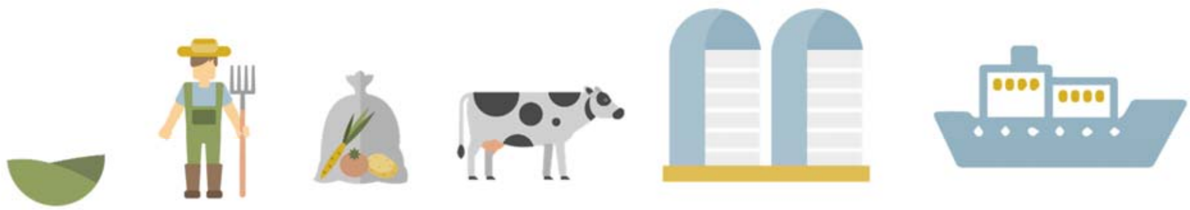
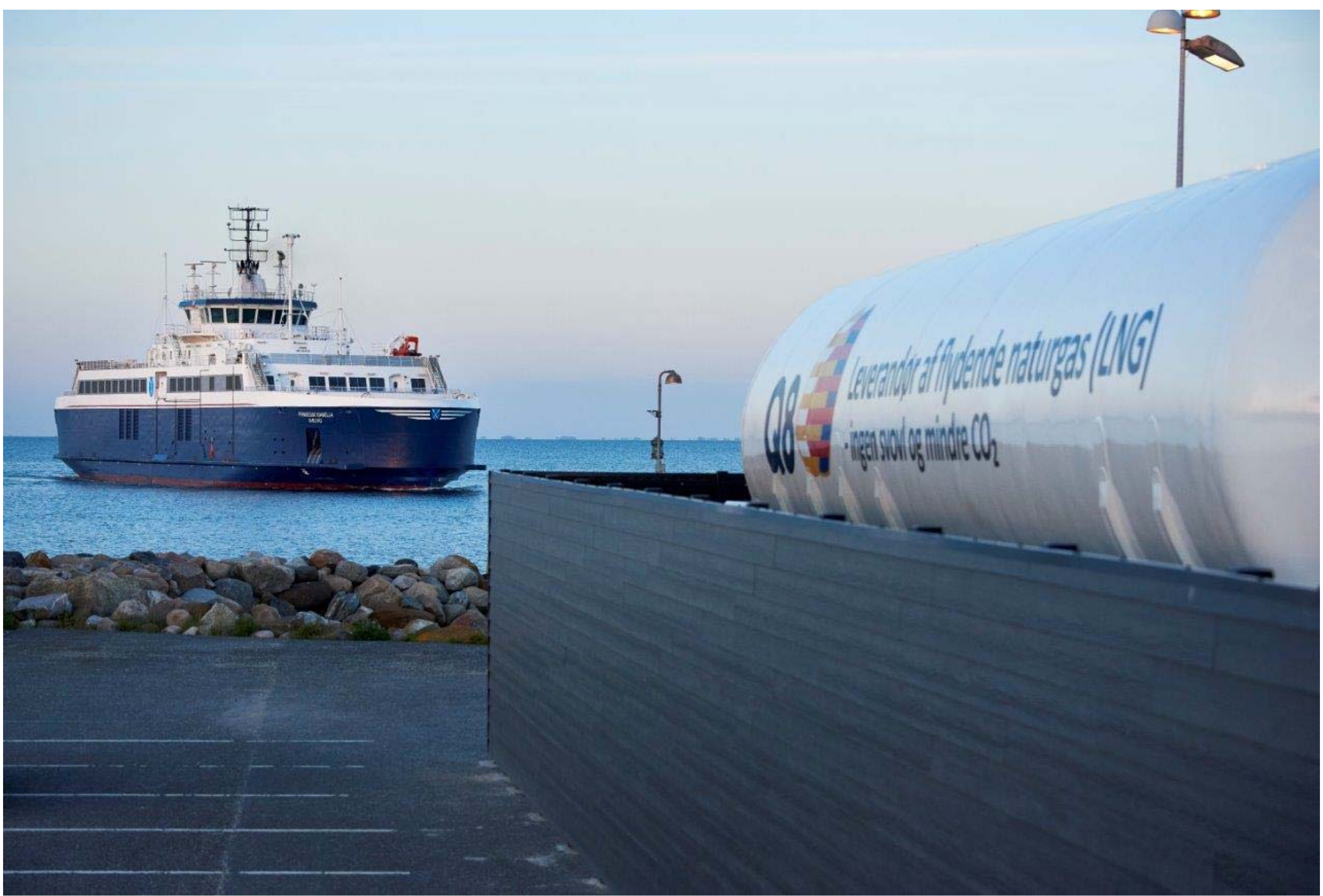
Liquid Biogas Business Concept

A business model concept for renewable shipping fuel from local resources in coastal communities in the Baltic Sea Region.





Summary

The report analyses briefly the emerging market for both Liquefied BioMethane for marine transport and the corresponding market for coastal communities to produce biogas and to concentrate the biomethane in a liquid form either for heavy duty road traffic, for trains or for ferries.

The Samsø Field to Ferry *business concept is perhaps a one-of-a-kind case, but inspiration can be taken for other localities with similar aims and options.*

The report combines the biogas planning manual from Denmark with a generalized business concept model and ideas of crowdfunding into a conceptual model for other coastal communities.

Colofon.

To be cited as: *Tybirk K., 2018. Biogas Liquefaction and use of Liquid Biomethane. Status on the market and technologies available for LNG/LBG/LBM of relevance for biogas actors in 2017.*

This work is supported by the Interreg Baltic Sea Programme, project GO-LNG, and builds heavily upon business concept development with support of the Interreg Øresund-Kattegat-Skagerrak programme project Biogas 2020 and Central Denmark Region.

Background –Field to Ferry concept

The Renewable Energy Island of Samsø, Denmark, with 3750 inhabitants, has a vision to become free of fossil fuels by 2030. The vision has been formulated in a long participatory process involving business and civil society. Samsø Energy Academy and the Samsø Municipality have been two major driving forces together with the civil society and the local small enterprises. The vision of becoming fossil free has been adopted by the municipal planning.

For this to be realized, the transport sector needs focus on alternative fuels, Therefore, the municipality started their own shipping company in 2013 and ordered a new LNG fueled ferry, inaugurated in 2015. An important part of the motivation for this investment was to pave the way for biogas production on the island. Biogas production has hitherto been difficult due to lack of profitable gas use opportunities. Much of Samsø is heated by straw and woodchip fired district heating and already we export renewable power from wind turbines and PV installations to the mainland.

It is the ambition to become a model society for the national 2050 goal of a 100% fossil free Denmark. The most crucial element in the infrastructure of Samsø is the ferry. It is the lifeline of the island, and at the same time by far the single largest consumer of fossil fuel.

In 2015, a feasibility study (Mikkelsen 2015) was carried out to document this new value chain concept *From Field to Ferry*. The main conclusion of the feasibility study was that there is a basis for establishing the planned biogas chain on Samsø for the production of fossil-free fuel for the ferry. Samsø Municipality is now working on the specific technical planning and the business plan (in Biogas 2020 and Go-LNG projects) to be able to produce gas for the ferry in 2018. Several EU and nationally funded projects support the development towards these ambitions and the present report is building upon work started in Biogas 2020. The work in GO-LNG supports further focus on the liquefied gas market and the business and financial models to enable Samsø to make the investments and to inspire other Baltic Sea Region coastal communities with the innovative approach for truly changing the sustainability of shipping.

In a broader sense, the background for this report is indeed the overall crucial need to replace fossil transport fuels with renewable energy sources. Numerous reports have shown (see Bouman et al. 2016) that this is the most difficult challenge towards a society less dependent on – or even free of - fossil fuels.

