bank of the project provides plenty of information, such as an introduction to circular economy⁴⁰, a list of tips on the best practices on circular economy for businesses⁴¹, and a webinar on how to market

⁴⁰ [Webinar with the theme of Introduction to Circular Economy - What, How and Why?](#)

⁴¹ [The best circular practices list businesses](#)

and communicate circular actions⁴². Some of these resources are in English while some are in Finnish.

A project called Kestävä RuokaHäme (HAMK, n.d.) again approaches sustainability from different perspectives. The project consists of five development paths with different themes, of which the fourth one is CSR communication – including environmental reporting. The theme is told to open up the operating models of responsible communication and the process of environmental reporting with data collection needs. Moreover, the theme covers topics such as the UN Sustainable Development Goals (SDGs) and responding to consumer needs through communication. Thus, the goal of this theme is for companies to know the UN Sustainable Development Goals, understand consumer values in their communications, and learn how to communicate responsibly in different ways.

Vastuullisempaa kattausta⁴³ (Instructions on effective CSR communication) project (Turunen et al., 2023) presents instructions on what kind of responsibility messages work, in which channels and how they work, and how to plan and organize the communication. It is a part of a wider Mission Positive Handprint project. Similarly, SEAMK's CSR communication handbook for SMEs (in Finnish)⁴⁴ (Kangas, Koivupuisto, & Hemminki, 2023) gives guidelines on analyzing the present situation, generating a plan, communicating in an understandable and transparent way, measuring CSR communication performance, and on being customer-oriented and inspiring towards others.

Some initiatives have been developed specifically for public food services. Vastuullisuusviestinnän vuosikello (Sustainable Public Meal) project (Sustainable Public Meal Toolkit (StratKIT), n.d.) presents an array of tools for planning the communication activities of public food services and procurement providers and on picking out ideas from the project to be applied to one's own operations. The tools are divided into the following Thematic Gateways:

- Strategies for Change
- Public Procurement
- Communication and capacity building
- Organic Food
- Healthy and plant-based diets
- Food Waste
- Resource Efficiency

⁴² [Webinar with the theme of Sustainability marketing and communication: How to market and communicate your circular actions?](#)

⁴³ [Vastuullisempaa kattausta -handbook](#)

⁴⁴ [Vastuullisuusviestinnän opas mikro- ja pienille yrityksille](#)

- Working with farmers
- Crisis Management

The core of the project is, however, the Communication visualization across the year⁴⁵ and a PowerPoint template to be filled which make the progress of sustainable development visible to both customers and the food service organization itself (Sustainable Public Meal, n.d.).

Following the same principle, Vastuulliset ruokapalvelut (Responsible foodservices) development program (Varuke) (Savon Koulutus kuntayhtymä (SAKKY), n.d.) is a tool suitable for all food services, with which the food service finds out the current state of CSR in its operations, identifies areas for development, creates a CSR plan and reports on CSR actions. One of the project's topics focuses on communication with customers. The program is free of charge, it is carried out independently, and no registration is required to use it.

5.2.2 Sustainable food labelling

This chapter provides examples of Good Practices in sustainable food labeling, focusing on both the food service sector and retail. It briefly introduces key initiatives aimed at enhancing transparency in the food market by highlighting the environmental impact of food products.

ECO-SCORE® by Beelong

The mission of Beelong is to promote transparency in the food market by highlighting the environmental impact of food products, thereby supporting more sustainable consumption. To address the current unsustainable food production practices, Beelong employs the ECO-SCORE® methodology, which evaluates food products based on their environmental impact. The ECO-SCORE® ranks products from A+ to E- using a life cycle analysis (LCA) approach, while also incorporating additional criteria such as biodiversity and animal welfare, to provide a holistic and comprehensive assessment of their environmental footprint. Two of the labels are presented on the right, in Figures 1 and 2. More than 200 community restaurants have already taken this service into use to measure and improve the sustainability of their food purchases and communication of their efforts to clients. (Beelong, 2022).



Figure 5: The best (A+) ECO-SCOREs by Beelong. Source: Beelong, (2022).



Figure 6: The worst (E-) ECO-SCOREs by Beelong. Source: Beelong, (2022).

⁴⁵ [Communication visualization across the year \(Sharing sustainability information\)](#) (in English)

Eco-score

The Eco-score is designed to help consumers make eco-friendly choices by rating products from A (best) to E (worst) based on their environmental impact. This score is calculated by considering the entire life cycle of a product, assigning a score out of 100, which is then adjusted by additional factors such as origin and packaging. The Eco-score is available on price labels at Colruyt and Bio-Planet stores, as well as in the Xtra and MyColruyt apps. By choosing products with higher Eco-scores, consumers can support environmental projects and reduce their ecological footprint. Moreover, if they purchase products with an Eco-score of A or B, they earn points in their Xtra app. With 100 points they can choose whether they want to support a charity, get free products, or attend a sustainability workshop at Colruyt Group Academy (Colruyt Group, n.d.a).



Figure 7: The second-best Eco-score, B. Source: Colruyt Group (n.d.b).

ENVIROSCORE

ENVIROSCORE is an intuitive 5-grade label from A to E, designed to communicate the environmental impact of food and beverages. Developed by AZTI and KU Leuven, it is based on the European Product Environmental Footprint (PEF) methodology. This standardized system combines 16 environmental impact categories into one, promoting sustainable consumption and production. ENVIROSCORE aims to provide clear, comparable information to consumers, encouraging eco-friendly purchasing habits and helping agri-food companies reduce environmental impacts throughout the supply chain (AZTI & KU Leuven, n.d.).

