RESPONSIBILITY HANDBOOK

Building a Resilient and Climate-Adaptable Food Province for Food Stakeholders in South Ostrobothnia

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2025

Funded by the European Union

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Executive Summary

South Ostrobothnia is Finland's Food Province — a region where agriculture, food processing and food services form the backbone of the economy and regional identity (Välisalo et al., 2022). The food sector contributes significantly to regional employment and value creation, making its long-term stability critical for economic vitality and social cohesion. At the same time, the region faces structural pressures. Agriculture accounts for 44.6% of regional greenhouse gas emissions (SYKE, n.d.), peatland cultivation increases emission intensity (Talvitie, 2025), and climate variability is expected to intensify. Global market volatility, input dependency and shifting regulatory expectations add further uncertainty.

This handbook exists to provide a strategic framework for navigating these challenges. It translates regional strategy goals and climate roadmap targets (Palomäki et al., 2022) into practical, coordinated action for farms, companies, food services and public authorities. Its purpose is not to introduce new obligations, but to align existing strengths with long-term resilience.

Why Resilience and Responsibility Matter Now

Resilience is no longer a theoretical concept — it is a business necessity. Climate risks, supply chain disruptions and regulatory tightening are already shaping operating conditions across the food chain. Responsibility is equally urgent. Consumers, investors and public procurement increasingly expect transparency, low-carbon production and sustainable practices. Regions that fail to adapt risk losing competitiveness.

For South Ostrobothnia, resilience and responsibility are interconnected. High production intensity provides economic strength but also increases exposure to climate and transition risks. Managing soil health, nutrient cycles, energy dependency, waste and consumer behaviour are not isolated environmental measures — they are strategic investments in long-term sustainability.

The Climate Roadmap sets a clear direction toward a climate-resilient and low-carbon food chain. Achieving this requires coordinated action across the value chain and fair distribution of responsibility. The question is no longer whether transition will occur, but whether it will be proactive and strategic — or reactive and costly.

Responsibility is often perceived as an additional cost. In reality, it is a driver of competitiveness.

- Improving soil health reduces yield volatility and input costs.
- Circular processing increases value addition and reduces resource waste.
- Climate-smart food services improve efficiency and align with procurement trends.
- Behavioural nudging strengthens market demand for sustainable products.

These measures enhance robustness, adaptability and long-term profitability. A responsible food system attracts investment, secures market access and builds consumer trust. It reduces regulatory risk and increases innovation capacity. In this context:

- **Responsibility strengthens resilience.**
- **Resilience strengthens competitiveness.**

South Ostrobothnia's ambition to be the best place for food business depends on embedding this principle across the regional ecosystem.

South Ostrobothnia as a Food System

South Ostrobothnia is not only a strong agricultural region — it is officially positioned as Finland's Food Province. The regional vision, articulated in the Food Province 2030 – The Best Place for the Food Business strategy, aims to refine the operating environment of food businesses so that companies in Southern Ostrobothnia "feel at home and flourish". The mission of the Food Province network is to create sustainable success for all its operators through exceptionally close cooperation across the farm-to-table chain.

This ambition is reinforced in the Regional Rural Development Plan 2023–2027 (Mäkimantila et al., 2021), which identifies the development of the Food Province as a key regional priority and highlights the comprehensive food chain, entrepreneurial spirit, and active development culture as core strengths. At the same time, the Climate Roadmap for the Food Sector sets a long-term vision for a climate-resilient and low-carbon food chain.

Understanding South Ostrobothnia as a food system therefore requires recognizing both its structural strengths and its systemic vulnerabilities. The same intensity that creates competitiveness also increases exposure to climate risks, input dependency and market volatility. A resilience-oriented and responsible approach must therefore build on strengths while addressing structural risks.

2.1 The Regional Strength

South Ostrobothnia has the highest share of GDP generated by the food sector among Finnish regions. The food sector contributes nearly 15% to regional value added and 21% to employment, with agriculture alone employing over 10% of the population (Mäkimantila et al., 2021). This structural importance makes food production not only an economic sector but a cornerstone of regional vitality.

The region's agricultural intensity is reflected in production volumes and concentration. South Ostrobothnia leads the country in potato production and broiler production, and ranks among the top regions in cattle, swine and cereal production (Statistics Finland, 2023). Over half of farms focus on crop production, while livestock density remains high (Statistics Finland, 2025). This concentration enables economies of scale, contract farming models and integration with processing industries.

The Regional Rural Development Plan emphasizes the strong agricultural base, well-networked business activity, presence of major food processors, and comprehensive value chain from primary production to processing. The region hosts significant national actors and specialized clusters in food, machinery and equipment industries. In 2023, 129 food manufacturing establishments and 15 beverage manufacturers operated in the region, generating 40% (€2.12 billion) of the total turnover of the regional industrial sector (Statistics Finland, 2024). This strong processing base increases regional value addition and reduces dependency on exporting raw materials alone. It also creates opportunities for circular economy solutions, side-stream utilisation and bio-based innovation — themes that align with the Smart Specialisation objective of developing a sustainable food ecosystem and climate-smart South Ostrobothnia.

Livestock concentration generates significant nutrient flows. While synthetic fertilizers remain widely used, manure contains phosphorus sufficient to meet local crop needs. Improved nutrient cycling therefore represents a major opportunity for enhancing circularity and reducing external input dependency.

Public food services further stabilize the system. In 2023, the region had 442 food service providers. Public procurement is explicitly recognized in the Climate Roadmap as a lever for promoting locally produced, sustainable and seasonal food. This institutional demand creates predictable markets and enables responsible purchasing criteria to shape production practices.

Finally, cooperation culture is repeatedly identified as a regional asset. The Food Province strategy emphasizes close collaboration within the innovation ecosystem, while the Rural Development Plan highlights active development orientation, entrepreneurial confidence and collaborative networks. This social capital forms a critical foundation for resilience and transition.

2.3 Systemic Vulnerabilities

The same structural intensity that strengthens the region also creates vulnerabilities. Agriculture accounts for 44.6% of total regional greenhouse gas emissions — significantly higher than the national average of 22.3%. Emissions have increased in recent years, partly due to livestock concentration and expanding cropland (Palomäki et al., 2022). A central structural challenge is peatland cultivation. South Ostrobothnia has the second-highest share of cultivated peat soils in Finland, and these soils are estimated to account for over 60% of the region's agricultural emissions (Mäkimantila et al., 2021). Transitioning toward climate-smart peatland management is therefore critical for achieving the Climate Roadmap's targets of carbon-negative primary production and low-carbon production inputs.

