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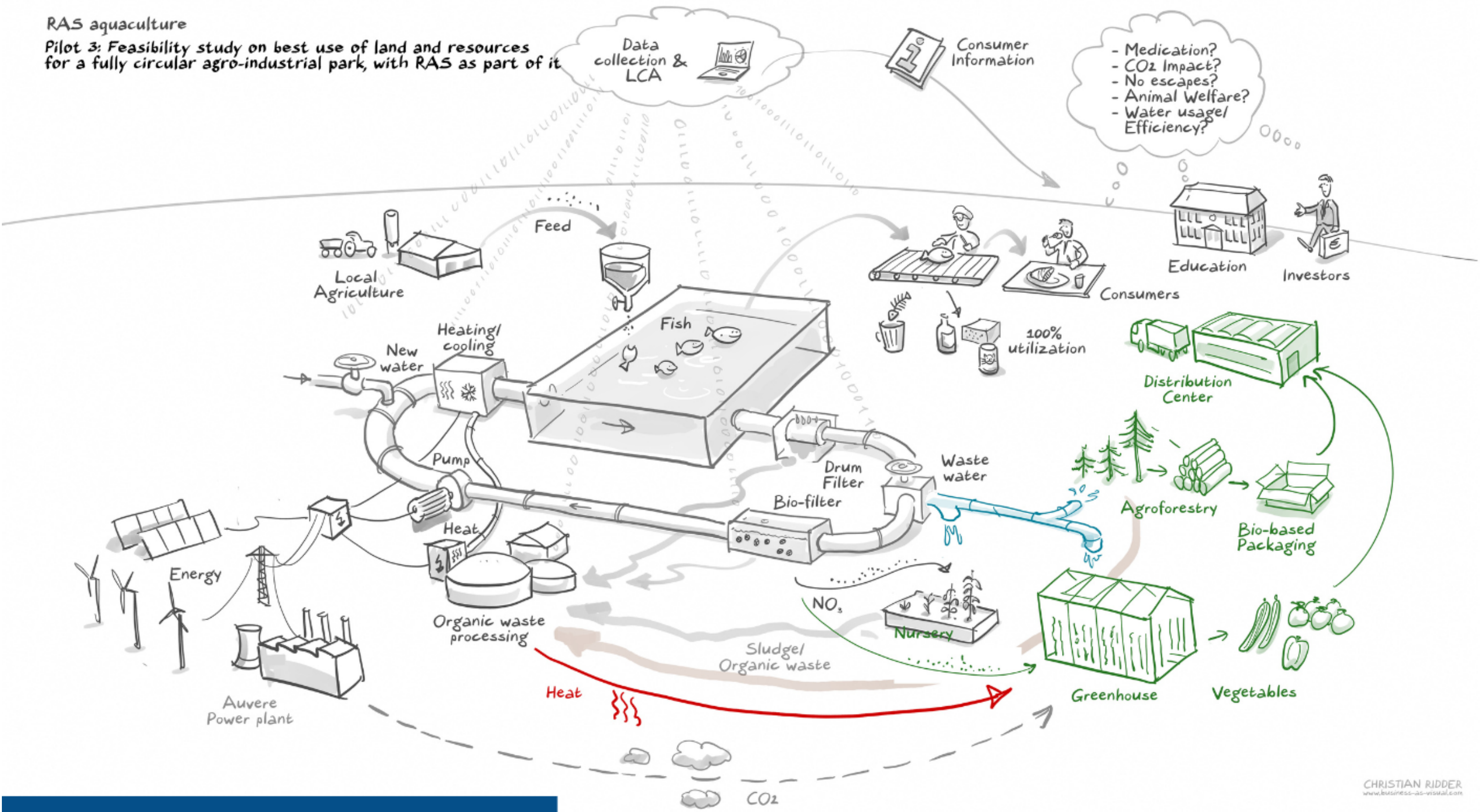

Chapter 3

Pilot 3 - Best Use of Land and Resources for a Fully Circular Agro-Industrial Park with RAS

Pilot Owner: IVIA EXPAND YOUR BUSINESS

Support: HOCHSCHULE WISMAR UNIVERSITY OF APPLIED SCIENCES TECHNOLOGY, BUSINESS AND DESIGN

WATER-SMART SOCIETIES

1. Executive Summary

This report presents the feasibility assessment of Pilot 3 under the TETRAS project. The pilot explores the potential establishment of an industrial symbiosis agropark (EISAP) in Ida-Viru County, Estonia, combining a land-based Recirculating Aquaculture System (RAS) with greenhouse vegetable production. The proposed model relies on the reuse of residual heat, carbon dioxide, and treated water from the nearby Auvere power plant, aiming to create a closed-loop production system in a post-industrial setting.

The analysis synthesises findings from the initial feasibility study conducted by Consultare (Estonia), the business model developed by Hochschule Wismar (Germany), and regulatory insights from the Cobalt licensing guidelines. The objective is to assess the spatial, technical, environmental, institutional, and economic viability of the project, while identifying transferable lessons for other regions in the Baltic Sea area.

Key Findings

The feasibility assessment confirmed that it is technically and environmentally feasible to establish a closed-loop aquaculture and greenhouse complex on a 30-hectare flat subarea within a former oil shale quarry near the Auvere Power Plant. The site benefits from proximity to industrial by-products: up to **13.7 MW of residual heat**, access to **technical water and CO_2**, and existing energy and transport corridors. The Mustajõgi River and surrounding hydrological conditions allow for controlled intake, though advanced treatment is required due to the biological load of surface water.

Among the evaluated production models, only **land-based Recirculating Aquaculture Systems (RAS)** met the environmental standards required in proximity to **Natura 2000** areas. The selected RAS design features a high water recirculation rate (≥95%), mechanical and biological filtration, and potential integration with hydroponic greenhouse units for further nutrient reuse.

The project, however, faces several critical implementation barriers. These include uncertainty regarding the future operation of the Auvere plant (currently operating on oil shale), which is essential for ensuring continuous flows of waste heat and CO_2; limited groundwater reserves in the area; and the site's classification within both a **national defence restriction zone** and a **protected environmental area**. Permitting remains complex, involving multiple agencies and lacking standardised procedures for symbiotic or integrated systems.

From an economic perspective, the full implementation was estimated to require a capital investment of **approximately €48 million**, making the project highly sensitive to energy prices, market access, and public co-funding. Despite these constraints, the model aligns with Estonia's "Estonia 2035" strategy, the National Energy and Climate Plan (NECP), and the EU Green Deal, demonstrating potential for regional transformation through sustainable industrial reuse.

Summary of Recommendations

The assessment identifies several enabling conditions for future projects aiming to replicate or adapt the EISAP model:

- **Regulatory frameworks** should be updated to support integrated permitting for circular and symbiosis-based systems, with specific guidelines for RAS operations and clearer procedures in sensitive zones such as Natura 2000 or defence areas.