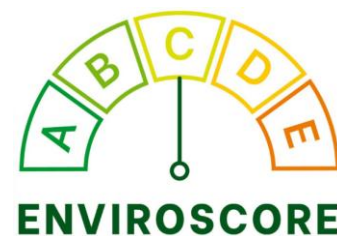


Figure 8: The ENVIROSCORE label. Source: AZTI & KU Leuven (n.d.).

M-check Migros

The M-Check is a sustainability scale developed by the Swiss brand Migros in collaboration with external experts. It uses a five-point rating system, similar to hotel ratings, to evaluate Migros own-brand products. The M-Check assesses products based on climate compatibility, animal welfare, environmentally friendly packaging, responsible fish sourcing, and recyclability – there are separate labels for each aspect. The more stars a product receives, the more sustainable it is, providing consumers with a clear overview of how each product compares within the range.

This initiative aims to make sustainable shopping easier and more transparent for customers (Migros, n.d.).

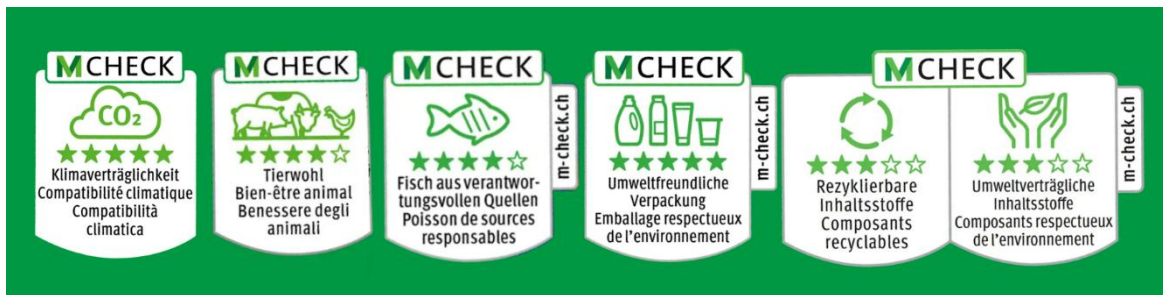


Figure 9: Different Migros' M-check labels. Adapted from Migros (n.d.).

Eaternity Score

Eaternity offers a different, comprehensive solution for private and professional kitchens to calculate and reduce the environmental impact of their recipes and menus. With detailed sustainability metrics, real-time calculations, and monthly reports, Eaternity helps restaurants track and improve their CO₂ emissions, water footprint, and overall environmental impact. To consumers these efforts are conveyed through the label with the 3-point scale marked by stars. The platform also provides the Eaternity Award to label climate-friendly menu choices, empowering customers to make informed decisions. Additionally, Eaternity's API integrates seamlessly with existing systems, providing smart insights into supply chains for better decision-making. (Eaternity Institut, 2024)

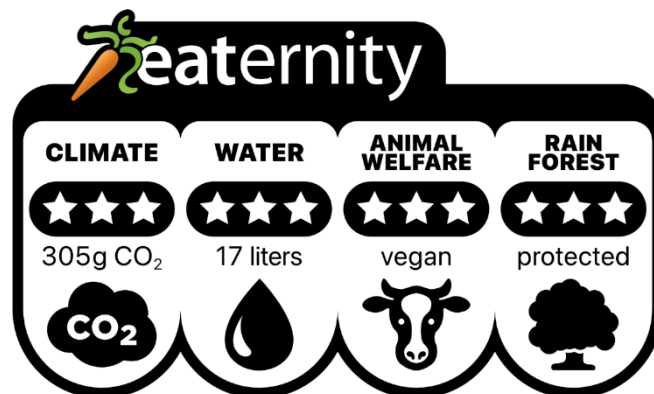


Figure 10: An example of an Eaternity score. Source: Eaternity Institut (n.d.).

Life Eco Food Choice project

The Life ECO FOOD CHOICE: Environmental Data & Ecolabeling for Sustainable Food Choice project aims to develop and harmonize environmental labelling across Europe. Funded by the LIFE program, it involves 8 partners from Spain, Germany, and the Netherlands, including researchers and companies specializing in agriculture, data, LCA, and consumer sciences. The goal is to present a validated environmental display system to the European Commission by 2028 – meaning that the label itself is yet to be developed. The project focuses on consumer research (testing and validating market effects) and farmer engagement - developing and testing sustainability-related supplier management programs (LIFE ECO FOOD CHOICE, n.d.).

5.2.3 Policy recommendations presented by research articles

In recent years, numerous research articles have provided valuable insights and recommendations for enhancing sustainability communication within the food services sector. These recommendations aim to promote more sustainable food consumption patterns by addressing various aspects of sustainability communication. By leveraging these research findings, policymakers and industry stakeholders can develop more effective strategies to encourage sustainable practices among consumers and businesses alike. This chapter highlights key policy recommendations from recent studies, focusing on improving sustainability communication to foster a more sustainable food system.

Recommendations on improving sustainability communication

Various research articles state policy recommendations for improving sustainability communication for more sustainable food consumption. The recommendations focus on differing perspectives or parts of sustainability communication.

Hoppe and Kleinen-von Königslöw (2023) studied the links people form between the ecological, economic, and social impacts of the food system and their own food choices. They did this by analyzing discussions on supermarket chains' Facebook pages. The results highlight that the term "sustainability" is never mentioned, while food is linked to various concrete sustainability issues. The authors emphasize in their conclusions that greater ambitions in sustainable development at the policy level are associated with increased awareness in everyday life discussions.

