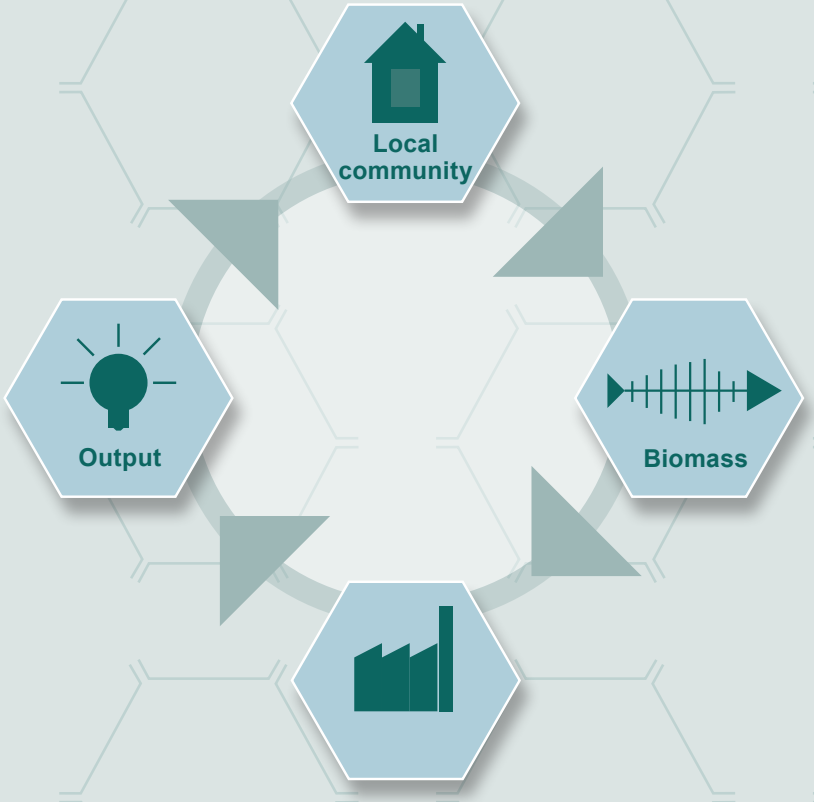
BIO ECONOMY PROGRAM

Report

Integrated local solutions for bioenergy



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Analysys Mason on behalf of Nordic Forest Research (SNS) and Nordic Agri Research (NKJ)

SNS Nordic Forest Research

Nordic Agri Research

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Table of contents

Background and objective

Context and background

SNS/NKJ identifies a need for sustainable development in the Nordic/Baltic bioeconomy, as well as a gap in structured knowledge-sharing mechanisms

Analysys Mason was commissioned by SNS and NKJ in 2024 to write a scoping paper about knowledge transfer in the Nordic-Baltic region for increased uptake of sustainable bioenergy

This was followed by four seminars on the recommendations put forth in the scoping paper, bringing together practitioners, academia, policy makers and bioenergy organizations

Insights from the seminars were consolidated into a report, which – in line with the seminars, – highlighted the key recommendation on identifying successful integrated local solutions for bioenergy

Objective

Identify and showcase successful integrated local bioenergy solutions across the Nordics and Baltics

Accelerating sustainable bioeconomic development by sharing practical examples and lessons learned

Facilitate knowledge transfer and inspiration for policymakers, industry, and regional stakeholders

Deliver a curated collection of case studies and outreach to promote wider adoption

For further information, read the scoping paper and the seminar report

Methodology

Case collection

- Leveraging previous reports and materials
- Utilising known examples and team networks
- Desk research

Case selection

- Validation for accuracy
- Criteria-based screening
- Selection and alignment with project team and external experts
- (Contacting and conducting interviews)

Compilation

- Finding common themes – strengths and weaknesses
- Develop central insights and conclusions

Key objective

Assembling an appropriate number of case studies of integrated local solutions for bioenergy

Key objective

A sorted, manageable collection of information

Key objective

A structured synthesis of insights and findings

Case collection

- The initial step in the gathering of potential case studies for inclusion was to leverage the previous reports and materials available – both from Analysys Mason reports for SNS/NKJ and reports by Nordic Energy Research.
- Having done that, other known examples from team members networks, as well as recommended examples from external experts consulted, were included.
- Finally, this was complemented by desk research into bioenergy solutions in the Nordic and Baltic countries, utilizing free searches and other relevant databases/sources.

Case selection

Having put together a large list, focused on diversity in terms of geographical spread, the following steps where taken:

- Validation for accuracy and quality according to four criteria (below)
- Alignment and agreement on a ”short list” with NKJ/SNS, utilizing expert help from Nordic Energy Research
- Continuous research for complementary examples, mitigating for lower than expected response rates