- **Technical planning** must account for topographical constraints, hybrid water sourcing, and the volatility of industrial by-product flows. Multidisciplinary design teams and modular implementation strategies are strongly recommended.

- **Governance models** should include early-stage coordination mechanisms across sectors, institutional recognition of industrial symbiosis, and capacity-building for permitting authorities unfamiliar with integrated systems.

- **Market strategies** require early development of sustainability branding, offtake partnerships, and blended finance schemes to manage capital intensity and risk.

- For other TETRAS pilots, the EISAP case highlights the importance of context-sensitive planning, modular deployment, administrative learning, and cross-pilot exchange. Even when full-scale implementation proves unfeasible, partial or phased approaches may preserve value and support long-term goals.

2. Background

Geographical and strategic context

The Estonian Industrial Symbiosis Agropark (EISAP) is located in Ida-Viru County, northeastern Estonia — a historically industrialized region shaped by over a century of oil shale extraction and thermal power generation. The proposed agropark area spans approximately **1,500 hectares**, most of which is classified as **technogenic land** following the cessation of open-cast mining activities in the Narva quarry. The central site under consideration is a **30-hectare flat subarea** adjacent to the Auvere power plant, selected for its **suitable topography and integration potential**. The surrounding landscape is ecologically degraded and sparsely populated, reducing land-use conflicts and making it appropriate for industrial redevelopment. Proximity to the **Enefit280 oil shale processing unit** and Auvere power station provides access to several underutilised by-products — notably **up to 13.7 MW of waste heat**, **high-purity CO_2**, **technical water from circulation systems**, and **oil shale ash**. These resources form the material foundation of the proposed circular economy model that underpins EISAP.

Rationale for the feasibility study

The feasibility study was conducted within the framework of the TETRAS project to assess the viability of establishing a closed-loop agro-industrial symbiosis system in a post-mining landscape. The proposed concept combines **Recirculating Aquaculture Systems (RAS)** with **Controlled Environment Agriculture (CEA) greenhouses**, leveraging the industrial by-products available at the Auvere site. The study aimed to evaluate the **technical feasibility**, **environmental compliance**, and **economic viability** of this integrated system, focusing on the circular use of **water**, **residual heat**, **CO_2**, and **nutrient-rich sludge** across multiple production units. In addition to engineering and spatial assessments, the analysis also explored institutional readiness and permitting pathways. A key goal was to determine whether the EISAP model could serve as a **replicable prototype** for other regions undergoing industrial transition, in line with **EU climate goals**, **circular economy principles**, and **national strategies for sustainable land reuse and food security**.

Precedents in industrial symbiosis

EISAP draws inspiration from several established examples of industrial symbiosis in Northern and Western Europe. The **Kalundborg Symbiosis** in Denmark, initiated in the 1970s, remains a landmark case, where energy, water, and material flows (such as steam, gypsum, and fly ash) are shared among power plants, refineries, and chemical producers. This model demonstrates how **co-location and contractual coordination** can reduce resource consumption and emissions while improving economic resilience. More recent examples include the **Sotenäs Symbiosis Centre** in Sweden, which links seafood processing, biogas generation, and aquaculture within a marine industrial cluster, and the **WA3RM project** in Frövi, Sweden, where excess heat from a pulp and paper mill is captured to support **year-round greenhouse production** of tomatoes and herbs. These precedents illustrate the operational feasibility and climate relevance of reusing industrial by-products in food production systems — a core principle of the EISAP concept.

Stakeholders and their interests

The development of the Estonian Industrial Symbiosis Agropark (EISAP) involved a diverse set of stakeholders, ranging from coordinating institutions and infrastructure providers to regulatory authorities, potential investors, and affected communities. In the context of this feasibility assessment, stakeholders are defined as individuals, organisations, or groups that (i) directly contributed to the project, (ii) influenced its approval and implementation, or (iii) were likely to be impacted by its outcomes. The following section outlines the most relevant stakeholder groups and their roles at the time of the study.

Core implementation partners

The project was coordinated by the **Ida-Viru Investment Agency (IVIA)**, a regional development organisation focused on promoting industrial investment and managing the development of industrial parks in northeastern Estonia. IVIA acted as the project integrator and site promoter, responsible for coordinating land readiness, investor engagement, and alignment with regional development goals.

The key industrial partner was **Enefit Power AS**, operator of the **Auvere oil shale power plant**, which provided access to essential by-products such as **residual heat (up to 13.7 MW)**, **CO_2**, **circulated technical water**, and **oil shale ash**—considered critical inputs for the planned symbiotic model.

Regulatory and planning actors

The **municipality of Narva-Jõesuu** was responsible for local **spatial planning** and the adoption of the detailed plan for the 1,500-hectare post-mining area where the agropark was to be located. National-level **environmental permitting**, Natura 2000 coordination, and strategic assessments were handled by the **Estonian Environmental Board (Keskkonnaamet)** in cooperation with the **Ministry of Climate**.

Knowledge and advisory partners

The business modelling component was developed by the **Wismar University of Applied Sciences: Technology, Business and Design**, using NABC analysis and the Product–Process Matrix framework. Legal and regulatory conditions—especially concerning RAS licensing and spatial restrictions—were analysed by the **COBALT Law Firm**, whose guidance informed the feasibility risk assessment.

Future-oriented stakeholders

Beyond the core project team, the feasibility study identified a broader ecosystem of stakeholders whose engagement would have been critical to successful implementation. These included **potential investors and operators** in aquaculture, greenhouse production, and downstream logistics. The model targeted **premium food markets**, such as **HoReCa suppliers, organic retail chains**, and **export-oriented distributors**. In parallel, the project's spatial footprint and reliance on industrial residuals were expected to draw attention from **local residents**, **environmental NGOs**, and **labour organisations**, particularly regarding Natura 2000 impacts and land-use transitions.

3. Outline of the Pilot Project

Description of the pilot

Pilot 3, implemented by Project Partner 5 (IVIA), focuses on the development of the Estonian Industrial Symbiosis Agropark (EISAP) near the Auvere power plant in Ida-Viru County. The pilot aims to establish a fully circular agro-industrial ecosystem that combines Recirculating Aquaculture Systems (RAS) with high-efficiency greenhouse agriculture. The core concept involves using underutilized resources from the nearby Enefit oil shale power plant — such as waste heat, excess CO_2, recirculated water, and oil shale ash — to support food production and industrial processes within the park.

The pilot explores the spatial, technical, and economic feasibility of co-locating aquaculture and horticulture facilities in a way that maximizes internal resource reuse. It also examines the feasibility of integrating RAS farms into the broader agro-industrial infrastructure, both as a source of nutrient-rich process water and as a consumer of technical heat and treated water. EISAP is designed as a testbed for sustainable, cross-sectoral industrial collaboration that could be replicated across similar post-mining landscapes in the Baltic Sea Region.

