ARCTIC FOOD ARENA

Description of potential value chains and symbiosis models

- Greenhouse
- Insect farming
- Aquaponic farming
- RAS shrimp farming
- Other waste stream possibilities
- Food processing

Macklean & Co Consulting AB, September 2025

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

Content

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

Introduction, overview

Selection criteria for value chains

This report focuses on the value chains of hydroponics, insect farming, aquaculture, and RAS shrimp farming. These areas were selected based on four key factors.

- First, the specific cases studied within each value chain demonstrate a high technology readiness level (TRL), indicating that the solutions are relatively mature and suitable for practical implementation.
- Second, the selected cases are all established or under development in Sweden, making them directly relevant in a national context.
- Third, all three value chains have the potential to benefit from the use of waste heat from other industries, contributing to resource efficiency and circular economy solutions.
- Finally, these value chains are well suited to the Nordic environment, where factors such as climate, infrastructure, and access to renewable energy create favorable conditions for their development.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

Methodolodgy and context

1.1

Description of value chains

Goal:
Comprehensive yet informative descriptions of each of the selected value chains and all its parts. Identifying the needs in each part.

- **Greenhouse**
- **Insect**
- **Fish**

→ **Set structure**

Set a **common structure** for the presentation of the three value chains

→ **Desktop analysis, case studies**

Conduct **desktop analysis and study relevant cases** to describe the different parts of each value chain.

→ **Interviews**

Conduct interviews with relevant actors within each value chain to complement the desktop analysis and to identify the needs in each of the value chain and its parts.

→ **Description of value chains**

Compilation of the collected information into a **report**, based on the set structure

1.2

Symbiosis potential

Goal:
Identify areas for collaborative symbiosis

→ **Analysis**

Map **overlapping processes** for the respective parts of the value chains to **identify areas with potential for symbiosis.** Use available tools if relevant.

→ **Report**

Summary and compilation to **report.**

This **Value chain description** is part of the work stream Solution Area 1 in the development of Arctic Food Arena. Based on the descriptions and analysis the symbiosis potentials will be identified as a next step.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Overview of chosen value chains

1. Greenhouse **Regenergy Frövi**	Preparations	Production	Distribution	Customer	Future plans
2. Insects **Tebrito and others**	Preparations	Production Meal worms Black soldier flies	Distribution	Customer Meal worms Black soldier flies Frass	Future plans
3. Aquaponics **Johannas Stadsodlingar** **RAS farming**	Preparations	Production Produce Fish	Distribution	Customer	Future plans

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Overview of chosen value chains

1. Greenhouse - Regenergy Frövi

Introduction

Regenergy Frövi greenhouse is an industrial project located in Frövi, Lindesberg, utilizing waste heat from the nearby Billerud papermill for tomato production. Covering an area of 100,000 square meters (10 HA), the facility is designed for year-round production. Its anticipated annual output is 8,000 tons, accounting for around 10% of Sweden's annual tomato consumption.

Since becoming operational in May 2024, the greenhouse contributes to reducing Sweden's reliance on imported tomatoes, which currently make up over 80% of the country's supply. The facility also adopts sustainable practices, minimizing environmental impact using hydroponic systems, which require up to 90% less water than traditional farming methods, and by avoiding fossil fuel-based heating.

The project was initiated in 2020, with WA3RM leading the planning, financing, and regulatory approval processes in collaboration with several stakeholders. Lindesberg municipality was involved throughout the project, particularly in the infrastructure setup.

Lindes Energi provides the renewable energy required for the facility's electrical systems. Regenergy owns the greenhouse, while FoodVentures rents and operates it. FoodVentures is a company specializing in greenhouse operations and manages the greenhouse using Controlled Environment Agriculture (CEA) techniques. The producer organization Odlarlaget handles the selling and marketing activities.

Sources: WA3RM, Billerud, FoodVentures, EQT foundation, Mississippi state university, desktop

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Greenhouse - Regenergy Frövi

Preparations → Production → Distribution → Customer → Future plans

Preparations

Energy infrastructure setup
One of the initial steps in establishing the greenhouse in Frövi was the setup of the energy infrastructure system that utilized heat from the Billerud papermill. It included assessments, designing, engineering, development, testing, operational integration, ensuring efficient energy transfer and system performance.

Construction process
The construction process of the Frövi greenhouse started in 2022. WA3RM managed permits and design while KUBO coordinated the construction.

Technology setup
The planning and installation of the Controlled Environment Agriculture (CEA) systems, included climate control, hydroponic systems and an advanced lighting setup.

Operational planning
The operational planning involved stakeholder alignment, efficient design collaboration, regulatory compliance and infrastructure coordination. The project also included staff training.

Production

Cultivation
The growing of tomatoes include using hydroponics techniques within the greenhouse, optimizing water use and nutrient delivery through precision irrigation systems. The plant is operated by FoodVentures who also implement biological pest control, natural pollination, and zero pesticide residue to maintain high food safety standards and promote sustainability.

Harvesting
The harvesting process for indeterminate tomato plants involves continuous monitoring for ripeness, assessing color, size, and firmness. Workers use rail-guided wagons to access and gather the ripe tomatoes, leaving others to mature on the vine. After collection, tomatoes are sorted, with the defective ones removed. The approved ones are packaged in food safe trays and placed in cold storage for same-day delivery.

Distribution

Logistics and transportation
The logistics for Frövi Greenhouse tomatoes include route planning by Odlarlaget, using temperature-controlled trucks for daily distribution, and transporting produce primarily to their Helsingborg center or directly to customers. Temperature is monitored throughout transit to maintain the cold chain, ensuring freshness during delivery.

Customer

Sales and marketing
Frövi Greenhouse targets the Swedish market, focusing on the demand for Swedish grown, sustainable produce. Tomatoes are sold through the Swedish retail chains Ica and Coop in the whole country, with Odlarlaget handling the marketing and sales activities. Odlarlaget supports with marketing activities such as social media and campaigns while the stores handle the in-store information.

Future plans

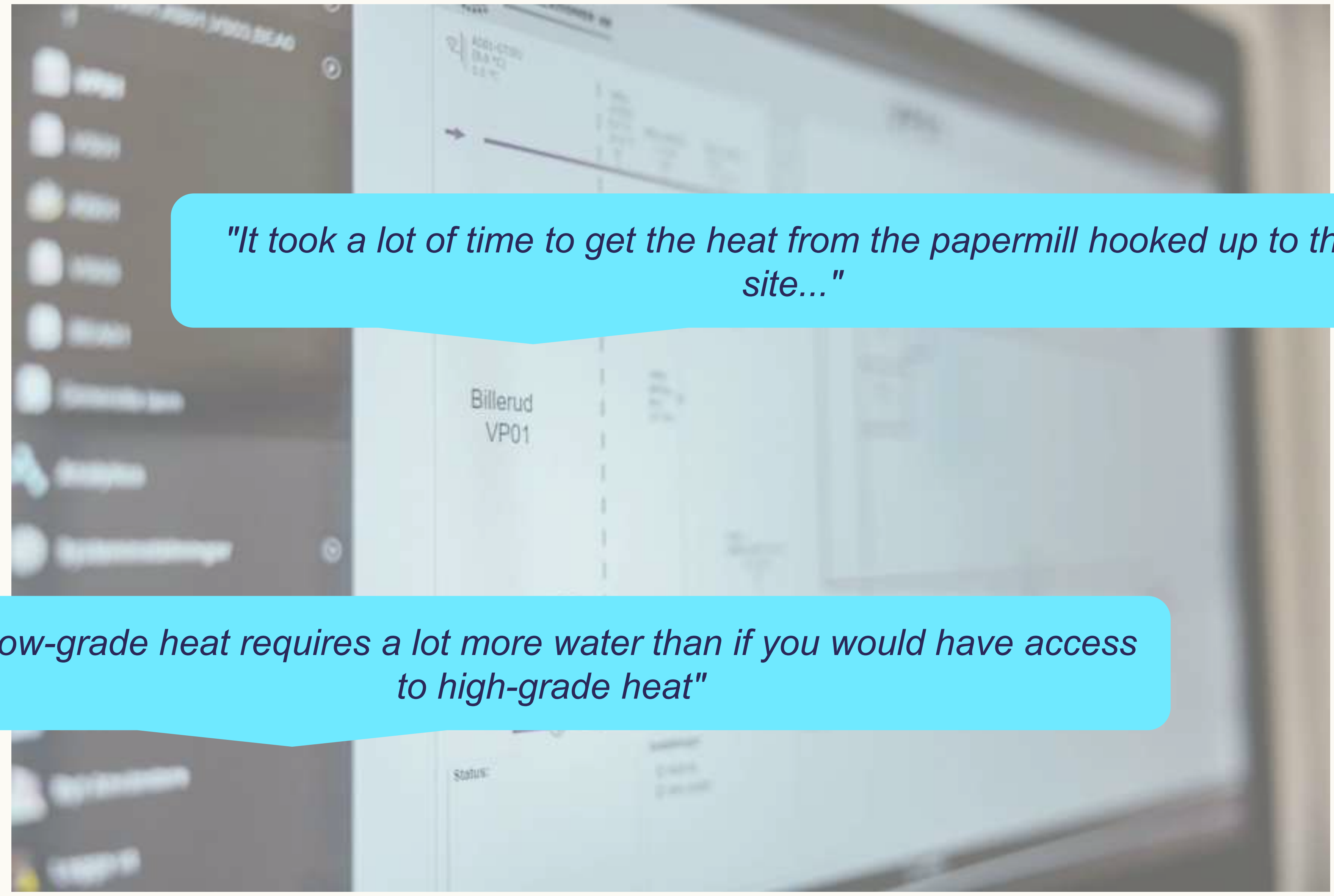
New greenhouses and choice of crops
WA3RM selects crops based on market demand and yield, favoring tomatoes, cucumbers and peppers for their high output. Cucumbers yield 170-220 kg/m², while tomatoes yield 80 kg/m². Exotic crops like avocados are less feasible due to low yields, despite the higher price.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

1. Energy infrastructure setup

- **Assessment and planning**
  - The process started with an assessment of the energy resources at the Billerud papermill. Engineers evaluated the quantity and consistency of low-grade waste heat produced by the factory to determine if it meets the greenhouse's year-round energy requirements. After assessment, an agreement of temperature of acquisition (45-55°C) and temperature of return (25°C) was established for the waste heat, with Billerud guaranteeing a certain megawatt effect. With low grade heat the greenhouse requires a larger amount of heated water than if it would have access high grade heat.
- **Design and engineering**
  - After the assessment, the design phase focused on creating a system to capture and transfer the waste heat. Engineers designed a closed-loop system with heat exchangers to capture the heat, insulated pipelines for transport, and pumps to regulate flow.
- **Infrastructure development**
  - The infrastructure development phase involved building the heat exchangers at the factory to capture waste heat and installing insulated pipelines to transport it to the greenhouse. Linde Energi contributed with planning for peak and reserve energy capacity as well as backup heating systems in collaboration with the company FVB.
- **Connection and testing**
  - Once the infrastructure was in place, the system was connected to the greenhouse's internal climate control system. Testing and calibration was conducted to ensure that the system operates efficiently and meets the required performance standards.
- **Operational integration**
  - The system is equipped with automated controls that monitor temperature, flow rates, and overall system performance. These controls allow for remote management of the system, enabling quick adjustments in responses to changes in heat availability or weather conditions.
- **Continuous optimization**
  - Continuous monitoring and data analysis are conducted to identify areas for improvement. This ongoing optimization process may involve adjusting flow rates, upgrading insulation or fine-tuning control systems to maximize energy efficiency.



Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

2. Construction process

- **Project planning and permitting**
  - The construction process of Frövi greenhouse began in 2021 with WA3RM hiring PE Teknik & Arkitektur to handle necessary permits and contributed to the design of the greenhouse. This included the greenhouses architectural design, VVS system design and accessibility planning. PE Teknik & Arkitektur also played a crucial role in explaining Swedish permitting laws and weather conditions to the Dutch construction companies.
- **Construction of the greenhouse**
  - The coordination of the greenhouse infrastructure was primarily managed by KUBO, a Dutch construction company and partner of WA3RM, focusing on aspects related to the greenhouse itself. However, the overall project development and planning for the Frövi symbiosis project were led by WA3RM. A Swedish construction company coordinated the rest of the construction activities.
- **Installation of electricity and other technological systems**
  - Eitech was hired to take care of the technical system planning and the installation of electricity throughout the greenhouse.
- **Installation of growing systems**
  - During the preparations and constructions of the greenhouse, FoodVentures initiated planning and hiring of staff. Once the greenhouse was finished, FoodVentures provided expertise, plants, bumblebees, nutrient solution and other necessary resources to operate aquaponic tomato production.