Climate variability poses additional risks. According to the regional risk assessment, South Ostrobothnia faces increasing threats from extreme weather events, including storms, droughts, heatwaves and heavy precipitation (Sisäinen turvallisuus, 2023). These events threaten crop yields, infrastructure, water systems and economic stability. Preparedness and adaptation — including irrigation development, wetland construction and soil structure improvement — are identified as necessary measures (Palomäki et al., 2022).

Input dependency further increases exposure. Modern production relies heavily on energy and mineral fertilisers, which are subject to global price fluctuations. The Climate Roadmap recognises the need to promote low-carbon production inputs and reduce fossil fuel dependency. Dependence on external feed production also contributes to nutrient imbalances and economic vulnerability.

Export dependency and global market volatility present additional risks. Agricultural profitability has been weak in recent years, particularly for grain farms, and the global economic outlook remains uncertain. Structural changes in farming, aging farmers, and high investment costs add pressure.

The Regional Rural Development Plan identifies further weaknesses: insufficient adaptation to climate change, lack of value-added innovation, gaps in entrepreneurial and digital skills, fragmented actor landscape and limited long-term strategic planning.

Importantly, stakeholders have also raised concerns about fairness in climate responsibility allocation. During the Climate Roadmap development, primary producers expressed that expectations placed upon agriculture may be disproportionate, and that responsibility must be shared across the entire food chain. This highlights that resilience is not only a technical issue but also a governance and equity issue.

Summary: A Strong but Exposed Food Ecosystem

South Ostrobothnia stands as a nationally significant and strategically ambitious food region. The Food Province vision positions the region as the best place for food business, grounded in cooperation, entrepreneurship and accountability. The region's strong agricultural base, processing capacity, innovation networks and institutional demand provide a powerful foundation for competitiveness and renewal.

At the same time, agricultural emission intensity, peatland cultivation, climate variability, input dependency and market volatility create structural exposure. Achieving the Climate Roadmap's targets requires systemic adaptation, technological innovation and shared responsibility across the value chain. Recognising this dual reality — strength combined with vulnerability — is the starting point for building resilience, advancing responsibility and aligning regional development with long-term climate and sustainability goals. The next section introduces the Responsibility and Resilience Frameworks that supports this transition.

Responsibility as the Foundation of Resilience

South Ostrobothnia's food system is strong, productive and nationally significant. However, strength alone does not guarantee long-term sustainability. In an era of climate volatility, geopolitical uncertainty, market instability and ecological pressure, the ability to withstand shocks, adapt to change and transform, when necessary, determines long-term success (Meuwissen et al., 2019).

Resilience is therefore not an abstract academic concept. It is a strategic condition for maintaining profitability, competitiveness and social legitimacy in the Food Province. The Climate Roadmap for the Food Sector explicitly aims at building a climate-resilient food chain. At the same time, the Food Province 2030 strategy emphasizes accountability, cooperation and sustainable success as guiding principles.

Responsibility and resilience are therefore inseparable. Responsibility defines how actors manage environmental, social and economic impacts (Timotijevic et al., 2021). Resilience determines whether the system can endure and thrive under pressure. Together, they form the foundation for the long-term viability of South Ostrobothnia's food ecosystem.

3.1 What is Resilience in Food Systems?

From Stability to Dynamic Capacity

In food systems, resilience refers to the capacity to absorb disturbances, adapt to changing conditions and transform structures when current pathways become unsustainable. It goes beyond short-term crisis management. It requires structural flexibility, knowledge sharing and strategic foresight (Meuwissen et al., 2019).

Three core dimensions of resilience are particularly relevant for South Ostrobothnia:

1. Robustness

Robustness refers to the ability to resist shocks without major disruption. In food systems, this includes stable supply chains, secure access to production inputs, reliable energy systems and well-functioning logistics networks.

For example, diversified crop rotations, strong soil structure, and effective nutrient management increase robustness at farm level. In processing, energy efficiency and renewable energy adoption reduce exposure to fossil fuel price volatility. Public food services increase robustness by providing stable demand. However, robustness alone is insufficient if shocks become structural and long-lasting.

2. Adaptability

Adaptability refers to the ability to adjust practices, processes and relationships in response to changing conditions. This includes introducing new crop varieties, modifying irrigation systems, shifting procurement criteria, or adjusting product portfolios to new consumer demands.

The Regional Rural Development Plan highlights the need to anticipate climate change and develop new solutions for energy and resource efficiency. Adaptability requires not only technical solutions but also entrepreneurial capacity, digital competence and cooperation networks — areas where regional weaknesses have been identified. Adaptability allows the system to continue functioning under new conditions without fundamental structural collapse.

3. Transformability

Transformability becomes necessary when incremental adaptation is insufficient. It refers to the capacity to shift to fundamentally different production or governance models when environmental, economic, social or regulatory conditions demand it.

In South Ostrobothnia, transformability may involve:

- Transitioning peatland cultivation to climate-smart models
- Strengthening plant-based protein value chains
- Redesigning nutrient cycles to reduce mineral fertiliser dependence
- Developing new bio-based side-stream industries

Given that peat soils account for over 60% of agricultural emissions in the region, transformative measures in peatland management seem especially structurally significant.

Multi-Level Resilience

Resilience must be understood at multiple interconnected levels (Tendall et al., 2015):

Farm Level

Farm-level resilience depends largely on soil health, crop diversity, water management, financial stability and succession planning. Structural changes in farming, aging farmers and investment pressures make farm resilience a central concern.

Company Level

Food processing companies depend for example on stable raw material flows, energy security and predictable market demand. The food industry generates 40% of regional industrial turnover, meaning its resilience directly affects regional employment and income.

Regional Level

At regional scale, resilience is strengthened by cooperation across actors, shared strategic direction and supportive governance structures. The Food Province strategy emphasises close cooperation and accountable action as the foundation for sustainable success. A resilient region is not merely a collection of resilient companies — it is an interconnected ecosystem capable of coordinated response.

3.2 Climate Adaptability as Strategic Risk Management

Climate change introduces both physical and transition risks for food systems. It is not a distant environmental issue. It is an operational and financial risk factor affecting every level of the food chain.