Selection criteria for final inclusion

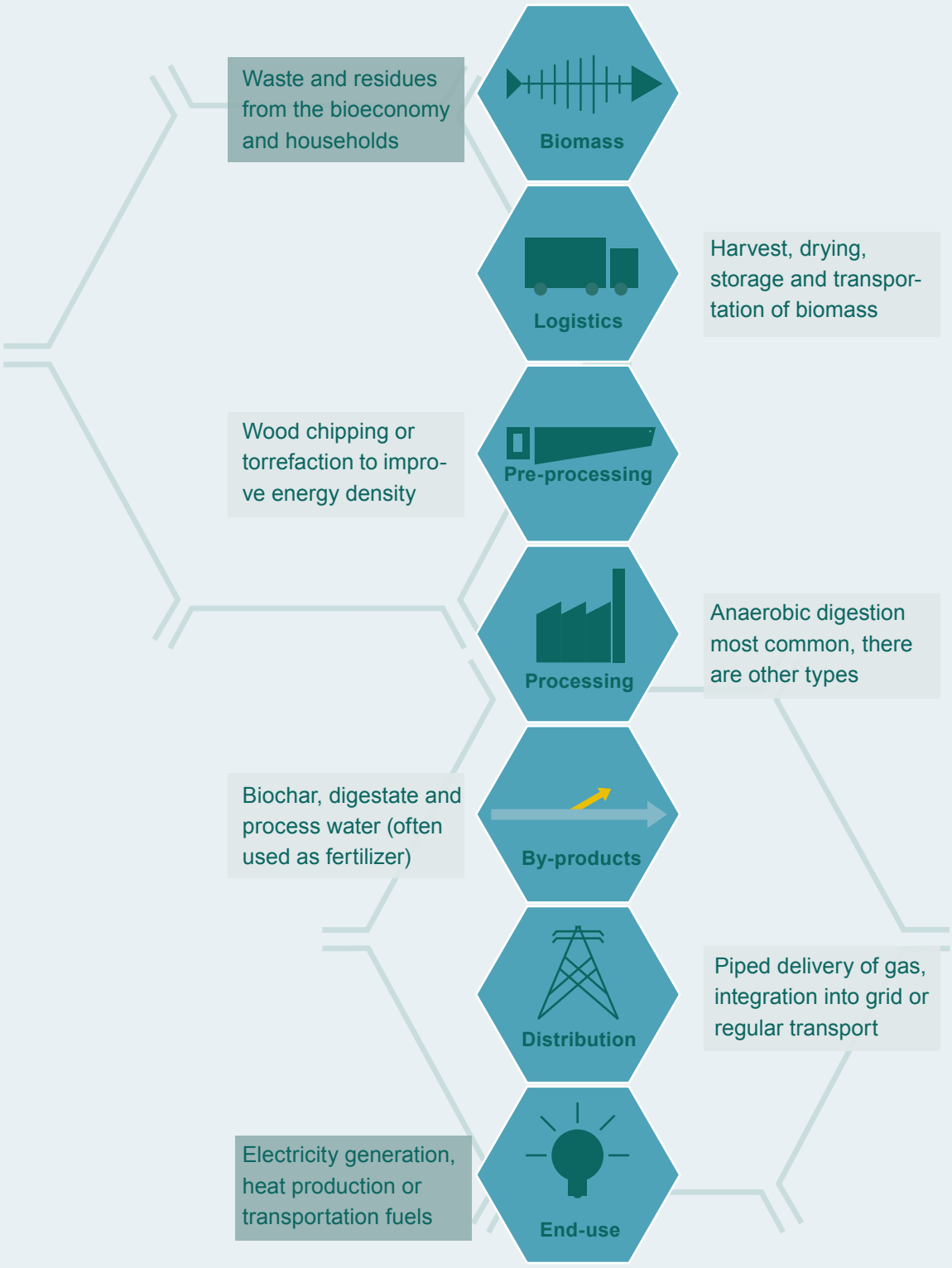
1. Solely sustainable local biomass (by-products/waste)
2. Circular resource management
3. Local demand matching
4. Private-public collaboration

Compilation

- Conduct interviews and thorough desk research
- Due to limited participation in interviews, most cases were presented with findings acquired through desk research
- Highlight strengths and weaknesses of different approaches
- Extract aggregated insights that can inform broader conclusions
- Provide a solid base for inspiration, recommendations and decision-making

Overview

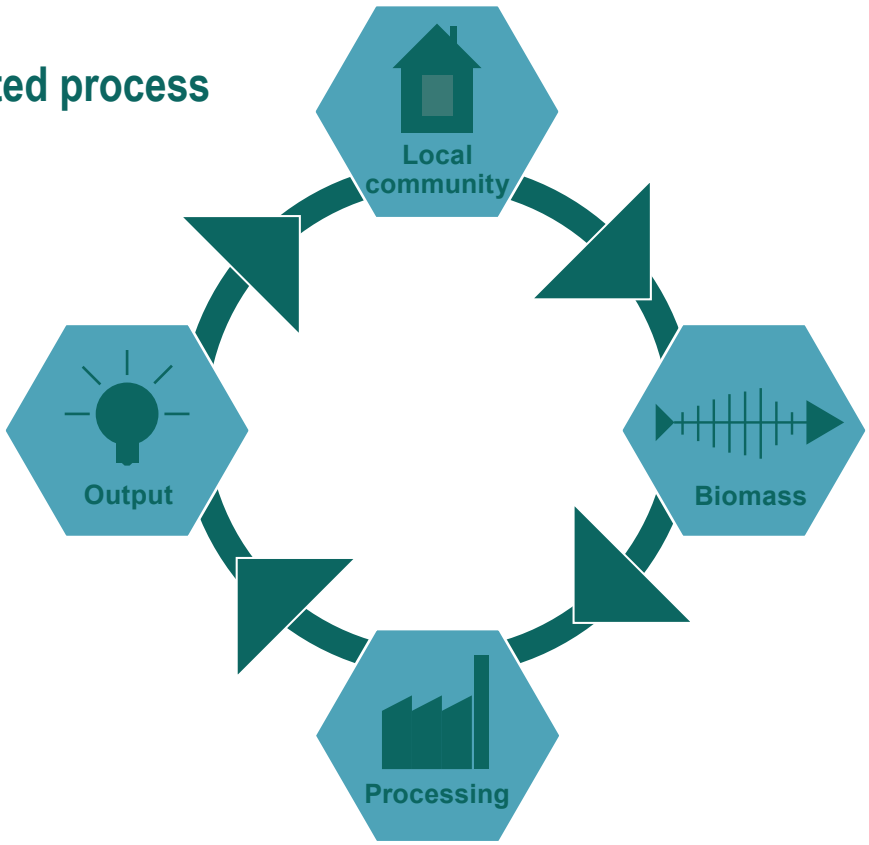
Bioenergy value chain



Integrated local solutions

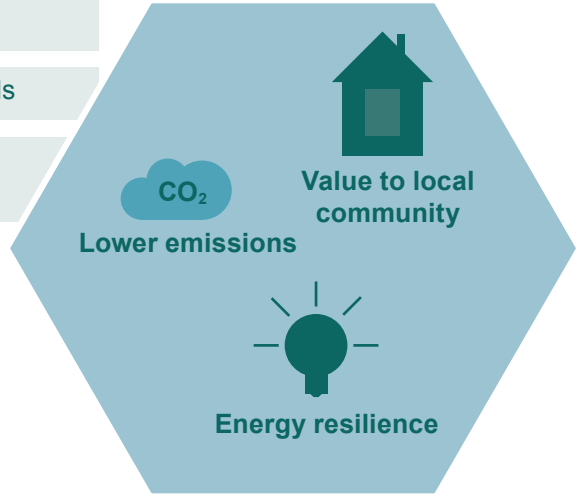
Integrated local solutions contribute to the resilience and sustainability of the local community at large.