Objectives

The main objective of the feasibility study for Pilot 3 (EISAP) was to assess whether an industrial symbiosis agropark—combining Recirculating Aquaculture Systems (RAS) with greenhouse vegetable production—could be viably implemented in a post-mining area adjacent to the Auvere oil shale power plant in Ida-Viru County, Estonia.

The study aimed to examine:

- The **technical feasibility** of integrating multiple resource flows (residual heat, CO_2, water, sludge) into a closed-loop production system;
- The **environmental compliance** of aquaculture and horticulture operations near protected Natura 2000 areas;
- The **spatial and infrastructural suitability** of the 30-hectare site selected within the 1,500-hectare post-industrial zone;

- The **economic viability** of the proposed model, including capital requirements, operational costs, and market potential;
- The **regulatory and permitting landscape** for implementing such a concept within the Estonian planning and licensing system.

Additionally, the study sought to determine whether the EISAP model could serve as a **replicable reference** for other post-industrial regions in the Baltic Sea area, in line with the objectives of the TETRAS project and the EU Green Deal.

Project timeline

Preparatory activities for the agropark began in 2019 with initial spatial planning and conceptual development. Environmental permitting and stakeholder consultations started in 2020 and intensified from 2021 onward. In 2023, IVIA joined the TETRAS project to conduct a feasibility and cost-benefit analysis focused on the integration of RAS into the EISAP model.

- **2023 (Q1–Q2):** Procurement procedures and environmental expert recruitment
- **2023 (Q3–Q4):** Agreement with Environmental Board on scope of species inventories; launch of expert studies
- **2024 (Q1–Q3):** Completion of expert reports and finalization of feasibility analysis by Consultare
- **2024 (Q4):** Delivery of final report assessing viability of RAS and greenhouse integration
- **2025:** Use of results in project-level synthesis and business model development under TETRAS

Expected outcomes

The main deliverables include a feasibility and cost-benefit analysis of implementing RAS within a circular agropark structure, as well as roadmap recommendations for licensing, spatial integration, and resource management. The pilot is also expected to contribute to knowledge exchange with other partners in the TETRAS consortium and support the wider uptake of RAS-based food production within industrial symbiosis contexts.

Geographical scope

The EISAP site spans approximately 1,500 hectares of post-mining land directly adjacent to the Auvere energy complex. It is located near the Narva River and within the administrative territory of Narva-Jõesuu Municipality. The site is constrained by defense-related zoning and Natura 2000 regulations, and includes both flat and rugged terrain. A 30-hectare flat plateau has been identified as the optimal area for initiating construction.

Connection to RAS

The pilot specifically investigates the feasibility of introducing RAS farming into the EISAP context, focusing on water availability, nutrient reuse, sludge management, and energy integration. Potential synergies include using residual heat and CO_2 for fish farming, reusing RAS effluent in greenhouse irrigation, and valorising organic waste for energy or fertilizer. The analysis also explores technological requirements, licensing barriers, and environmental risks linked to RAS operation in a symbiotic setting.

4. Methodology

Methodological Objective and Scope

The methodology of the EISAP feasibility study was shaped by the project's primary objective: to assess the viability of establishing a Recirculating Aquaculture System (RAS)-based agro-industrial park within a former oil-shale mining area, using industrial symbiosis as its foundation. The analysis focused on validating the technical, economic, environmental, and regulatory feasibility of a large-scale RAS farm integrated with other agro-industrial functions, powered by residual resources from the Auvere Power Plant.

Problem-Driven Comparative Approach

The study applied a problem-driven approach. The baseline assumption was that conventional aquaculture models (e.g., pond or cage farming) would be unsuitable due to environmental, spatial, and regulatory constraints. A comparative analysis was therefore conducted between these conventional systems and closed-loop RAS technologies. This assessment relied on literature reviews, expert interviews, and site-specific environmental and infrastructural evaluations. Key selection criteria included water availability and quality, integration potential with industrial waste streams (heat, CO_2, and purified water), regulatory permissibility, and long-term economic sustainability.

The feasibility work incorporated site visits, stakeholder consultations, and regulatory screenings. Notably, feedback from the Environmental Board (Keskkonnaamet) played a role in shaping assumptions regarding water intake and discharge, affecting the final design logic for the RAS module. These consultations informed key assumptions used in cost modelling and operational risk projections.

System Comparison: Pond, Cage, and RAS

To validate the assumption that conventional aquaculture models were unsuitable, the study compared three production systems: pond farming, cage farming, and RAS (Recirculating Aquaculture Systems). The analysis highlighted the following:

- Pond farming was rejected due to land constraints and risks of eutrophication in the EISAP context.
- Cage farming was ruled out due to Estonia's strict regulations and ecological concerns regarding open-water aquaculture in the Narva River.
- RAS emerged as the only viable alternative, offering minimal environmental impact, controlled production conditions, and synergy with industrial flows such as residual heat and CO_2 from Auvere Power Plant.

Regarding water resources, the feasibility study confirmed that:

- Narva River has excellent nutrient status, with phosphorus and nitrogen levels well below thresholds (Ptot: 0.034 mg/l vs. 0.041–0.060 mg/l; Ntot: 0.61 mg/l vs. 1.6–3.0 mg/l), making it suitable for additional industrial load.
- Mustajõgi River, while smaller, also showed very good nutrient status. Its flow (minimum: 0.4 m^3/s) was deemed sufficient for RAS operations though inadequate for conventional flow-through systems.
- Groundwater was considered less favorable due to poor chemical status in two out of three local aquifers.

This comparative and site-specific evaluation shaped the study's conclusion that a closed-loop RAS integrated with industrial flows in the EISAP area is both environmentally and technically feasible, while other models are not viable.

PESTLE Framing and Policy Context

The process began with a PESTLE analysis to frame the project's broader external environment. Political alignment with the EU Green Deal, the National Energy and Climate Plan (NECP), and Estonia's strategic vision "Estonia 2035" provided a favourable policy context for initiatives combining circular economy and industrial innovation. These priorities influenced the decision to focus on RAS technologies, which—despite higher capital and operational costs—are compatible with environmental regulations and resource reuse goals.

From a labour market perspective, Ida-Viru County is characterized by a combination of relatively high unemployment (10.1% vs. 6.4% national average) and lower-than-average wages (EUR 1508 vs. EUR 1904). The region has a workforce with industrial experience, which may be adapted to support new sectors such as RAS and greenhouse horticulture, particularly with targeted training efforts.

Technological and environmental assessments indicated that RAS offers better control over water use, emissions, and nutrient cycles than other production methods. It also allows for the use of residual heat, CO_2, and technical water from the adjacent Auvere Power Plant, aligning with the project's integration objectives.

The legal and regulatory review showed that environmental permitting, food safety compliance, and water usage licensing would be more manageable under a closed-loop system. This consideration contributed to the decision to focus on RAS instead of open or flow-through systems.