"In the Netherlands, the ground is made of dirt while in Sweden it is rock, which is significantly different to construct on top of. We had to develop new methods of building the foundation of the greenhouse to account for these differences".

Greenhouse – Regenergy Frövi

2. Technological setup

- **Assessment and planning**
  - The process began with a comprehensive assessment of the greenhouse's technological needs. This involved a technology needs analysis to evaluate requirements for climate control, lighting, irrigation, and crop management. A feasibility study followed, assessing the costs, energy efficiency, and environmental impacts of potential systems.
- **Design and engineering**
  - Once the needs were identified, the next phase was the design and engineering of the greenhouse's core systems; climate control, irrigation and lighting systems.
- **Infrastructure development**
  - Climate control systems, including HVAC (heating, ventilation and air circulation) and CO2 systems, were installed, with ductwork, vents and automated controls. Hydroponic systems were implemented with plumbing, pumps, and sensors to efficiently manage water and nutrient delivery. The LED lighting installation completes the setup, extending growing seasons by simulating natural daylight cycles during periods of low natural light.
- **System integration and testing**
  - After the physical infrastructure was in place, the various systems were integrated and tested to ensure they work as intended. System integration involved connecting all technological components - climate control, irrigation, and lighting - into a centralized control system that allows for unified management of the greenhouse environment. This is followed by testing and calibration.
- **Continuous monitoring and optimization**

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

Preparations | Production | Distribution | Customer | Future plans

3. Operational planning

- **Stakeholder alignment and objective setting**
  - The first step in the operational planning for the Frövi greenhouse project was aligning stakeholders and setting clear objectives. This involves gathering all key parties - WA3RM, FoodVentures, Lindesberg municipality, Linde Energi, Region Örebro, Odlarlaget and investors - to establish a unified vision. Initial meetings focus on discussing overall goals, such as production targets, sustainability objectives, and community impact. The company Regenergy was set up as the greenhouse owners, now responsible for renting out the facility to FoodVentures.
- **Greenhouse design collaboration**
  - After aligning stakeholders, the next step was collaborating on the greenhouse design. Architects, engineers, and agricultural experts from FoodVentures worked to develop a layout that maximizes space, integrates technologies, and supports efficient production. Key considerations included the placement of hydroponic systems, climate control installations, and lighting setups. Input from relevant stakeholders was necessary for effectively incorporating residual heat from the Billerud factory into the greenhouse's heating and cooling systems. Ground conditions also needs to be taken into consideration when designing and calculating cost for greenhouse establishment.
- **Sustainable agricultural practice planning**
  - In collaboration with FoodVentures, strategies were developed to minimize water use, optimize nutrient delivery, and reduce the environmental impact. This includes the implementation of hydroponic systems, biological pest control, LED lighting, etc. The life span of an industrial greenhouse is estimated to be 20 years.
- **Regulatory compliance and permitting**
  - This involved working closely with Lindesberg municipality to navigate zoning laws, environmental impact assessments, and building codes. Key considerations for Frövi was access to water, renewable energy and heat. Securing necessary permits is essential before construction can begin.
- **Infrastructure and utility coordination**
  - With the design and regulatory frameworks in place, the focus shifted to coordinating essential infrastructure and utilities. This involves collaboration with Linde Energi to establish a reliable energy supply. Additionally, partnerships with local utility providers ensured the availability of water, electricity, waste management services, and the construction of logistic infrastructure such as roads connected to highways.
- **Operational training and handover**
  - A part of the setup and continued operation of the greenhouse required preparation of different operational teams. Staff training was conducted to equip the greenhouse staff with the knowledge and skills necessary to harvest and store the tomatoes as well as to operate and maintain the systems. The first year of production was estimated to produce less because of the staff learning period.

"The municipality was involved in the entire project,... especially in discussions revolving around permits and logistics"

Sources: WA3RM, FoodVentures, Billerud,

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

Preparations | Production | Distribution | Customer | Future plans

1. Cultivation

- **Preparation of nutrient solution**
  - Cultivation at the Frövi greenhouse starts with preparing a nutrient solution containing primary macronutrients, secondary nutrients, and micronutrients. This solution, free of soil, provides essential minerals and nutrients in a controlled environment, ensuring consistent and optimal plant growth.
- **Planting**
  - Frövi greenhouse utilize two different tomato plants for production; Provine and Prunaxx. These are all so called *indeterminate* plants which means that they continually produce fruit until killed by over-production or external causes. Tomato seedlings are planted in substrate consisting of coconut fiber, which support root growth while allowing the nutrient solution to reach the roots effectively.
- **Nutrient delivery**
  - The nutrient solution is delivered to the plants through a drip irrigation system that provides precise amounts of water and nutrients directly to the roots of each individual plant.
- **Environmental control**
  - Advanced climate control technologies manage temperature, humidity, CO_2 levels, airflow and light in the greenhouse. The temperature is kept at 20-25°C during the day and 18 °C during the night. Natural pest control in the form of ladybugs is also utilized.
- **Monitoring and maintenance**
  - The tomato plants are allowed to grow for 6-8 weeks before fruiting is forcibly initiated by cutting the growing tip, after which the plant produces fruit for up to 41 weeks. Plants are continuously monitored for growth and potential issues such as nutrient deficiencies or pests. Pruning removes excess leaves to direct the plant's energy toward favorable growth or fruit production, while training (tying plants to supports) promotes organized growth, enhances light penetration and air circulation.

- **Pollination**
  - Bumblebees are used for natural pollination, ensuring a high rate of fruit set. This method supports plant health and aligns with the greenhouse's sustainability goals.
- **Sustainability practices**
  - The sustainability practices of the Regenergy Greenhouse in Frövi are tied to previously mentioned aspects of the greenhouse production:
    - Efficient water use:
      An inherent feature of hydroponic systems is the reduction of water usage by up to 90% compared to traditional farming.
    - Energy conservation and recycling:
      The utilization of residual heat from the Billerud papermill in combination with energy efficient LED lighting results in more energy conservation.
    - Waste reduction and recycling:
      Waste in the form of pruned leaves, stalks, spent tomato plants and defect tomatoes is sent to local farmers and other companies to be used for compost.

Sources FoodVentures, Mississippi State University

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

2. Harvesting process

Since this type of indeterminate tomato plants continually produces fruit, an overarching goal is to harvest as uniformly as possible. Before harvesting, tomatoes are monitored for ripeness, focusing on color, size and firmness using visual checks. Ripe tomatoes are harvested while the others are left on the vine to mature.

The harvesting process is conducted by utilizing wagons running on rail between the rows of tomato plants allowing workers to reach high growing tomatoes and then easily transport them to an off-loading area.

Once off-loaded, the tomatoes are sorted and tomatoes with defects are removed. Approved tomatoes are then packaged in food-safe trays and moved into cold storage in preparation for distribution the same day.

Greenhouse – Regenergy Frövi

Preparations | Production | **Distribution** | Customer | Future plans

- **Route planning and transportation**
  - Odlarlaget is responsible for planning optimal distribution routes of the tomatoes produced at the Frövi Greenhouse. Odlarlaget have their own distribution center and can ship directly to the customers own distribution center if this is agreed in advance. Odlarlaget generally strives to minimize travel time for all produce sold by them.
- **Loading onto temperature-controlled vehicles**
  - The packed tomatoes are loaded onto refrigerated trucks to maintain the cold chain. These vehicles keep the tomatoes at a consistent temperature throughout the journey. The greenhouse in Frövi needs two to four trucks for tomato distribution each day and one truck for transportation of biowaste once a week.
- **Distribution to distribution centers, wholesalers, or retailers**
  - The majority of the harvested tomatoes are first transported to Odlarlagets own distribution center in Helsingborg and then shipped to retail customers. Depending on previous agreements, Odlarlaget may ship tomatoes directly from the Frövi Greenhose to their customers own distribution centers. Upon arrival at distribution centers the tomatoes are unloaded and prepared for distribution to predetermined retail stores.
- **Monitoring and adjustments**
  - Temperature is continuously monitored during transport. Any deviations corrected to maintain the cold chain.

"There are a lot of trucks delivering to the north and driving back south empty. A greenhouse in Gällivare could utilize this"

"With a new production location in the north it will make sense to have another distribution center close by. This new distribution center could facilitate export to stores in Norway or Finland."

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

Preparations | Production | Distribution | **Customer** | Future plans

- **Identify target market**
  - Market positioning for Frövi greenhouse tomatoes begins with identifying the target market. WA3RM utilized public production data to analyze Sweden's import, export and consumption of tomatoes and found that there is a big gap between production and consumption of tomatoes. Then they analyzed the Swedish population as consumers and found that Swedish people care about locally grown and sustainably produced food.
- **Selling to customers**
  - Tomatoes produced in the Frövi greenhouse are sold to Swedish retail chains with the help of Odlarlaget. The company negotiate pricing, distribution options and are responsible for the customer contacts. Odlarlaget is a cooperative and therefore tries to ensure that their members products compete with imported products rather that their own domestic production.
- **Retail partners**
  - Through Odlarlaget, the tomatoes are sold to Ica and Coop. As of now, Frövi greenhouse tomatoes are sold in stores throughout the country.
- **Marketing and promotion**
  - Odlarlaget support the producers with marketing activities such as planning of marketing campaigns, information & sales material, social media activities and in-store campaigns. Odlarlaget also utilize their own social media to promote their members. Once Frövi tomatoes are in the stores, the stores are responsible for in-store promotion.

"In the planning phase, explored what kind of labels (märkningar) we could get and which ones we should focus on?"

Regenergy Frövi – Competence requirements

Preparations → Production → Distribution → Customer → Other

Preparations

Planning and permits
- Consultants or engineers with experience in greenhouse and controlled environment agriculture (CEA).
- Legal or environmental advisors for land use, construction permits, and water rights.
- Agronomists or horticultural experts for crop planning and system design.

Technical design and construction
- Engineers or technical planners for climate control, irrigation, and lighting systems.
- Installation specialists for hydroponic systems.
- General contractors experienced with greenhouse construction.

Production

Crop management
- Horticulturists or agronomists with expertise in hydroponic crops.
- Plant health specialists for nutrient balancing, disease control, and pest management

System operation and maintenance
- Technicians for daily operation and maintenance of pumps, irrigation, and climate control
- Staff trained in monitoring pH, EC, and nutrient levels
- Data monitoring personnel for managing yield tracking and environmental conditions

Distribution

Post-harvest handling
- Staff for washing, sorting, and packaging produce.
- Knowledge in post-harvest management to maintain freshness and shelf life.

Logistics and transport
- Logistics coordinators for managing short supply chains.
- Drivers and distributors with cold-chain handling expertise (if necessary).

Customer

Sales and marketing
- Sales staff with knowledge of local food systems, retailers, and restaurants.
- Market strategists to identify customer segments and tailor offerings. (e.g., pesticide-free, local, sustainable)

Branding
- Marketing professionals for storytelling, sustainability communication, and value proposition.

Certifications and standards
- Staff familiar with food safety certifications (e.g., KRAV, EU Organic if applicable)
- Knowledge of procurement requirements from retailers and wholesalers.

Other

R&D
- Data analysts for optimizing yield, resource use, and system performance.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Greenhouse – Regenergy Frövi

Preparations | Production | Distribution | Customer | Future plans

New greenhouses and choice of crops

When building new greenhouses the current market, annual yield of different produce and economic viability is considered when choosing which crop to focus on. While any kind of produce can be produced in greenhouse environment, tomatoes, cucumbers and peppers are the usual choices because of their calculated annual yield and sales price per fruit. Cucumbers, as an example, have an annual yield of 170-220 kg per square meter of crop, with the fluctuation in these numbers' dependent on how well the greenhouse environment is managed for optimal growth. Frövi tomato production have an annual yield of approximately 80 kg per square meter.

Most of the, so called, risk produce such as avocado, cacao, and coffee beans can be cultivated in greenhouse environment since it is adaptable. The problem is that it is challenging to motivate the production of these produces from an economic perspective. Since greenhouses are operational for 20+ years the total cost of construction and operation needs to be covered and exceeded within this timeframe. So, while avocado fruit sells for three times the price of a tomato the estimated yield per year is 1kg per square meter of crop.

Reenergy Frövi has had a production stop since May 2025 due to heating problems and technical shortcomings but also a disagreement between the tenant and the site owner. Appr. 100 workers have been effected.

"You cannot build too many greenhouses that produces the same crop or you will start to compete with yourself"

2. Insect production – Tebrito and others

Introduction

The most common types of insect production are based on mealworms (MW) or black soldier flies (BSF).

Tebrito is a Swedish company that focuses on the sustainable production of protein from mealworms, addressing the growing demand for alternative protein sources in the food and feed industries. The project behind Tebrito started in 2016, driven by the need for more sustainable solutions in agriculture and protein production. Through research and development, Tebrito sought to create a viable process for large-scale mealworm farming, focusing on minimizing environmental impact while maximizing resource efficiency.