Based on Saber and Weber's (2019) comparative analysis of sustainability reports, there are difficulties in the comparability of sustainability reports across companies due to the lack of

common reporting and data standards. Thus, legislation regarding reporting and data transparency should be strengthened to ensure comparability and to increase consumer awareness of retailers' sustainability performance. Although the analysis focused on supermarkets and discounters, the policy recommendations may be relevant regarding food services too.

Camelo and Nogueira (2024) too emphasize the necessity for transparent and innovative communication strategies, particularly for SMEs, to build trust and credibility and avoid greenwashing. They highlight the challenges SMEs encounter in implementing proactive sustainable practices due to resource constraints and the influence of larger corporations. Thus, the authors address the research gap regarding sustainable practices within SMEs. They recommend relying on external certifications, rather than specific internal metrics, as a practical approach to implementing sustainability.

Sustainability certifications are also at the center of Lumby and Ngwenyama's (2023) research, as they studied whether attaining certification alters companies' external communication about sustainability. Their comparative analysis shows that certification affects the frequency and volume of sustainability claims. Certified firms made up 67.6% of the total claims and were more transparent about their goals and achievements, emphasizing social aspects like community engagement, while uncertified companies focused more on greening production processes. Thus, the authors argue that sustainability certifications can foster radical innovations, helping food and beverage companies pursue sustainability beyond their current practices.

Schifferstein, de Boer, and Lemke (2021) have a partly different take on conveying sustainability information in an accessible way. They argue that the formulation of rules and regulations depends partly on what can be explicitly stated in written rules and how these rules can be enforced. As a stated example, legislators often use technical descriptions and require scientifically accurate claims but may not focus on how consumers interpret and use this information. Although the claims may be technically correct, they may not align with consumers' interpretations. Therefore, to support consumer decision-making, the authors urge legislators to not only ensure that rules and regulations are formally correct but also consider the impact of how a message is communicated. This includes aspects such as content, typeface, size, use of images, and stylistic features, which can influence buyers.

Similarly, Culliford, Bradbury, and Medici (2023) list recommendations on improving the communication of the UK Sustainable Healthy Dietary Guidelines – also known as the Eatwell Guide. The improvements are reviewing the language and tone of nutrition and sustainability-related messages; targeting food-based dietary guidelines (FBDG) and communications to specific population segments; addressing barriers to and highlighting benefits of adopting the

Eatwell Guide recommendations; developing practical tools and resources to support guideline implementation; leveraging social media and social marketing techniques to boost public engagement. These guidelines clearly highlight the accessibility of sustainability information in various ways.

One of Culliford and colleagues' (2023) suggestions, utilizing population or consumer segments in sustainability communication, is supported in other studies as well. Annunziata and Mariani (2018) identified three consumer segments with significantly different perceptions of sustainability attributes: a large segment focused on self-interest, an environmentally oriented segment, and a small segment of sustainability-oriented consumers. The authors urge policymakers and institutions promoting sustainable consumption patterns to consider these varying levels of sensitivity to sustainability attributes in organic and local food among the identified segments. They propose specific actions for the two first segments. Consumers in the first segment should be educated about the social and environmental benefits of organic and local consumption, beyond health and quality aspects, by using communication strategies that foster a sense of belonging and self-identity in the shift towards sustainability. For consumers in the second segment, the additional social and economic benefits of organic and local consumption could be highlighted, beyond the recognized environmental benefits. Here the focus should be on fostering a sense of belonging to the local community, promoting short supply chains as models based on community-building relationships and shared responsibility.

A study by Van Loo, Hoefkens, and Verbeke (2017) identified consumer segments based on their involvement in healthy and sustainable eating, noting that involvement in sustainable eating often implies involvement in healthy eating, but not necessarily the reverse. More specifically, segments with high involvement levels were found to be more likely to consider detailed information, evaluate arguments, and make informed decisions. The authors emphasize that it is crucial to provide these consumers with credible information that empowers them to make healthy and sustainable food choices. Conversely, segments with low involvement levels process information peripherally and require persistent, frequent informational actions with attractive and persuasive cues. Thus, drawing their attention through the message's characteristics (such as color, size, location, saliency) is essential in an information-overloaded environment. The authors conclude that the study offers behavioral insights supporting 'soft' policy approaches, such as public information campaigns, education, and labeling, which aim to increase awareness, involvement, and engagement. 'Hard' approaches, on the other hand, would target the market environment and include product reformulations, mandatory standards, regulations, and fiscal measures.

Continuing on consumer segmentation, Sacchettini et al. (2021) observed three distinct seafood consumer segments: cluster 1 (Health Seekers who eat seafood out of obligation), cluster 2 (Health Seekers and Seafood Lovers), and cluster 3 (Low Commitment to Health and Indifferent

to Seafood). Clusters 1 and 2 were found to be more knowledgeable about sustainable seafood products, including their origin and seasonality. The authors highlight how understanding the common characteristics of these clusters, such as attitudes toward health, beliefs, and behaviors, helps distinguish them from other groups. The study's results have significant implications for policymakers and educational institutions, highlighting the importance of recognizing consumer differences to design effective communication strategies and content. According to Sacchettini and colleagues, targeted information campaigns are more likely to succeed in reaching their intended audience than broadly oriented efforts.