The aim of this report

The aim of this report is to analyse the emerging market for both liquefied biomethane for marine transport and the corresponding market for coastal communities to produce biogas and to concentrate the biomethane in a liquid form either for heavy duty road traffic, for trains or for ferries. We will explore, analyze and assess the biogas value chain as a case on Samsø and as potential for replicating to other coastal communities. Furthermore, we will describe a potential model for crowdfunding of Samsø 'Field to Ferry' value chain for inspiration.

The goal is to *provide a case study on liquid biomethane (LBM[1]) production from technical, economic, environmental and social aspects for decision support* and to discuss the market perspectives in the Baltic Sea Region.

We will start with a short intro to the LBG market and continue with the planning for a biogas plant, which in many cases is not just straight forward and take into consideration the opportunities and constraints for

[1] In this report we use the term LBM for Liquid Bio Methane, and biomethane for upgraded, but not liquefied biogas. LNG is the market dominant fossil alternative to LBM.

liquefaction and delivering of the LBM to the customers. The set-off is the Samsø Case and we will describe this case rather detailed to inspire for other coastal communities in the Baltic Sea Region and other regions.

Shipping industry energy consumption

The energy source for the propulsion of ships has undergone significant transformations over the last 150 years, starting with sails (renewable energy) through the use of coal to heavy fuel oil (HFO) and marine diesel oil (MDO), now the dominant fuels for this sector. The consumption of these fuels has been increasing over the years in line with rising demand for shipping.

The shipping industry is worldwide a huge consumer of fossil fuels and the shipping industry has increased since the fossil fuels were implemented in shipping. However, the registration and therefore also statistics for the energy consumption for the sector is rather uncontrolled and poor. In the following we use the Danish statistics for an exemplified insight.

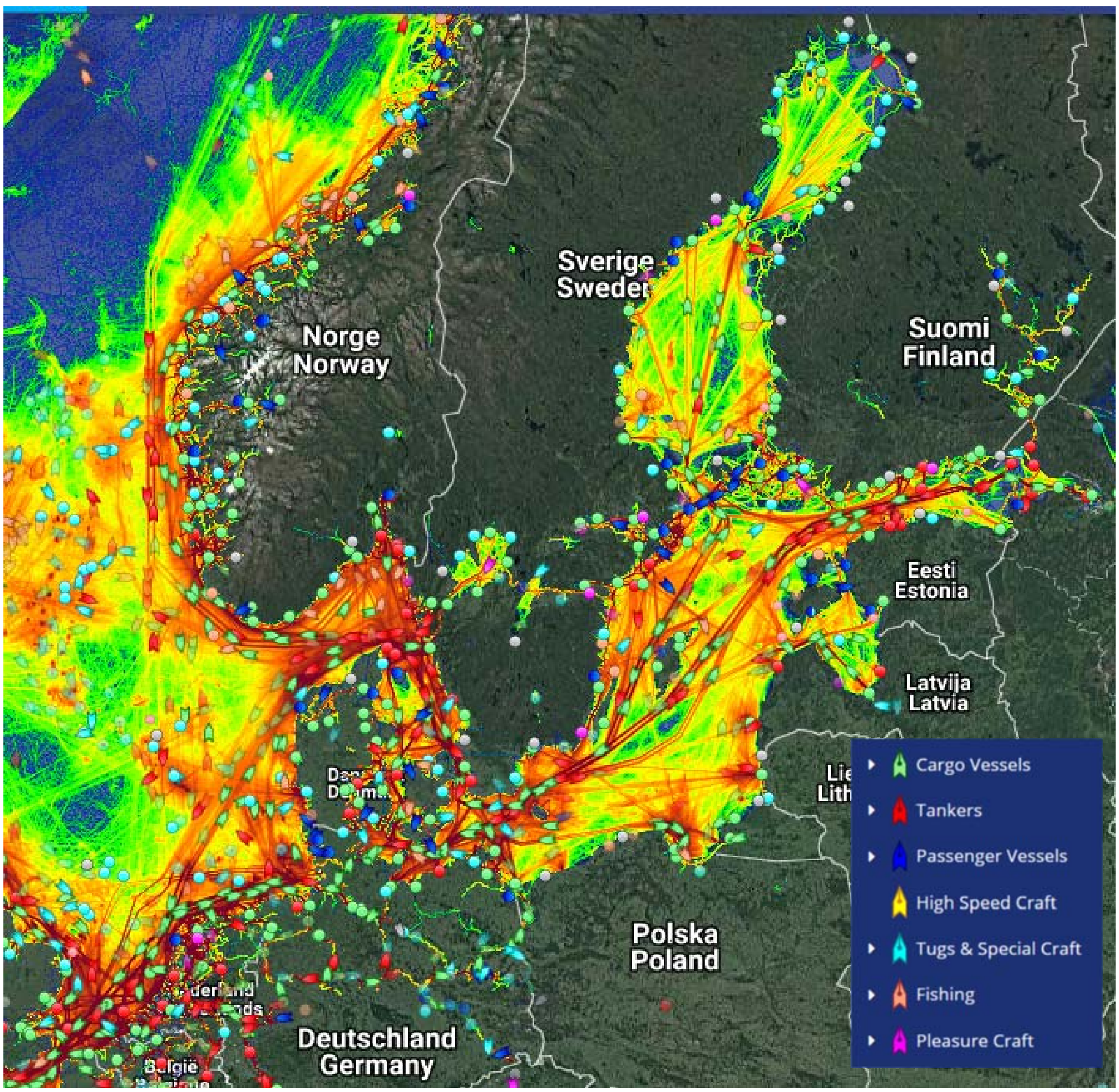


Figure 1. Source marine traffic.com, November 27 2017

Present and future energy consumption

Shipping energy consumption is not a straightforward task to calculate and only recently it has become mandatory for ships to register the energy purchase/use, exemplified by the Danish marine energy consumption data. Energy consumption can be calculated based on

- sailing within Denmark,
- sailing under Danish flag or
- including half of international voyages from/to Denmark or
- ships run by a Danish Company (e.g. Mærsk)

Table 1. Danish Shipping sector energy consumption, depending om calculation method. Source: Danish Technical University calculations (Wiese, Pers. Comm. 2017)

	Energy (PJ)	Emission (Mt CO_2/yr)
Danish ships within DK (Energistyrelsen 2015)	6	0.4
Danish ships (Danmarks Statistik)	10	0.8
Incl. half voyages from/to Denmark	280	21.6
Ships run by a large Danish company (Mærsk 2016)	445	34.3

However, the sector is now facing more registrations and in the future probably more regulation towards less CO_2 emissions.

Shipping energy scenarios

The International Maritime Organisation (IMO) estimates that between 2007 and 2012, on average, the world's marine fleet consumed between 250 and 325 million tonnes of fuel annually, accounting for approximately 2.8% of annual global greenhouse gas emissions. Emissions are expected to rise with shipping demand and could triple by 2050 if left unchecked.

Potential renewable energy sources for shipping applications include wind (e.g. soft sails, fixed wings, rotors, kites and conventional wind turbines), solar photovoltaics, biofuels, wave energy and the use of super capacitors charged with renewables. The transition to a clean energy shipping sector requires a significant shift from fossil fuel-powered transport to energy-efficient designs and renewable energy technologies, starting today. The International Maritime Organisation under United Nations (IMO) have launched a strategy, not only to comply with sulphur and NOx emissions ceilings, but also to comply adequately to the goals set in the Paris Agreements (European Commission, 2017b).

IMO has in April 2018 decided to fulfil their 'fair share' of global GHG emission reductions as agreed upon in Paris 2016, by reducing the sector CO_2 emission by 50% in 2050 as compared to 2008 (Figure 2). For this to be effective, the sector has to look more into the biofuel alternatives, and the draft of EU Renewable Energy Directive(article 25) (European Commission, 2017a) propose an incentive for blending of biofuels for the marine sector within EU from 2021.