Physical Climate Risks

South Ostrobothnia faces increasing threats from extreme weather, including storms, droughts, heavy rainfall and heatwaves. These events directly impact:

- Crop yields
- Soil structure
- Water availability
- Livestock welfare
- Infrastructure and transport

Drought increases irrigation needs and reduces feed production. Flooding damages soil structure and increases nutrient runoff. Warmer winters alter pest dynamics and increase plant disease risks. Peatland soils are particularly vulnerable to emissions and degradation under changing climatic conditions (Palomäki et al., 2022). These physical risks translate into economic exposure.

Economic Implications of Climate Risk

Climate adaptation literature increasingly frames these risks as strategic economic considerations rather than purely environmental concerns (Galanakis et al., 2025). Agriculture already accounts for 44.6% of regional greenhouse gas emissions, placing the sector under increasing regulatory and market pressure. As carbon pricing mechanisms and sustainability reporting requirements expand, emission-intensive production models may face higher compliance costs. Global economic uncertainty, trade tensions and weak agricultural profitability further increase vulnerability. Climate impacts may reduce yields while increasing input costs, compressing margins.

Climate adaptability must therefore be understood as strategic risk management. Investments in:

- Soil carbon sequestration
- Improved drainage and irrigation
- Renewable energy
- Nutrient cycling
- Diversified product portfolios
- Strengthening climate risk monitoring and forecasting

are not only environmental actions — they are risk mitigation strategies. Forward-looking tools such as scenario planning and climate stress testing support proactive decision-making. Regions that invest

early in adaptation can maintain employment stability and strengthen food security, while delayed adaptation may increase vulnerability and inequality. Climate adaptability can therefore be understood as a form of strategic resilience management integrating environmental foresight with economic governance (Isoard, 2011). The Climate Roadmap emphasises adaptation, preparedness and the promotion of low-carbon production inputs. These measures reduce exposure to both physical and transition risks.

From Compliance to Competitive Advantage

Companies that proactively manage climate risk are better positioned to:

- Secure financing
- Meet procurement requirements
- Access export markets
- Build consumer trust

Public procurement criteria promoting sustainable and local food further strengthen the business case for climate responsibility. Climate adaptability therefore becomes a strategic asset rather than a regulatory burden (Kandel et al., 2025).

3.3 Responsibility and the SDGs

Responsibility in food systems extends beyond compliance with regulations. It involves recognising interconnected impacts on ecosystems, workers, consumers and future generations. Therefore, responsibility in South Ostrobothnia's food system is not only regional policy alignment — it is also part of global sustainability commitments reflected in the United Nations Sustainable Development Goals (SDGs) (UN DESA, 2025).

Five SDGs are particularly relevant for the Food Province:

SDG 2: Zero Hunger

SDG 2 aims to end hunger, achieve food security and promote sustainable agriculture. South Ostrobothnia's strong agricultural base contributes significantly to national food security. However, SDG 2 also emphasizes sustainable productivity, resilience to climate extremes and soil health.

Actions aligned with SDG 2 include:

- Improving soil fertility and structure
- Diversifying crops and protein sources
- Strengthening local supply chains
- Supporting generational renewal in farming

Ensuring long-term production capacity under changing climatic conditions is essential for maintaining regional and national food security.

SDG 8: Decent Work and Economic Growth

SDG 8 promotes sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all. Food systems are key drivers of regional employment and entrepreneurship. Responsible business practices, including skills development, innovation investment and fair working conditions, support inclusive economic growth. In South Ostrobothnia, the relevance of SDG 8 is particularly strong. The food sector contributes nearly 15% of regional value added and 21% of employment. Agriculture alone employs over 10% of the population. The food industry generates 40% of regional industrial turnover (Mäkimantila et al., 2021). This makes the resilience of the food system directly tied to regional economic vitality.

SDG 8 in the context of South Ostrobothnia therefore includes:

- Ensuring profitable and competitive primary production
- Supporting SMEs in scaling, innovation and internationalization
- Strengthening competence development in food-related education and RDI
- Enhancing attractiveness of food careers
- Supporting generational succession and new entrepreneurship

The Food Province 2030 strategy explicitly positions the region as “the best place for food business” and highlights entrepreneurship, competence development and accountable growth as strategic priorities. Economic vitality and responsibility are not contradictory goals — they are mutually reinforcing. A profitable business has greater capacity to invest in renewable energy, carbon sequestration or circular solutions. At the same time, responsible practices enhance long-term competitiveness and market access.

SDG 12: Responsible Consumption and Production

This goal highlights resource efficiency, circular economy practices and food waste reduction. Responsibility is distributed across the value chain, requiring engagement from producers, processors, retailers, food services and consumers. In South Ostrobothnia, responsibility under SDG 12 includes:

- Reducing food waste across processing and food services
- Utilising side streams and by-products
- Enhancing nutrient cycling
- Improving energy efficiency

The Food Province strategy's emphasis on accountable action directly reflects SDG 12 principles. Public procurement promoting seasonal and sustainable food choices further operationalizes responsible consumption.

SDG 13: Climate Action

Given agriculture's emission intensity in the region, SDG 13 is central to the regional transition. Key measures include:

- Reducing peatland emissions
- Promoting carbon sequestration
- Phasing out fossil fuels
- Supporting climate-smart farming

The Climate Roadmap's 2035 vision of a low-carbon and climate-resilient food chain represents a direct regionalization of SDG 13.

SDG 15: Life on Land

SDG 15 focuses on biodiversity, soil health and ecosystem protection. Livestock concentration and nutrient surpluses highlight the need for improved phosphorus management. Protecting water systems, enhancing biodiversity in agricultural landscapes and restoring peatlands are essential to aligning food production with ecosystem integrity. Climate-smart peatland cultivation and diversified crop rotations support both emission reduction and biodiversity enhancement.

Together, SDGs 2, 8, 12, 13 and 15 form a coherent framework for South Ostrobothnia's food system transformation. They connect food security, economic vitality, responsible production, climate mitigation and ecosystem protection. When aligned with the Food Province strategy and the Climate Roadmap vision, they provide both direction and legitimacy for the region's resilience pathway.

3.4 Conclusion: Responsibility Enables Resilience

Resilience in South Ostrobothnia's food system is not achieved through productivity alone. It requires responsible management of environmental impacts, fair distribution of climate responsibility across the value chain, and long-term strategic cooperation consistent with the Food Province vision.