The integrated process



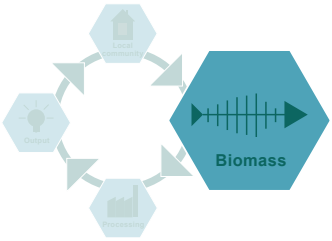
Key characteristics:

1. Resource-matching: Tailored to local feedstock mix and seasonal availabilities
2. Multi-output: Delivers electricity, heat and biofuels
3. Closed-loop: Recycling of nutrients, reduces waste transport



Local community

- Local solutions build on the resources, needs, and engagement of the community itself.
- By matching locally available residues with local demand for energy, the system strengthens self- sufficiency and ensures that value creation stays within the community
- This way, households, farms, and businesses become active participants in a circular energy cycle rather than passive consumers

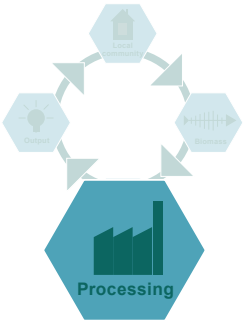


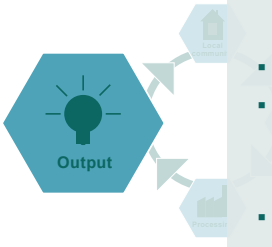
Biomass

- Organic residues from agriculture, forestry, food chains, or households are regarded not as waste, but as resources.
- By capturing and mobilizing these streams where they arise, the system ensures efficient use of local materials and minimizes the need for long-distance transport
- The diversity of biomass sources provides flexibility and resilience, forming the foundation for a sustainable energy loop

Processing

- Collected biomass is converted into usable energy through locally adapted technologies.
- The choice of process depends on available resources and demand, allowing for efficient transformation into heat, electricity, fuels, or useful by-products.
- What distinguishes an integrated approach is the system's design: it connects different resource streams to different outputs, ensuring that minimal value is lost along the way





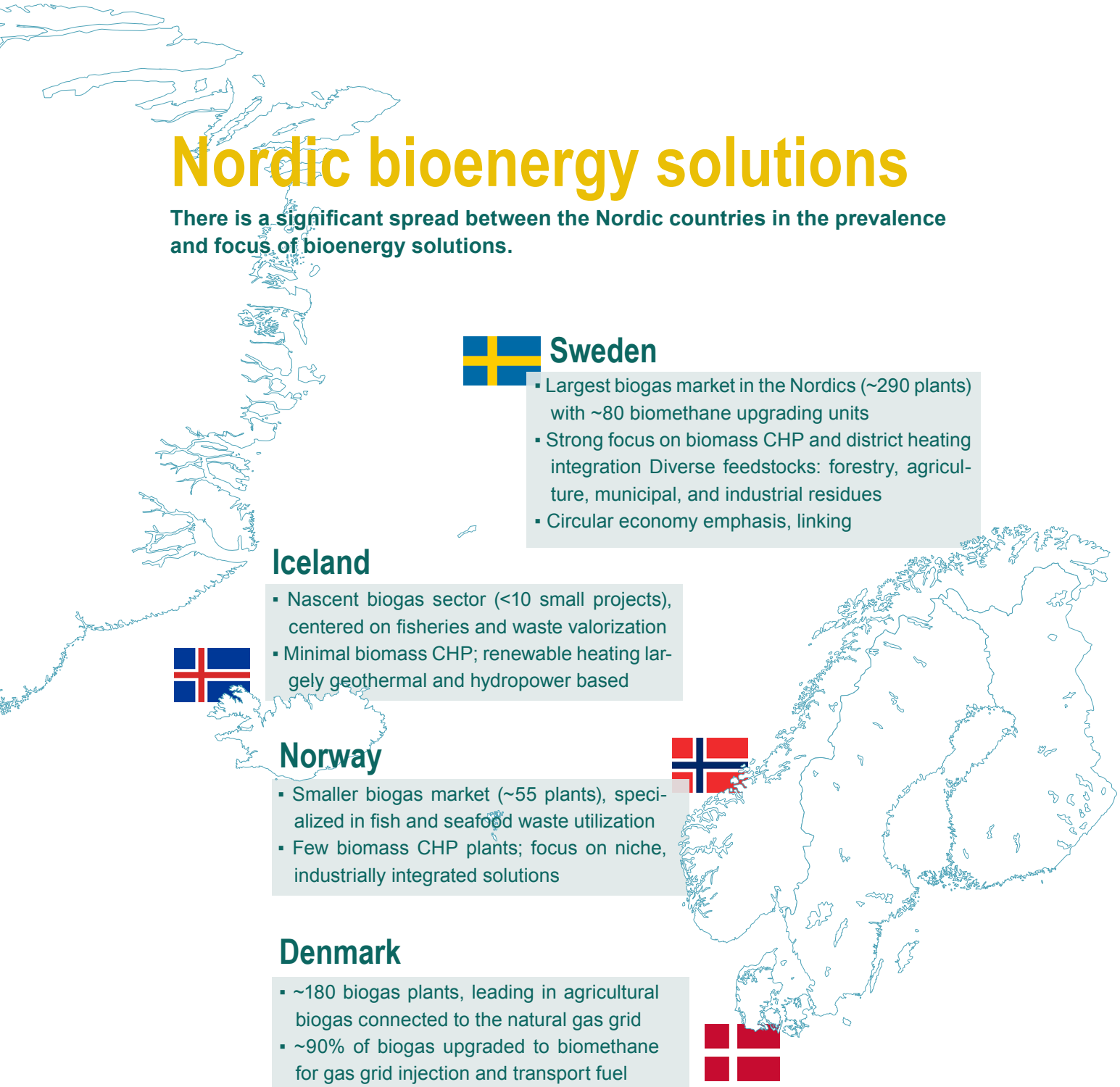
Output

- The resulting energy can take multiple forms, such as heat for households, electricity for the grid, or fuels for transport, directly matched to community needs
- By-products like nutrients and soil improvers can be returned to local land use
- Outputs can also include CO_2 capture and use (CCU), where CO_2 becomes a resource in fertilizer production, green hydrogen, or green fuels, or CO_2 storage (CCS) in geological deposits
- In other cases, outputs may be energy storage solutions such as batteries, methanol, or other green fuels
- The cycle closes when energy and resources flow back to the community, creating a resilient, circular system that reduces reliance on external inputs

Multiple overlapping cycles are possible, but all share common features: local agreements, cooperation with neighbors, short transport routes, and strong frameworks with authorities and investors

Nordic bioenergy solutions

There is a significant spread between the Nordic countries in the prevalence and focus of bioenergy solutions.