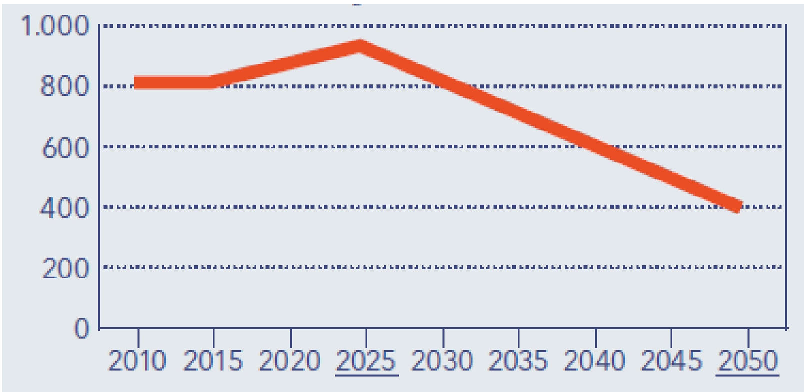


Figure 2. CO_2 emission (in Mio. t Annually) with an expected increase due to global growth until 2025 and a proposed emission reduction of 50% by 2050 (Danske Rederier, n.d.)**.**

In 2011, the IMO agreed upon the first binding CO_2 emission regulations with focus on improving the energy efficiency by 30% in 2025. But with increase in world trade, energy efficiency is not enough to contribute to the global climate goals (Smith et al., 2016). IMO recommend a gradual transition, net emissions will need to peak in 2025, with absolute emission reductions amounting to approximately 400 million tonnes in net emissions, by 2050. Consistent with the Paris Agreement, emissions will then need to reduce to zero during the second half of the 21st century.

Bouman et al. (2017) shows that 75% of CO_2 emission reductions could be achieved by existing technologies, such as Hull designs, alternative fuels, power and propulsion systems, alternative energy sources (wind, sun, fuel cells) and operation. By far the largest potential for GHG emission reduction has been found in biofuels, such as LBG.

Smith et al. (2016) showed that a number of energy efficiency interventions, alternative (low carbon) fuels such as biofuel and hydrogen become preferable to the use of extremely low operational speeds in combination with fossil fuels.

Purchasing 'offset' tickets or bio-tickets can also be an option to reduce carbon footprint and the calculation scenarios for the take up of biofuels varies among the scenarios based on the assumption used on bioenergy availability. Scenario 10 has the largest take up of biofuels in accordance with the high bioenergy available in this scenario. In this case biofuels reaches about 35% of the total fuel supply in 2050. The take up of biofuels is also significant in other scenarios (about 10 - 13%) of the total shipping energy demand in 2050. The gap between the price of biofuels and conventional marine fuels is not modelled in the report (they are set at the same price as their fossil fuel equivalents) because it is assumed that it will become small, therefore, the key parameter is their availability.

One of the consequences of this demonstrated potential significance of the role of biofuels in shipping's decarbonisation is that it raises the importance of shipping increasing its involvement and awareness in the debates around bioenergy's availability, use and wider impacts (e.g. issues associated with land-use and life cycle emissions).

Scenario 7, which involves the largest rate of take-up of LNG, demonstrates the consequence of lower capital costs (both for alternative main engine machinery (LNG and hydrogen main machinery and storage technology), and energy efficiency equipment). In scenario 7, LNG gains a larger market share, because it is the machinery of choice from 2015 onwards (extract from Smith et al 2016, see also figure).

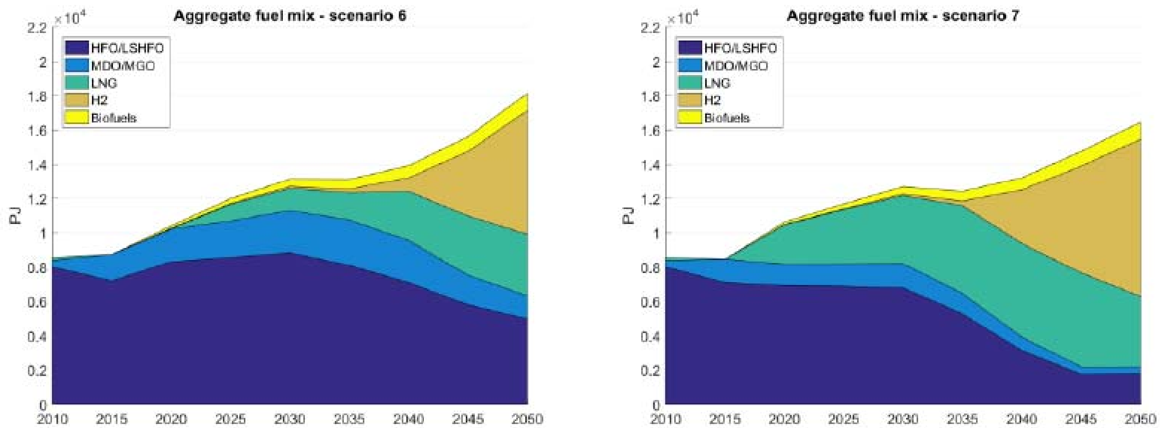


Figure 3. The aggregate fuel mix for two of many scenarios (from Smith et al. 2016)

Most of the existing LBM production (2017) is based on land-fill gas producing in total around 43,000 tons annually (Tybirk et al. 2018), but expected to increase in the near future.

Although the need for sustainable marine transport fuel is next to immense and the potentials for LBM production in coastal communities is limited, we see the potential showcase and the analysis of preconditions to take into consideration as a major step in inspiring more states, regions and municipalities to move in this direction.

Biogas market development

The biogas sector accounts for 66,000 jobs in Europe, out of which most are in rural areas, generating inclusive growth. In 2015, Europe had > 17.000 biogas plants and >350 biomethane upgrading installations and these numbers are increasing (European Biogas Association 2015). Germany by far outnumbers other countries, but the development here is stagnant. However, many plants are developing and increasingly biogas is understood as a potential engine for circular economy and also a necessity to be able to supply the transport sector with increasing demands for renewable fuels.

Upgrading and injection into the gas grid is an option in many areas which – with biomethane certificates can make biogas available for transport in many regions. The various usages are supported with incentives as most other renewable sources, but the incentives vary between countries and use. The support for biogas is typically reflecting the energy content, whereas other positive environmental effects (GHG emission reduction, recycling of societal waste, production of circular fertilizer, storage of energy in gas grids etc.) are not directly acknowledged. Until now, no support for liquefaction of biogas has been implemented in Baltic Sea Region or EU as such. Incentives will be discussed more in the section of constraints and opportunities.

However, it is expected that the tendency towards liquefied natural gas for heavy vehicles and for shipping is going to drive the next step towards the phasing out of fossil fuels by conversion of biogas into biomethane and further on to Liquefied Biomethane (LBM) a very concentrated fuel comparable to fossil fuels.

Two of the main advantages of LBM are that it can be transported relatively easily and that it can be dispensed to either LNG vehicles or CNG vehicles. LBM is transported in the same manner as LNG, that is, via insulated tanker trucks designed for transportation of cryogenic liquids. Still, very few installations producing LBM are running, notably one plant in Sweden, 2-3 in Norway, and few demo plants around the world.

New technologies for this scale are emerging such as a recently inaugurated plant in Ireland. A major challenge is that the Liquefaction technology has been developed for large scale installations for liquefaction of natural gas, and the technology for micro- or nano- scale liquefaction (in case of most biogas plants) in the range of 250-200 Nm^3 hourly of biogas production is still young technology (Tybirk et al. 2018).

However, recent workshops show that the producers of the technologies are ready to install nano-scale liquefaction plants where biogas is produced in areas without a gas grid – either for transporting the biomethane in liquid form by truck to inject into a gas grid or to deliver the LBM for local ferries.

Potentials for biogas in shipping industry

The global LNG shipping industry has grown rapidly in recent years, supporting the increasing use and availability of natural gas and the drive to cut costs in LNG processing and transport. It took 34 years from the commencement of commercial LNG shipments for the in-service fleet of LNG carriers to reach 100 vessels, in 1998, but the 200-vessel barrier was broken in 2006 and by June 2017 500 vessels are on the global market.