Robustness protects against immediate shocks. Adaptability enables adjustment. Transformability prepares the region for structural change.

Responsibility — grounded in SDGs, regional strategy and shared accountability — ensures that resilience is not only reactive but proactive.

In the following chapters, these principles are translated into concrete good practices and strategic actions for different parts of the food system.

Pilot Area 1 – Soil Resilience through Manure-Enriched Biochar

Why This Good Practice

South Ostrobothnia's food system is deeply dependent on soil quality. Agricultural intensity, livestock concentration and peatland cultivation make soil management a central determinant of both productivity and climate performance. Agriculture accounts for 44.6% of regional greenhouse gas emissions, and peat soils alone are estimated to account for over 60% of agricultural emissions in the region (Mäkimantila et al., 2021). At the same time, intensive livestock production has led to regional nutrient imbalances. Although manure contains sufficient phosphorus to meet crop needs, synthetic fertilisers are still widely used, and nutrient surpluses accumulate in certain areas. This creates environmental pressure and economic inefficiency.

The Climate Roadmap for the Food Sector identifies soil carbon sequestration, low-carbon production inputs and adaptation to climate change as priority actions. Improving soil structure, increasing carbon storage and strengthening nutrient cycling are therefore not marginal improvements — they are core strategic measures.

Manure-Enriched Biochar (MEB) is selected as Pilot Area 1 because it directly addresses three systemic challenges simultaneously:

- Soil degradation and vulnerability
- Nutrient imbalance and fertiliser dependency
- Agricultural greenhouse gas emissions

It is a practice that combines climate mitigation, adaptation and circular economy principles in one integrated solution.

Soil as Strategic Infrastructure

Soil is often treated as a production input. In reality, it is strategic infrastructure. Healthy soil regulates water retention, supports root development, enhances nutrient uptake and stabilizes yields under climatic stress. In a region facing increasing risks from drought, heavy rainfall and extreme weather, soil resilience determines the stability of the entire food chain.

Degraded soil increases vulnerability. Compacted soil reduces infiltration and increases surface runoff. Poor organic matter levels reduce water retention capacity. Nutrient leaching contributes to water pollution and financial loss. Peat soil, when intensively cultivated, release significant amounts of greenhouse gases. Viewing soil as infrastructure changes the perspective from short-term yield optimization to long-term system stability. Investments in soil health are comparable to investments in

transport networks or energy grids — they protect productivity, reduce risk and increase adaptive capacity. In this context, Manure-Enriched Biochar functions as a soil resilience technology.

What is Manure-Enriched Biochar (MEB)?

Biochar is a carbon-rich material produced through pyrolysis — a thermochemical process where biomass is heated in limited oxygen conditions (Torabian et al., 2021). The result is a stable, porous carbon structure with high surface area and adsorption capacity. When biochar is combined with manure before application to fields, the product is referred to as Manure-Enriched Biochar (MEB). This enrichment process allows biochar to absorb and stabilise nutrients from manure, particularly nitrogen and phosphorus, reducing volatilisation and leaching losses.

The functionality of MEB is based on several mechanisms:

1. Carbon Stabilisation
Biochar contains stable carbon that decomposes very slowly in soil (Muhonen, 2024). When incorporated into agricultural fields, it functions as a long-term carbon sink, supporting the Climate Roadmap's objective of increasing soil carbon sequestration.

2. Nutrient Retention
The porous structure of biochar binds nutrients from manure, reducing nutrient losses during storage and after field application (Schmidt et al., 2021). This improves fertiliser efficiency and supports circular nutrient flows, reducing dependence on synthetic fertilisers.

3. Soil Structure Improvement
Biochar improves soil aggregation, increases porosity and enhances water holding capacity. This is particularly valuable under drought conditions and heavy rainfall events, both of which are expected to increase in frequency (Leppänen et al, 2025).

4. Emission Reduction Potential
MEB can reduce nitrous oxide emissions from soils and improve nitrogen use efficiency (Kalu et al., 2022). In peatland cultivation areas, where emissions are structurally high, such measures contribute directly to climate mitigation.

Through these combined effects, MEB enhances robustness (improved soil stability), adaptability (better performance under climate stress) and potentially transformability (transition toward carbon farming models).

Climate & SDG Relevance

Manure-Enriched Biochar directly supports several Sustainable Development Goals identified in this handbook:

SDG 2 – Zero Hunger

By improving soil fertility and stabilizing yields, MEB strengthens long-term production capacity and food security.

SDG 12 – Responsible Consumption and Production

MEB promotes circular economy by converting manure and biomass residues into value-added soil amendments, reducing nutrient waste and external input dependency.

SDG 13 – Climate Action

Biochar sequesters carbon in soil and can reduce greenhouse gas emissions from manure management and cultivated peatlands.

SDG 15 – Life on Land

Improved soil structure reduced nutrient leaching and enhanced biodiversity in soil ecosystems support ecosystem integrity and water protection.

SDG 8 – Decent Work and Economic Growth

Developing regional biochar production and related services can create new business opportunities in machinery, technology services and advisory sectors, aligning with the Food Province's innovation ecosystem vision.

Thus, MEB is not merely a technical soil amendment — it is a strategic resilience intervention.

Implementation Pathway

Successful implementation of Manure-Enriched Biochar in South Ostrobothnia requires coordinated steps across actors.

Step 1: Feasibility Assessment

- Identify suitable biomass feedstocks (e.g., agricultural residues).
- Assess manure streams and nutrient surpluses in livestock-dense areas .
- Evaluate logistical integration with existing farm operations.

Step 2: Pilot Demonstration Projects

- Establish regional pilot farms applying MEB in different soil types (mineral soils and peat soils).
- Monitor yield stability, soil carbon levels, nutrient efficiency and emission impacts.
- Integrate results into advisory and RDI networks.

The Food Province ecosystem and RDI actors provide a strong platform for coordinated experimentation.

Step 3: Capacity Building & Advisory Support

- Train farmers and agronomists in biochar application techniques.
- Develop cost-benefit models to demonstrate financial viability.
- Provide guidance on regulatory compliance and certification.

The Regional Rural Development Plan highlights gaps in skills and the need for strengthened competence development. MEB deployment can be integrated into these capacity-building efforts.