As another piece of sustainability communication, the relationship between sustainability and health communication has been researched. Tepper, Kaufman-Shriqui, and Shahar (2020) suggest that health aspects should remain the primary focus when communicating and promoting healthy and sustainable diets. Additionally, they emphasize the importance of investing in public education to raise awareness about the environmental impacts of dietary choices, which can increase public engagement and shift preferences toward more sustainable and healthy options.

On the other hand, Castellari and colleagues' (2019) study's results demonstrate that health and environmental messages both have significant impacts that support each other, although the health message has a larger influence. However, the willingness to pay (WTP) remained unchanged regardless of the order in which the messages were presented. This suggests that the concepts may either support each other symmetrically or that no synergy effect is present. In conclusion, the authors state that these findings contrast with previous studies that prioritized health messages as the main drivers, suggesting a broader range of communication strategies for marketing and policy objectives.

Policy recommendations regarding ecolabels

Numerous studies have specifically investigated different ecolabels as a method for enhancing sustainability communication to promote more sustainable food consumption. Such articles are highlighted below.

Based on their study on sustainable food labelling, Stein and de Lima (2022) conclude that clearly defining the components of a sustainability label would be beneficial. According to the authors it is important to avoid the proliferation of labels, encourage competition among suppliers on sustainability, and empower consumers to purchase products that excel in areas they value. Additionally, operators should not face market access restrictions and should have incentives to enhance their sustainability performance. Policymakers can therefore leverage information to harness market forces and strengthen demand for more sustainable products.

According to Ferreira and Fernandes (2022), policymakers should consider supporting private companies in their efforts to comply with ecolabels as a viable alternative to fund public campaigns aimed at educating consumers about environmental issues. This approach is justified by the potential of ecolabel awareness to enhance individual environmental consciousness. Alternatively, policymakers could evaluate ecolabels' compulsory instead of voluntary use. Moreover, the authors highlight that citizens should continue to be informed and educated about sustainability and ecolabels are of major importance to achieve that goal.

Dreist and colleagues' (2024) study investigated consumers' perception and objective knowledge of various existing label types, including climate-neutral, reduction, carbon footprint, best-in-class, and multi-level traffic light labels. The results of the study indicate that a traffic light label is distinctly better understood by consumers than the other label types analyzed, as the participants demonstrated a high level of both positive perception and objective knowledge regarding the traffic light label. Therefore, traffic light labeling has the greatest potential to encourage climate-friendly dietary choices and reduce consumer confusion in the food market. Thus, the authors conclude that traffic light labeling provides clear guidance in selecting climate-friendly products and should be favored in political discourse. Moreover, to mitigate the proliferation of different climate labels, prevent greenwashing, and promote climate-friendly purchasing decisions, all other types of labels should gradually be phased out from the market in the long run.

Similarly, Rossi and Rivetti (2023) researched consumer's perception through studying the role of skepticism in young consumers' purchase behavior of third-party sustainably labelled food products. Their findings indicate that purchase behavior is positively influenced by two interrelated factors: socio-environmental concern and the producer's declared socio-environmental commitment. Rossi and Rivetti emphasize the valuable insights this study offers to practitioners and policymakers, underscoring the need to reassure consumers about the credibility of third-party sustainability labels and equipping them with tools to differentiate genuine sustainability efforts from superficial claims.

Kaimakoudi (2024) focused on policy initiatives for improving consumer knowledge and reducing consumer confusion specifically in aquaculture sector. According to them, consumer knowledge and consequently consumer confusion are strongly indicating the necessity for the adoption of targeted products' communication strategies but also for a common eco-labeling certification regime within the European market for organic aquaculture products under the frame of EU's Common fisheries policy (CFP). Kaimakoudi states that such policy initiatives could be crucial for the sustainable development of the sector, benefiting both local and global communities.

The labels presented previously, already in use within European markets, reflect well many of the aspects highlighted by the research. Still there is room for significant improvement. Together,

these policy recommendations illustrate the complexity and diversity of approaches needed to strengthen sustainability communication within the food sector. By enhancing transparency, tailoring messages to different consumer segments, improving the clarity and credibility of ecolabels, and integrating both health and environmental perspectives, policymakers and industry actors can better support consumers in making informed, sustainable food choices. Collectively, the reviewed studies highlight that effective communication is not merely about providing information, but about ensuring that it is accessible, trustworthy, and aligned with the motivations and needs of different audiences.

6 Pilot 4: Encouraging Responsible Consumer Choices

Following section 5 focused on food services' responsibility, this section concentrates on consumers' responsible choices. It therefore emphasizes the Food Province strategy's (Välisalo et al., 2022) priority of *The Food Province family* through its focus on consumers' consciousness regarding their food behaviour and the role of active consumers in reducing environmental impacts of food consumption. *The Food-PRO-vince* is represented as well, as educating food field professionals on practices such as nudging can have a significant influence on customers' choices.

6.1 Behavior Change Models

This chapter delves into various research studies that explore how food services can promote sustainable food choices beyond traditional labeling. The presented research include empirical evidence on strategies that food services can implement to encourage consumers to make environmentally friendly decisions.

An EU-project called FoodSMART aims at shaping smarter consumer behaviour and food choice through an innovative technical menu solution (FoodSMART, n.d.). It is designed to support informed consumer choices when dining out by considering individual factors such as cultural background, dietary needs, and age group, along with product specifications, to deliver personalized food recommendations. The field testing of the mobile application focused on providing information regarding canteen food quality, especially food sustainability, safety, hygiene and freshness (FoodSMART, 2018). Meanwhile, country context must be adapted into specific features regarding app functions, interface, information provision and ethical issues.