However, these are LNG carrier vessels using boil-off gas and LNG as fuel for other vessels is also increasing. LNG as a fuel is both a proven and available commercial solution. LNG offers huge advantages, especially for ships in the light of ever-tightening emission regulations. The growth in LNG shipping is concentrated in Norway/ The Baltic Sea and China, but other regions are coming too.

Until now, the market has been seen as a pure LNG market, but recently also the LBM has been found to become a player in the future market. Typically, it is seen as the LNG to pave the way for an ultimate substitution by LBM to reduce GHG emission, but another option could also become a part of the future market. The blending of biomethane and fossil methane from the gas grid where biomethane has been injected could be an intermediate step under certain conditions. This aspect will be treated and exemplified in a later section.

Still, however, the next huge step for emission reductions is to replace LNG with LBM, and for this to happen, the planning in very different sectors, such as agriculture, marine industry and local/regional transport planning has to be aligned.

The obvious place to start is where a local /regional ferry has a strong connection to a coastal community and serves as the main transport to mainland and the market for agricultural produces. In such a case we have mutual interests to build the innovative cooperation around local energy consumption and sustainable development, job creation and world connectivity.

Methane liquefaction technologies

The choice of liquefaction processes has diversified during recent years, but basically it is the same overall technology to purify and cool down the methane for liquefaction. This report is, however, not a detailed technological comparison of the different technologies, but we merely try to describe the currently available solutions from a technical market specific point of view. This section is an update from the LBM status (Tybirk et al. 2018).

The scale of Liquefaction

Liquefaction is usually done in large scale (> 1000 metric tonnes per day or 365.000 tonnes annually) at larger refineries, but when we are looking into biogas the process has to become downscaled, as biogas is usually not produced in large quantities.
We have to look into another scale of gas liquefaction as described by Cryonorm:

- Small-scale <500 Metric Tons LBM per Day or 182,500 tonnes annually
- Micro-scale <75 Metric Tons LBM per Day or 27,000 tonnes annually
- Nano-scale <10 Metric Tons LBM (or 13,800 Nm3 Biomethane) per Day (575 Nm^3 Biomethane /hour) or 3,650 tonnes LBM annually

The promotion of LNG as marine fuel, requires the development of small-scale gas liquefaction facilities at the biogas plants i.e. with a capacity (much) below 100.000 tonnes annually per unit and corresponding bunkering facilities in harbours, (Nguyen et al. 2017). The matching of the biogas production in nano-scale, requires either the match of a corresponding ferry to utilize the fuel, or perhaps future biomethane/natural gas blends to reduce CO_2 emissions of the Marine transport sector.

A recent study (Nguyen et al. 2017) mentioned a methane input of two tonnes/hour, which could be considered 'Micro-scale' production facility. However, in the project plan of Samsø Biogas, the annual estimated biomethane production is expected to be approx. 3,5 mio. Nm^3 of biomethane annually (approx. 30 GWh or 0.1 PJ), corresponding to 6-7 tonnes LBM per day (Samsø Kommune, 2017).

Large scale liquefaction technologies

LNG liquefaction can be grouped into two main categories (Roberts et al. 2015):

- Small to mid-scale LNG which relies on single pure refrigerants
- Large-scale LNG which relies on mixed refrigerants

For large-scale LNG, there are several variations of the mixed refrigerant (MR) technologies including:

- Propane pre-cool (C3MR), single mixed refrigerant,
- Dual mixed refrigerant (DMR),
- Parallel mixed refrigerant,
- Mixed Fluid Cascade Process (MFCP), and
- C3 MR with a nitrogen refrigeration cycle (AP-X) process.

More details on these technologies can be found http://hub.globalccsinstitute.com/publications/ccs-learning-lng-sector-report-global-ccs-institute/38-lng-liquefaction (Global CCS Institute, n.d.).

The most energy-efficient large scale liquefaction process is a cascade system (Andress, 1996) based on propane, ethylene and methane in three refrigeration cycles. It requires a high equipment inventory and is therefore not suitable for small-scale applications. Expander-based layouts build on different configurations of reverse Brayton cycles are compact, simple, and inherently safe, since nitrogen is the most common refrigerant medium (Roberts et al., 2015).

However, they are generally less efficient than mixed-refrigerant processes (Nguyen et al. 2017), which operate with a mixture of hydrocarbons and nitrogen as working fluid. The refrigerant changes phase in the cryogenic heat exchangers, which presents the advantage of high heat transfer coefficients. The refrigerant composition may also be adjusted over time, if there are leaks of the most volatile components, or variations of the feed gas composition.

For large-scale Liquefaction of natural gas, a couple of companies seem to dominate the marked:

- Air Products' liquefaction processes accounted for nearly 80% of existing plants in 2016, mainly the so-called
    - Nitrogen recycle LNG liquefier or single mixed refrigerant for below 250.000 tonnes annually,
    - Propane precooled mixed refrigerant process (above 250.000 ton annually)
- ConocoPhillips Optimized Cascade® process increasingly gathering market share for large plants
    - The Optimized Cascade process is based on three multi staged (Propane, Ethylene and Methane as refrigerants), cascading refrigerant circuits using pure refrigerants, brazed aluminium heat exchangers and insulated cold box modules.
- Mixed Fluid Cascade Process (MFCP) is a combination of cascade and mixed refrigerant technologies was developed by Statoil and Linde for the Snøhvit LNG Project in Hammerfest, Norway
- Shell's Dual Mixed Refrigerant is an evolution of the C3MR design, where the pure propane refrigeration circuits are replaced by a heavy MR circuit and spiral wound heat exchangers.

Other and increasingly smaller-scale processes make up a limited portion of existing liquefaction but this sector may see an increase in market share going forward. We will in the following explore this part of the market for micro-scale liquefaction (< 27,000 ton) and nano-scale (<3,650 ton annually).

The present LBM production globally

Most of the existing LBM production (2017) worldwide is based on land-fill gas producing in total around 44,000 tonnes LBM annually (corresponding to 56 mio. Nm^3 of biomethane) (Table 1). For comparison, the largest Danish biogas plant produces around 21 mio. Nm^3 biomethane annually, so the global LBM production is still very limited. Bio-LNG/LBM production in 2016 (partly according to Groengas Nederland, 2016) and experiences gathered in this study is represented by the following (Table1).

Table 2. List of known existing Liquid biomethane production units.

Company/Technology	Country	Biomass source	Annual production of LBM (tonnes)
Hamworthy/Wärtsila Mixed refrigerant	Norway	waste	3,600
Hamworthy/Wärtsila Mixed refrigerant	Norway	waste	3,300
Air Liquide	Sweden	waste	4,900
Air Liquide	Italy	?	3,100
Cryo Pur	Ireland	Agriculture	1,100
Gasrec, Mixed refrigerant	UK	landfill	6,000
Gasrec, Mixed refrigerant	UK	landfill	5,000
Linde, Single mixed refrigerant	US	landfill	7,200
Linde, Single mixed refrigerant	US	landfill	10,000
Total LBM production			**44,200**

The Norwegian Biokraft Skogn will inaugurate a new biogas plant with a Wärtsila LBM production facility in 2018, planning to reach 10.000 tonnes LBM annually in first phase and doubling that level in the future. In any case, the production of LBM is still at a very limited scale – and that is exactly the challenge. Biogas is produced in small quantities locally, and thus requires micro- to nano- scale liquefaction plants (typically < 10.000 tonnes LBM annually).

The niche for LBM is minimal in 2017, but is expected to increase, as the need for biofuels in transport sector will indeed increase due to UN climate agreements and EU directives. The advantages of introducing LBM in the marine sector are:
1) emission reduction of CO_2 from Marine sector and
2) all the well-known secondary benefits ('on land') of creating jobs by producing waste based energy and fertilizer for the local farming systems.