Step 4: Business Model Development

- Explore cooperative pyrolysis facilities.
- Integrate MEB into carbon farming initiatives and emerging carbon markets.
- Link biochar production with renewable energy generation.

Public support mechanisms and EU funding instruments (e.g., rural development funding) can support initial investments.

Step 5: Scaling & Integration

- Embed MEB into regional climate strategies and procurement criteria.
- Communicate measurable climate and soil benefits to consumers and buyers.
- Align with carbon-negative primary production targets of the Climate Roadmap

Manure-Enriched Biochar demonstrates how responsibility and resilience intersect in practice. It strengthens soil as strategic infrastructure, reduces climate risk, enhances nutrient circularity and creates innovation potential within the Food Province ecosystem. In a region where agricultural intensity and peatland emissions create structural climate exposure, soil-focused solutions are not optional improvements — they are foundational resilience measures. Pilot Area 1 therefore positions soil not as a passive resource, but as the cornerstone of a climate-resilient and accountable food system in South Ostrobothnia.

Pilot Area 2 – Circular Processing through High-Value Side Stream Valorization

Why This Good Practice

South Ostrobothnia is one of Finland's most significant food processing regions. In 2023, the region hosted 129 food manufacturing establishments and 15 beverage manufacturers, and the food industry generated 40% (€2.12 billion) of the total turnover of the regional industrial sector (Statistics Finland, 2024). This strong processing base is a central pillar of the Food Province vision.

However, high processing intensity inevitably generates side streams: whey from dairy processing, blood and bone fractions from meat processing, potato peels and starch residues, distillery by-products, fish processing leftovers and other organic fractions. Traditionally, these streams have been treated as low-value animal feed, compost material or, in some cases, waste requiring disposal.

The Climate Roadmap emphasizes low-carbon food chains, resource efficiency and reduced emissions across all stages of the value chain. Valorizing side streams into high-value ingredients directly contributes to these objectives. Instead of viewing by-products as waste, circular processing reframes them as raw materials for new products, new markets and new business models.

Pilot Area 2 was selected because it strengthens competitiveness, reduces environmental impact and increases system resilience simultaneously. It operationalizes the Food Province strategy's emphasis on accountable business, innovation and value-added development.

From Waste to Resource

Food processing side streams contain significant nutritional and biochemical value. Whey contains high-quality proteins and lactose (Scotto di Uccio et al., 2023). Potato side streams contain starch, fibre and bioactive compounds (Gebrechristos & Chen, 2018). Meat processing fractions contain proteins, minerals and functional ingredients (Pihlanto et al., 2012). Many of these components are suitable for food, feed, nutraceutical or biobased material applications.

When side streams are not valorized, two losses occur simultaneously:

- Economic loss – missed opportunities for value addition
- Environmental loss – unnecessary resource use and emissions

The Finnish Food Industries Federation's roadmap (2020) highlights that most emissions in the food chain stem from raw materials and energy production rather than from processing itself. This means that maximizing the value extracted from each unit of raw material is a direct emission reduction strategy. Producing more value from the same primary production base reduces the need for additional resource extraction.

Circular processing strengthens regional autonomy. By keeping material flows within the region and upgrading them into higher-value products, companies reduce dependency on imported ingredients and external supply chains. In times of market volatility or geopolitical uncertainty, diversified product portfolios and localized circular value chains increase economic resilience.

High-value side stream valorization involves technological processes that isolate, purify and stabilize valuable components from by-products. Several extraction pathways are relevant in the South Ostrobothnian context:

1. Protein Fractionation

Protein-rich side streams such as whey, blood plasma or plant-based residues can undergo membrane filtration, centrifugation or enzymatic hydrolysis to separate functional protein fractions (Pihlanto et al., 2012; Rantamäki et al.,2019; AFI, 2020). These proteins may then be dried into powders for use in:

- Functional foods
- Sports nutrition
- Plant-based alternatives
- Animal feed with improved digestibility

Protein extraction increases product value compared to selling unprocessed by-products at low margins.

2. Fibre and Starch Recovery

Potato processing generates peel residues and starch-rich water streams (Gebrechristos & Chen, 2018). Through mechanical separation and drying processes, starch and fibre fractions can be recovered and used in:

- Bakery products
- Thickening agents
- Biodegradable packaging materials
- Feed formulations

This reduces organic waste load and enhances resource efficiency.

3. Bioactive Compound Extraction

Advanced extraction methods (e.g., supercritical CO_2 extraction, solvent extraction, fermentation) can isolate antioxidants, peptides and micronutrients from side streams (Chetrariu & Dabija, 2021). These compounds can be used in:

- Nutraceuticals
- Functional ingredients
- Natural preservatives

Such technologies align with the Smart Specialization objective of strengthening innovation ecosystems and sustainable bioeconomy development.

4. Energy and Biochar Integration

Side streams unsuitable for food-grade applications can be directed toward biogas production or pyrolysis (Muhonen, 2024), contributing to renewable energy generation and potentially linking with biochar production systems (as discussed in Pilot Area 1). This closes material loops and reduces fossil energy dependency.

Climate & Resilience Impact

Circular side stream valorization contributes to resilience at multiple levels:

Emission Reduction - maximising value from raw materials reduces the need for additional primary production, indirectly lowering agricultural emissions. Improved resource efficiency also reduces waste-related methane emissions (Erwiha et al., 2020).

Input Dependency Reduction- recovered proteins and fibres can substitute imported ingredients, strengthening supply security during global market disruptions (Keegan et al., 2024).

Economic Diversification - companies develop multiple revenue streams, reducing reliance on a single product category. This enhances financial robustness and adaptability.

Energy Efficiency & Circularity - integrating extraction with renewable energy systems supports the Climate Roadmap's low-carbon production input targets.

Regional Competitiveness - by moving up the value chain, South Ostrobothnia strengthens its position as a high-value innovation ecosystem rather than a bulk raw material supplier — directly supporting the Food Province 2030 vision.

SDG Link

Circular processing strongly supports the Sustainable Development Goals identified in this handbook:

SDG 12 – Responsible Consumption and Production

Reduces waste, enhances resource efficiency and promotes circular economy practices.

SDG 13 – Climate Action

Improves emission efficiency across the food chain by maximizing value per unit of raw material and reducing landfill-related emissions.

SDG 8 – Decent Work and Economic Growth

Creates new business opportunities in ingredient innovation, biotechnology and advanced processing, supporting regional employment.