As a part of the FoodSMART project, Price, Bray, and Brown (2017) have explored the industry perspective on consumer information needs and the challenges faced by foodservice providers in workplace settings. Contract caterers demonstrated a good understanding of what matters to customers and recognized the growing demand for information about food eaten outside the home. However, they currently offer limited information in workplace canteens, mainly via menus and digital screens. The study highlighted interest in technical solutions like smartphone apps to manage information overload and boost customer engagement. Key barriers include insufficient detail in supply chain information, administrative burdens, and the risk of cluttered menus. Therefore, technological tools could help caterers communicate enhanced dish information more effectively, which has been shown to support healthier consumer choices.

Rocha and Viegas (2023) introduce six strategies on how food service actions can enhance healthy and sustainable food patterns:

- Focus on Plant-based Menus
- Improve the Gastronomic Quality of Vegetable Items
- Educate Consumers to Eat Food Instead of Nutrients: Placing menu compliance on food portions instead of nutrients
- Use Nudging Strategies to Change Consumer Behavior
- Use Emotional Marketing Strategies to Modulate Behavior
- Create Opportunity from an Adverse Context: The present context of war, energy and economic crisis could be an opportunity to accelerate the food offer and consumer behavior changes.

These studies demonstrate that food services play a crucial role in shaping healthier and more sustainable eating habits. By combining technological innovations with strategic menu design, behavioral nudges, and context-sensitive communication, food providers can effectively guide consumers toward more environmentally responsible choices. It highlights the importance of integrating both digital tools and practical service strategies to support meaningful, long-term change in food consumption patterns.

6.2 Nudging

Nudging can be defined as subtle changes in the decision environment that influence people's behaviour in a predictable way without restricting options or significantly changing economic incentives (Thaler & Sunstein, 2008). It has been proven by various studies to be efficient in affecting consumers' food choices. Such studies are presented below.

Menu design

Firstly, nudging has been utilized in menu design. Two international research projects, VeggiEAT and Veg+, investigated the impact of nudging strategies on vegetable intake in out-of-home settings. They also examined the factors influencing vegetable preferences and consumption across different age groups and countries. The findings show that the use of a nudging strategy, such as promoting a vegetable option as the "dish of the day" in a workplace canteen, was effective in increasing vegetable choices among adolescent females, but showed limited impact on males and older adults. Moreover, the authors highlighted that consumer emphasis on natural or healthy ingredients, prevailing social norms, being female, and having a positive attitude toward nudging were associated with higher vegetable consumption. Sensory characteristics played a role as well—bitterness and sourness tended to reduce liking, while sweetness had a positive effect. (Hartwell et al., 2020)

Gavrieli et al. (2022) investigated the impact of using appealing names for plant-rich dishes in four workplace, self-service cafeterias located in Chicago, Sydney, São Paulo, and Singapore. The study found that in English-speaking locations, these enhanced dish names significantly increased the quantity of plant-rich food selected per plate compared to basic naming. However, the strategy did not lead to a reduction in meat consumption, and the effect was not observed in non-English-speaking sites. The researchers concluded that, in suitable contexts, using attractive dish titles can be a simple, scalable, and cost-effective method for food service providers to promote more sustainable, plant-rich food choices.

Parkin and Attwood (2022) conducted two studies examining the effects of nudging strategies on vegetarian food choices. The first study tested menus containing varying proportions of

vegetarian options—75%, 50%, or 25%. Results showed that meat-eaters were significantly more likely to choose a vegetarian dish when 75% of the menu consisted of vegetarian options, suggesting that a higher saturation of vegetarian items is necessary to influence food choices effectively. The second study investigated the effect of placing vegetarian ‘V’ symbols on menus. It found that the presence or positioning of the symbols did not significantly impact meal selection. However, the authors suggest that these symbols can still serve a valuable purpose by fulfilling legal labelling requirements without deterring meat-eaters, unlike separate vegetarian menu sections, which have previously shown negative effects on selection behaviour.

Also focusing on the use of symbols for vegetarian and plant-based dishes, Buratto and Lotti (2024) examined how different menu symbols for such dishes influence consumer choices. Their study found that removing these symbols entirely led to a 10.2% increase in sales of starters and a 6.2% increase in main dishes. Replacing the original symbols with a low-emissions symbol had no significant effect on sales. However, when this environmental nudge was accompanied by a clear explanation of its purpose on the menu, sales of the targeted starters rose by 14.1%. These results suggest that transparent and ethically framed nudges can be both effective and acceptable, highlighting their potential as low-cost strategies to promote more sustainable food choices in the hospitality industry.

Filimonau and colleagues (2017) investigated how various types of food-related information—such as health and environmental attributes—affect consumer choices in restaurant settings. Their findings indicate that consumers are influenced by nutritional information and the origin of ingredients, suggesting that including such details on menus can support healthier and more sustainable choices. The study recommends that this information be presented clearly and concisely, ideally using labels and color coding. While calorie content was less influential overall, it may still be important for specific groups, particularly female diners. The study also highlights a notable gap in consumer understanding of the environmental impact of local versus imported ingredients, especially in relation to carbon emissions.

Franchini and colleagues (2023) examined the impact of menu item placement as a nudging strategy in a university dining hall. For five weeks, menu ingredients were listed in order from highest to lowest carbon footprint, followed by five weeks in reverse order—from lowest to highest. The study found a significant association between the order of ingredients and students’ food choices across most categories. While beef selection remained unchanged, students were more likely to choose lower-carbon options when these were listed first. The findings highlight that simple adjustments to menu design can influence more sustainable food choices.