Technical feasibility analysis

Technical feasibility analysis included a detailed mapping of existing infrastructure, assessment of terrain suitability, and identification of opportunities to integrate residual industrial resources. The EISAP site is located adjacent to the Auvere and Eesti power plants, with access to 330 kV transmission lines and direct railway connectivity to the Sillamäe port and other industrial hubs. However, road access remains limited, with most routes unpaved and prone to dust and mud, which may pose challenges for transport logistics.

The **topographical assessment** revealed that much of the site is rugged, with an average slope of 13.1%. Nonetheless, a 30-hectare area in the south-east corner was identified as relatively flat (slope <6%), making it suitable for building infrastructure such as greenhouses and RAS tanks.

From an **industrial symbiosis** perspective, the Auvere power plant produces up to 2.6 TWh of electricity annually and releases significant amounts of residual heat and CO_2. This includes up to 1,500,000 tons of flue gas and cooling water flows of 13.5 m^3/s per energy block. Cooling water is drawn from the Eesti EJ inflow channel and Mustajõe canal, heated by 7–11°C, and discharged back into the Mustajõgi River. These thermal flows present viable integration points for greenhouse heating and aquaculture temperature control.

Surface water availability from the Narva River (400 m^3/s) is more than sufficient to support RAS operations; however, the biological contamination risk from this source limits its direct use in aquaculture, favoring closed-loop water systems like RAS with filtration and disinfection technologies.

Engineering and modelling phase

During the engineering pre-design phase, Consultare developed process flow scenarios for a large-scale RAS facility, focusing on integration options for residual heat, CO_2, and technical water from the Auvere Power Plant. The analysis included spatial configuration of RAS units, energy demand projections, and preliminary infrastructure planning. However, Consultare's scope did not include financial modelling of the project. No investment payback calculations, detailed CAPEX/OPEX breakdowns, or revenue forecasts were provided in the feasibility study .

Instead, the financial assessment was conducted by Wismar University of Applied Sciences as part of the TETRAS project. Their contribution included a business model with investment assumptions, economic forecasts, and scalability scenarios.

Business modelling tools and conceptual framing

Methodologically, the work drew upon prior experience with industrial symbiosis and circular economy frameworks. The complementary study conducted by Wismar University applied two analytical tools to structure the logic of the agro-industrial model: the **Need–Approach–Benefit–Competition (NABC)** framework and the **Product–Process Matrix (PPM)**.

The **NABC model** was used to identify key environmental and economic needs in the Ida-Viru region (e.g. underutilized industrial by-products, high unemployment), match them with the project's approach (resource reuse, integration of RAS and greenhouse production), define the expected benefits (reduced waste, added economic value), and situate the concept in comparison to other agro-industrial developments in Europe.

The **Product–Process Matrix** was applied to classify the technological components of the agropark according to their production complexity and standardization level. This helped determine which parts of the system (e.g. RAS units, CO_2 utilization modules, or greenhouse heating systems) could follow modular or scalable designs, and which would require site-specific customization. The matrix also supported the selection of operational strategies aligned with the maturity and variability of each process component.

Financial Modelling and Cost Structure

These estimates were based on industry analogues, benchmark pricing, and assumed production volumes over a five-year horizon. Wismar's model included revenue projections, labour and operational costs, and sensitivity to market conditions, and indicative investment support from EU programmes such as the Green Deal and the Just Transition Fund.

Cost projections from this phase indicated:

- **Estimated total CAPEX: €48 million, including**:
  - RAS and greenhouse infrastructure: €20–30M
  - Water treatment systems: ~€5M
  - Energy systems and CO_2 capture: ~€10M.

- **OPEX estimates included**:
  - Labour: €3–5M/year for 600–1,000 workers
  - Utilities and maintenance: ~€2M/year
  - Feed, logistics, and agricultural inputs: ~€4–5.5M/year.

To contextualize these figures, benchmark data from comparable RAS projects (e.g. Kalundborg Eco-Industrial Park, Seawater Cubes, and DIGIRAS project) were used to verify technical ratios (e.g. fish output per m^3) and validate expected economic performance.

Key Assumptions and Economic Forecasts

Assumptions regarding future electricity prices, labour availability, fish market development, and EU funding opportunities were based on policy documents from 2023–2024, supplemented by expert judgment and reference data from similar European facilities. These assumptions were explicitly incorporated into the financial model developed by Wismar University as part of the TETRAS project.

Key input values included:

For example, the production targets for fish were set at:

- 500 tonnes in Year 1
- up to 5,000 tonnes by Year 5

with a market selling price of €8/kg.

The financial modelling projected **break-even between Year 3 and 4**, with **cumulative profit reaching €94.1 million by Year 5**.

Summary of Methodology

The methodological approach to the EISAP feasibility study combined site-specific technical assessments, regulatory analysis, stakeholder consultations, and conceptual business modelling. The analysis began with a comparative evaluation of aquaculture technologies, leading to the selection of a closed-loop RAS system as the only viable option under the environmental, spatial, and regulatory constraints of the Auvere site. Environmental data confirmed the suitability of surface water sources, while topographic analysis identified viable construction areas.

Technical feasibility was further examined through infrastructure mapping and integration modelling with the Auvere Power Plant's residual flows. Engineering pre-design by Consultare established the spatial and technological layout of core systems, whereas the financial modelling was conducted separately by Wismar University. Their business model included investment projections, operational costs, and scalability scenarios based on benchmark cases across Europe.

To frame the investment logic and operational design, Wismar applied structured tools including the NABC framework and the Product–Process Matrix. Regulatory feedback from the Environmental Board influenced critical technical assumptions, especially regarding water use and licensing timelines. The resulting methodology provided a robust foundation for evaluating the feasibility and integration potential of RAS within a circular agro-industrial park.

5. Overview of Alternatives

As part of the feasibility study for the Estonian Industrial Symbiosis Agropark (EISAP), several development scenarios were considered by the consulting team (Consultare OÜ). The aim was to identify a technically and environmentally sound model that fits the spatial, infrastructural, and regulatory conditions of the Auvere site. The analysis was conducted as a desk study and incorporated environmental data, infrastructure assessments, and experience from comparable European cases such as Kalundborg (Denmark), Sotenäs (Sweden), and Frövi (Sweden), known for their industrial symbiosis models. The alternatives were compared with regard to resource efficiency, integration potential, implementation complexity, and alignment with circular economy funding priorities and strategic policy goals

Alternative 1: Stand-alone industrial activities (no symbiosis)

A scenario in which aquaculture, greenhouse agriculture, and other industrial functions operate independently—without sharing resources such as heat, CO_2, or treated water—was examined as a baseline. This model offers operational simplicity, especially in terms of permitting, technical interdependencies, and risk management. However, the absence of industrial symbiosis would significantly reduce overall resource efficiency. For example, aquaculture and greenhouses would each require separate heating systems, leading to duplicated energy consumption. Likewise, water treatment would need to be performed in parallel for each activity, increasing CAPEX and OPEX requirements.