By 2020, Tebrito's facility became fully operational, providing a scalable solution for producing proteins, fats, and other by-products from mealworms. The company continued to refine its processes, up until 2024 when they were forced to file for bankruptcy because of lack of additional investments for scale up.

The principles of producing mealworm are still relevant and described in this section.

A description and comparison to the production of black soldier flies is also included to broaden the perspective on insect rearing for animal feed and frass production purposes.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Insect production – Tebrito and others

Preparations | Production | Distribution | Customer | Future plans

Preparations

Technological and infrastructure setup

The setup of the insect production facility involved assessing technological needs, designing rearing and climate systems, developing infrastructure with HVAC and production racks, and integrating systems into a centralized control. Testing and calibration followed, ensuring efficient operations, with continuous monitoring for optimal climate and waste management using local vegetable waste as feed.

Operational planning

Tebrito's mealworm production aimed for large-scale development, initially supported by a Vinnova competition. With investments totaling 60 MSEK, Tebrito collaborated with experts for efficient facility design and ensured compliance with strict food safety regulations. Infrastructure setup involved utility coordination, while continuous system monitoring maintains optimal production conditions.

Production

Cultivation

Tebrito's mealworm cultivation uses grain and vegetable waste trays, maintaining 24-30°C and 50-70% humidity. Regular monitoring controls pests, while cooling balances the heat. A starter colony initiates production, with 5% of worms maturing for sustainable breeding.

Black soldier fly cultivation uses vegetable waste feed in netted, stacked trays. Eggs hatch in warm, humid condition, the larvae grow at 25-35°C. Feeding intervals vary, and larvae are monitored for pests. Some larvae are allowed to mature for breeding sustainability.

Harvesting process

Tebrito's mealworm harvesting involves monitoring for pupation, separating larvae from frass, fasting them, and sorting healthy specimens. Larvae processed and packaged for transport.

Black soldier flies are monitored, separated from frass, sorted, euthanized, processed into protein products or sold whole, then packaged for transport and storage.

Distribution

Logistics and transportation

Insect logistics at Tebrito involves planning efficient routes, using temperature-controlled vehicles for unprocessed or frozen insects, and ensuring dried products maintain low moisture. Packaged insects are transported to distribution centers or customers, with continuous temperature monitoring to preserve quality and prevent gas buildup.

Customer

Sales and marketing

Different insect products are more or less suitable different application areas i.e. BSF protein for animal feed, dehydrated mealworms for human and pet food. Although, frass products required additional marketing efforts.

Mealworms provide protein for human, pet, and animal consumption, with high demand in the pet food industry. Extracted fat is used for animal feed or bio-diesel. Chitin, from their exoskeletons, is valuable for industries.

BSF larvae provide protein for animal feed, fat for similar uses as mealworm oil, and chitin for various industrial applications.

Frass, a by-product from insect harvesting, enhances plant growth and re-blooming, boosting yields. Frass can be processed it into pellets for easier use.

Tebrito rely on media exposure and conventions, with minimal marketing investments.

Future plans

Tebrito

Tebrito ceased operations due to insufficient investor support for scaling up. Despite the financial difficulties, the project has contributed to advanced insect rearing and protein extraction research and method development. The owners hope to contribute with knowledge to future insect rearing initiatives in Sweden.

Other insect rearing projects

NovaPro focuses on decentralized insect farming for circular animal feed production, replacing fishmeal and soybeans with insect protein. Farmers use food waste to rear insects, integrating them into animal feed. **Rang-Sells** in collaboration with Feed of the Future to scale insect protein pro-duction from food waste, promoting sustainability and reducing the carbon footprint.

Insects for human consumption

Public opinion in Sweden is divided into eating insects as protein. Many find the appearance and texture of unprocessed mealworms unappealing. Changing this perception is essential for large-scale production.

Insect production – Tebrito and others

Preparations | Production | Distribution | Customer | Future plans

Technological and infrastructure setup

- **Assessment and planning**
  - The process begins with a comprehensive assessment of the insect production facility's technological needs. Key tasks include selecting rearing systems, climate control technologies, quality control processes and waste management solutions. Equipment for feedstock handling, breeding, and processing is planned to ensure efficient operations.
- **Design and engineering**
  - Once the needs are identified, the next phase is the design and engineering of the insect production facility's core systems; Rearing, climate control, waste management systems as well as heating, cooling and ventilation. Placement of quality control and processing machinery is also planned to allow optimal operation.
- **Infrastructure development**
  - Climate control systems, including HVAC are installed, as well as machines for insect rearing and quality control. Logistics solutions for distribution as well as access to insect feed is established, preferably waste streams from local vegetable producers. Production racks, able to stack insect production trays, are constructed with enough vertical spacing to allow air circulation and ease of access.
- **System integration and testing**
  - After the physical infrastructure is in place, various systems are integrated and tested to ensure they work. System integration involves connecting all technological components from the different systems into a centralized control system that allows for unified management of the facility's environment. This is followed by testing and calibration.
- **Continuous monitoring**

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Insect production – Tebrito and others

Preparations | Production | Distribution | Customer | Future plans

Operational planning

- **Stakeholder alignment and objective setting**
  - Since the beginning, Tebrito's main goal has been to facilitate and achieve large scale production of mealworms. In Tebritos case, it started with the participation in a competition in sustainable protein production by Vinnova. Having performed well, Tebrito received 500 TSEK to move their project forward, resulting in further optimization of insect protein refining and insect rearing processes. As the project moved forward discussions regarding the securing of financing, regulatory requirements, partnerships with waste streams and logistics as well as a decision on which part of the market to target were held.
  - The total investments in Tebrito amounts to 60 MSEK. Some of the investors and providers of risk capital are ALMI Invest Norra Mellansverige, Diamond Head AB and Bror and Syster Holding AB.
- **Facility design collaboration**
  - After aligning stakeholders, the next step is collaboration around the production facility's design. Tebrito worked closely with insect farming experts to develop a layout that maximizes space, integrates technologies and support efficient production. Key considerations include the placement of feeding and sorting machines, climate control installations and logistics solutions.
- **Infrastructure and utility coordination**
  - With the design and regulatory frameworks in place, the focus shifts to coordination of infrastructure and utilities. This involves collaboration with energy providers and partnerships with local utility providers to ensure the availability of water, electricity, waste management services and the construction of necessary insect cultivation infrastructure.
- **Regulatory compliance and permitting**
  - This involved ensuring that the facility and processes followed regulations and requirements for food production facilities. Since insect products became legal to utilize for human consumption in Sweden in 2020, regulations regarding food safety were and still are strict. Tebritos facility needed to be sanitized and treated before food production could be initiated. This process included the purchasing of 200 square meters of post-processing surfaces.
- **Operational training and handover**
  - A part of the setup and continued operation of a large-scale insect production facility requires preparation of different operational teams. Staff training is conducted to equip the facility staff with the knowledge and skills necessary to harvest and store the insects as well as to operate and maintain systems and machines.
- **Sustainable practices**
  - Insects can feed on food waste streams from agricultural production and restaurants.
  - mealworms are energy efficient as they produce heat.
  - At Tebrito, a large amount of research and development has been put into the quality assurance to uphold food safety standards and insect rearing efficiency.

"There is no lack of demand, but you have to decide on which market segment you want to deliver to"

Insect production – Tebrito and others

Preparations | **Production** | Distribution | Customer | Future plans

Cultivation

Mealworms

- **Preparing feed and production trays**
  - MW production trays are prepared with a suitable amount of grain for the worms to burrow into and eat. MW can use 0-70% wet feed, i.e. Vegetables, spent brewers grain or broccoli stems, and they can also consume old/moldy produce, acting as a biological filter. In Sweden, it is only allowed to feed the insects vegetable waste streams from pre-consumer situations. This mean you cannot use household food waste or waste that is been in contact with animal products. The trays used to house the insects can easily be stacked vertically.
- **Starting the cultivation process**
  - Preferably, a starting colony of MWs are implanted into the production facility to start production as soon as possible. If no considerable number of mealworms are available, it will take time to grow the colony to a large enough scale.
- **Environmental control**
  - MW produce a significant amount of heat during their growing phase, making cultivation comparably energy efficient. The optimal temperature and air humidity for meal worm growth is between 24-30°C and 50-70% respectively. Because of the heat produced during meal worm production, there is a need for cooling rather than heating. If necessary, the MW growth can be delayed by storing the larvae in temperatures below 11°C, making them dormant with minimal metabolism.
- **Monitoring and maintenance**
  - MWs are fed regularly and continuously monitored for diseases and pests such as mold mites and mill matt.
- **Breeding**
  - During production in Tebritos facility, 5% of the MWs were allowed to mature into full beetles for breeding purposes, and colony sustainability

Black soldier flies

- **Preparing feed and production trays**
  - BSF production trays are prepared with a suitable substrate partly consisting the intended food source. Currently it is only allowed to feed the insects vegetable waste streams from pre-consumer situations. This mean you cannot use household food waste or waste that has been in contact with animal products. The trays used to house the insects can easily be stacked vertically but should be encased in netting to contain flies that have matured.
- **Starting the cultivation process**
  - Adult BSF's lay eggs near or on organic waste. One female can lay 500-900 eggs, and these can be collected in specifically designed traps placed next to waste substrate. Collected eggs are kept in a warm, humid environment and hatch in approximately four days. Once hatched, young larvae are introduced to organic substrate in which the larvae will grow to maturity.
- **Environmental control**
  - BSF have a larger energy requirement than MW as more ventilation is needed. The optimal temperature and humidity for BSF growth is between 25-35°C and 30-60% respectively. If necessary, the BSF larvae growth can be delayed by storing the larvae in temperatures around 11°C.
- **Monitoring and maintenance**
  - Since the larvae lives in the food that they consume, feeding is not always necessary during the growth period. Some methods involve feeding the larvae substrate every 3-7 days depending on the growing facility's rearing process. During this time, the larvae is continuously monitored for diseases and pests.
- **Breeding**
  - During production, a pre-determined number of larvae are allowed to mature into full flies for breeding purposes, and colony sustainability

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Insect production – Tebrito and others

Preparations | **Production** | Distribution | Customer | Future plans

Harvesting process

Mealworms

- **Monitoring**
  - When the growth period of approximately 9 weeks is approaching its end, batches of MWs are monitored for signs of pupation. When the first larvae start to pupate, the harvesting process begins.
- **Harvesting**
  - Harvesting begins with the separation of mealworms from the produced frass. This is done with machines utilizing the different properties of the two products. Examples of sorting machines include utilizing wind to blow the frass off the mealworms into a separate container. Another method is using machines straining the worms from the frass with fine mesh.
- **Pre-processing and quality control**
  - The matured MWs are initially put on a net for 24 hours without access to food to empty their bowels. Before processing, the gathered larvae are sorted by healthiness and quality. The exact process depends on the scale of the production facility. In this process the natural instincts of the larva can be utilized to separate unhealthy from healthy specimen. The larva can be placed on a conveyor belt made of a material that the larva instinctively grabs on to. The conveyor belt then overturns and the unhealth larva automatically fall off while the healthy larva, being able to hold on, is brushed off into a separate container. Healthy larvae aversion to light and heat can also be utilized.
- **Processing/refining**
  - Once harvested, the mealworms are euthanized using steam or blanching which also reduces microbiological load and inactivates enzymes, increasing shelf life. The mealworms can be sold as they are or processed into concentrated insect protein and oil depending on the customer needs. There are processes which yield high quality protein powder.
- **Post-processing**
  - At Tebrito, the worms are frozen using a blast freezer, packaged in 10 kg boxes and then palletized.

Black soldier flies

- **Monitoring**
  - When the growth period of approximately 4-6 weeks is nearing its end, batches of black soldier fly larvae are monitored for beige coloration, commonly called the 5th instar in the BSF life cycle. Once this is done the harvesting process is initiated.
- **Harvesting**
  - Harvesting begins with the separation of black soldier fly larvae from the produced frass. This is done by machines that leverage the different properties of the two products. The most commonly used method involves utilizing a sieve with a mesh of 3-5 mm, letting the frass fall into a separate container. This process can be automated or done manually.
- **Pre-processing**
  - The matured BSF larvae are cleaned and sorted using manual visual checks or automated machines. Healthy larvae appear comparably plump, active and have a uniform color while unhealthy ones are thinner and may be unevenly colored.
- **Processing/Refining**
  - Once harvested, the black soldier fly larvae are euthanized using steam, blanching or freezing. They can either be sold whole, dehydrated or processed into concentrated insect protein and oil, depending on customer requirements. Some processes yield high-quality protein powders suited for various applications such as substitutes in animal feed.
- **Post-processing**
  - Processed or un-processed larvae are packaged and prepared for transportation as well as put into cold chain storage if necessary.