Lastly, in the context of a restaurant's wine menu design, Soregaroli and colleagues (2021) studied whether providing carbon footprint labels and adding a price component for carbon emissions would influence customer choices towards lower-emission options. The results showed that carbon footprint information alone did not change purchasing decisions; however, when combined with proportional price increases, customers were more likely to choose wines with a lower carbon impact. Moreover, when the additional price for offsetting emissions was made explicitly visible, the opposite effect occurred, with more customers choosing higher-emission wines. These findings suggest that the way such information and price signals are presented play a crucial role.

Food placement

Some studies have concentrated on the impacts of nudging through food placement. First of all, food placement regarding availability of certain foods has been found to influence choices. Using data from over 94,000 meals, Garnett and colleagues (2019) found that doubling vegetarian options from 25% to 50% significantly boosted vegetarian meal sales—by up to nearly 79% in some cases—while meat meal sales declined accordingly. The biggest impact was seen among diners who rarely chose vegetarian meals before. Importantly, offering more vegetarian options did not affect total sales or cause diners to compensate by eating more meat at other meals.

In a Finnish study Kaljonen and colleagues (2020) tested informational and nudging strategies to promote sustainable eating at restaurant SYKE. They found that placing vegetarian dishes first in the buffet line helped reduce meat consumption among those already inclined toward plant- or fish-based diets and made these options more accessible to others. The authors note that success relied on offering satisfying, culturally familiar vegetarian recipes—often including dairy—developed through careful menu planning and ongoing kitchen adjustments. Larger shifts in meat consumption followed broader changes in kitchen practices. While climate labels prompted the use of sustainable fish, they were seen as limiting, whereas nudging allowed more creative freedom. Frictions from both strategies spurred further development, highlighting the importance of responsiveness to customer preferences.

Wansink's and Hank's (2013) research supports the Finnish findings too. Their buffet dining study found that food order strongly affects choices: over 75% of diners picked the first item they saw, and the first three items accounted for two-thirds of all food taken. Furthermore, placing unhealthy foods first led to 31% more total items and more unhealthy combinations. Rearranging items to present healthier options first can nudge diners toward better choices

Default options

Presenting diners with default options is another nudging option, either through menu design or food placement. Campbell-Arvai, Arvai, and Kalof (2014) tested how default menu configurations influence meal choices by presenting participants with either appealing or unappealing meat-free options as the default, compared to conventional menus. Results showed that default menus significantly increased the likelihood of selecting a meat-free meal, especially when the default options were appealing. Providing additional information or considering participants' environmental values had no significant effect. The findings suggest that default-based strategies can effectively promote pro-environmental food choices and complement longer-term educational efforts.

Similarly, Zhang and colleagues' (2024) results showed that participants were 43 % more likely to choose the plant-based meal when it was the default. In the study attendees selected their meal via RSVP forms that randomly featured either a plant-based or meat-based default. The consistent effect across settings suggests this nudge is both effective and broadly applicable for promoting sustainable dietary choices in university event contexts.

In another experiment conducted during events, this time conferences, participants were randomly assigned to receive either a standard lunch registration with a non-vegetarian buffet as the default or one with a vegetarian buffet as the default, with an option to actively switch. Hansen, Schilling, and Maltheisen (2021) state that across all the events, the vegetarian default significantly increased vegetarian meal choices. Results also showed that men were more likely than women to opt out of the vegetarian default. Moreover, most participants viewed the nudge positively.

Focusing on vegan food choices, Radnitz and colleagues' (2023) research compared six menu conditions based on default type (optimal, suboptimal, or free choice) and familiarity with vegan dishes—both in an online simulation and a college dining hall. Results showed that optimal default menus significantly increased the selection of vegan entrees compared to menus without defaults, without leading to increased food waste. The level of familiarity with vegan dishes did not affect this outcome, suggesting that optimal default menus are a practical and effective approach for promoting sustainable eating, even with less familiar options.

Also utilizing both online and field experiments, Taufik and colleagues (2022) investigated whether subtly redesigning restaurant menus to make plant-based meat alternatives appear as the default could increase their selection in Dutch context. The online experiment showed that framing the plant-based option as the default led to consumers choosing it more often over meat. Similarly, the field experiment in a restaurant confirmed that a default nudge significantly boosted orders of plant-based meat alternatives compared to equivalent meat dishes, demonstrating the potential of default-based menu design to encourage more sustainable dining choices.

Finally, Vecchio and colleagues (2023) studied whether using a default option nudge, framed as a “Dish of the Day,” could steer Millennials (aged 19–30) toward healthier food choices. The results showed that the healthy default had only a modest impact, increasing healthy choices by 3.9%. The effect was stronger among individuals who already prioritized health in their daily lives and among those who did not perceive a conflict between health and taste.

Online experiments

Nudging towards more sustainable food choices has been researched through distinct online experiments too. A study by Wongprawmas and colleagues (2023) examined how different nudges influence university students’ meal choices when pre-ordering online in campus canteens. Students were assigned to a control group or one of three treatment groups: a healthy and sustainable logo, dish placement (ordering dishes so healthier options appear first), or a combination of both. Results showed that reordering dishes significantly increased the selection of healthy and sustainable meals, especially for students who already had strong pro-sustainability and healthy eating habits. However, nudges had little effect on students with less healthy eating patterns. The findings highlight that factors like age, gender, diet habits, and living situation should be considered when designing effective nudging strategies.