From a funding perspective, this configuration would not qualify for EU instruments such as the Just Transition Fund or Green Deal mechanisms, which explicitly prioritize integrated and circular economy models. Moreover, the decoupled nature of operations fails to align with the sustainability focus embedded in Estonia's NECP and “Estonia 2035” strategy, which promote resource synergies and carbon efficiency.

Environmentally, the stand-alone model lacks mechanisms for residual heat and CO_2 reuse, resulting in lower emissions savings compared to symbiotic alternatives. The reduced circularity would also compromise eligibility for eco-certifications and undermine the project's contribution to green transition goals. Ultimately, while administratively simpler, this option was excluded due to its incompatibility with long-term sustainability and funding frameworks central to EISAP’s strategic vision.

SWOT Summary – Alternative 1: Stand-alone industrial activities (no symbiosis) (*based on Consultare feasibility study*)

Strengths	**Weaknesses**
• Lower design and permitting complexity due to absence of interdependent systems • Conventional business logic easier to implement for investors familiar with standard industrial setups • Potential for step-by-step development, allowing independent actors to establish operations autonomously	• No shared use of resources (e.g., heat, CO_2, treated water), leading to significant inefficiencies • Increased demand for primary energy and water per unit of output • No valorisation of residual flows from Auvere power plant • Higher cumulative CAPEX/OPEX due to duplicated infrastructure • Does not support regional or EU circular economy targets
Opportunities	**Threats**

• Suitable for conventional industrial investors who prefer operational independence • May attract niche industries with no need for symbiosis • Easier to phase in development without full system integration	• Not eligible for circular economy or green transition funding (e.g., Just Transition Fund) • Risk of underperformance in sustainability KPIs • May face resistance from permitting authorities due to inefficient land and resource use • Conflicts with long-term regional policy goals promoting industrial synergy and resource efficiency

Alternative 2: RAS facility with flow-through system using river water

This alternative involves a traditional open-loop RAS configuration where freshwater is continuously abstracted from the Narva River and discharged after limited on-site treatment. While operationally simpler and potentially less capital-intensive, this model raised significant regulatory and environmental concerns during the feasibility study.

In particular, the potential for nutrient discharge (nitrogen, phosphorus) into a river catchment with sensitive downstream ecosystems—including Natura 2000 protected areas—would likely trigger a full Environmental Impact Assessment (EIA). Moreover, the Estonian Environmental Board (Keskkonnaamet) expressed reservations regarding the biosecurity risks of using untreated surface water, particularly the possibility of introducing or spreading fish pathogens. As a result, this option was assessed as highly uncertain in terms of obtaining necessary environmental permits within a reasonable timeframe.

Additionally, continuous intake and discharge would significantly increase the project's water abstraction license obligations, administrative burden, and long-term operational costs for water purification and effluent control. These constraints, combined with limited alignment with circular economy principles, led to the conclusion that this model is environmentally and regulatorily unfeasible under current conditions.

SWOT Summary – Alternative 2: RAS facility with flow-through system using river water (*based on Consultare feasibility study*)

Strengths	Weaknesses
• Lower initial capital investment due to simplified water infrastructure • Established technology widely understood by traditional aquaculture operators	• High environmental risks due to continuous nutrient discharge into the Narva River • Likely requirement for full Environmental Impact Assessment (EIA) • Strong regulatory opposition due to proximity to Natura 2000 areas • Biosecurity concerns related to use of untreated surface water • Increased operational complexity related to water abstraction licenses and discharge permits
Opportunities	**Threats**
• Faster initial setup due to simplified engineering requirements • Potential short-term cost savings before full environmental compliance is enforced	• High risk of permit denial for discharge and water intake • Potential reputational risk for project stakeholders due to ecological impact • Long-term operational costs associated with compliance and monitoring • Incompatibility with EU and Estonian circular economy and sustainability goals

Alternative 3: Full RAS with integrated sludge valorisation and greenhouse symbiosis (selected approach)

This concept involves a fully closed-loop Recirculating Aquaculture System (RAS), integrated with greenhouse horticulture and supported by industrial symbiosis with the adjacent Auvere Power Plant. The system is designed to recirculate water internally, supplemented by multi-stage treatment technologies including mechanical filtration, biofilters, UV disinfection, and denitrification units.

Residual heat and CO_2 from the power plant are reused to maintain optimal water temperature and support greenhouse operations, while excess treated water may be diverted for irrigation or further reuse. Organic sludge from fish farming is collected, dewatered, and foreseen for valorisation—either as input to a future biogas plant or as agricultural fertilizer, subject to regulatory approval.

This configuration enables high resource efficiency, reduced environmental footprint, and compliance with Estonia's and EU's circular economy strategies. Unlike open systems, it minimizes water abstraction and discharge, improving the project's acceptability under environmental permitting. The alternative aligns with the Just Transition Fund and EU Green Deal priorities, providing access to supportive funding instruments and increasing the project's resilience to future regulatory tightening. This model also reflects successful patterns observed in European reference cases such as Kalundborg (DK) and Sotenäs (SE), adapted to local conditions in Ida-Viru County.

SWOT Summary – Alternative 3: Full RAS with integrated sludge valorisation and greenhouse symbiosis (selected approach) (*based on Consultare feasibility study*)

Strengths	Weaknesses
• High resource efficiency through reuse of heat, CO_2, and treated water • Alignment with EU Green Deal, Just Transition Fund, and Estonia 2035 strategic objectives • Minimized water abstraction and discharge due to closed-loop design • Innovation potential through integration of aquaculture, horticulture, and energy flows • Improved environmental compliance and lower emissions per unit of output	• Higher technical and operational complexity requiring skilled workforce • Longer permitting process due to cross-sectoral integration and potential EIA requirements • High upfront capital investment • Reliance on emerging technologies for sludge treatment and valorisation
Opportunities	**Threats**
• Access to multiple EU funding mechanisms supporting circular economy and innovation • Positive visibility and stakeholder support due to sustainability focus • Potential to serve as a replicable model for other post-industrial sites • Scope for innovation in sludge reuse and precision aquaculture technologies	• Operational dependence on stable output from Auvere power plant (heat, CO_2,) • Limited local experience with RAS technology and industrial symbiosis • Uncertainty in regulatory approval for waste stream reuse (e.g., sludge to fertilizer) • Exposure to market volatility in fish and horticultural sectors

Justification for the Selected Model

Among the four conceptual configurations reviewed during the feasibility study, only Alternative 3—full RAS with integrated sludge valorisation and greenhouse symbiosis—demonstrated a viable balance of technical feasibility, environmental performance, economic potential, and policy alignment. Alternative 1 lacked integration and circularity, rendering it incompatible with the project's sustainability goals. Alternative 2 presented major regulatory and ecological risks due to its reliance on continuous water abstraction and discharge. The idea of relocating the RAS module outside the agropark area was ruled out early due to the loss of symbiotic advantages and the need for separate spatial planning. In contrast, Alternative 3 maximized resource efficiency through industrial symbiosis with the Auvere Power Plant, supported Estonia's and the EU's strategic goals, and ensured eligibility for green transition funding mechanisms. For these reasons, it was selected as the preferred implementation model.