LBM can be transported relatively easily and it can be dispensed to either LNG vehicles (trains or heavy-duty trucks) or CNG vehicles (light duty trucks and buses)– thereby 'extending' the gas-pipe system, by 'connecting' more distant biogas plants to the grid – or 'extending' the gas grid to distant gas costumers (virtual pipeline), such as the shipping industry.

This requires a liquid-to-compressed natural gas refuelling station equipment which creates CNG/CBG from LNG/LBM feedstock. Liquid natural gas is transported at relatively low pressures (e.g. 1.5 – 10 bar), but because it is a cryogenic liquid (i.e., temperatures at -162 °C) it requires special handling. A significant disadvantage of LBM is that storage duration should be minimized to avoid the loss of fuel by evaporation through tank release valves, which can occur if the LBM heats up during storage. However, this can be avoided by new re-liquefaction technologies on the market.

Five steps towards LBM

The process from biogas to LBM has several major steps that can be solved in an integrated upgrading/ liquefaction or in separate steps combining different technologies followed by transport and bunkering facilities.

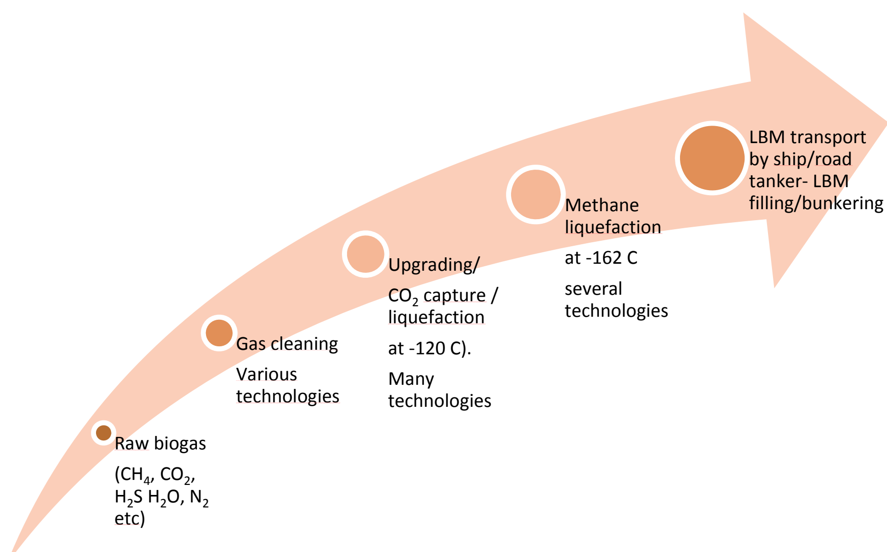


Figure 4. The major steps from biogas towards LBM. For further explanation, see text.

Depending on the following processes, the H_2S removal from the raw biogas can be done by coal filters, biological scrubbers and precipitation by Iron Cloride. All are standard technologies at existing biogas plants (Alleque & Hinge 2012). The purity of the resulting gas depends on the gas use.

After step one, the 'upgrading' of the biogas to pure methane has been developed into numerous techniques, each with their advantage/disadvantages – and the technology selected is depending on the further use of the gas. The most common separation is by adsorption/absorption or membrane separation (Alleque & Hinge 2012), and in most cases the CO_2 is emitted to the atmosphere.

However, when using cryogenic separation, the CO_2 can be extracted as liquefied and a food-grade marketable product. In addition, when seen in the context of a biogas plant, the need of energy for the processes and the use of excess heat are very important factors for the specific business case. See Table 2 for existing technologies on the market.

Existing nano-scale liquefaction technologies

Based on a Samsø 'Field to Ferry' concept for liquefied biomethane (LBM) the companies below have given their potential solutions for this nano-scale gas treatment solution from raw biogas to LBM. The case expects to produce some 6 mio. Nm^3 of biogas (some 685 Nm^3/hour) or 3,5 mio. Nm^3 biomethane (400 Nm^3/hour). The resulting LBM production would be around 2700 tons annually, fulfilling the energy need of the ferry Prinsesse Isabella.

The specific assets of the existing nano-scale liquefaction technologies can be found in Tybirk et al. 2018.

Local shipping planning

Concomitantly with the biogas planning, the planning for the local use of the gas should be started. Traditionally the planning of shipping in a coastal community and biogas planning are two independent planning processes. It may be two independent private companies with no mutual interests, and even if both are being planned for by the municipality, the connection may not exist at all. However, if there is a local plan for reaching certain sustainability or GHG emission reduction targets, the municipality or planning authority may wish to merge the two planning groups or planning processes.

In the following we will take the 'simple case' of a local ferry to an island as a case where the 'Field to Ferry' concept can be applied.

Ferry procurement

Ferries can be owned by the state, the municipality, be private or mixed ownerships. Generally, however, routes are procured for certain duration, e.g. 5-10 years. The local communities at both harbours will have a certain interest in the procurement and the results, as it influences the traffic and the logistics of both sides for quite a period of time.

Therefore, the strategic interests of both coastal communities have to be discussed quite some time before to define the procurement. The decision on fuels for the ferry is only one of numerous criteria in the decision and traditionally the shipping industry has not been forced by strong environmental requirements.

However, recent international agreements in the International Maritime Organisation under United Nations has presented a climate strategy. Still, however, biogas as a fuel is still not considered in these calculations.

Ferry procurement took place in the Samsø case in the following way:

- Public debate and work by Samsø Energy Academy and the municipality had formulated a strong vision of carbon neutrality by 2030 - and the most challenging task here is the transport sector – of which the main municipal ferry consumption is the largest.
- For the procurement in 2013 it was decided to make the municipal 'own bid' in competition with external/private operators that had been running the ferry for decades.
- The own bid was much cheaper than the commercial ferry company and it was easy for the municipality to make the decision. The decision, however, required the building up of new competences and new organisation for this to be established
- two years later the ferry fuelled by LNG was sailing – and has been a great success ever since. The success has been due to several supporting factors: dramatic reduction in LNG world market price and state support for Danish ferries to stimulate rural development.

Ferry energy decision

For ferry tendering, the energy consumption and CO_2 emissions are but few criteria among many. Net price of the service was the key criteria in the Samsø case, and the decision on the purchase of the specific ferry had to fulfil the CAPEX and OPEX requirements before the energy wishes of the municipality. The reality was therefore that the decision on the fuel type and consumption ranked lower than the overall economy of the ferry service.

At present, several alternative energy options are emerging, but the choice should take numerous aspects into account. Many reports recommend batteries as a future technology – already being applied in few small/short distance ferries and for hybrid energy systems. Methanol or LNG can be seen as transition fuels towards Bio-methanol and LBG, but they cannot replace the fossil energy needs of the marine sector. (Wiese, pers-. Comm). Wind, solar and batteries, electro-fuels (hydrogen, methane made by e.g. wind-power) and hybrid solutions are expected to become part of the future energy mix.

In addition, the ship design, the operational efficiency, the speed and on-shore charging is to become part of more sustainable marine sector.

The future of ferry fuels may include batteries for small/short ferry routes (less than 30 min) and this has to be evaluated on the local scale before ordering a ferry. Natural gas in compressed or liquefied form are commercially available, and this choice depends on storage capacity and length of route and bunkering solutions. Either of these can be replaced by biogas and compressed gas should be considered for new vessels to integrate the needed storage capacity and the bunkering system. Compressed biogas will usually require 'slow fill' during night from a gas grid, whereas LBM can be fast fill (like 15 min) from a truck tank.

Two important aspect to be taken into account in relation to LBG are

- the resulting job creation and local farming and environmental improvements due to the handling of agricultural and societal wastes
- The emission of unburnt methane for the ship engine (especially for dual fuel engines), reducing the total GHG emission advantages of LBG

Biogas Planning

Planning for biogas encompasses some general features, but all of these have to be adapted locally to the specific conditions, the national energy policy and the environmental legislation. Although we have EU Renewable Energy Strategy, Common Agricultural Policy and Water Framework Directive giving us common framework and common visions, the national and local conditions and implementations of legislation still gives a large variation to the specific solutions needed.