In a similar study Weijers and colleagues (2024) tested three practical menu nudges for restaurants: a hedonic label (e.g., “artisanal vegetable burger”), a chef’s recommendation (highlighting the vegetarian dish as the chef’s favorite), and a salience nudge (boxing the vegetarian option). Results showed that both the hedonic label and the chef’s recommendation significantly increased vegetarian meal choices, while the salience nudge did not. The hedonic label boosted perceptions of indulgence but not tastiness, aligning with restaurants’ focus on pleasure. Participants generally accepted the nudges and reported a high intention to revisit the (virtual) restaurant. Overall, the hedonic label was seen as the most promising strategy for promoting vegetarian choices.

In another online study Bacon and Krpan (2018) examined whether different restaurant menu designs affect the likelihood of ordering a vegetarian dish, depending on how often people already

eat vegetarian meals. Participants were randomly assigned to one of four menu conditions: control, chef's recommendation, appealing description, or a separate vegetarian section. Results showed that the recommendation and descriptive menus increased vegetarian choices among people who rarely eat vegetarian meals, but had the opposite effect for frequent vegetarian eaters. The separate vegetarian section did not influence infrequent eaters and actually reduced vegetarian choices among frequent vegetarian eaters, suggesting that menu design strategies should consider diners' existing eating habits.

Lastly, Catarci, Laasner Vogt, and Reijnen (2024) A two-part smartphone-based study explored how menu recommendations and dish placement interact with price and personal preferences when nudging food choices. In the first study, participants chose between two menu options while recommendation, position, and price were varied. Results showed that recommending the more popular meal reduced its selection when it was the more expensive option, but not when it was cheaper. The second study further tested how personal preference influenced this effect and found that when differences in preference were larger, price effects became less significant, and the earlier interaction effect could not be replicated. Overall, some effects of recommendations were seen, but more research is needed to understand when they work best.

Multiple nudging strategies

Various nudging strategies have been researched and compared with each other too. Vidal-Mones, Diaz-Ruiz and Gil (2022) assessed the effectiveness of three nudging strategies to reduce food waste among students in four school canteens in the Metropolitan Region of Barcelona. The results suggest that well-designed nudges could prevent up to 41% of plate waste, especially fruit waste. Strategies included visual cues (posters displaying the menu, a hunger traffic light, and fruit-eating instructions), participatory actions by canteen staff (discussing the menu and demonstrating fruit preparation), and educational components (messages during coordinator speeches and weekly lessons about food waste habits). Overall, staff-led participatory nudges were more effective than visual cues alone.

Moving from school canteens to university dining, Pandey and colleagues (2023) found that interventions focusing on presentation, availability, and information were the most promising. Specifically, nudges that altered food properties had a small effect, while changes to food placement produced a medium effect, suggesting that subtle changes in how food is offered can support more sustainable consumption in similar settings.

Ohlhausen and Langen (2020) focused on out-of-home dining in more general: their three consecutive studies compared the effectiveness of different nudges and their combinations to encourage sustainable food choices. The nudges tested included descriptive name labels for

highlighting sustainable dishes and the decoy effect, which involved adding a less attractive dish to boost the appeal of a more sustainable option. The results showed that using the labels alone was more effective in increasing the selection of sustainable meals, while the decoy effect actually reduced sustainable choices. Consumers particularly favoured regional and sustainability-focused descriptive labels, indicating that combining the labels with the decoy effect is not advisable.

Pollicino, Blondin, and Attwood (2024) have created *The food service playbook for promoting sustainable food choices*⁴⁶. The playbook, an update of the World Resources Institute's 2020 food service playbook, compiles 90 evidence-based behavior change techniques that food service providers can use to influence diners' choices, drawing on insights from 346 academic trials. These techniques fall into six key categories:

- Price: modifying how much plant-rich dishes cost
- Placement: food displays and the physical food service environment
- Promotion: communication, marketing, advertising and campaign approaches
- Presentation: modifying the language, imagery and layout of menus, signs and labels
- Product: modifying the food being served
- People: targeting food service employees

Eighteen techniques are identified as “priority” actions recommended for immediate adoption, as they consistently proved effective and feasible in real-world settings based on expert and trial evidence. An additional 34 techniques are labeled “promising,” showing positive results but judged slightly less impactful or feasible. For each priority technique, the playbook offers practical guidance, real-life case studies, and further resources to help the food service sector encourage more sustainable dining choices. The priority techniques are presented below in Table 2.

⁴⁶ [The food service playbook for promoting sustainable food choices](#)

Table 2: Eighteen priority behavior change techniques for implementation without delay in the food service sector. Source: Pollicino, Blondin, and Attwood (2024).