SDG 2 – Zero Hunger

Enhances food system efficiency and protein availability, strengthening food security.

SDG 15 – Life on Land

Reduces pressure for additional land use by extracting more value from existing production.

Circular side stream valorisation represents a shift from linear production logic toward regenerative industrial ecosystems. In a region where the food sector forms the economic backbone, upgrading side streams into high-value ingredients strengthens both environmental responsibility and economic resilience. Pilot Area 2 demonstrates that climate action does not necessarily require reducing production — it can mean producing smarter. By transforming waste into resource, South Ostrobothnia reinforces its identity as an Accountable Food Province while enhancing long-term competitiveness.

Pilot Area 3 – Climate-Smart Food Services

Why This Good Practice

While primary production and processing are often the focus of climate action, food services represent a powerful and underutilized leverage point in the regional food system. In 2023, South Ostrobothnia had 442 food service providers. These include public kitchens in schools, hospitals and municipal services, as well as private restaurants and catering businesses. Together, they influence purchasing decisions, dietary patterns and food waste levels across the region. The Climate Roadmap for the Food Sector sets explicit targets for carbon-neutral food services, carbon-neutral wholesale and retail trade, and climate-resilient consumer choices. Public procurement criteria are identified as a strategic instrument for promoting locally produced, sustainable and seasonal food. This positions food services not merely as end-of-chain actors, but as active shapers of production practices and consumption patterns.

Climate-Smart Food Services is selected as Pilot Area 3 because it bridges environmental responsibility, public health, economic stability and consumer engagement. It operationalizes responsibility at the interface between production and citizens, reinforcing the Food Province vision of accountable and cooperative development. Food services influence climate impact through two primary mechanisms:

- What is served
- How much is wasted

Both are manageable through systematic approaches.

Carbon-Aware Menu Planning

Carbon-aware menu planning integrates climate considerations into procurement and recipe design. This includes:

- Increasing plant-based protein options (Frehner et al., 2020)
- Reducing high-emission ingredients (Filimonau et al., 2017)
- Prioritising seasonal and locally sourced products (Smaal, 2022)
- Using whole ingredients and reducing over-processing

Agriculture accounts for 44.6% of regional greenhouse gas emissions. Menu choices therefore indirectly influence production emissions. For example, increased use of plant-based proteins may reduce demand pressure on emission-intensive production systems, while supporting diversification goals identified in regional development priorities. Carbon-aware planning also aligns with the Climate Roadmap's objective of building a low-carbon food chain across all stages. By embedding sustainability criteria into

procurement, food services create predictable demand signals that encourage climate-smart production practices.

Digital tools can support this transition (Lefadola et al., 2018). Menu planning software can estimate emission intensity, compare ingredient options and simulate the climate impact of different recipe adjustments. While exact carbon accounting remains complex, even directional guidance improves decision-making.

Systematic Waste Monitoring

Food waste is both an environmental and economic loss (Painter et al., 2026). Waste represents:

- Lost raw materials
- Lost energy
- Lost labor
- Avoidable emissions

Monitoring food waste allows kitchens to adjust portion sizes, improve forecasting and optimize procurement (Papargyropoulou et al., 2016). Technologies such as digital scales, waste-tracking software and data dashboards enable systematic monitoring.

Reducing waste directly supports SDG 12 on responsible production and consumption and strengthens profitability by lowering food costs. It also reduces upstream production pressure; indirectly lowering emissions associated with raw materials. In South Ostrobothnia, where public kitchens serve large populations daily, even small percentage reductions in waste translate into significant cumulative climate and cost benefits.

Resilience Impact

Climate-Smart Food Services contribute to resilience in multiple ways.

1. Diversification of Supply

Climate variability, including droughts, heavy rainfall and extreme weather events, threatens agricultural production. Flexible menus that adapt to seasonal availability reduce vulnerability to supply disruptions. Rather than relying on fixed ingredient lists, adaptable menus allow substitution based on availability.

2. Reduced Pressure on Vulnerable Production Systems

Peatland cultivation accounts for a large share of regional agricultural emissions. By influencing demand patterns, food services can gradually support production models that reduce climate pressure, aligning consumption with resilience-oriented production transitions.

3. Financial Stability

Food waste reduction improves cost control, particularly in times of volatile food prices and economic uncertainty. Lower input waste increases financial robustness for municipal and private operators.

4. Behavioural Adaptation

Food services are powerful platforms for shaping consumer awareness Marthinsen et al. (2012). Introducing climate-smart meals in schools and public institutions supports long-term behavioural change. When consumers become accustomed to diverse, seasonal and plant-forward meals, demand patterns gradually shift. This aligns with the broader Food Province objective of accountable action and conscious consumers.

SDG Link

Climate-Smart Food Services directly support several Sustainable Development Goals:

SDG 12 – Responsible Consumption and Production

Through waste reduction, sustainable procurement and resource efficiency.

SDG 13 – Climate Action

By lowering lifecycle emissions of meals and supporting low-carbon production signals.

SDG 2 – Zero Hunger

By improving efficiency and reducing waste, increasing overall food system effectiveness.

SDG 8 – Decent Work and Economic Growth

By improving financial performance of food service operations and strengthening local supply chains.

SDG 15 – Life on Land

By reducing pressure on emission-intensive and biodiversity-sensitive production systems.

Climate-Smart Food Services demonstrate how responsibility can be implemented at the consumption interface. By combining carbon-aware menu planning with systematic waste monitoring, food services strengthen both environmental and economic resilience. In a region where the food sector is central to employment and identity, food services hold strategic power. They connect producers and citizens, influence dietary norms and provide stable institutional demand. Pilot Area 3 shows that resilience is not only built in fields and factories but also shaped in kitchens and dining halls.

Pilot Area 4 – Enabling Responsible Consumer Choices through Nudging

Why This Good Practice

A resilient food system does not depend only on production technologies and processing innovation. It also depends on consumer behavior. Demand patterns shape agricultural production, processing investments and retail strategies. In South Ostrobothnia, where the food sector forms a central pillar of the regional economy, consumer choices have direct implications for climate impact, economic viability and long-term competitiveness. The Climate Roadmap for the Food Sector recognizes that achieving a low-carbon food chain requires action across the entire value chain, including consumer-level behavior. Similarly, the Food Province 2030 vision emphasizes accountable action and cooperation among all actors. Responsibility is therefore shared — not limited to farmers or processors.