"To compare cultivation of mealworms and black soldier flies is like comparing chicken and pig production. They are both warm blooded animals but still very different."

Insect production – Tebrito and others

Preparations | Production | **Distribution** | Customer | Future plans

Logistics and transportation

- **Route planning and transportation**
  - Routes are planned to minimize travel time. Processed insects are more stable and have a longer shelf life than unprocessed insects. Therefore, it is easier to transport i.e. dehydrated larvae longer distances while untreated insects need cold transport. It is beneficial to have easy access to a local sustainable sources of insect feed such as farms, gardens, etc.
- **Loading onto temperature-controlled vehicles**
  - The packaged insects are loaded into suitable vehicles depending on if processing has been done. Dried or powdered insect products do not need cold chain storage as long as moisture levels are kept below a safe level. Unprocessed insects require cold chain storage below 8°C. At Tebrito, the frozen insects are kept at -18°C during transportation.
- **Distribution to distribution centers, wholesalers or production companies**
  - When the insect products have been properly packaged and loaded onto trucks, they are shipped out to distribution centers or directly to customers depending on previous agreements.
- **Monitoring and adjustment of temperatures**

Insect production – Tebrito and others

Preparations | Production | Distribution | **Customer** | Future plans

"The market demand for mealworms is growing faster than Sweden's current production capacity".

Marketing and selling process

- **Identify target markets**
  - Insects can be used for many purposes. Depending on which insect is produced and how they are processed, different application areas are suitable. For example, refined insect protein and oil from BSF is more suitable as substitute ingredients in other products such as animal feed. Dehydrated MW is more suitable for human consumption and pet food.
- **Partnerships**
  - Tebrito have partnered with companies such as Tetra Pak. If Tebrito had been able to scale up their production, they could have partnered with a larger pet-food producer and provide a predetermined amount of dehydrated MWs at regular intervals. Within the EU Tebrito had a demand of 40 tons of meal worms per month, to which the majority of their production went.

- **Marketing and selling process**
  - In Tebrito's case, most marketing was conducted in the form of media exposure through interviews or attending relevant conventions. No major costs went into the marketing of insect products as most customers approached Tebrito themselves. Frass, on the other hand needed marketing such as product branding since in this application area it competes with other garden nutrient supplements.

Mealworms

- **Protein**
  - The larvae are mostly sold in a dehydrated form and can be utilized for human, pet and animal consumption. The larvae can also be consumed in unprocessed form. Tebrito has found that there is a large demand for Swedish produced insect protein within the pet food industry.
- **Oil**
  - MW contains a substantial amount of fat which is extracted during protein refinement processes. This can be used in animal feed or processed into bio-diesel.
- **Chitin**
  - This is a valuable by-product present in the MW's exoskeleton. In a large-scale production chitin can be extracted and sold for approximately 1000 SEK per kilo to a wide selection of industries such as the cosmetic industry.

BSF

- **Protein**
  - BSF larvae are more suitable for animal feed because of the experienced taste. The larvae is mostly sold in dehydrated form or as insect powder for use as substitute ingredients in animal feed.
- **Oil**
  - BSF larvae contains fat which is extracted during protein refinement processes and has the same application areas as insect oil extracted from MWs.
- **Chitin**
  - This valuable by-product can also be extracted from the BSF larvae and have the same application areas as the chitin extracted from MWs.

Frass

The harvesting of frass is done parallel to the harvesting of insects, since this involves separating the two for individual processing and packaging. For every 1kg of insects, 2kg of frass is produced as a by-product.

- Frass is a plant stimulant and is proven to increase some plants growth rate. The frass also stimulates re-blooming for some plants, making i.e. a strawberry plant producing 30-50% more berries. Tebrito sells frass as supplemental manure to local gardeners.

- Before distribution, the frass may be processed into pellets for later ease of use.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Tebrito and others – Competence requirements

Preparations

Planning and permits
- Regulatory experts for animal feed, food production, and waste handling permits.
- Consultants familiar with food safety standards and risk management.
- Site planners to ensure appropriate zoning, proximity to input streams (e.g. residuals), and biosecurity.

Technical design and construction
- Engineers for climate-controlled systems. (temperature, humidity, ventilation).
- Designers of automated or semi-automated rearing and processing systems.
- Specialists in waste and substrate handling (e.g. pre-treatment of side streams).
- Facility constructors familiar with industrial-scale indoor farming.

Production

Insect biology and rearing
- Entomologists or insect-rearing specialists to optimize growth, breeding, and health.
- Nutritionists for developing optimal feed mixes based on residual streams.

System operation and maintenance
- Technicians to manage machinery for feeding, climate control, and harvesting.
- Operators skilled in monitoring growth cycles, waste-to-feed ratios, and hygiene standards.
- Staff to perform quality control and ensure biosecurity protocols.

Harvesting and processing
- Workers for collection, cleaning, and processing (drying, grinding, oil extraction etc.).
- Specialists in food/feed-grade processing equipment.
- Staff for waste management (frass separation and treatment).

Distribution

Post-harvest handling
- Knowledge of shelf-life management for dried and processed insect products.
- Warehouse and logistics personnel experienced with sensitive materials (e.g. feed, protein powders, oils).

Logistics and transport
- Transport coordinators with knowledge of food/feed safety transport requirements.
- Compliance officers familiar with labelling, traceability, and packaging standards.

Customer

Sales and marketing
- Sales professionals with understanding of B2B sales to feed producers, pet food, agriculture, or food sectors.
- Market developers for positioning novel proteins and byproducts (e.g. oil, frass).

Branding
- Educational outreach staff to help build acceptance in conservative sectors.

Certifications and standards
- Experts on certification schemes for feed, food, organic inputs or novel foods (e.g. EU Novel Food Regulation).
- Staff to manage documentation for audits and traceability.

Other

R&D
- Researchers working on refining rearing cycles, feedstock efficiency, or frass applications
- Product developers for new applications of insect products (e.g. functional food, pet nutrition)

Business development and partnerships
- Business developers for partnerships with food companies, farms, and feed mills.
- Financial analysts to model cost structures and returns in a niche but growing market.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Insect production – Tebrito and others

Tebrito
- The company is now out of business. Due to lack of investors willing to provide capital for upscaling efforts, the insect rearing operation conducted by Tebrito did not become financially sustainable. Since insect rearing is relatively new in Sweden, a lot of resources went into research and development of efficient rearing and protein extraction methods. The founder of Tebrito has now acquired all knowledge material and patented designs that was developed during the company's operation. The founder hope that the knowledge generated throughout the project will not be lost and that they can contribute to future insect rearing projects.

Other insect rearing projects

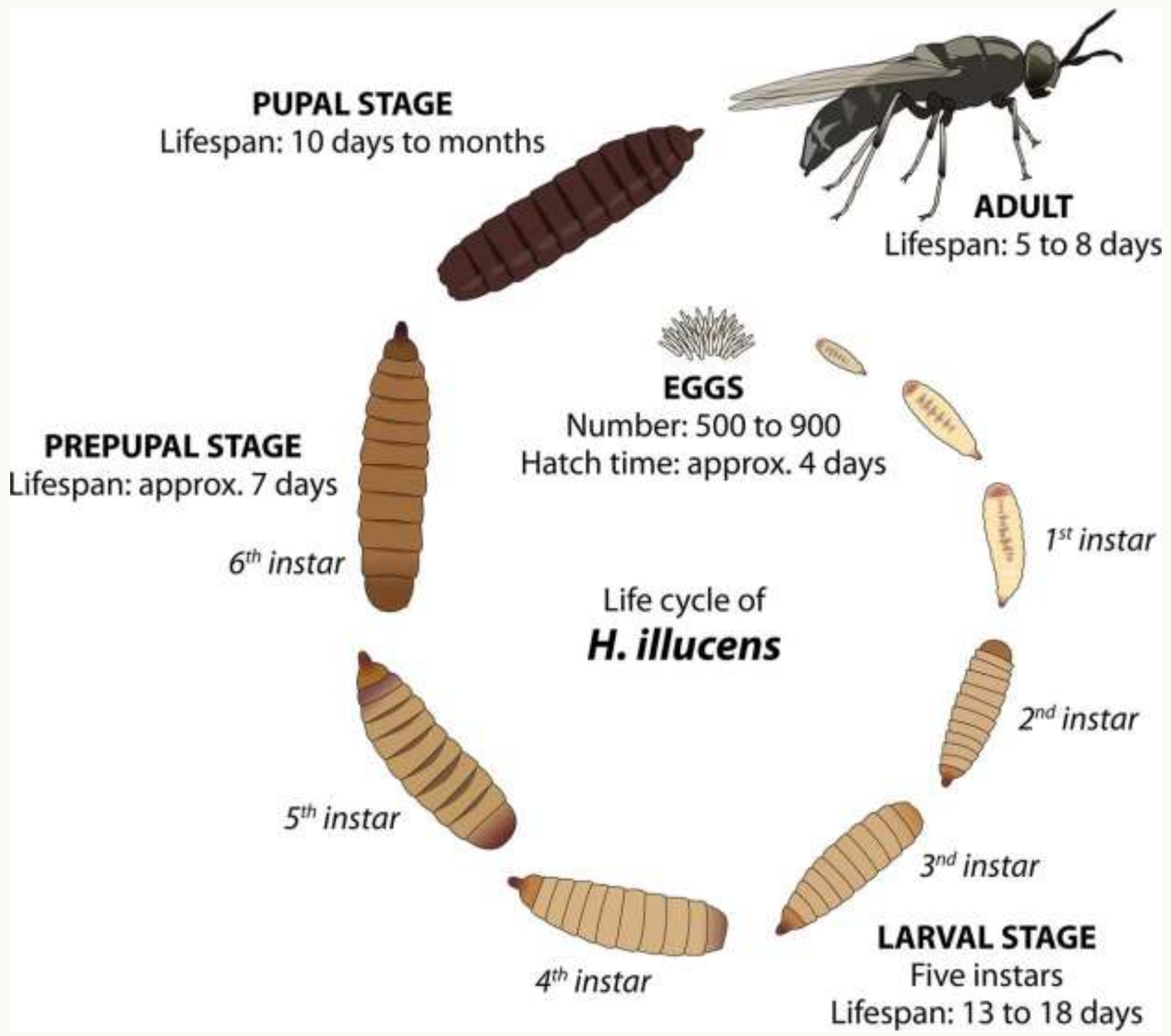
- **NovaPro**
  - This project is focused on circular animal feed production, with the aim of replacing fishmeal and soybeans in animal feed with insect-derived protein. Instead of relying on a large, centralized production facility, the initiative promotes decentralized insect farming. In this model, farmers collaborate with NovaPro to establish insect rearing units on their own property. This approach enables them to utilize food waste to feed the insects, who are then processed and incorporated into animal feed.

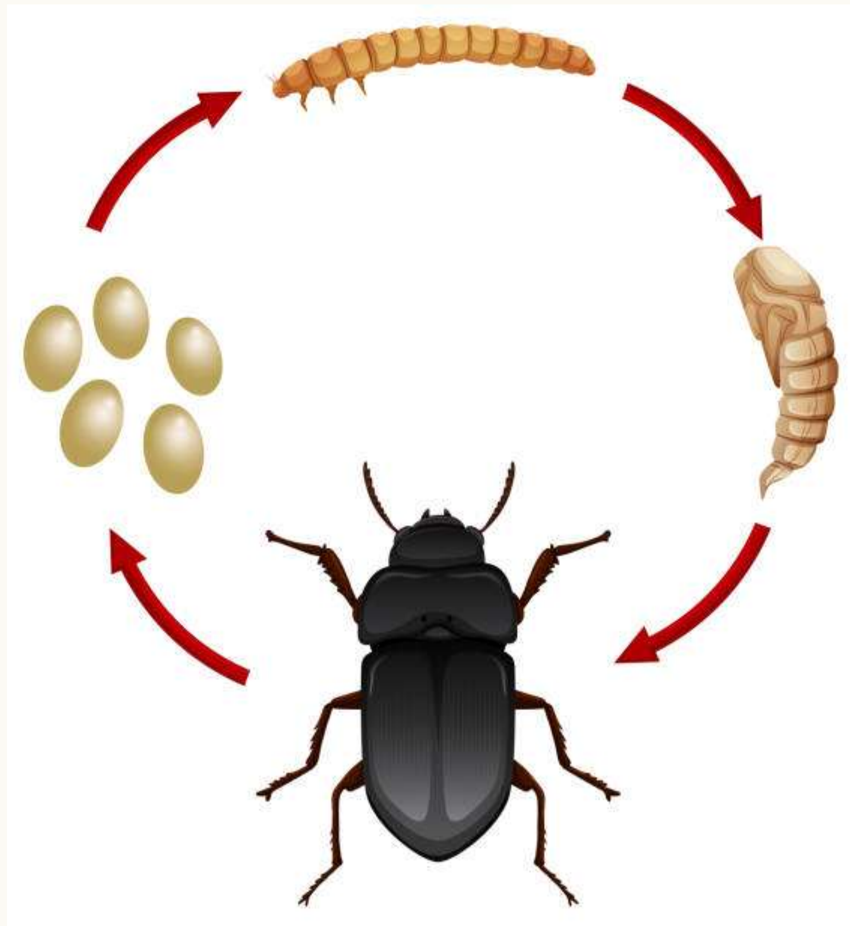
- **Rang-Sells**
  - In collaboration with the project Feed of the Future (initiated by Axfoundation and SLU), a demonstration facility has been built to investigate if it is possible to scale up a technology to create an insect protein from food waste that can then be used for animal feed. If the feed is used to a large enough extent, it can contribute to a more sustainable food system with a lower carbon footprint.