6. Guidelines for licensing a RAS farm in Estonia and in the EU

The establishment and operation of a Recirculating Aquaculture System (RAS) facility in Estonia is subject to a range of legal requirements governed by national and EU-level regulation. The legal framework relevant to RAS includes land use planning, environmental permitting, construction permissions, and operational licensing. The following section summarises key procedures and regulatory acts, based on the legal review prepared by law firm **COBALT** in 2023.

Planning and Spatial Regulation

Before any construction activities can commence, the intended use of land must comply with **spatial plans**. In most cases, this involves the preparation and approval of a **detailed spatial plan (detailplaneering)** in accordance with the **Planning Act**.

In the case of EISAP, the planned activities fall under "industrial buildings and land" and "energy production" purposes, both of which are allowed in industrial zones. However, **no activities are permitted** within **Natura 2000 sites**, and the **impact on surrounding protected areas** must be assessed at the planning stage.

Construction and Building Permits

Construction works require:

- A **building permit (ehitusluba)**, under the **Building Code**, for structures such as aquaculture facilities, greenhouses, or water treatment systems.
- A **use and occupancy permit (kasutusluba)** is required before operations can begin.

These permits are issued by the **local municipality**, based on conformity with spatial plans and building requirements.

Environmental Permitting

Operations involving **water intake**, **wastewater discharge**, **air emissions**, or **waste management** require a **comprehensive environmental permit (keskkonnaluba)** under the **General Part of the Environmental Code Act**. The environmental permit may consolidate multiple sub-permits, such as:

- **Water abstraction permit**
- **Wastewater discharge permit**
- **Pollution permit**
- **Waste handling authorisations**

Depending on the **scale and impact** of the facility, an **Environmental Impact Assessment (EIA)** may be required. Key criteria triggering EIA include:

- Location near **protected areas** or **groundwater abstraction zones**
- Use of **hazardous substances**
- Discharge of **nutrients** into natural water bodies

In some cases, a **screening decision** may be obtained to confirm whether full EIA is mandatory.

Food Safety and Veterinary Requirements

Although not analysed in detail in the COBALT review, it is noted that fish farming and related food processing activities may require:

- **Registration or approval** under the **Veterinary Act**
- **Compliance with the Animal Health Regulation (EU 2016/429)** for biosecurity, traceability, and fish health

Relevant authorities include the **Agriculture and Food Board**.

Additional Restrictions and Considerations

If **alien aquatic species** are used, permits under the **Nature Conservation Act** may be required.

- The **use of water bodies** is further regulated by the **Water Act**, particularly concerning **ecological flow**, **cumulative abstraction**, and **downstream sensitivity**.
- Any **planned discharge into public water bodies** (e.g., Narva River or Mustajõgi) must be assessed in terms of its **nutrient content** and **ecological impact**.

Timeline and Complexity

The COBALT analysis highlights that licensing a RAS facility is **administratively complex**, typically involving:

- **6–12 months** for planning and permitting
- Multiple stakeholders (municipality, Environmental Board, Land Board, etc.)
- Potential **delays** due to inter-agency coordination, particularly for large-scale or innovative projects

Conclusion

The licensing of a Recirculating Aquaculture System in Estonia involves a multi-tiered legal framework spanning spatial planning, construction, environmental compliance, and operational authorisation. While recent developments under national and EU-level strategies aim to **streamline procedures**, successful implementation still requires **early engagement with authorities**, **integrated planning**, and a strong focus on **environmental compatibility**.

7. Risks

The EISAP project, as evaluated through the feasibility study and legal analysis, is subject to several clearly identified risks in the following categories:

1. Operational and Technical Risks

- **System Complexity**: According to the Consultare study, closed-loop RAS requires advanced filtration, UV disinfection, and sludge management systems. These systems demand careful integration and technical reliability to ensure optimal water quality and fish health.
- **Workforce Limitations**: Both the Wismar model and the feasibility study note that the successful operation of RAS facilities requires qualified personnel, which may be scarce in the region. This risk is exacerbated by the novelty of RAS in the Estonian context.
- **Infrastructure Dependencies**: As indicated in the Consultare study, RAS operations are technically dependent on the continuous availability of industrial residuals (heat, CO_2, technical water) from the Auvere power plant.

2. Financial Risks

- **High Capital Expenditure (CAPEX)**: Wismar University's modelling estimates total investment needs of approximately €48 million, including €20–30M for aquaculture and greenhouse infrastructure. This level of upfront cost poses financing and implementation risks.
- **Operational Expenditure (OPEX) Sensitivity**: Operational costs for energy, labour, and input materials (e.g., feed) are high for RAS. Profitability depends on efficient resource integration and sustained market pricing, as outlined in the Wismar scenario analysis.

3. Regulatory and Permitting Risks

- **Environmental Permits**: The Cobalt report confirms that establishing a RAS facility requires a comprehensive environmental permit, including provisions for water abstraction and discharge. These processes can involve Environmental Impact Assessment (EIA), particularly when located near Natura 2000 sites.
- **Zoning and Planning Delays**: As noted in the Cobalt study, detailed spatial planning and construction permits must be secured prior to development. These procedures are time-intensive and subject to local government coordination.
- **Licensing Uncertainty**: The need for coordinated approvals from multiple authorities — including environmental, veterinary, and municipal bodies — introduces risk of procedural delays and regulatory inconsistency.

Conclusion

While the EISAP project benefits from a well-aligned strategic framework and access to industrial residuals, its implementation is subject to technological, financial, and administrative challenges. Proactive risk management — including early stakeholder engagement and phased development planning — will be essential to mitigate these risks and ensure regulatory compliance.

8. Conclusion & Recommendations

1. Feasibility Confirmed: Technical, Environmental, and Spatial Assessment

The feasibility study for Pilot 3 (EISAP) confirmed that it is technically and environmentally feasible to establish a closed-loop Recirculating Aquaculture System (RAS) integrated with greenhouse production and industrial symbiosis in the former oil shale mining area near the Auvere Power Plant. The selected site offers sufficient access to industrial residuals (heat, CO_2, and technical water), favourable water conditions (notably in the Mustajõgi and Narva rivers), and partial infrastructural readiness. Among the production models analysed, only RAS met the environmental regulations and sustainability thresholds necessary for development in proximity to Natura 2000 zones.

The assessment also demonstrated that RAS-based production can be aligned with national policy goals such as Estonia's "Estonia 2035" strategy and the National Energy and Climate Plan (NECP), while contributing to the EU Green Deal objectives on circular resource use and regional development. From a spatial and infrastructural perspective, a 30-hectare subarea was identified as suitable for implementation, based on topography and integration potential.