However, expecting consumers to make fully informed and rational sustainability decisions without structural support is unrealistic (Wognum et al., 2011). Food choices are influenced by habit, convenience, price signals, social norms and cognitive shortcuts (Wongprawmas et al., 2023). For this reason, behavioral nudging is selected as Pilot Area 4. Nudging provides practical, evidence-based tools for guiding responsible choices without restricting freedom of choice. Nudging does not impose regulation. Instead, it redesigns the choice environment so that sustainable options become easier, more visible and more attractive (Van Loo et al., 2017).

Behavioural Nudging Explained

Behavioral nudging is based on behavioral economics and decision science. It recognizes that individuals do not always act according to long-term rational calculations (Thaler & Sunstein, 2008). Instead, choices are often shaped by:

- Default options
- Visual placement
- Social norms
- Simplicity
- Immediate cues

A “nudge” is a subtle change in how options are presented that predictably influences behavior while preserving freedom of choice. In the food context, nudging can include:

Default Options - making climate-friendly meals the default option in public food services, while still allowing alternative selections (Parkin & Attwood, 2022).

Placement Strategies - placing plant-based meals at eye level in buffet lines or retail shelves, increasing visibility and convenience (Garnett et al., 2019).

Portion Design - adjusting plate size or serving order to reduce food waste without reducing consumer satisfaction (Wongprawmas et al., 2023).

Social Norm Messaging - communicating that "most customers choose the climate-smart option" to leverage peer influence (Hartwell et al., 2020).

Carbon Labels and Visual Cues - using simple color-coded or symbol-based indicators to highlight lower-emission choices (Buratto & Lotti, 2024).

These interventions are low-cost, scalable and adaptable across retail, food service and event catering contexts. Importantly, nudging supports behavioral adaptation without requiring high levels of technical climate literacy from consumers. It simplifies decision-making in line with regional sustainability goals.

Shared Responsibility

A recurring concern in climate policy discussions has been the distribution of responsibility. During the Climate Roadmap development process, primary producers expressed concern that climate expectations are often placed disproportionately on agriculture. This highlights the importance of shared responsibility across the entire value chain.

Nudging strengthens this shared responsibility model by recognizing that consumers also influence system outcomes. Demand for high-emission products, excessive portion sizes or resource-intensive diets shapes production decisions. However, responsibility must be enabled, not merely transferred. Consumers operate within structural constraints of price, availability and information. Nudging ensures that the environment supports rather than obstructs responsible behavior.

In South Ostrobothnia, where cooperation culture is recognized as a regional strength, coordinated nudging strategies can be implemented across:

- Public food services
- Retail stores
- Local food events
- Educational institutions

Such coordination ensures that sustainability messages are consistent and mutually reinforcing.

Nudging also complements other pilot areas. For example:

- Carbon-aware menu planning (Pilot Area 3) becomes more effective when supported by behavioral cues.

- Circular products from side-stream valorization (Pilot Area 2) gain market acceptance when positioned attractively.
- Climate-smart soil practices (Pilot Area 1) gain legitimacy when consumers understand and support responsible production.

Behavioral nudging therefore operates as a connective strategy across the entire resilience framework.

Climate & Resilience Impact

Nudging contributes to resilience in several ways:

1. Demand Diversification- encouraging plant-based and seasonal choices reduces pressure on emission-intensive production systems and supports climate-smart transitions.

2. Waste Reduction - portion design and serving order adjustments reduce food waste, improving economic efficiency and lowering upstream emissions.

3. Market Stability - stable demand for sustainable products increases predictability for producers and processors, strengthening economic robustness.

4. Cultural Adaptation - over time, repeated exposure to climate-smart defaults reshapes norms. This long-term behavioral adaptation reduces resistance to necessary structural transitions. Because nudging is incremental and non-coercive, it reduces social friction while still generating measurable impact.

SDG Link

Nudging directly supports the Sustainable Development Goals embedded in this handbook:

SDG 12 – Responsible Consumption and Production
By guiding consumers toward sustainable choices and reducing waste.

SDG 13 – Climate Action
By lowering demand-driven emissions and supporting low-carbon production pathways.

SDG 2 – Zero Hunger
By improving system efficiency and reducing avoidable food loss.

SDG 8 – Decent Work and Economic Growth
By strengthening demand for local and value-added products, supporting regional employment.

SDG 15 – Life on Land
By gradually reducing pressure on high-emission and biodiversity-sensitive production systems.

Enabling responsible consumer choices through nudging acknowledges a fundamental truth: food system resilience is shaped not only by producers and policymakers but also by everyday decisions made in kitchens, cafeterias and supermarkets. In a region that aspires to be the most accountable and innovative Food Province, aligning behavioural environments with sustainability goals is both strategic and necessary. Pilot Area 4 demonstrates that resilience is not built solely through infrastructure and technology — it is also built through culture, habits and shared responsibility.

Cross-Cutting Strategic Theme – Climate Risk Management & Fair Responsibility

South Ostrobothnia's ambition to be the most accountable and competitive Food Province requires more than isolated technical solutions. Soil innovation, circular processing, climate-smart food services and behavioural nudging all contribute to resilience. However, without systematic climate risk management and a fair distribution of responsibility across the value chain, these efforts risk remaining fragmented. The Climate Roadmap for the Food Sector defines a vision of a climate-resilient and low-carbon food chain. Achieving this vision requires cross-cutting coordination that integrates risk assessment, scenario planning, governance structures and equitable burden-sharing. This section provides the strategic framework that binds the previous pilot areas into a coherent regional transition pathway.

Climate Risk Assessment

Climate change represents both a physical and a transition risk to the regional food system.

Physical Climate Risks

The regional risk assessment identifies increasing threats from extreme weather events, including storms, heavy rainfall, droughts and heatwaves. These risks affect:

- Crop yields and soil conditions
- Livestock welfare and feed availability
- Infrastructure and transport systems
- Energy reliability

In South Ostrobothnia, where agricultural production is intensive and geographically concentrated, such disturbances can propagate rapidly across the value chain. Yield instability at farm level affects processing supply; infrastructure disruption affects logistics; energy price shocks affect production costs. Additionally, peatland cultivation significantly increases emission exposure, making the region particularly sensitive to regulatory tightening and carbon pricing mechanisms.