Insects for human consumption
- The public opinion regarding utilization of insects as a protein source for human consumption is divided in Sweden. Many consider the look and texture of unprocessed MWs to be unappetizing. To facilitate large scale production for human consumption, this opinion needs to be changed.

"Mealworm production has an amazing symbiosis potential. If combined with i.e. a papermill, feeding the worms left over sludge, the worms are able to bind nitrogen and heavy metals into the frass they produce.

"If I would rank the willingness to pay within different application areas it would be: 1. Human consumption, 2. Pet food, 3. Fish feed, 4. Bird feed, and 5. Pig feed"





3. Aquaponic farming– Johannas Stadsodlingar

Introduction

Johannas Stadsodlingar is an urban farming initiative established in 2018 by seven founders. The company specializes in sustainable, locally grown produce and fish, and was founded with the mission of addressing food production challenges in urban environments by aquaponic farming. Through their cultivation methods, Johannas Stadsodlingar want to reduce the ecological footprint associated with traditional farming, such as water consumption, pesticide use, and long-distance transportation. The project started as an innovation project funded by Vinnova but has since attracted additional investors such as Katapult, Kull & Partners and STING.

Johannas Stadsodlingar operated their pilot aquaponic facility, situated on Husby Gård in Vallentuna, north of Stockholm, with a growing field of 100 sq m, until the company went into bankruptcy in February 2025. Other than the actual building, the facility was built and operated by the owners of the company. Over the years, the team invested approximately 20.000 unpaid man hours into the development of the facility. During this time, the team at Johannas Stadsodlingar have gathered and developed information and processes to increase the efficiency of the aquaponic systems as well as facilitate the end goal of large scale aquaponic farming.

Aquaponic farming– Johannas Stadsodlingar

Preparations	Production	Distribution	Customer	Future plans
General technological and infrastructure setup for aquaponics Aquaponic facility setup involved assessing needs, designing core systems (fish tanks, biofilters, HVAC, water systems), and integrating digital monitoring. Infrastructure development included climate controls and biosecurity. Systems were connected to a centralized control for testing, calibration and continuous monitoring to maintain efficiency and health of fish and crops. **Operational planning** Johannas Stadsodlingar, developed a sustainable aquaponic system using integrated fish tanks, biofiltration, and digital controls. Investors like Kull & Partners AB and Katapult joined after proof of concept could be presented. The facility integrates digital, biological, and technological systems for efficiency. It emphasizes on sustainability, circularity and regulatory compliance,	**Cultivation** Johannas' aquaponics system starts by cycling water to establish beneficial bacteria in biofilters. The fish waste fertilizes plants, and purified water recirculates back to the fish tanks. The farm grows rainbow trout with temperature-compatible crops like pak choi and sorrel, maintaining a stable 15.5°C environment while monitoring nutrient and water quality for stability. **Harvesting** The cultivation at Johannas involves lifting crops from rafts and harvesting fish using nets. The fish is then harvested in a separate room within the facility. Harvested plants and fish are stored in separate cold chains. The facility produces up to 500 kg of trout and 30 000 leafy green plants annually, with a 99.97% water reuse efficiency at full operational capacity .	**Logistics and transportation** Distribution at Johannas involves minimizing travel time and using temperature-controlled vehicles. Crops are kept at 4-8°C and fish at below 0°C. Products are shipped directly to local restaurants, with temperature monitoring ensuring product quality throughout transport.	**Customer** Johannas conducted local market analysis and targets Stockholm based customers. Due to its small scale, it partners with local restaurants like The Winery. Marketing focuses on media exposure, social media, trade fairs, and podcasts to highlight the benefits of aquaponic production. Future scaling requires broader market analysis.	**Johannas Stadsodlingar** Johannas intend to develop scalable, automated aquaponic farms using stackable platforms and producing 100kg trout and 10-12 times crop yield daily. Currently, since lack of investors, the focus is to optimize the patented nutrient circulation design and plan for closed-loop fish food production using insect farms.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Aquaponic farming– general

Preparations | Production | Distribution | Customer | Future plans

General technological and infrastructure setup for aquaponics

- **Assessment and planning**
  - The process begins with a comprehensive assessment of the aquaponic production facility's technological and infrastructural needs. Key tasks include, selecting a location for the facility, which fish species and crops to produce, climate control technologies, quality control processes, logistics solutions as well as digital monitoring systems and eventual waste management processes. Equipment for keeping, feeding, breeding, and processing the fish is planned to ensure efficiency and the biofilter setup is assessed. Furthermore, access to water, energy and fish feed is established.
- **Design and engineering**
  - Once the needs are identified, the next phase is the design and engineering of the aquaponic facility's core systems, growing pools, fish tanks, biofilter setup, HVAC systems, lighting as well as water circulations-, aeration- and drainage systems. Furthermore, digital systems such as sensors and data management systems are implemented into the design.
- **Infrastructure development**
  - Fish tanks, growing pools and biofiltration units are installed and connected with piping for water transfer. Climate control systems and equipment for biosecurity processes are installed to ensure fish and crop health during production. Sensors are put where necessary in order to allow digital system integration and finally the system is filled with water and ready for the initiation of bacterial culture establishment.
- **System integration and testing**
  - After the physical infrastructure is in place, the installed sensors and data management systems integrated and tested to ensure that they are operational. After which the systems are connected to a centralized control system that allows for unified measurements and control of the facility's systems. This is followed by testing and calibration.
- **Continuous monitoring**

Aquaponic farming– Johannas Stadsodlingar

Waiting for response from Johannas Stadsodlingar regarding regulations, permitting processes and temperature

Preparations | Production | Distribution | Customer | Future plans

Operational planning

- **Stakeholder alignment and objective setting**
  - Johannas Stadsodlingar started as a passion project and is still a smaller pilot aquaponic production. The project acquired initial funding from Vinnova. Once a proof of concept was presentable other investors and stakeholders such as Kull & Partners AB, Katapult, and STING got involved. The work that was put into the development, operation and maintenance of the facility was and still is done by the eight owners.
  - When setting up future large-scale production, aligning stakeholders and setting objectives will be done in the initial stages of the project.
- **Aquaponic facility design collaboration**
  - Aquaponic production requires several interacting technological, digital and biological systems for a facility to function at optimal efficiency. Architects, engineers and aquaponic experts collaborates in designing the facility layout, considering, fishtanks, piping pumps, biofiltration, lighting, heating/cooling as well as the integration of digital control systems.
- **Sustainable practice planning**
  - The pilot facility run by Johannas strives towards the development of an automated, closed circuit aquaponic system. Sustainability is a large driving force behind the initiation of this facility.
- **Regulatory compliance and permitting**
  - For the small-scale pilot aquaponics facility, applications for environmental permits as well as all permits related to aquaculture were needed.
- **Infrastructure and utility coordination**
  - With the facility design and regulatory frameworks in place, the focus shifts to coordinating essential infrastructure and utilities. This involves collaborating with energy and water providers as well as ensuring or setting up access to logistic infrastructure such as roads.
- **Choice of fish and produce**
  - As a result of the closed system production that aquaponics entails, the water temperature tolerances of chosen fish and produce needs to be the same. I.e. Johannas grows rainbow trout in conjunction with plants such as pak choi and sorrel, all thriving in a water temperature of 15.5°C.
- **Operational training and handover**
  - At Johannas, the daily operations are handled by the founding team. At larger aquaponic facilities, part of the setup and continued operation requires preparation of different operational teams. Staff training is then conducted to equip the future staff with the knowledge and skills necessary to cultivate, harvest and store fish and produce as well as to operate and maintain systems.

Aquaponic farming – Johannas Stadsodlingar

Preparations | **Production** | Distribution | Customer | Future plans

Cultivation

- **Cultivation process**
  - After infrastructure and system setup there are still necessary preparations before full-scale production can be achieved. Before adding fish or plants, the system is cycled to allow beneficial bacteria to colonize the biofilters. Selected plants can then be planted in the growing beds. Once a suitable bacterial culture is established the selected fish species can be acclimated and introduced to the water system.
  - The water from the fish tank, containing waste from the fish, is pumped into a moving bed biofilter. The filter is an aerated container filled with several free-floating small wheel-shaped media, providing as much surface area for the bacteria to attach to as possible. The bacteria converts ammonia into nitrites and then nitrites into nitrates which acts as nutrients for the plants. Once filtered, the water is pumped into the plant growing pools.
  - At Johannas, the seeds are initially sprouted in a separate room, before being placed in holes on growing rafts floating directly on top of biofiltered water pumped from the fish tanks. Once inserted into the rafts, the plants roots sprout into the water and the plants begin to grow.
  - When the water have been purified by its path through the growing pools, it is pumped back into the fish tanks and the process begins again.
  - Johannas continually monitors nutrient levels throughout the system as well as air and water quality and intervene if any part of the system becomes unstable.
- **Selection of fish and crop**
  - When setting up an aquaponics system the chosen crop and fish species should have the same water temperature tolerance in order for the system to operate at an efficient level.
  - At Johannas, the production of rainbow trout have been combined with crops such as Pak choi, Sorrel, Cress, Barbarossa, Kiribati, Red salad bowl, Xandra, Crystal lalique, Black cabbage, Mizuna, Amaranth, Shiso, Tatsoi and Pensé. All these crops are thriving in a water temperature of 15.5°C.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Aquaponic farming– Johannas Stadsodlingar

Harvesting

- **Crops**
  - Once the crops have grown to a predetermined size, the crops are harvested by simply lifting the whole plant out of their respective growing holes in the raft. The roots of the plants grows directly into the water and are thus not attached to any substrate. The roots of the crops are then cut, and the plants are stored and prepared for transport.
- **Fish**
  - At Johannas, the rainbow trout is easily harvested from the fish tanks using nets. The harvested fish is then placed in a second purging tank, where they are left without food for 10-14 days, intended to enhance the taste of the fish by letting it empty its digestive track. Once purged, the trout is slaughtered in a separate room before being stored and prepared for transport to customers.
- **Packaging and storage**
  - The plants and fish are placed into separate cold chain storages in preparation for distribution to customers to avoid cross contamination. Plants are stored in the recommended temperature of 4-8°C in food safe trays while fish is stored in ~2°C, in trays filed with ice.
- **Input and yield**
  - The input of 1.1kg fish food becomes approximately 1kg fish and 10-12kg produce. Johannas aims for a continual harvesting and replanting process and thus harvests approximately every two weeks. As of right now, the pilot facility has the capacity to produce up to 500 kg rainbow trout and 30 000 leafy green plants annually. The system has a water reuse efficiency level of 99.8-99.97% depending on if the water and sludge recycling system is operating at full or partial capacity. This system only requires an additional 30 liters of water per day.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

Aquaponic farming– Johannas Stadsodlingar

Preparations | Production | **Distribution** | Customer | Future plans

- **Route planning and transportation**
  - Routes are planned to minimize travel time and different transportation methods are utilized depending on if plants or fish are being distributed. Aquaponic grown crops are of comparably high quality and thus have a longer expected shelf life while the transportation of fish has the same requirements as any other production facility. Currently, Johannas only sell their produce, not the fish, commercially.
- **Loading onto temperature-controlled vehicles**
  - The packaged crop and fish are loaded into suitable vehicles. Because of the short distances to customers, the vegetables from Johannas do not require cooled transport. At a future large-scale facility, the crops would be transported at the recommended temperature of 4-8°C, while fish would be transported at below 0°C.
- **Distribution to local restaurants**
  - When the products have been properly packaged and loaded onto trucks, they are shipped out directly to the respective customer from Johannas Stadsodlingar's facility.
- **Temperature monitoring**

"In the long run and at a larger scale we would be able to sell to any kind of customer".