Sweden

- Largest biogas market in the Nordics (~290 plants) with ~80 biomethane upgrading units
- Strong focus on biomass CHP and district heating integration Diverse feedstocks: forestry, agriculture, municipal, and industrial residues
- Circular economy emphasis, linking

Iceland

- Nascent biogas sector (<10 small projects), centered on fisheries and waste valorization
- Minimal biomass CHP; renewable heating largely geothermal and hydropower based

Norway

- Smaller biogas market (~55 plants), specialized in fish and seafood waste utilization
- Few biomass CHP plants; focus on niche, industrially integrated solutions

Denmark

- ~180 biogas plants, leading in agricultural biogas connected to the natural gas grid
- ~90% of biogas upgraded to biomethane for gas grid injection and transport fuel

Finland

- 90 biogas plants with rapid growth in biomethane and small/medium biomass CHP
- District heating reliant on biomass (>50% share), particularly forestry residues.
- Focus on circular bioeconomy using agricultural, municipal, and industrial feedstocks

Sources: European Biogas Association, Nordic Energy Research, Swedish Energy Agency, Danish Energy Agency, Luke Finland, Avfall Norge

Selected inspiring case studies

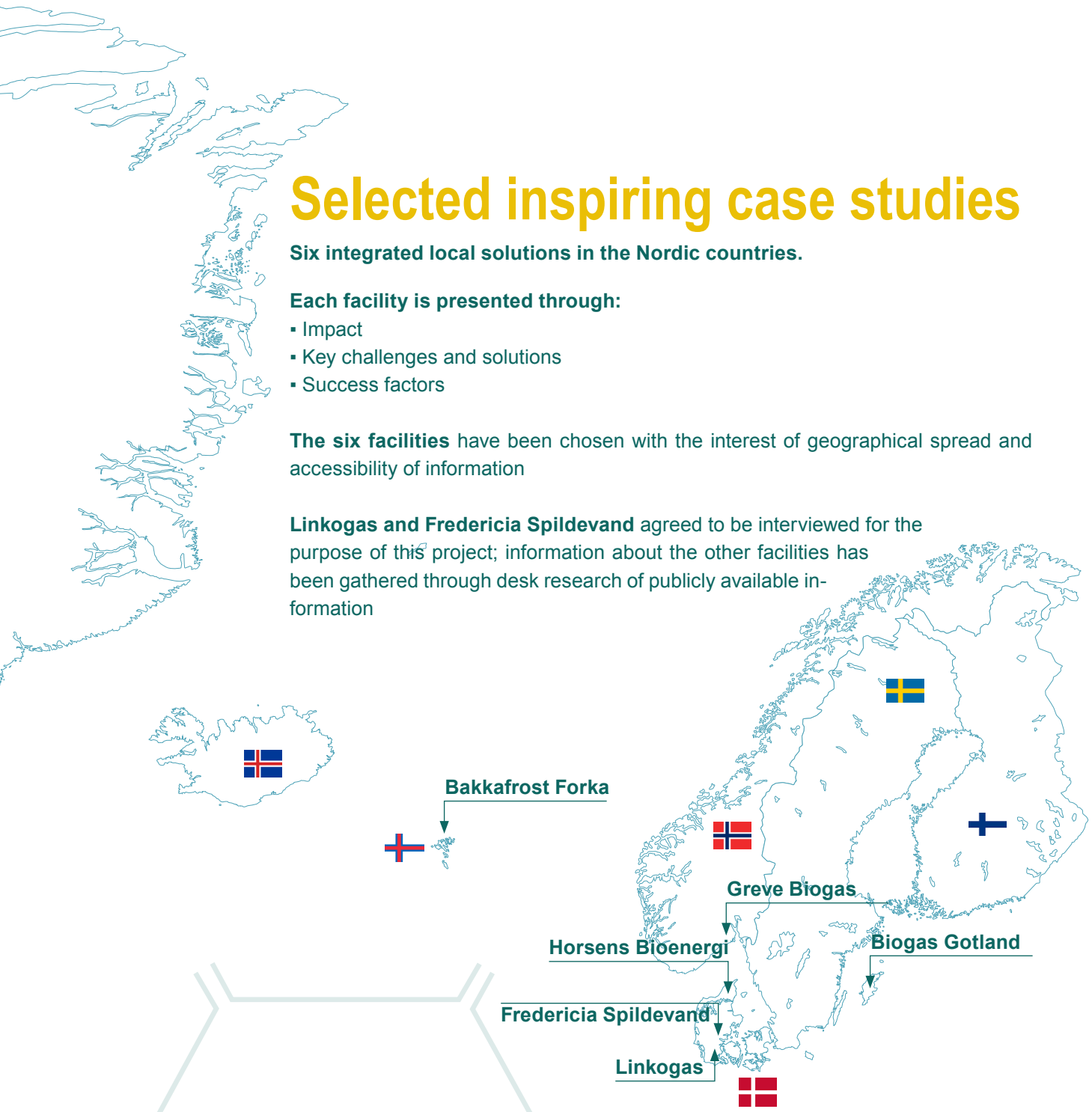
Six integrated local solutions in the Nordic countries.

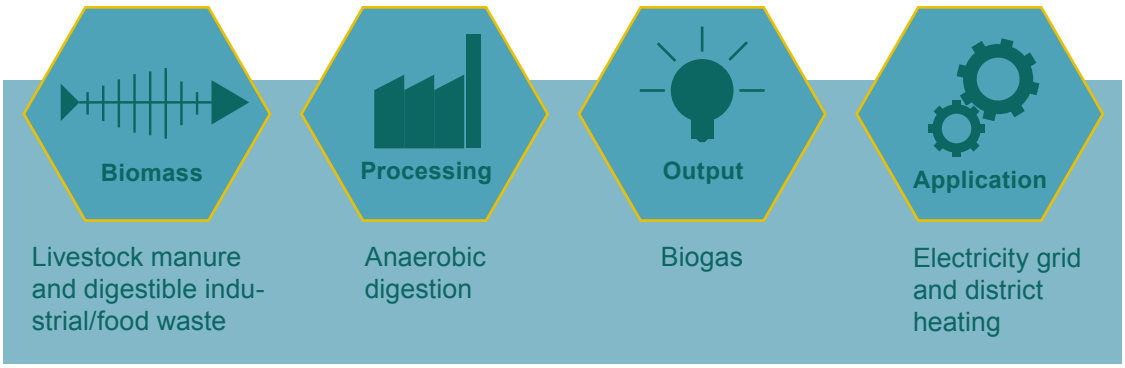
Each facility is presented through:

- Impact
- Key challenges and solutions
- Success factors

The six facilities have been chosen with the interest of geographical spread and accessibility of information

Linkogas and Fredericia Spildevand agreed to be interviewed for the purpose of this project; information about the other facilities has been gathered through desk research of publicly available information





1 LinkoGas

Denmark

KEY CHARACTERISTICS
Region: South Jutland
Employees: Circa 31
Established: 1990
Type: Farmer-owned cooperative

IMPACT
- Handles 600 000 tonnes of substrate/year
- Reported production of 17M m^3 of CO_2-neutral biogas
- Digestate is returned to member farms, closing the nutrient loop
- Integration of local farms into sustainable practices

KEY CHALLENGES AND SOLUTIONS
- Obtaining permits and addressing neighbors' concerns is solved through proactive dialogue and engagement.
- Biomass supply and price volatility countered through long-term contracts with local suppliers
- Building and maintaining strong relationships with farmers and neighbors mitigates resistance

SUCCESS FACTORS
- **Integration with local farmers:** Deep-rooted partnerships and rolling contracts secure reliable supply and community support.
- **Business acumen:** Effective business management underpins financial sustainability and growth.
- **Operational stability:** Full control over biomass sourcing, agreement on payment terms, and consistent supply are critical for success.
- **Support for local goals:** The plant provides meaningful backing to farmers, enhancing their ability to achieve economic and environmental objectives.

Sources: LinkoGas, Danish Energy Agency, IEA Bioenergy, Proff.dk

HOW IT WORKS – BEYOND THE NUMBERS

The Linkogas plant serves as one of Denmark's pioneering centralised biogas facilities, established in 1990 to transform local agricultural waste into renewable energy.

It processes primarily manure and agricultural by-products sourced from a network of over 70 local suppliers within 30 km, forging a cooperative model that emphasizes long-term relationships.

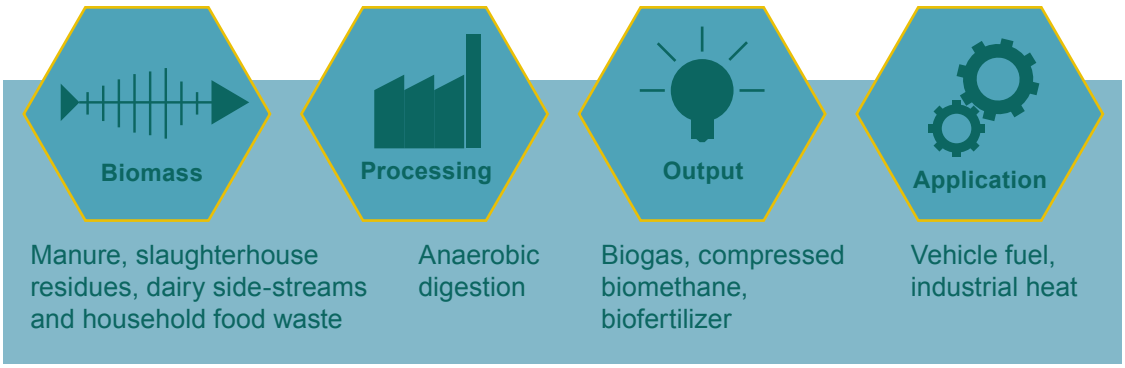
The facility is capable of handling up to 820,000 tonnes of biomass annually, with an output of 17 million cubic meters of methane gas that is largely fed into the Danish electricity and gas grids.

By integrating local waste streams and engaging deeply with community stakeholders – farmers, municipalities, and neighbors – the plant not only enables efficient and sustainable resource use but also provides employment.

Its operational stability is secured by meticulous supply chain control, open stakeholder communication, and ongoing evolution with new technologies such as CO_2 collection and pyrolysis.

The Linkogas model demonstrates how committed partnership and innovation can drive lasting impact in bioenergy, supporting both economic advancement and environmental goals for the region.

Sources: LinkoGas, Danish Energy Agency, IEA Bioenergy, Proff.dk



2 Biogas Gotland

Sweden

KEY CHARACTERISTICS
Region: Gotland
Employees: Not official
Established: 2008
Type: Private company with local investor backing

IMPACT

- Reported production of roughly 20-30 GWh/year (funding by Klimatklivet to increase to ~45GWh/year)
- Reduced imports of fossil fuels and transport of waste off-island, lower transport emissions
- Island nutrient loop is closed via digestate

KEY CHALLENGES AND SOLUTIONS

- **Challenge:** The island logistics results in constrained feedstock volumes and higher per-unit capex
- **Solution:** Concentrate local sources (slaughterhouse, Arla dairy, municipal food waste collections), pipeline to Visby (reduces truck movements) and target end-uses

SUCCESS FACTORS

- Used grants and local investor support to bridge initial economics with regards to financing and permits
- Strong local value chain (feedstock ➔ plant ➔ local industry/fuelling stations)
- Municipal and private investor support
- Infrastructure aligns outputs to local demand

Sources: Gotland & Energi, Länsstyrelsen Gotland, Biogas Gotland

Biogas Gotland

Sweden

HOW IT WORKS – BEYOND THE NUMBERS

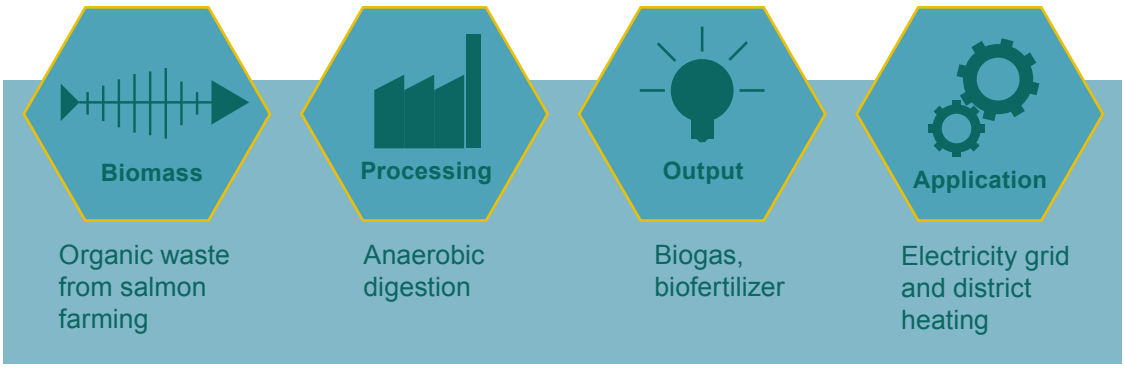
Biogas Gotland stands as an example of locally integrated bioenergy, supporting Gotland's ambition to become climate-neutral by 2040. The company produces biogas entirely from local agricultural residues, food industry by-products, and household organic waste, implementing a fully circular economy approach where the output is returned to the island's fields through 90 000 tonnes of processed biofertilizer/year.