In the following we will extract the major planning steps from a Danish manual for biogas planning (Tybirk 2014) and discuss this in the Baltic Sea Regional context.

Nine steps towards biogas

In the Danish planning manual, nine steps have been identified and described, from the birth of the idea to the tendering of the biogas plant. This has now in this context to be aligned with the planning of the biomethane fuelled ferry procurement – although these two can be seen separately. In the specific Samsø case, the purchase of the LNG fuelled ferry in 2015 (an investment of approx. 25 mio. €) paved the way for the establishment of the biogas plant (an investment of approx. 10 mio. €), but this line of decisions could also be reversed.

In any case, these nine steps could serve as a guide to the locally adapted process in any Baltic Sea Region or coastal community, whether for a ferry or other gas usages. In the specific Samsø Case, we have taken the first 7 out of 9 steps towards biogas realization.

Step 1. Initial contact between stakeholders

The first step is to identify and get in contact with the key stakeholders for this idea to develop. Typically, the initiators could be a group of farmers, and they have to find the right buyer for the energy produced. This could in turn be a local district heating company, a national gas grid owner, a ferry or a bus company.

When these two key groups have decided to work more on the case together, they should immediately involve the local planning authority in the municipality or the region. This first meeting should outline a rough timeline for the process, the roles of the major stakeholders and a working plan for each of the three major stakeholders. Typically, an advisor specialised in the process is involved rather early in the process.

Step 2. Specification of the idea

Already at this stage the key stakeholders have to decide: do we need professional assistance for this step? In most cases it is needed by step 5-8 anyway as specialized knowledge can avoid costly mistakes.

Step 2 consist of a stakeholder analysis and to line up all the arguments for establishing a biogas plant in this particular community. It may seem unnecessary, but many cases have shown that when you know all the stakeholders and try to ask the ‘Why-question’ from each stakeholder’s point of view, more and more nuances will appear. Which problem are we proposing to solve with the biogas plant?

Suppliers of biomass and gas/energy users are obvious stakeholders in all cases, but how to make optimal use of the digestate[2] – is there a market for liquid fertilizers? And how should you explain the Why-question for a neighbouring village concerned about traffic and smell influencing the value of their home?

[2] Digestate is the anaerobically treated ’slurry’ used for crop fertilization

With a list of stakeholders, the definition of roles for each stakeholder is very valuable. What is/could the role be of local politicians, municipal employees, farmer's association, agricultural advisory service, green NGOs, energy companies, bank, technical suppliers etc.? What are their interests in the biogas production?

Step 3. Dialogue with the local community

Quite often, in Denmark, the dialogue with the local community has been neglected, until too late in the process. Some cases are described on the website www.peopleandbiogas.com . Often a strong local 'Not In My Back Yard' – NIMBY - effect is present and has to be dealt with. In some cases, biogas has not been possible to implement due to wrong or lack of communication leading to massive protests and when local politicians have to make the decision on the localisation, they might react on these protests.

Involvement of local stakeholders and the possibility for them to come up with ideas for the process and the biogas plant at an early stage can seem time consuming and unnecessary. The ideas may not survive the planning process, but the active involvement shows willingness to listen. Ideally this could lead to co-ownership of the biogas plant (co-operative or the like) this establishing our biogas plant – not theirs. Consider a strategy for this in all cases –no cases are similar (see also section on Crowdfunding).

Dissemination of knowledge and timing of communication are crucial factors. Make a communication strategy for how and what to communicate to whom – and when. It can be an informative website, via facebook, via the local newspaper, trip to existing biogas plants or a combination of all, but make a plan and be prepared to change the plan according to the reactions.

Step 4. Organisation of the following phases

The initial stakeholders – and possible others identified – will have to formalize the following work. Often funds are needed and for this the formation of an association or another structure is needed to apply for or to gather funds for the next preparatory work.

The organisation might have to have different branches, such as an association for manure/biomass delivers, a holding company and a plan for the following steps. Juridical advice is often needed, and a way to finance the next steps should be clarified.

Step 5. Pre-project/feasibility

Now the more serious investigation of the feasibility of the biogas project has to be carried out. Quite some data has to be gathered, and mostly technology neutral engineers have to calculate the specific project feasibility. A suitable localisation for the biogas plant has to take into consideration numerous factors. Transportation of either the gas or the input/output biomasses are often crucial factors determining the biogas feasibility.

How much manure/other biomasses do we have in the area, how much transportation is needed, are there any industrial symbiosis possible, what is the expected price for the produced gas, electricity, heat, fuel etc.? Can we make conditional agreements with the major groups of supplier and costumers? What is the expected hydraulic retention time in the reactor, what design of biogas plant is needed to solve the specific local problem, and do we have sufficient storage capacity?

The will result in a business plan and a rather specific biogas plan design and investment plan. This will be the basis for the coming environmental impact assessment.

Step 6. Scenarios for the economy

In order to ensure investors interest in the project rather detailed economic and financial analysis is needed. The market development for the produced gas needs a detailed analysis – or do we have fixed feed-in tariffs? Depending on the gas use, different options for gas treatment have to be analysed. In the

case of liquefaction of biogas for heavy transportation, the gas has to be cleaned for sulphur and upgraded to pure methane before the liquefaction or compression.
The energy balance of the plant – the need for process heat and the cost of using local (renewable) sources has to be taken into account. This need differs between summer and winter and this is often the case also for the gas sale. Do we have alternative customers in place – do we have a gas grid for injection?

Usually at least three calculations have to be made: The farmers make their calculation – in some cases a subtle advantage of receiving digestate as a better fertilizer after the biogas process is a major asset. In some cases, the biogas plant can pay the farmers for 'borrowing' their manure if the dry matter content is high, in other cases the farmers have to pay to have the thin slurry treated. Local conditions will determine these balances.

The extract of the financial calculations and uncertainty analysis should be presented for the investors in a business prospect for investment decision. The business canvas model is a sound structure to use for the resulting business plan.

Step 7. Environmental impact assessment and permissions

A biogas plant will in most cases need to go through an environmental impact assessment, depending on the size and the national interpretations of many EU directives on the issue. Depending on the size different planning procedures may be needed. Danish biogas plants receive typically between 100 and up to 2000 tonnes of manure and other biomasses daily. The large industrial plants have to focus very much on transport, whereas a farm-scale plant often has the biomasses on the site.

Mutual planning of the permission procedure is valuable to agree on the expectations and data needs. In some cases, several localisations are possible and different requirements may be needed depending on proximity of Natura 2000 areas, landscape and ground water susceptibility, road size, population density etc. In some regions, the 'feeding plan' of the biogas plant may also influence on the planning, e.g. if sewage sludge or organic household wastes are to be treated.

Mostly the environmental permits are prerequisites for construction permits and final agreements with farmers etc. The procedure may take years and the time planning and role determination can reduce the time loss. For some initiators this can seem a waste of time and resources, but the process allows the society to judge the real impacts of the biogas plant. Often, the process requires public meetings and public debate before the final politically agreed permission is granted.

Step 8. Agreements

As a biogas plant is a rather complex and in many cases innovative element in the local treatment of major streams of resources, the agreements with the stakeholders may be rather complex. In some situations, standard agreements can be used for inspiration, but usually locally adapted agreements are needed. Basically the local streams of carbon, nutrients and water is affected and the job creation may be significant.

Often preliminary agreements are signed early in the process, but as 'the devil is in the detail' the final agreements may cause changes in the business plan for the farmer, for the plant and for the gas user. For instance, the needed dry matter content of the manure may exclude some farmers, or impurities in the gas for the grid may become more expensive for the plant.   In addition, agreements may be needed with transport companies, the gas or power grid administrators, with land owners, with financial institutions, with the local municipality etc.