Aquaponic farming– Johannas Stadsodlingar

Preparations | Production | Distribution | Customer | Future plans

Customer

- **Identify target markets**
    - Because the production facility is located in Stockholm, the owners decided to conduct a market analysis of the Stockholm area to find suitable target customers. Future up-scaled production facilities would need additional market analysis to identify new, larger sales opportunities.
- **Strategic partnerships**
    - Currently, the production at Johannas is not large enough to be profitable for distribution to the large grocery chains or other food distribution companies. Therefore, they ship directly to partner restaurant such as for example The Winery, located in the north of Stockholm. In order to justify traditional fish and produce distribution, an aquaponic production facility needs to be at the least 1000 sq m.
- **Marketing and selling process**
    - In Johannas' case, most of the marketing has been media exposure through digital and physical news articles. The owners of the facility also take an active role at relevant trade fairs and have attended podcasts where they have presented the benefits of circular aquaponic production. They also utilize social media channels, such as Instagram, where they post information about the facility.

"We already have designs of how to close the entire loop using insects and blue mussels as fish feed"

Future plans

- **Johannas Stadsodlingar**
    - The pilot facility operated by Johannas was built to develop methods and processes for scalable aquaponic production. The facility now serves as a proof of concept of the viability of such productions. The end goal of this project is to facilitate automated aquaponic farms using stackable growing platforms with a combined growing area of 1 hectare. A facility like this can produce 100kg rainbow trout per day and 15 times that amount of crops (i.e. 500-600 tons of leafy greens per year).

      Today, Johannas lack investors willing to provide capital for this scale up. Due to this, the owners of the company have chosen to focus on the development of a patented fish sludge handling method, to close the feed chain of the aquaponic system, all while keeping the aquaponic facility running at current capacity.

Johannas Stadsodlingar – Competence requirements

Preparations	Production	Distribution	Customer	Other
Planning and permits • Consultants or advisors with experience in integrated aquaculture and horticulture. • Legal and regulatory experts for environmental permits, food safety, and water usage. • Urban planning or land use specialists. (especially for urban/ peri-urban settings) • Sustainability professionals for environmental assessments and circular system planning. **Technical design and construction** • Engineers or system designers specialized in aquaponic system integration. (hydroponics + aquaculture) • Biologists or aquaculture experts for species selection and system compatibility. • Construction contractors familiar with greenhouse and indoor growing environments. • Water systems engineers for plumbing, filtration, and oxygenation infrastructure.	**Aquaculture operation** • Aquaculture technicians or fish farmers for daily fish health monitoring, feeding, and tank management. • Water quality managers for pH, nitrogen cycles, oxygenation, and ammonia/nitrate monitoring. **Horticulture and plant care** • Horticulturists with hydroponic expertise for nutrient management and plant health. • Crop technicians for seeding, transplanting, pruning, and harvesting. **System maintenance** • Technicians to manage pumps, filtration systems, biofilters, and automation tools. • Staff trained in biosecurity and integrated pest management (IPM).	**Harvesting and post-processing** • Workers for manual harvesting, cleaning, and packing of both plants and fish. • Quality assurance personnel for food safety and shelf-life management. **Logistics** • Logistics coordinators for short supply chains. (common in urban aquaponics) • Knowledge of cold chain management for fish and fresh produce.	**Market development** • Sales professionals experienced in local food networks, restaurants, and other sales models. • Relationship builders to connect with grocers, chefs, and public sector buyers. **Marketing** • Marketing experts to communicate the ecological and circular benefits of aquaponics. • Staff for branding and packaging design tailored to sustainability-conscious consumers. **Certifications and standards** • Experts familiar with food safety standards and traceability systems. • Understanding of certifications relevant to aquaculture, organics, or sustainable production.	**Business strategy and scaling** • Business developers to explore models for upscaling, franchising, or integrating into urban development. • Financial planners for cost modeling and long-term economic sustainability.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

4. Shrimp farming

Introduction

Land-based shrimp farming could also be an option for circular food production in the North.

- The consumption of fish and shellfish is continuing to increase globally, much due to improved technology in both production and logistics.
- The aquaculture production of Vannamei shrimp has increased by 8 % annually since 2010, which has resulted in a global oversupply and a lower price. Vannamei shrimps are imported to Europe mostly from South America and Southeast Asia.
- In Sweden, the average consumption is 25 kg seafood per capita, which is 22 % above the global average, although there has been a decrease in recent years. Despite this, steadily increasing prices and a refinement in the seafood-category contributes to yearly increases in monetary sales.
- In 2011 it appeared that mangrove swamps in Southeast Asia were pillaged to make way for production and farming of some varieties of giant shrimp, mostly scampi. The consequences in Sweden were that many retail chains withdrew the affected shrimp varieties from their assortments.
- Aquaculture Stewardship Council (ASC) was founded in 2004, to create a transparence by certifying manufacturers/farmers in how to fulfill certain requirements to minimize any negative environmental and social impact. The number of certified products in Europe has increase 14-fold since 2014.
- From the total aqua cultivated fish and seafood production worldwide, ~12% are shellfish, and 50 % out of these are Vannamei shrimps.
- Shrimp farming with a RAS system was tried by the Swedish company Vegafish in Lysekil during 2017-2019, but was then put into bankruptcy.
- The RAS-technique can be applied for both shrimp and fish farming, with very similar set-up.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV

ARCTIC FOOD ARENA

RAS shrimp farming

Preparations	Production	Distribution	Consumer	Future plans

Preparations

The preparations for shrimp farming in a RAS system (Recirculating Aquaculture Systems) are similar for fish- and shrimp farming. Saltwater farming requires extra cleaning equipment for the water.
Land preparations and construction of production building is the first step of preparation. The system set-up includes:

Culture Tank: Where the shrimp are raised, usually filled with a controlled environment of water.

Water Treatment System: Includes filters (mechanical, biological, chemical, degassing, UV and ozone) to maintain water quality.

Aeration System: Provides oxygen to the shrimp and maintain water quality.

Heating/Cooling Systems: Regulates the temperature to optimize shrimp growth.

Monitoring Equipment: Sensors to track parameters like pH, ammonia, nitrite, nitrate, temperature, and dissolved oxygen.

RAS systems can be designed to different scales, from small hobbyist setups to large commercial operations and set up in urban areas or regions with limited freshwater resources, reducing the environmental footprint.

Production

Stocking
Source healthy post-larvae or juveniles from reputable hatcheries. Gradually acclimate the shrimp to the RAS environment, adjusting temperature and salinity as needed.

Feeding and Growth Management RAS allows for efficient feeding strategies. Staff can closely monitor shrimp growth and adjust feeding rates to maximize feed conversion and minimize waste.

Temperature
Ideal temperatures usually range between 28-32°C

Disease Management
The controlled environment of RAS helps reduce the risk of diseases and parasites that can plague traditional shrimp farming.

Harvesting
It takes about 3 to 6 months depending on different factors for the shrimps to reach market size in a RAS system.
Sorting and Grading
The harvested shrimp is sorted by size and quality and graded accordingly.

Distribution

Distribution form
The most common distribution form for shrimps are either frozen or fresh (in jars in "lake" (water).

In the Swedish grocery trade ~56% of the scrimps sales is frozen, ~36 % are in jars. In larger supermarkets, shrimps are also sold in a frozen pick&mix format.

The different distribution forms require its specific logistics. A producer most likely needs to decide on which format to go for. It is expensive to have packaging facilities and logistics solutions for both.

Consumer

Consumption
Unlike fish, consumption of crustaceans is increasing in Sweden. Since the turn of the millennium, the consumption of prepared crustaceans has increased by ~40% in volume.

A changed consumption pattern with more seafood with a generally higher price point probably contributes to the increase in value being even higher than the increase in volume.

Future plans

Today there is no active shrimp farming in Sweden.

There are five crayfish farms (plus four for input crayfish), five mussel farms and one oyster farm. Almost all are found in southern Sweden.
Aquaculture in Sweden is covered by the following legislation:

- Fisheries legislation
- Environmental legislation
- The infection control legislation
- Animal welfare legislation
- Food legislation

RAS farms are based on full control over input feed and a system where the water is purified. Currently, the degree of environmental verification is based on added feed, which is not considered a fair measure of the environmental burden for this type of cultivation.

Cold Lake AB in Åre, Jämtland, has received approval to build a RAS farm for producing char. The facility will be approximately 18,000 square meters in size and is expected to be ready at the end of 2025.

Source: Previous Macklean assignments, www.coldlake.com, https://www.svt.se/nyheter/lokalt/jamtland/nu-ar-bygget-igang-i-kall-av-sveriges-forsta-forsta-fiskodling-pa-land

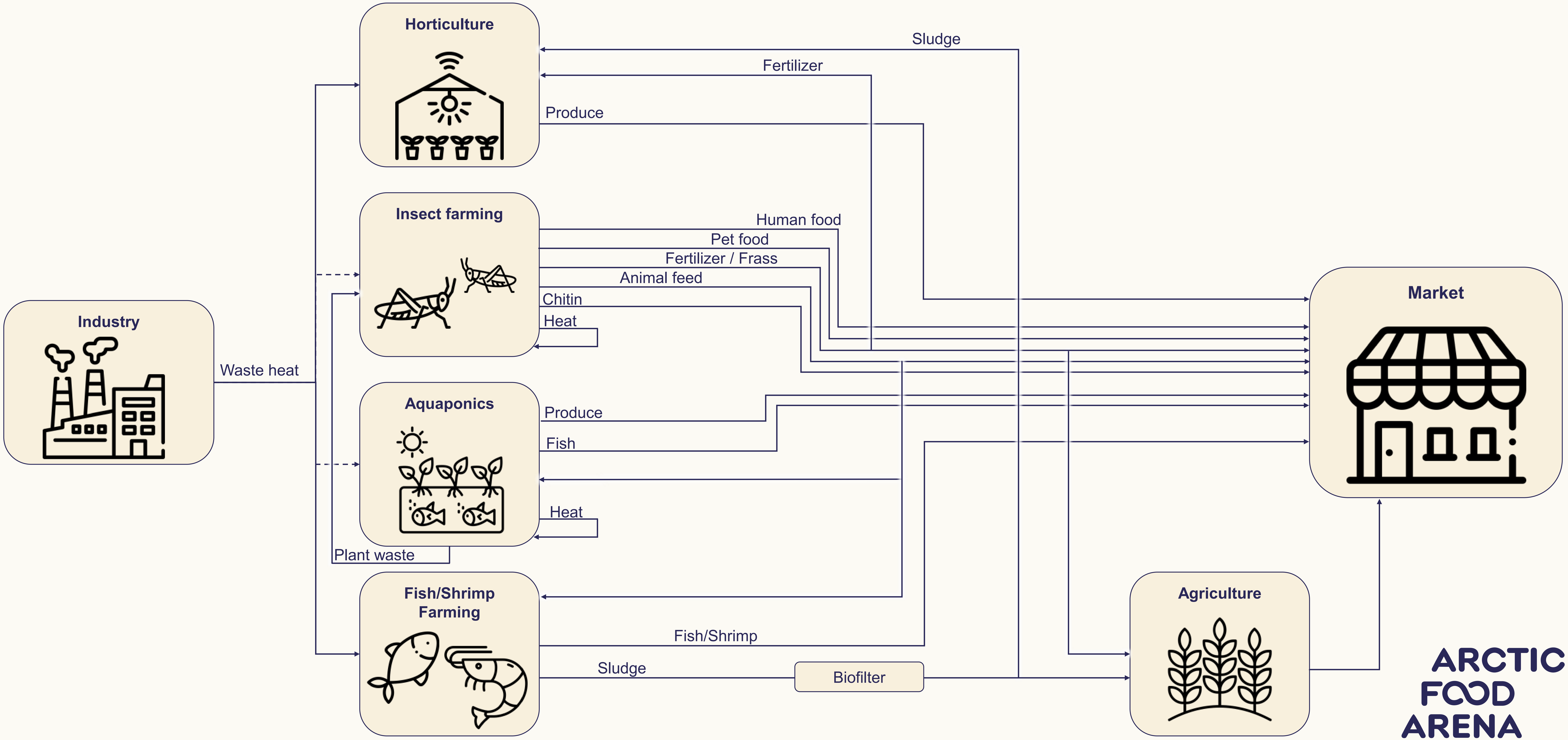
Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

RAS shrimp farming– Competence requirements

Preparations	Production	Distribution	Customer	Other
Planning and permits • Consultant with experience in aquaculture and environmental permits • Legal expertise in permit process. • Personnel with knowledge of geographical requirements. **Technical design and construction** • Engineers with understanding of RAS technology and construction • Biologist with knowledge of organism needs. • Specialist for slaughterhouse and workspace design • General contractors with experience in aquaculture or similar facilities	**Technical Operation and system maintenance** • Technicians with expertise in operating RAS systems. • Chemists for large or complex facilities. **Biology and water** • Biologists for monitoring animal welfare and water quality. • Staff for daily inspection of organisms, system status and feed management as well as the slaughtering facilities. **Staffing** • The complexity of general operating tasks requires a higher competence among workers than traditional greenhouses.	**Logistics and transportation** • Logistics personnel with knowledge of food safety requirements and cold chains • Transport planners, especially for fresh products (truck transport most common). **Product Quality** • Expertise in additives and measures to extend shelf life (e.g. preventing shell discoloration in shrimp).	**Sales and marketing** • Sales staff with understanding of the market and customer preferences. • Marketing expertise, especially for new or less established products. **Branding** • Expertise in packaging design and branding. **Certification and Business Development** • Knowledge of certification requirements (ASC, MSC) • Business developers with networks to major buyers.	**Holistic Understanding and Scaling** • Teams with a comprehensive understanding of the system and challenges in scaling up. • Experience with proof of concept and common pitfalls when scaling RAS facilities.