The biogas network includes multiple production and refueling stations, stretching across Gotland from Lärbro in the north to Alva in the south, with two stations in Visby. Biogas Gotland's capacity is under ongoing expansion, with additional facilities planned to meet both increasing local transportation needs and industrial demand. Already, the public bus fleet and several converted private vehicles operate using locally produced biogas, generating social and climate benefits.

Key innovations include highly collaborative local partnerships with farmers, businesses and the regional municipality, as well as demand stimulation programs, purchase and conversion incentives, and resource flows between urban and rural actors. Environmentally, biogas from Gotland achieves significant reduction of emissions of carbon dioxide and nitrogen oxides, substantially outperforming fossil fuels in reducing particulate and greenhouse gas outputs. Socially and economically, the sector spurs new investments and job creation, with surplus returns and energy savings remaining on the island, supporting region-wide sustainability and energy independence.

Biogas Gotland exemplifies the potential of circular local solutions for decarbonizing transport and industry and offers a scalable model for other regions seeking collaborative, low-impact energy systems.

Sources: Länsstyrelsen Gotland, Science Park Gotland, Biogas Gotland, Gotlandsbolaget



3 Bakkafrost FÖRKA

Faroe Islands

KEY CHARACTERISTICS
Region: Eysturoy island
Employees: Not official
Established: 2020
Type: Private ownership (publically listed company)

IMPACT

- Waste valorization by transforming 50 000 tonnes/year of salmon farming organic waste and cow manure into renewable biogas
- Substitution of fossil fuels by producing biomethane
- Recycling digestate by-products into high-quality organic fertilizer

KEY CHALLENGES AND SOLUTIONS

- Complex island-wide collection required partnerships and logistics optimization achieved via stakeholder
- Meeting Faroe Islands' strict environmental standards required extensive stakeholder engagement and communication

SUCCESS FACTORS

- Strong anchor company: Bakkafrost's industry leadership and financial commitment enabled project development and feedstock security.
- Public-private collaboration: Close cooperation with Faroese authorities facilitated permits and secured community support.
- Circular economy principal: Full resource looping from waste to energy and fertilizer, fitting Faroe Islands' sustainability model
- Technological adaptation: Customized anaerobic digestion and biomethane upgrading suited to local conditions.

Sources: Bakkafrost, bio-energy news, niras, SMJ consulting engineers

Bakkafrost

Faroe Islands

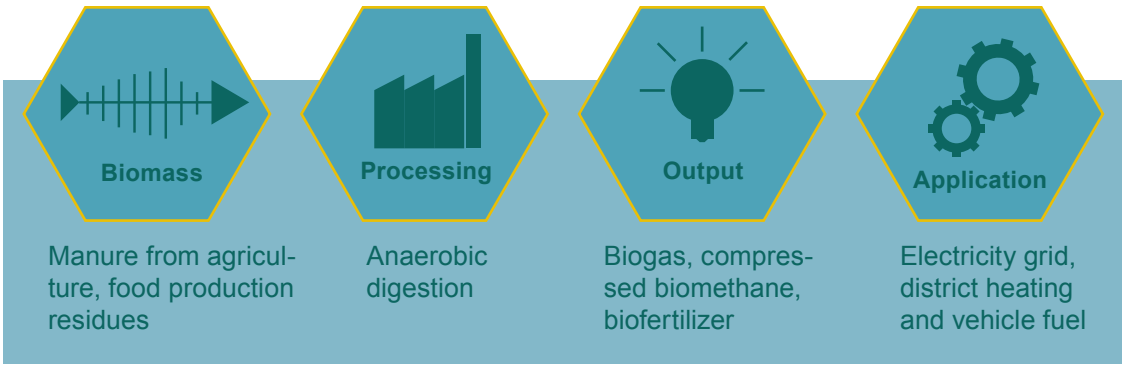
HOW IT WORKS – BEYOND THE NUMBERS

The Bakkafrost Förka biogas plant in the Faroe Islands represents an integrated bioenergy initiative led by one of the region's foremost aquaculture companies. This facility is specifically designed to valorize organic waste streams primarily from salmon farming operations, embodying circular economy principles by converting nutrient-rich residues into renewable energy and biofertilizers. The plant supports local agriculture and helps reduce environmental impacts. Using advanced anaerobic digestion technology, it processes fish farming by-products alongside other organic materials to produce biogas. This biogas is then upgraded to biomethane quality that goes into the local natural gas grid, contributing to the Faroe Islands' renewable energy goals.

Operating in close coordination with local authorities, regulatory bodies, and community stakeholders, the Förka plant overcame considerable challenges - including developing efficient island-wide waste collection logistics, securing regulatory permitting under stringent environmental standards, and deploying cutting-edge gas upgrading technologies adapted to the island's unique conditions.

Förka has created specialized jobs in plant operation and logistics, enhanced regional energy independence, and fostered knowledge exchange around renewable technologies in a remote island context. The digestate by-product, safely recycled as organic fertilizer, supports sustainable local farming practices, reinforcing closed nutrient cycles essential for island ecosystems. The project exemplifies how industry-led public-private partnerships can deliver replicable, integrated bioenergy solutions that combine environmental benefit with community resilience and economic vitality.