2. Selected Option and Its Rationale

While several production alternatives were analysed—including pond-based and cage aquaculture—only land-based RAS provided the necessary control over emissions, resource efficiency, and site compatibility. Its technical complexity is balanced by high adaptability to industrial symbiosis and by-product valorisation.

3. Current Barriers to Implementation

At the same time, the project currently faces a set of critical constraints. These include the uncertain future of the Auvere Power Plant, on which the symbiotic concept depends for heat and CO_2 supply; limited groundwater reserves and the need for advanced treatment infrastructure; as well as institutional and permitting barriers, especially related to Natura 2000 and the site's location within a defence restriction zone. Market-wise, high CAPEX requirements and competition from established producers pose additional risks, especially in the absence of guaranteed offtake agreements or subsidies for initial investments.

4. Transferability Beyond Estonia

These findings are highly contextual but carry broader relevance. The EISAP case exemplifies the potential and challenges of implementing a circular agro-industrial model in peripheral industrial regions with access to energy by-products. However, the model's transferability to other regions depends on access to similar flows of residual energy, regulatory acceptance of industrial symbiosis, and clear governance structures. In that sense, the approach is more replicable in post-industrial or energy-transition zones than in agricultural heartlands.

5. Key Lessons Learned for TETRAS

For the TETRAS project, the EISAP pilot offers key lessons. First, early-stage integration between spatial planning, industrial actors, and licensing bodies is crucial to reduce procedural bottlenecks. Second, the viability of symbiosis-based aquaculture hinges on securing long-term utility flows—such as waste heat and CO_2—which are often dependent on third-party energy providers. Third, RAS systems require cross-sectoral governance reforms, capacity-building for regulators, and targeted workforce development to address skill gaps and ensure operability in remote regions.

6. Future Perspectives and Conditional Opportunities

Although currently on hold, the project retains long-term potential. Should the Auvere plant undergo transition to biomass or alternative low-carbon fuels, the utility streams could remain viable. Alternatively, modular RAS deployment on the identified 30-hectare plot may be pursued in phases, starting with components that do not rely on external heat or CO_2. Such pathways could serve as stepping stones toward gradual implementation or repurposing under updated market and policy conditions.

9. Recommendations

1. Regulatory Recommendations

The implementation of a symbiosis-based RAS agro-park such as EISAP revealed several regulatory challenges that require targeted policy and administrative improvements. In particular, the intersection of environmental, aquaculture, construction, and land-use regulations presents procedural complexity that can delay or obstruct investment-ready projects, especially in non-traditional industrial locations.

First, the integration of circular economy principles and industrial symbiosis into environmental permitting processes remains underdeveloped. Although EU and Estonian strategies encourage resource efficiency and reuse, current permit regimes (e.g. for emissions, water abstraction, and wastewater discharge) evaluate each activity in isolation, without accounting for the cumulative benefits of integrated systems. Policymakers are encouraged to develop *bundled or system-level permitting frameworks* for agro-industrial clusters where waste heat, CO_2, and treated water are reused across sectors.

Second, the licensing of Recirculating Aquaculture Systems (RAS) remains a highly specialized and time-consuming process, involving multiple authorities, including those responsible for food safety, veterinary control, spatial planning, and environmental protection. To address this, Estonia should consider introducing **specific RAS guidelines**—similar to those developed in Denmark or Germany—that provide clear technical standards and shorten review times through pre-approved system typologies or model designs.

Third, project sites that overlap with **Natura 2000** or **defence restriction zones**, such as the EISAP location, require more **predictable and risk-sensitive screening procedures**. While conservation and security objectives are valid, the current legal uncertainty around such zones hinders planning and discourages investment. A clearer early-warning system and proactive zoning updates could mitigate such risks without compromising regulatory integrity.

Finally, cross-sectoral cooperation between ministries (e.g. climate, agriculture, defence, economy) needs to be institutionalized in early-stage planning for strategic projects. EISAP has demonstrated that permitting bottlenecks often stem from unclear administrative coordination, not substantive objections.

Key recommendation: Estonia and other TETRAS countries should create *inter-ministerial working groups on circular agro-industrial development*, coupled with one-stop-shop regulatory units to support integrated projects that combine aquaculture, greenhouse agriculture, and industrial by-product reuse.

2. Technical & Infrastructure Recommendations

The feasibility analysis of the EISAP pilot highlights several critical technical and infrastructural considerations that should inform future planning and implementation of industrial symbiosis agroparks, particularly those involving RAS technology.

First, **site selection** must prioritise not only land availability but also **surface characteristics, water access, and integration potential**. In the case of EISAP, only a 30-hectare flat area within a larger quarry zone was found suitable for development due to topographical irregularities, unstable ground, and ongoing mining activities. Future projects should include early-stage **geotechnical surveys and hydrological assessments** to avoid costly reengineering and delays.

Second, RAS installations depend heavily on **stable, high-quality water supply**. In regions with limited groundwater reserves and biologically loaded surface water—such as near Narva River—advanced water treatment becomes a prerequisite. **Integrated filtration, UV disinfection, and biosecurity infrastructure** should be treated as core CAPEX elements, not optional add-ons. Moreover, hybrid water sourcing (combining treated surface water with backup wells) provides resilience and reduces ecological risk.

Third, the symbiotic use of **residual energy** (heat and CO_2) from nearby industrial operations offers substantial efficiency gains but requires **precise thermohydraulic design**. Temperature management in fish tanks is critical, and fluctuations in waste heat supply may impair biological performance. Projects should include **thermal storage systems or smart energy balancing technologies** to ensure consistency in thermal conditions, even when industrial flows are intermittent or seasonal.

Fourth, **connectivity infrastructure** (roads, logistics, pipelines) must be considered from the outset. In EISAP, the moderate quality of transport links and the need for new energy and water pipelines added significant cost layers.

Early coordination with utility providers and local governments can optimise routing, avoid duplication, and enable shared-use corridors with other industries.

Finally, digitalisation should be embedded into system architecture from the beginning. RAS operations benefit from **AI-driven monitoring and control systems** for oxygen, pH, temperature, and pathogen risk. Similarly, digital dashboards can visualise symbiotic flows (heat, water, CO_2) in real-time, improving operational efficiency and reporting transparency.

Key recommendation: Technical design teams should be multidisciplinary from the outset, involving **aquaculture engineers, water treatment specialists, energy system designers, and digital monitoring experts** to ensure fully integrated system performance under real-world conditions.

3. Governance & Institutional Recommendations

The EISAP pilot demonstrates that the success of complex agro-industrial systems depends not only on technical feasibility or environmental compliance but equally on **governance architecture**, institutional alignment, and partnership models. In the absence of coherent cross-sectoral coordination, even well-designed projects can stall.

First, **inter-agency fragmentation** poses a major barrier. In the EISAP case, permitting processes involved separate procedures across environmental, spatial planning, food safety, aquaculture, and defence sectors, with limited coordination. This underscores the need for **integrated governance frameworks** that allow joint planning and parallel processing of permits under a unified timeline. Ideally, a **project-specific steering mechanism** or task force should be established early, combining national, regional, and sectoral actors.