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

5. Overview of symbiosis potential

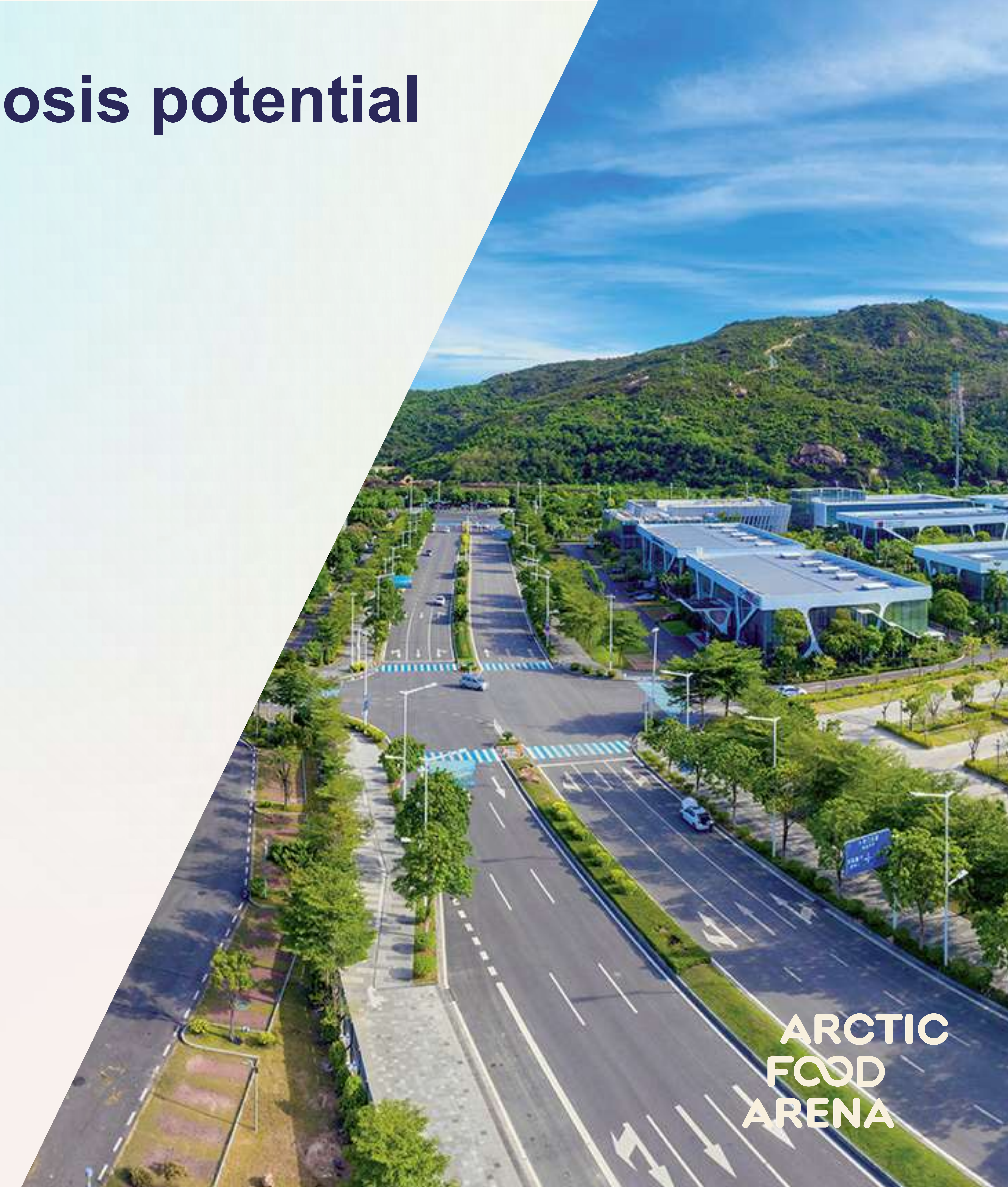


ARCTIC FOOD ARENA

6. Other side streams with symbiosis potential

Introduction

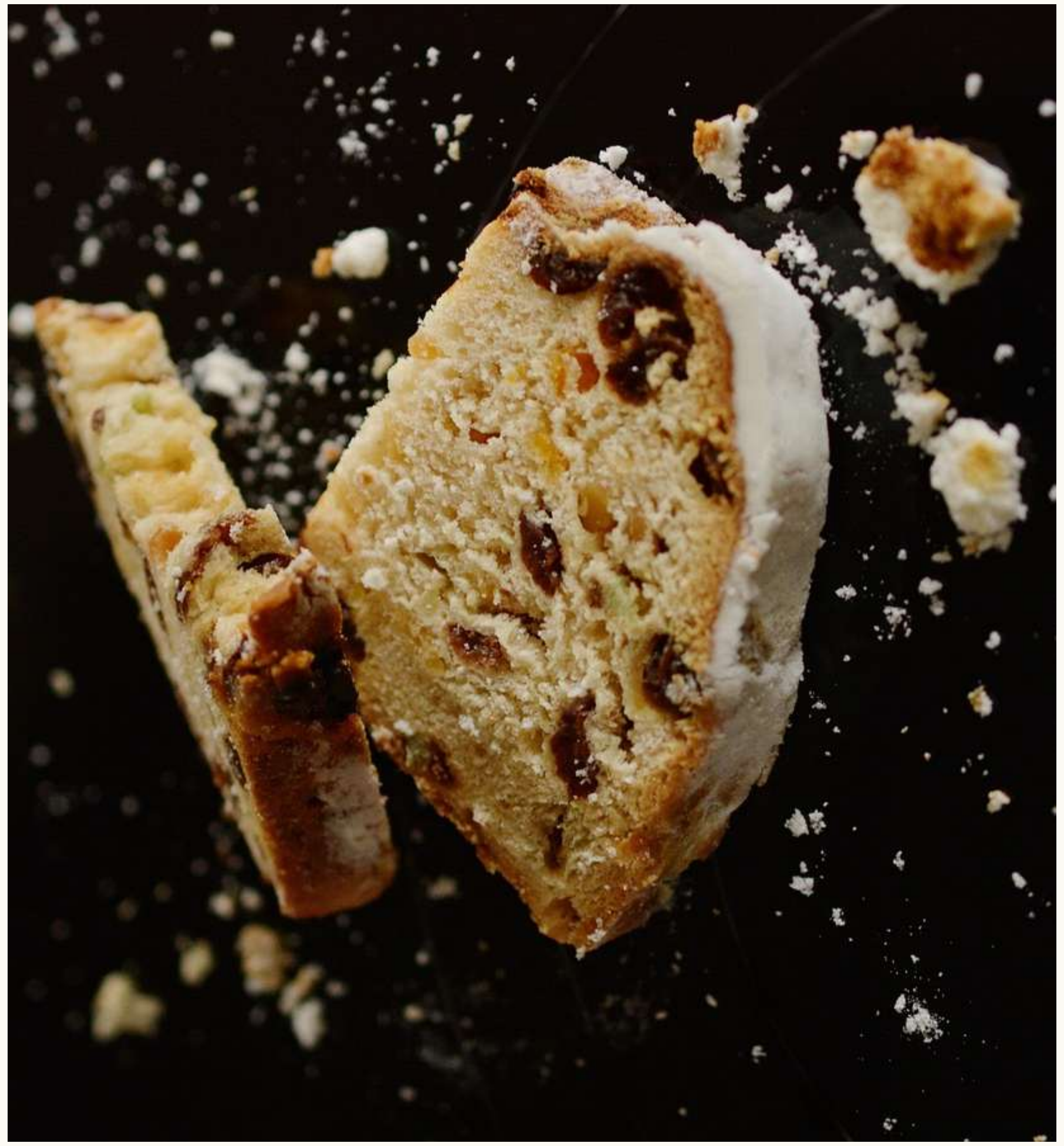
In March 2025, Arctic Food Arena, in collaboration with Invest in Norrbotten and Boden municipality, held a workshop in Boden focusing on the identification of waste streams with symbiosis potential in northern Sweden. The approximately 80 participants, ranging from large industry actors to local famers, were divided into 9 groups. A total of 27 waste stream were identified. Out of these, three were chosen to be integrated into this report and the symbiosis potential chart. This was based on their regional relevance, available volumes, and potential for integration with the value chains handled in this report; hydroponics, aquaponics, insect farming and RAS fish and shrimp farming.



Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV

Waste bread

Overview	Symbiosis potential	Other information/comments
Description Bread waste is a substantial component of post-consumer food waste, mainly generated by grocery stores, bakeries and restaurants due to overproduction, expiration dates and aesthetic standards. It is classified as "former foodstuff" meaning it was intended for human consumption but has lost market value without being consumed. **Characteristics** This waste stream is categorized by a relatively homogenous composition, with high levels of starch, simple carbohydrates and an easily processed texture. Bread is microbiologically active and therefore highly perishable, requiring swift handling and processing to avoid mold or spoilage. **Relevance** In the context of northern Sweden, bread waste offers a resource stream suitable for local circular economy initiatives. Given the regions dispersed population and relatively long food supply chains, bread waste from supermarkets offers a consistent, localized and organic feedstock that can reduce dependency on imported inputs.	**Insect production** Bread waste is a well suited, carbohydrate-rich addition, to incorporate into the diets of *BSF and **meal worm production. These insects can efficiently convert bread waste into high value biomass (protein and fat), while their frass can be used as a biofertilizer. Some operational pilot facilities, such as DC Farming in Boden, already demonstrate the feasibility of integrating this waste stream into BSF production. **Biogas** In biogas production, bread waste is a highly digestible input due to its simple carbohydrate composition. It can be used as a standalone feedstock or co-digested with other organic materials.	**Regulatory compliance** EU and national regulations (e.g., feed safety, traceability and hygienization standards) affect how this waste bread must be processed and handled when used as animal or insect feed. Specifically limiting from where waste bread can be taken from. **Pre-processing** Drying, grinding, or ensiling (controlled fermentation) can extend shelf life and reduce spoilage risk. **Logistical and infrastructural challenges** Bread waste is often produced in small and dispersed quantities across retail and food service locations, making it potentially complex to collect, transport and store efficiently. This highlights the advantage of co-location synergies between e.g. a grocery store, insect production and a potential pre-treatment facility. **Volume fluctuation** Bread waste generation may peak during certain holidays (e.g., Christmas, Easter), requiring flexible logistics



Source: Arctic Food Arena Boden WS 2025, *Interview with DC Farming, **King Saud University article, Commission regulation (EU) No 68/2013

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Algaculture

Overview | Symbiosis potential | Other information/comments

Description
Algaculture refers to the controlled production of micro or macroalgae (seaweed) in water-based systems. Microalgae can be grown in open ponds, photobioreactors, or integrated into wastewater treatment processes. They often thrive on inputs such as CO_2 emission, nutrient-rich water, or residual heat from industrial processes. Algae production

Characteristics
Algae are highly efficient photosynthetic organisms capable of rapid growth under the right conditions. They absorb CO_2 and nutrients, mainly nitrogen and phosphorus, from water, converting them to biomass rich in proteins, lipids, or pigments depending on the species. The performance of different algae species may vary depending on the intended function and design of the utilized production system

Relevance
Due to limited sunlight and heat during winter months, application of algaculture in a northern environment may be limited to indoor photobioreactors. Access to clean water, available land and the potential for co-location with industries that emit CO_2 or excess heat further improves feasibility by supplying essential inputs

Insect production
Algae can enrich insect feed with fatty acids or pigments. Insect facilities can also supply CO_2 and heat to boost algae growth. This creates a symbiotic loop where emissions become inputs, reducing resource loss and improving overall system efficiency.