Transition Risks

Transition risks arise from evolving climate policies, market expectations and investor requirements. As agriculture accounts for 44.6% of regional greenhouse gas emissions, increasing regulatory pressure is likely.

Examples of transition risks include:

- Stricter emission accounting requirements
- Carbon pricing or emission trading mechanisms

- Sustainable procurement criteria
- Financial institutions integrating climate risk into lending conditions

Companies and farms that do not anticipate these shifts may face higher costs, reduced competitiveness or restricted market access.

Systematic climate risk assessment should therefore include:

1. Identification of emission hotspots
2. Evaluation of vulnerability to extreme weather
3. Mapping of input dependencies (energy, fertilisers)
4. Financial stress testing under different climate and price scenarios

Risk assessment transforms uncertainty into structured knowledge and supports informed decision-making.

Scenario Planning

Climate risk management requires moving beyond reactive adaptation toward forward-looking scenario planning. Scenario planning does not predict a single future (Sellberg et al., 2020). Instead, it explores multiple plausible futures and prepares strategic responses accordingly.

For South Ostrobothnia, relevant scenarios may include:

Scenario A – Gradual Policy Tightening

- Incremental emission reduction requirements
- Gradual carbon pricing
- Increased sustainability reporting

In this scenario, early adopters of low-carbon practices gain competitive advantage.

Scenario B – Rapid Regulatory Shift

- Accelerated carbon pricing
- Mandatory peatland emission reductions
- Strict procurement standards

In this scenario, actors without prior adaptation face high compliance costs and rapid restructuring pressure.

Scenario C – Climate Shock Scenario

- Consecutive drought years
- Severe flooding events
- Major supply chain disruptions

This scenario tests robustness of soil systems (Pilot Area 1), circular resource efficiency (Pilot Area 2), adaptive food services (Pilot Area 3) and diversified consumer demand (Pilot Area 4).

Scenario planning enables:

- Stress-testing business models
- Identifying investment priorities
- Strengthening cooperation across actors
- Reducing surprise effects

The Food Province strategy emphasizes strategic foresight and coordinated development. Embedding scenario planning into regional governance structures strengthens adaptive capacity at system level.

Fair Distribution of Responsibility

Climate transition discussions often generate tension regarding burden-sharing. During the development of the Climate Roadmap, primary producers expressed concerns about disproportionate expectations placed on agriculture. Given that agriculture represents a significant share of regional emissions, mitigation efforts are unavoidable. However, fairness is critical for maintaining legitimacy and cooperation.

Fair responsibility implies:

1. Shared action across the entire value chain
2. Recognition of economic constraints at farm level
3. Distribution of transition costs proportionally
4. Alignment of climate ambition with profitability

Producers cannot carry the transition alone if input costs rise and market prices remain volatile (Coyral & Batt, 2023). Processors, retailers, food services and consumers must also contribute through:

- Sustainable procurement practices
- Investment in circular processing

- Behavioural nudging
- Willingness to pay for climate-smart products

Fairness also implies that public policy instruments support early adopters and provide transition assistance where necessary. Without perceived fairness, climate policy risks social resistance and fragmented implementation. With fairness, climate responsibility becomes a shared regional project.

Regional Cooperation

South Ostrobothnia's strong structural asset is its cooperation culture. The Regional Rural Development Plan emphasises strong networks, entrepreneurial confidence and active development orientation. The Food Province strategy highlights close collaboration across the farm-to-table chain. Regional cooperation enables:

- Knowledge sharing on soil resilience and biochar
- Joint investments in side-stream valorisation facilities
- Coordinated procurement standards
- Unified communication to consumers

It also strengthens innovation capacity by linking farms, companies, research institutions and public authorities. In a context of climate uncertainty, cooperation reduces fragmentation and duplication Sacchi et al. (2022). It accelerates scaling of good practices and ensures that pilot projects evolve into mainstream solutions (Stoeva et al., 2024).

Climate risk management is not a separate activity — it is the backbone of a resilient Food Province. Systematic risk assessment clarifies exposure. Scenario planning prepares actors for multiple futures. Fair responsibility ensures legitimacy and cooperation (INTIA, 2023). Regional coordination accelerates transformation. South Ostrobothnia's ambition to be the most accountable and innovative food region requires recognising that resilience is collective. The transition toward a climate-resilient food system cannot be achieved by isolated actors. It requires shared foresight, shared responsibility and shared commitment. By integrating risk management with fairness and cooperation, the region strengthens not only its environmental performance but also its economic stability and social cohesion.

Conclusion – Towards the Most Resilient Food Province in Finland

South Ostrobothnia stands at a defining moment. The region is already recognised as Finland's Food Province, with a strong agricultural base, a powerful processing sector and an active culture of cooperation. Yet the structural strengths that have enabled growth also to expose the region to climate variability, emission intensity, input dependency and global market volatility.

This handbook has framed responsibility not as an external obligation, but as a strategic asset. The four pilot areas — soil resilience through manure-enriched biochar, circular processing of side streams, climate-smart food services and behavioural nudging — demonstrate that environmental responsibility, economic vitality and social cooperation are mutually reinforcing.

Soil resilience strengthens the ecological infrastructure of production. Circular processing maximises value from existing resources and reduces dependency on external inputs. Climate-smart food services align institutional demand with sustainability goals. Nudging empowers consumers to participate in the transition. Climate risk management and fair responsibility ensure that these measures are coordinated, legitimate and forward-looking. Together, these actions respond directly to the Climate Roadmap's vision of a low-carbon and climate-resilient food chain, while reinforcing the Food Province strategy's commitment to accountable and competitive development.

The pathway forward requires:

- Systematic climate risk assessment
- Scenario-based planning
- Fair distribution of responsibility across the value chain
- Continuous cooperation among farms, companies, public authorities and consumers

Resilience is not achieved through isolated projects. It emerges from integrated action and shared commitment. It is built in soils, in processing facilities, in kitchens and in everyday consumer choices. The transition toward the most resilient food province in Finland is not about reducing ambition — it is about aligning ambition with long-term sustainability.

Responsibility strengthens resilience.
Resilience strengthens competitiveness.

By embracing this logic, South Ostrobothnia does not merely respond to climate and market pressures — it positions itself as a pioneer of sustainable, competitive and future-proof food systems. The most resilient Food Province is not the one that avoids change, but the one that anticipates it, shapes it and leads it.

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