Step 9. Procurement and tendering

If a public entity will be part of the biogas plant a public tendering procedure is needed. If it is a purely private company a closed tendering procedure can be used to ensure the best offer. Many companies will be able to provide solutions, but it should be considered whether the tenders should be prepared for a turn-key solution on specific performance indicators or tendering for functional entities (or even sub-delivers) in the value chain that can be united. This latter procedure requires more detailed engineering skills/advice in the decision making process.

In any case, the guarantees for function of the parts, or the whole solution, may be crucial for the plant operation – and for the business case as such. If the future biogas plant manager is involved in the decision making process, more detailed knowledge can be transferred.

Business model considerations

Many types of business models can be used to describe the Field to Ferry concept. However, when starting to analyze the opportunities it is clear that this concept contains several interrelated business models that should perhaps be analyzed as a Business Model Ecosystem (*sensu* Lindgren and Bandsholm 2016). In this context a variety of different business models interacts. Some can be considered vertical cooperation (suppliers or customers) others as colleagues, and in addition we can see new potential business to be associated with the Field to Ferry value chain.

Especially the biogas plant establishment in an island society will open for numerous side businesses to appear, within the farming community (e.g. new logistic solutions), within the waste treatment (e.g. sorting out the organic fraction for biogas), within industrial symbiosis (e.g. exchange of biomass, heat and gas) etc. Furthermore, biogas business is increasingly considered as a dynamo in circular economy where again other business models should be applied. Circular economy is a new paradigm for value chains, organizations, business models, and value creation and innovative business models are being created.

In the traditional open-ended economy, the principle was 'Take, Make, Dispose'. The circular economy is grounded in the study of feedback-rich (non-linear) systems, particularly living systems, creating cascades, value circles and redesign reducing the 'Take' (of fossil resources) and 'Dispose' to a minimum. In the Samsø context this means that we should integrate the nutrient, the carbon and the water cycling on the island. This can recycle the sewage water and nutrients back into the faming system producing biomass input to the biogas plant and methane into the ferry. In addition, this bio-refining system also produces better quality fertilizers for the farmers, and the cascading of the biological values of the island.

However, this Business model ecosystem and circular economy paradigm will become complex and very site specific too, so we will in the following restrict ourselves to describe the Samsø Case and a suggestion for a Field to Ferry business model for other coastal communities in the Baltic Sea Region based on the Business Canvas Model (Osterwalder and Pigneur, 2010). This model has a certain degree of complexity allowing us to discuss most aspects of a business model (Figure 5).

In the theory of Osterwalder and Pigneur, a business model is a blueprint for implementation of a given strategy through different organizational structures, systems and processes. They consider a business model as a canvas, which consists of nine basic building blocks: Customer segments, Value Propositions, Channels, Customer Relationships, Revenue streams, Key Resources, Key Activities, Key Partnerships and Cost Structure.

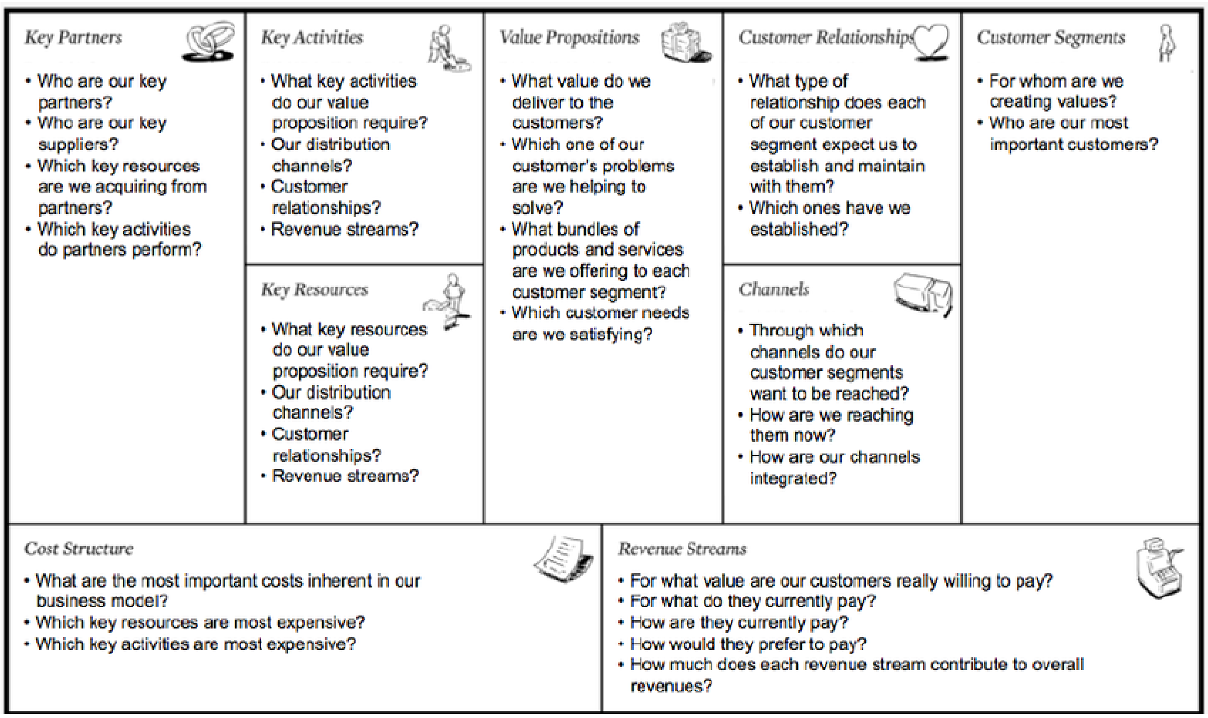


Figure 5, Generalized Business Model Canvas unfolded in the following sections (from Osterwalder and Pigneur, 2010)

However, in this context and depending on the stage of the concept development for the specific coastal community, one could use the Lean Canvas Model for start-ups (www.blog.leanstack.com). This is an actionable and entrepreneur-focused business plan quite alike The Business Model Canvas, but as some activities have not started yet, three parameters should be changed, where

- 'Key partners' are described as 'The problem/the Challenge' and
- 'Key activities' are described as 'The proposed solution' and
- 'Costumer relationships' are described as 'the Unfair advantage'

In the following we will briefly present three cases with certain applicability in the Baltic Sea Region. The first two cases are under specific planning and the third concept is when applying parts of these into new cases in the BSR.

Field to Ferry concepts

In the Baltic Sea and North Sea Region, the number of initiatives on LNG is increasing, but still the number on project/ideas on Liquefied Biogas application for marine transportation is very limited in 2018. In Norway, a LNG ferry was tested with LBG late 2016, but just as a demo-test. However, we have a case we can describe in some details for inspiration and a couple of other cases we can describe more overall in the following sections.

The Samsø Case

The Samsø Case as the basis for this business concept consists of the following major elements in the value chain 'From Field to Ferry':

Figure 6. The Samsø Field to Ferry Value chain.

Samsø has in 2017 both ends of the value chain, namely the farming system and the ferry, but the missing link is the biogas plant and the gas handling system. The vision is that the ferry LNG should be replaced by locally produced Liquefied BioMethane (LBM/ LBG) in 2020, when the biogas plant is expected to be in operation.

Community planning

However, the Business Canvas Model is 'only' the business plan as part of a broader planning work with the local community. As a wider frame for discussing the specific business model concept, four basic questions should be applied for all community planning:

1. **Do we like it?** Is it in the interest of the local society as such to establish this value chain?
2. **Can we get the legal permissions** to operate? This includes safety, environmental and juridical aspects that have to be answered positively during the feasibility study
3. **Is it technically possible** to establish the value chain? For instance, when innovative technology for Biogas liquefaction we need to prepare for technical challenges
4. **Can we make a living from it?** Can the local community make a broader profit (jobs, pride, better environment etc.) apart from the business model?