Sources: Bakkafrost, bio-energy news, niras, SMJ consulting engineers



4 Horsens Bioenergi

Denmark

KEY CHARACTERISTICS
Region: Midtjylland
Employees: Not official
Established: 2014
Type: Private ownership

IMPACT
- Handles 550 000 tonnes substrate/year
- Reported production of ~20M m^3 biomethane/year, ~67 GWh/year
- Contributing towards closing the loop by sourcing substrate from local farms and industries
- Truck refueling stop established at the plant

KEY CHALLENGES AND SOLUTIONS
- Using biofilters and ventilation control to mitigate odor and air emissions
- Operational planning and traffic engineering to manage logistic/traffic concerns
- Municipal planning and involvement facilitating regulatory/permit challenges

SUCCESS FACTORS
- Strong local feedstock base & industrial symbiosis: Proximity to food production and pre-treatment facilities reduces transport, secures stable inputs
- Grid connection and offtake model: Long-term arrangement to upgrade and inject biomethane to grid
- Scalable design and phased expansion: Demonstrated ability to scale while addressing environmental and traffic constraints.
- Public funding & local anchoring: Project has referenced EU Rural Development Fund support, plus strong municipal ties

Sources: Horsens bioenergi, Malmberg SE, Idus.se, Envidia

Horsens Bioenergi

Denmark

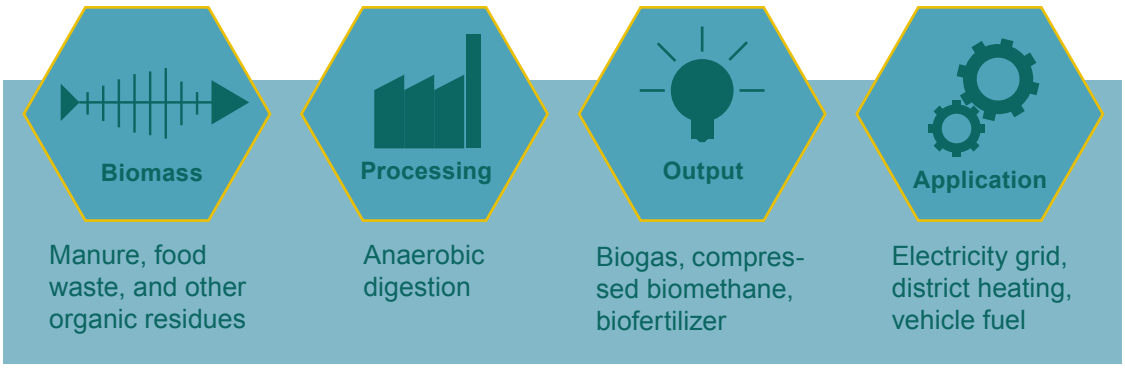
HOW IT WORKS – BEYOND THE NUMBERS

Horsens Bioenergi in Denmark exemplifies an integrated bioenergy facility that combines local resource utilization with advanced biogas production technologies to support sustainable energy and agricultural practices in the region. Established to serve the Horsens municipality and surrounding areas, the plant focuses primarily on transforming organic waste streams, mainly agricultural residues, manure, and by-products from local industries, into renewable biogas. The produced biogas is either converted into electricity and heat or upgraded to biomethane and injected into the natural gas grid, contributing significantly to Denmark's renewable energy targets and circular economy objectives.

This facility is notable for its collaborative supply network, which consists predominantly of local farmers and businesses within a defined radius, ensuring the continuity and quality of biomass feedstocks. Through long-term agreements and rolling contracts, Horsens Bioenergi secures stable biomass input, which is crucial for its operational consistency and economic viability. The plant also emphasizes community engagement and environmental stewardship, exemplifying how biogas plants can integrate into local ecosystems with minimal disruption. Horsens Bioenergi has been instrumental in creating local employment opportunities, supporting a workforce responsible for plant operations, transport logistics, and technical maintenance. Furthermore, it plays a pivotal role in reducing methane emissions that would otherwise be released from the decomposition of organic waste in less controlled environments.

The success of the Horsens Bioenergi plant is rooted in several key factors: strong business acumen, solid partnerships with local suppliers, and attentiveness to technical and environmental standards. The integration of state-of-the-art anaerobic digestion technologies permits high-efficiency conversion rates, while ongoing innovation, such as advancements in CO_2 capture and resource recovery, ensures the plant remains at the forefront of sustainability efforts.

Sources: Horsens bioenergi, Malmberg SE, Idus.se, Envidia



5 Greve Biogass

Norway

KEY CHARACTERISTICS
Region: Vestfold
Employees: Not official
Established: 2013
Type: Municipal co-ownership

IMPACT
- Handles ~135 000 tonnes of substrate/year
- Produces 9M m^3 biomethane/year, 120 GWh~/ year.
- Supports sustainable agriculture by recycling nutrient-rich digestate as biofertilizer
- Reduces methane emissions from waste decomposition

KEY CHALLENGES AND SOLUTIONS
- Gaining environmental permits required proactive dialogue with authorities and impact assessments
- Ensuring biomass supply and community acceptance through long-term contracts and agreements
- Maintaining community acceptance by transparent communications and responsiveness to local concerns

SUCCESS FACTORS
- Cooperative ownership and strong collaboration with local biomass suppliers secured feedstock stability and aligned interests
- Adoption of advanced anaerobic digestion and biogas upgrading technologies improved methane yield and gas quality
- Focus on environmental compliance and community relations fostered regulatory success and social license to operate
- Strategic long-term planning and financial oversight ensured operational stability and resilience to market fluctuations

Sources: NLI, Den magiske fabrikken, Malmberg EN

Greve Biogass

Norway

HOW IT WORKS – BEYOND THE NUMBERS

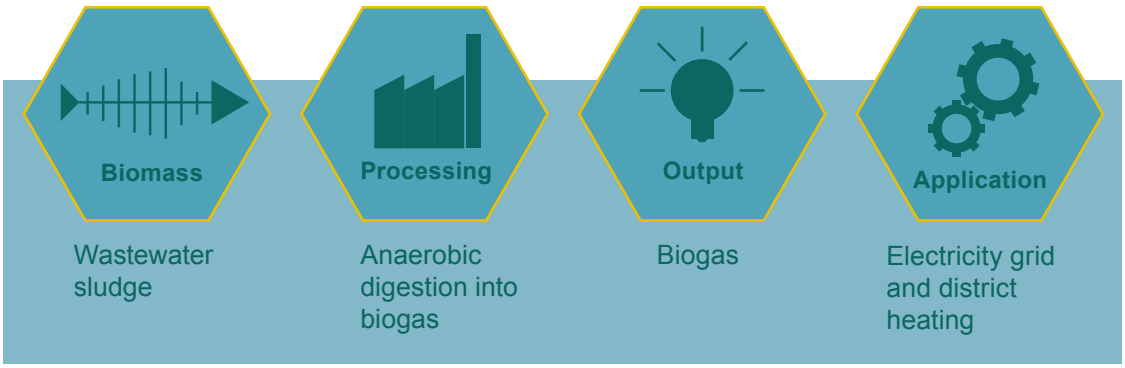
Greve Biogass, known locally as “Den Magiske Fabrikken” (The Magic Factory), is a large-scale biogas facility located outside Tønsberg in Norway. Established through a unique collaboration between Vestfold and Grenland regions, and officially launched in 2015, the plant is municipally owned by a consortium of local waste management companies and municipalities, including Vesar AS and Vestfold’s and Grenland’s key communities.