Aquaponics
Controlled use prevents unwanted growth in plant or fish tanks. When properly managed, algae can stabilize nutrient levels and improve water quality without interfering with core system components.

RAS Fish & Shrimp farming
Algae can clean nutrient-rich water in RAS, reducing discharge and supporting reuse. Some species may also be processed into feed for shrimp or fish.

Biogas
Digestate from biogas plants can be used to feed algae with nutrients, while algae biomass can be sent back into digestion for added gas yield.

System sensitivity
Algae cultivation requires careful control of light, nutrients, and temperature to avoid contamination and ensure stable yields. Even small imbalances can lead to system crashes or unwanted microbial growth.

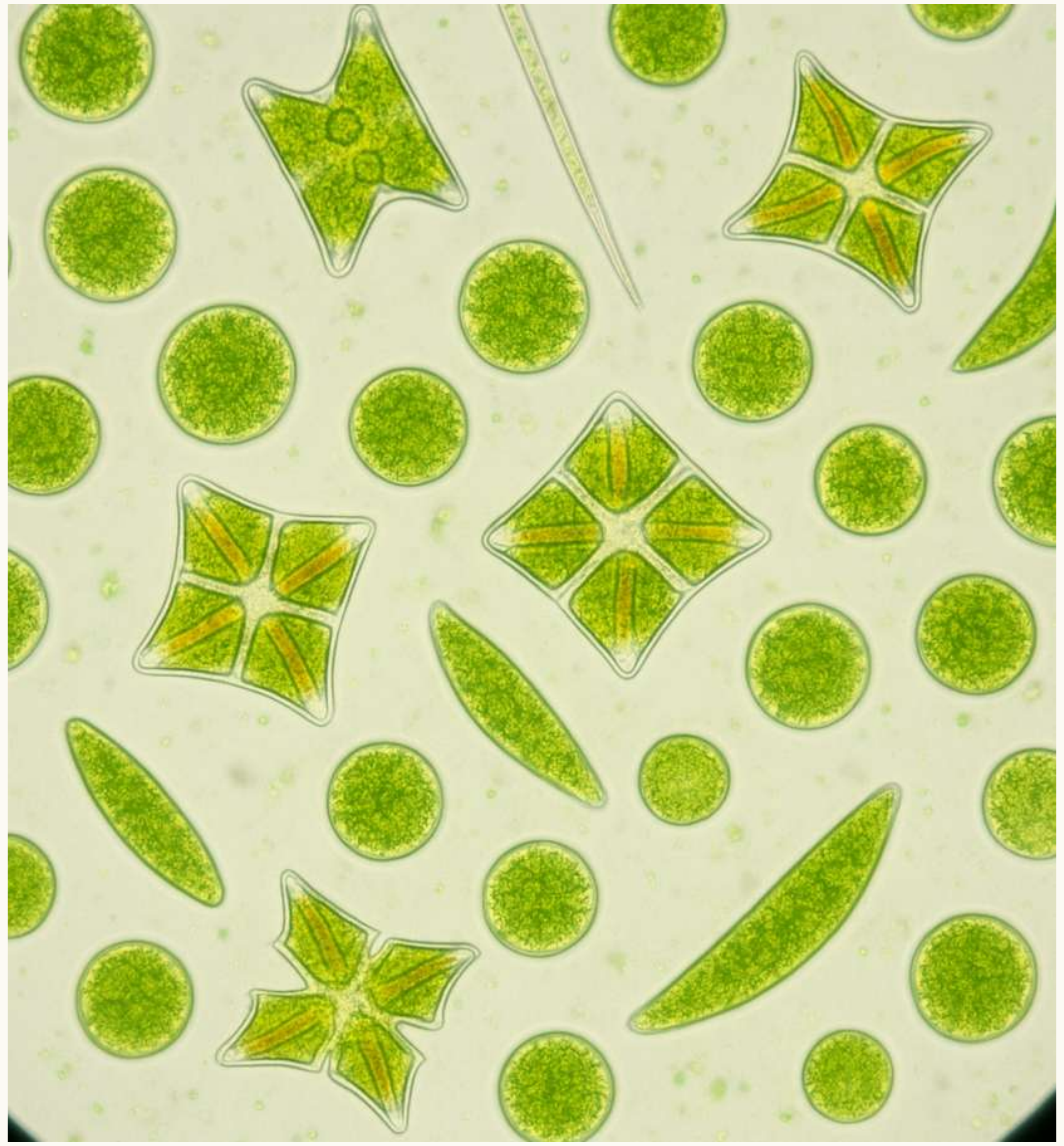
Species selection
Different algae types perform better depending on system goals such as nutrient removal, biomass output, or feed enrichment

Climate adaptation
Outdoor cultivation is limited in Northern Sweden during winter, but indoor or seasonal setups can work if supported by local waste heat and CO_2

Infrastructure needs
Scaling algae systems relies on affordable access to water, space, and integration with nearby waste or energy streams. Industrial areas or farms with excess nutrients or CO_2 are ideal locations.

Harvesting and processing
Harvesting and dewatering are still cost-intensive, but ongoing innovation is gradually improving efficiency and feasibility

.



Source: Arctic Food Arena Boden WS 2025, Environmental advances, Bioeng Biotechnol, Biogas symbiosis, Algae in aquaponics,

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

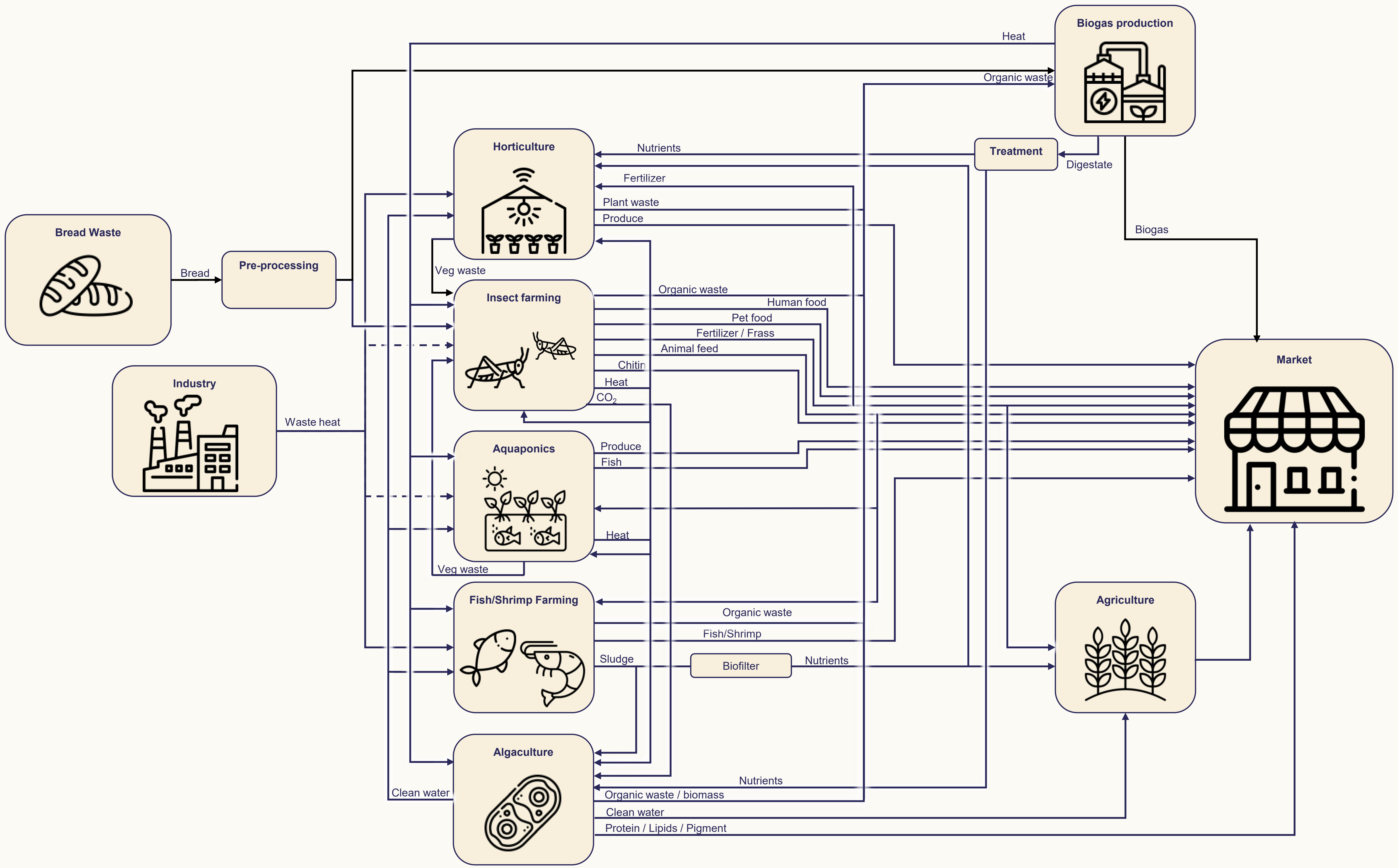
Biogas

Overview	Symbiosis potential	Other information/comments
Description Biogas production involves the anaerobic digestion of organic materials such as food waste, manure, agricultural residues, or industrial by-products. In this process, microorganisms break down the material in an oxygen-free environment, producing biogas (a mix of methane and CO_2) and a nutrient-rich residue called digestate. **Characteristics** Biogas systems are flexible in terms of feedstock and can handle a wide variety of biodegradable waste streams. Their efficiency depends on feedstock, temperature, retention time, and microbial balance. The resulting biogas contains around 50-70% methane, depending on the input materials. Digestate, the solid and liquid by-product, contains nitrogen, phosphorus, and other valuable plant nutrients. Biogas plants can be scaled from small farm-level installations to large industrial units. **Relevance** Biogas production is particularly relevant for Northern Sweden as a means to reduce waste, generate local renewable energy, and support nutrient cycling. Cold climates require insulation or heat recovery for year-round operation, which can be supported by co-location with heat-generating industries or greenhouses.	**Hydroponics** Digestate from biogas plants can be processed into liquid fertilizers suitable for hydroponic systems. While it requires treatment to ensure nutrient balance and remove solids, it provides a renewable alternative to synthetic inputs. **Insect production** Residues from insect farming, such as frass and uneaten substrate, can be used as feedstock for biogas production. **RAS Shrimp farming** Organic waste from RAS, such as fish sludge or uneaten feed, can be co-digested in biogas plants. This reduces environmental discharge and offers a solution for managing nutrient-rich effluents. **Algaculture** Digestate serves as a nutrient source for algae systems, especially in side-stream cultivation setups. Algae biomass, in turn, can be sent back into the digester to enhance gas yield and close the loop.	**Feedstock variability** Biogas systems can process a wide range of organic materials, but the consistency and quality of inputs affect gas yield and process stability. Co-digestion with complementary materials often improves performance and balances nutrient content. **Regulations and digestate use** Digestate is rich in nutrients but may require treatment before being used in plant systems or discharged. Regulations on heavy metals, pathogens, and nutrient loading vary and must be considered for safe and legal use **Energy needs** Maintaining optimal digestion temperatures in cold climates can be challenging. However, waste heat from nearby facilities or combined heat and power systems can help maintain performance throughout the year **Policy incentives** Sweden supports biogas through national energy goals and subsidy schemes, making it a financially attractive option in many regions. Increased demand for fossil-free fuel alternatives may further boost long-term investment.

Source: Arctic Food Arena Boden WS 2025, Anaerobic digestion, Feedstock flexibility & technology overview,

Medfinansieras av Europeiska unionen
UTVECKLA NORRBOTTEN EN DEL AV REGION NORRBOTTEN
GÄLLIVARE NÄRINGSLIV
ARCTIC FOOD ARENA

Overview of symbiosis potential, extended



ARCTIC FOOD ARENA

7. Food processing

Based on the different produce that has been described in the symbiosis models in this report, there are also potential possibilities to process this into food and feed in the region. Ideally, some of the food processing should be done in the region to cater for the regional consumption needs.

- Tomatoes that are second range or damaged can be processed into juices, marmalades and other consumer products based on tomatoes. There are several jam and juice manufacturers in the region, which could be possible to partner up with.

- Insects should probably be further processed in larger scale plants specialized on producing pet food, feed or fertilizer from the insects. Transportation costs are relatively low, and the insects can therefore be transported to this kind of factory basically anywhere in Sweden or Scandinavia.

- For the fish or shrimp farming further processing could be investigated in connection to the current processing of fish and roe in Kalix. There are also plans for fish farming in the Luleå area and joint processing of seafood could be a possibility to explore further.

Medfinansieras av Europeiska unionen

UTVECKLA NORRBOTTEN
EN DEL AV REGION NORRBOTTEN

GÄLLIVARE NÄRINGSLIV