Second, the concept of **industrial symbiosis**—central to EISAP—still lacks formal recognition in many national governance frameworks. Without a dedicated policy domain or regulatory recognition, projects that reuse CO_2, waste heat, or treated wastewater remain administratively "invisible" or treated as exceptions. Governments should work towards **institutionalising industrial symbiosis as a horizontal policy area**, with designated contact points and enabling provisions (e.g. legal status of by-product flows, exemption rules for internal exchanges between co-located operators).

Third, **public-private collaboration mechanisms** need to be formalised beyond ad-hoc cooperation. Large-scale agro-industrial projects require long-term engagement between municipal authorities, energy providers, landowners, investors, and environmental regulators. EISAP showed the value of early engagement with mining and energy operators, but lacked institutionalised channels for continuous co-design and dispute resolution. Establishing **local governance platforms**—such as agropark development agencies or symbiosis clusters—could help coordinate actors, align incentives, and manage risks dynamically.

Fourth, **capacity-building for local authorities and permitting bodies** is essential. RAS and industrial symbiosis are still emerging fields in most countries, and permitting officers often lack experience in evaluating such projects. This results in longer processing times, risk aversion, and overly strict interpretations of vague provisions. National administrations and TETRAS partners should develop **training programmes, knowledge-sharing tools, and regulatory handbooks** to support institutional learning.

Key recommendation: Establish *dedicated governance models for agro-industrial symbiosis zones*, including formal recognition of symbiotic flows, inter-ministerial coordination platforms, and local development entities empowered to manage multi-stakeholder processes.

4. Market & Investment Recommendations

The EISAP pilot reveals that technical and regulatory readiness alone are insufficient to ensure project viability—**market positioning and financial structuring** are equally critical. Agro-industrial symbiosis models such as EISAP must be designed with clear commercial logic and realistic financing pathways from the outset.

First, **market differentiation** is essential. The premium cost structure of RAS and greenhouse production, especially when combined with advanced treatment and symbiosis infrastructure, requires access to **high-value customer segments**. EISAP identified opportunities in the HoReCa sector, organic retailers, and export markets in the Nordic region. However, early engagement with potential buyers and the development of a **distinct sustainability brand** are necessary to justify higher price points. Certification schemes (e.g., organic, carbon-neutral, traceability) can support this differentiation.

Second, **offtake agreements** should be explored in advance. The lack of long-term sales contracts increases investment risk, especially in capital-intensive RAS projects. Strategic partnerships with retail chains, food processors, or institutional buyers (e.g., public catering under green procurement rules) can provide predictable revenue streams and enhance bankability.

Third, **blended financing models** are needed. The EISAP business plan relied heavily on public funding sources such as the EU Green Deal and Just Transition Fund, which remain essential. However, to attract private capital, project developers must structure **risk-sharing mechanisms**: e.g., subordinated loans, guarantees, or co-investment platforms that de-risk early stages. Public-private partnerships (PPPs) or special-purpose vehicles (SPVs) can facilitate this.

Fourth, **cost transparency and benchmarking** are important to gain investor confidence. High CAPEX levels—estimated at €48 million in EISAP—can discourage conventional investors. To address this, projects should present **detailed cost breakdowns**, lifecycle models, and sensitivity analyses, drawing on best practices and reference cases from similar implementations across Europe.

Fifth, logistics and location-based cost factors must be integrated into the market strategy. In EISAP, the **remoteness of the site** from major distribution hubs adds cost layers. Mitigation strategies include investment in cold-chain logistics, clustering with other producers to pool transport, and leveraging export corridors through ports or rail.

Key recommendation: Integrate *market access planning and financial structuring from the earliest project stages*, including brand strategy, offtake agreements, blended financing, and cost benchmarking, to increase investor confidence and commercial viability.

5. Recommendations for Future Pilots and TETRAS Uptake

The EISAP pilot delivers valuable strategic insights for other regions and TETRAS partners considering the implementation of Recirculating Aquaculture Systems (RAS) and industrial symbiosis models. While the concept holds promise, its realisation requires careful adaptation to **local conditions, administrative capacity, and economic context**.

First, early-stage feasibility assessments must include **multi-dimensional risk analysis**, beyond technical viability. In EISAP, latent risks—such as dependency on a single energy supplier, Natura 2000-related restrictions, and defence zone conflicts—were identified too late to adjust the original concept without major redesign. Future pilots should apply **integrated feasibility frameworks** that assess regulatory, infrastructural, spatial, hydrological, and institutional constraints from the outset.

Second, **RAS technology** presents a high-potential yet high-risk profile. It is suitable only in regions with access to stable and treatable water sources, affordable energy, and proximity to premium markets. TETRAS partners should consider RAS only in **post-industrial or urban-peripheral zones** where symbiotic flows (heat, CO_2) are realistically accessible, and where regulatory readiness exists or can be developed in parallel.

Third, **scalability must be modular and flexible**. EISAP's full-scale implementation was blocked, but the concept could have evolved through **phased development**—starting with a greenhouse-only model, testing water treatment technologies, or deploying smaller pilot RAS units. Other pilots should consider such modular deployment models to de-risk investment and maintain project momentum.

Fourth, administrative learning is key. Most barriers encountered in EISAP were not due to active opposition but to **lack of preparedness among permitting authorities**, especially in evaluating integrated systems and assessing cumulative impacts. TETRAS should prioritise **knowledge transfer and regulatory training** as part of its capacity-building package, including handbooks, case studies, and site visits across the pilot network.

Fifth, **cross-pilot dialogue** should be institutionalised. Each pilot operates in a specific legal and spatial context, but the underlying systemic challenges (e.g. fragmented governance, investment gaps, regulatory silos) are often shared. The TETRAS project should support structured exchanges between pilots—e.g., through joint workshops, peer reviews, and common benchmarking indicators.

Key recommendation: Future TETRAS pilots should adopt *phased, context-sensitive, and cross-learning-oriented strategies*, combining integrated feasibility, modular implementation, administrative training, and interregional coordination.

10. Summary

The EISAP pilot underscores that the transition to circular, symbiosis-based agro-industrial systems requires not only technical innovation, but also enabling regulatory frameworks, tailored infrastructure design, multi-level governance, strategic market planning, and a readiness to learn and adapt. While the project did not proceed to implementation, it offers a comprehensive reference case for both the opportunities and systemic obstacles associated with RAS deployment in post-industrial settings.

The recommendations derived from this pilot aim to guide future initiatives—within Estonia and across the TETRAS partnership—toward more resilient, scalable, and policy-aligned approaches. By integrating spatial, regulatory, technical, and financial planning from the earliest stages, and fostering collaboration among stakeholders, future pilots can better anticipate risks and seize the transformative potential of industrial symbiosis for regional sustainability.