The biogas plant receives sorted food waste from approximately 1.2 million citizens, along with animal manure supplied by local farmers, particularly cattle and pig livestock operations in Vestfold. Together, this amounts to ~135 000 tonnes of organic material processed annually, making Greve Biogass Norway’s largest biogas and biofertilizer facility by volume. Farmers in the region benefit directly from the arrangement, receiving natural, nutrient-rich biofertilizer in return.

Biogas is produced via anaerobic digestion, with the resulting biomethane upgraded and distributed through pipelines for industrial use and as transport fuel, notably serving buses, garbage trucks, and the region’s CBG/LBG refueling stations. The integration of manure and food waste into the biogas process not only cuts greenhouse gas emissions by diverting methane-producing substrates from landfills but also improves regional energy independence and security.

The plant’s innovation extends to utilizing the green CO_2 from biogas upgrading for local greenhouse operations, such as commercial tomato production, creating even more value for the local food economy. Operational flexibility is built into the site’s design, allowing it to serve as a peak load biogas provider when energy demand is highest.

Sources: NLI, Greve Biogass, Malmberg EN, Reklima



6 Fredericia Spildevand og Energi A/S

Denmark

KEY CHARACTERISTICS
Region: Southern Denmark
Employees: Ca 50
Established: 1978
Type: Municipal

IMPACT

- Integrates biogas production into municipal CO_2 and energy balance, contributing to the green agenda.
- Supplies electricity to grid and heat to district heating
- Energy neutrality for wastewater sector by balancing own high energy use with in-house generation.

KEY CHALLENGES AND SOLUTIONS

- Declining sludge volumes from industries result in reduced production
- Slow policy adaption keeps legislative barriers in place, such as ban on upgrading biogas to biomethane for grid
- Long investment horizons vs fast-changing wastewater flows

SUCCESS FACTORS

- Monopoly structure: Municipality-owned utility with stable demand base and regulated revenues
- Strong technical expertise ensures reliable plant operation
- Strategic partnerships with major industrial stakeholders
- Incremental and phased scaling over 40-50 years has ensured a stable matching of industry and municipal needs

Sources: Fredericia Spildevand

Fredericia Spildevand og Energi A/S

Denmark

HOW IT WORKS – BEYOND THE NUMBERS

Fredericia Spildevand og Energi A/S operates an integrated wastewater treatment and bioenergy facility in Fredericia, Denmark. The plant processes all municipal wastewater sludge using anaerobic digestion, where the organic material in the sludge is broken down in large biogas reactors. This process reduces the volume and treatment costs of sludge and produces biogas as a renewable energy source.

The biogas generated is converted on-site into electricity and heat using a gas engine. The electricity is sold to the national grid, and the heat is supplied to the local district heating, contributing directly to the community's energy supply. This approach helps the municipality meet its sustainability and CO_2 reduction targets, as the plant's energy production is included in the local energy and emissions balance. The facility relies solely on internal municipal sludge without external organic waste.

Fredericia Spildevand og Energi has explored advanced options like biogas upgrading and pyrolysis, but legislative and economic constraints have limited their adoption. As a result, the plant focuses on proven, reliable solutions to deliver environmental and operational benefits within a highly regulated, public-sector framework.

Sources: Fredericia Spildevand

Insights and recommendations

Partnership, trust and diversification are key success factors

Stakeholder alignment and trust-building

- Farmer-owned cooperative structures secure feedstock stability and long-term community buy-in
- Municipal co-ownership builds legitimacy and resilience against policy or market shocks
- Early dialogue with authorities and neighbours eased permitting challenges and conflicts

A stable supply of feedstock over time

- Predictable input streams over time are essential for operational stability
- Long-term contracts with farmers, industry by-product integration and coordinated logistics is necessary to ensure consistent input

Diversity of outputs and business models

- Facilities enhance viability by producing not only biogas but also biofertilizers and captured CO_2
- Multi-output strategies hedge against market volatility and unlock additional revenue

Establishment can meet a wide variety of obstacles

Permit processes and community resistance

- Odour, traffic, or environmental impact concerns surface repeatedly. Projects that neglected community engagement faced delays; those that engaged early built lasting acceptance

Feedstock logistics and volatility

- Remote locations such as islands struggle with higher transport costs and constrained volumes
- Mainland plants depend on continuous farmer cooperation and transparent payment structures

Economic and financial constraints

- High upfront capex and long payback periods, particularly for smaller or isolated projects, necessitate public grants, favourable regulation, or strong private anchor investors

Scalability limitations

- While plants demonstrate local success, scaling across regions requires harmonized regulations, improved infrastructure (e.g., gas grids, refuelling networks), and access to financing

What can policymakers, industry and communities do to strengthen integrated bioenergy solutions?

Policymakers

- Streamline permitting processes and establish predictable regulatory frameworks to lower entry barriers
- Provide targeted financial instruments (grants, guarantees, feed-in tariffs) that address long pay-back periods
- Support infrastructure investments (e.g., gas grid extensions, CO_2 utilization) that enable multi-output business models

Industry actors

- Build resilient supply chains by forming cooperative agreements with farmers and food industries
- Explore diversified revenue streams to strengthen economic sustainability

Regional stakeholders

- Ensure that benefits (jobs, reduced emissions, nutrient recycling) are clearly visible and locally retained
- Leverage locally integrated bioenergy as a tool for both environmental goals and rural development, strengthening the bond between agriculture, industry, and municipalities

Concluding remarks

Continue enabling knowledge transfer and bridge building

- Continue curating and disseminating inspiring local solutions
- Facilitate exchange between municipalities, farmers, utilities, and industry

Strengthen policy & funding frameworks

- Advocate harmonized regulations across the Nordic-Baltic region
- Support pilot projects and scale-up

Position the Nordics/Baltics as leaders

- Showcase regional successes internationally
- Promote the aligning of bioenergy solutions with broader EU climate, energy, and circular agendas