PRESENTATION	
PRS4: Add environmental footprint labels to menus	PRS14: Remove unappealing language describing plant-rich dishes from menus (e.g. meat free, vegetarian)
PRS15: Use indulgent language on menus to describe plant-rich dishes	PRS16: Use language on menus to selectively recommend plant-rich dishes (e.g. chef's special, dish of the day)
PLACEMENT	
PLC5: Integrate plant-based meat alternatives into meat sections in a display (e.g. buffets, shelves, food carts, or stations)	PLC6: Introduce a dedicated plant-rich food section (e.g. buffet section, shelf section, food carts, or stations)
PRODUCT	
PRD1: Arrange plant-rich dishes so that more appealing ingredients are most visible (e.g. via layering, stacking, toppings, or other arrangements)	PRD2: Blend plant-based ingredients into ground or minced meat-based dishes to reduce the meat content
PRD5: Improve the appearance of plant-rich dishes (e.g. arrangements, color, garnishes, balance)	PRD6: Improve the flavor and texture of plant-rich dishes
PRD7: Increase the ratio of plant-rich to meat-based dishes available	PRD8: Increase the variety of plant-rich dishes on offer
PEOPLE	
PPL8: Train chefs and food preparation staff how to cook and prepare appealing plant-rich dishes	
PROMOTION	
PRM3: Create social media or other group forums where diners can share ideas, recommendations, and reviews of plant-rich dishes	PRM23: Publicize the local benefits of plant-rich dishes using marketing materials (e.g. posters, social media, leaflets, table tents, or TV screens)
PRM20: Publicize the environmental benefits of plant-rich dishes using marketing materials (e.g. posters, social media, leaflets, table tents, or TV screens)	PRM26: Publicize the taste and flavor benefits of plant-rich dishes using marketing materials (e.g. posters, social media, leaflets, table tents, or TV screens)
PRICE	
PRC7: Run cross-product promotions (e.g. meal deals, set menus) on plant-rich dishes and selected drinks, side dishes, or desserts	

This pilot area shows that consumer-facing climate action is not only about information, but about how choices are structured in real contexts. By drawing on behavioural science and practical

evidence from food service settings, the chapter demonstrates that nudging can increase selection of plant-rich meals, reduce food waste, and support lower-carbon choices through simple adjustments such as defaults, placement, naming, and menu design. The examples also highlight an important lesson: nudges work best when they fit the local context, protect consumer autonomy, and are implemented transparently and ethically. Ultimately, responsible consumption cannot be achieved by consumers alone. It requires shared responsibility across the Food Province ecosystem—food services, businesses, public actors, and professionals—so that sustainable choices become the easy, normal, and attractive option.

7 Summary and Key Takeaways

South Ostrobothnia has strong foundations for becoming a more sustainable and responsible food region, but its future success depends on how well it can turn those strengths into coordinated transition. The region is one of Finland's most important food production areas, with a very high share of value added and employment linked to the food sector, strong flagship companies, established education and RDI capacity, and an existing Ruokaprovinsi identity that supports collaboration and visibility. At the same time, the report makes clear that the regional food system faces structural pressures: the number of farms is declining, the farming population is aging, many small actors struggle to scale, and climate adaptation and renewal are too slow in relation to the scale of change required. Agriculture also remains the region's dominant source of greenhouse gas emissions, which makes sustainability work especially urgent in South Ostrobothnia.

A central conclusion running through the whole report is that sustainability cannot be advanced through isolated measures or by placing responsibility only on primary producers. There is a need for whole-chain cooperation: among farmers, processors, food services, retailers, researchers, public actors, and consumers. The report repeatedly frames collaboration as the key enabler of both climate adaptation and environmental impact reduction. Stronger coordination between businesses, better cross-sector information exchange, joint planning, needs-driven participation, and the integration of research into practice are all presented as necessary conditions for building a more resilient regional food system. In other words, the transition is not only technical but organizational: South Ostrobothnia needs better networks, better knowledge flows, and more shared responsibility across the food chain.

The pilot sections reinforce this broader message by showing that many practical solutions already exist, but that their success depends on context, scale, and implementation. In agriculture, biochar emerges as a promising but not one-size-fits-all solution. The report highlights its potential to improve soil structure, water retention, nutrient efficiency, and carbon sequestration, while also noting that results vary according to feedstock, pyrolysis conditions, soil type, and application method. Manure-enriched biochar appears particularly interesting because it can improve nutrient retention and soil fertility, but the report also stresses that profitability, certification, regulatory compliance, and market development are essential if biochar is to become a realistic regional opportunity rather than a niche experiment. In food processing, the report shows clearly that side streams should no longer be viewed mainly as waste. Whey, distillery residues, potato peels, slaughterhouse blood, and fish side streams all contain value that can be redirected into new foods, feed, fertilizers, coatings, biomaterials, and biochemical products. The larger takeaway is

that circular economy thinking offers South Ostrobothnia a way to reduce waste, create new business, and strengthen resource efficiency at the same time.

The report also identifies food services as a highly practical leverage point for sustainability work. Kitchens, canteens, and restaurants can reduce waste and emissions through better planning, more accurate forecasting, and more strategic communication. Especially important are tools such as pre-booking systems, long-term meal data analysis, and AI-based demand forecasting, which the report presents as promising ways to reduce overproduction and improve operational efficiency. At the same time, communication with diners matters: sustainability information, environmental labels, and transparent claims can support better choices, but they must be credible, understandable, and linked to concrete practices rather than vague messaging. The examples in the report suggest that food services can act as everyday transition arenas where environmental goals, operational efficiency, and consumer education come together.

Finally, the report underlines that consumer choices are not fixed; they can be guided through well-designed food environments. The evidence reviewed in the final pilot area shows that relatively small interventions can influence decisions: appealing names for plant-rich dishes, better menu structure, placing lower-impact options first, using default plant-based choices, and combining several nudges can all increase sustainable selections. At the same time, the report does not suggest that behavior change is automatic or universal. Effects depend on context, language, target group, prior habits, and how the nudge is framed. The broader takeaway is therefore not simply that consumers should make better choices, but that food system actors should make responsible choices easier, more visible, and more attractive. Taken as a whole, the report argues for a transition that is systemic, practical, and regionally grounded: South Ostrobothnia's path toward a sustainable food system lies in combining cooperation, circular resource use, better tools for professionals, and smarter choice environments for consumers.

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