The first question is in many biogas cases neglected before starting the process. Establishing a biogas plant and servicing a ferry with less pollutant fuel is to take care of the common goods in a society, and the decision to change the way to handle common goods and waste and turn it into resources and services, is indeed a question that calls for public and open participation.

This accounts surely for biogas production but should also account for ferry planning. The idea goes far beyond the official planning system in Denmark but could inspire other coastal communities to take hand on their own development. For this to happen, the mobilization of the local resources is crucial.

Business Model case for Samsø

During workshops in the GO-LNG project the business Canvas model has been filled out to describe in a 'one-pager' the main elements of the business model. Below we will discuss each of these elements briefly.

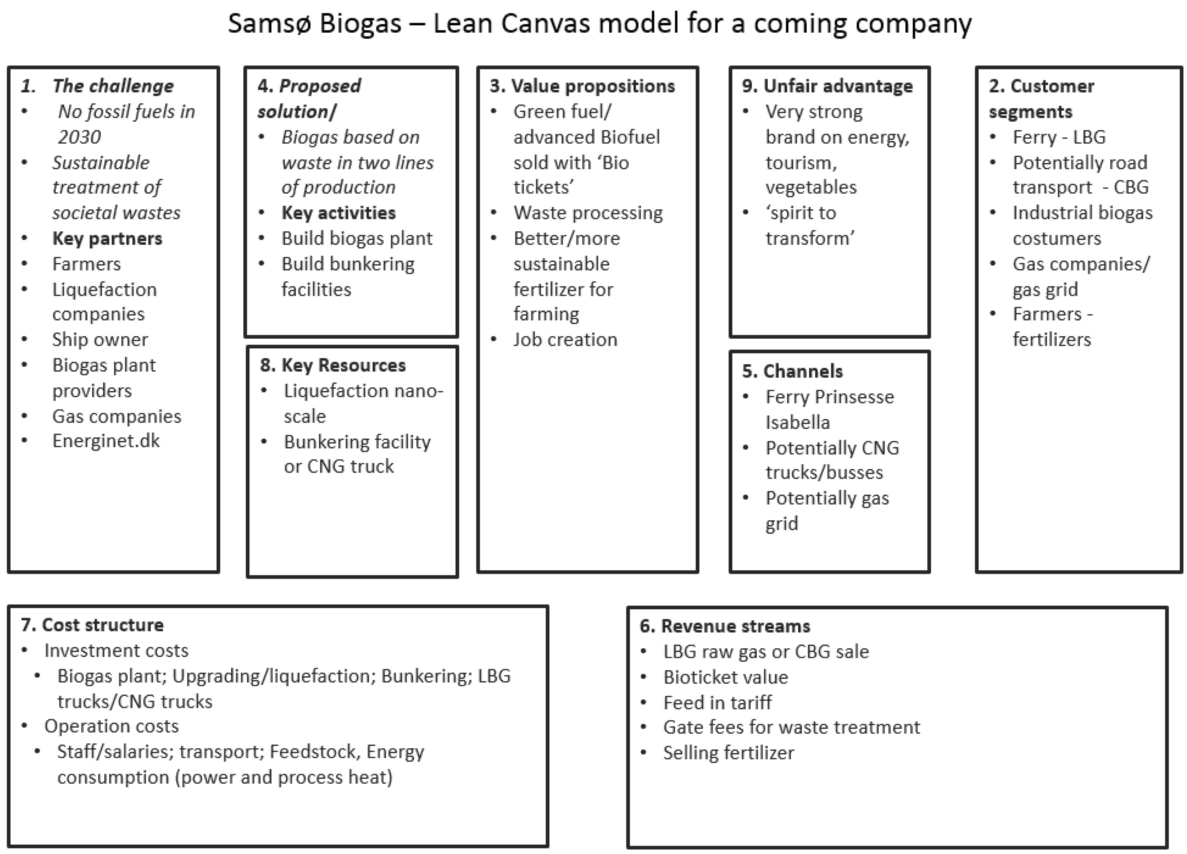


Figure 7. Potential Business model for Samsø Biogas

1. The problem and key partners

Using the Lean Canvas Model, the challenges for Samsø are:

- We have to replace the fossil ferry fuel to become an island free of fossil fuels,
- the intensity of vegetable growing agriculture is jeopardizing the soil fertility and the ground water
- Traditional treatment of societal wastes (incinerated of the island) is not very sustainable in a circular economic context)
- As intense agriculture requires irrigation we will have to reuse waste water and waste nutrients for crop production

These challenges have led to the following gathering of partners to develop the business model.

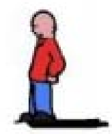
The key partners to establish the business model are the farmers and the shipping company, which in this case, is owned by Samsø Municipality. Both parties do have their own businesses running but can see opportunities in the new value chain. The farmers can foresee a better organic fertilizer and a sustainable way to treat some of their farming wastes – giving positive feedback on the marketing of their products.

The ferry has a potential marketing value from using a green fuel, and the municipality has a strong motivation to market the island through the ferry as a green destination.

The potential consortium partnering up to establish the link between the farmers and the ferry could consist of a green gas company involved in biogas production and sale on a national and international market. Such a partner should team up with a biogas plant supplier, including the upgrading and liquefaction technologies and possibly a gas handling company to handle the bunkering system using the biogas in the future.

Several variation of the dream team could be relevant if, for instance some technical or financial constraints for the innovative liquefaction part will appear. An alternative partnership in the first years could be selling Compressed Natural Gas via the national gas grid for city busses. This would require partnerships with the national gas grid owner and operators and possibly a bus company too.

2. Customer segments



The primary costumer is going to be the ferry Prinsesse Isabella, if the liquefaction proves technically and financially viable. However, having one single costumer makes the business model fragile, if for instance the ferry becomes too small and a new ferry is needed. The next ferry could be fueled with compressed biogas (CBG) and thus we could consider other potential customers using CBG.

The costumer for CBG could be one of several gas grid operators in Denmark. They have their costumes willing to pay for green gas and it is expected that this market could increase very much with the coming VE 2020 directive. Added value of delivering advanced biofuels based on waste for transport companies could achieve considerable green ticket value.

This could be local tractors on the Island, consuming around 1/3 of the ferry energy consumption, or trucks, delivery vans, diesel cars etc. summing up to the energy consumption equivalent of the ferry. However, their fleets and vehicles are private and we have the classic 'chicken and egg' challenge: they will not buy gas fueled vehicles before we have the gas and we cannot establish the biogas before we have the costumers.

Further, the local pickling factory (pickling vegetables, a traditional Danish food) has a considerable energy consumption of around 4,000 Mwh and a significant heat loss. They can use raw biogas instead of LPG and this could be a potential costumer with industrial symbiosis for the biogas plant – as they are planned to be neighboring industries.

Finally, we hope to establish a bio-economical visitor center at the biogas plant to show business tourists and other guests the perspectives and the specific results of establishing biogas as a dynamo in circular island bio-economy.

3. Value proposition

Basically the value proposed for the costumers is a green fuel to fulfill coming requirements in the transport sector. Depending on the coming regulations and implementation of the VE 2020 directive, road transport will have to fulfill stronger requirements as compared to shipping industry. Therefore, the tradeable Green Ticket value can become the most valuable asset for either gas costumer. A leading Danish Gas company has recently estimated this value to reach up to 1 €/Nm^3 of biomethane in a few years.

Another value proposition is a more sustainable waste handling process on the Island of Samsø. The farmers are fully aware of the value of this (but also worried about a few potential drawbacks on their specialized cropping rotations. Especially the organic farmers on the island are aware of their need for good fertilizers for this sector to increase their marked share. Further, the public, the restaurants, the shops are becoming aware of the marketing value of showing how we can turn waste into resources through the biogas plant on the island. For Samsø Municipality the reduction of CO2 emission by 13.000 t annually is very positive and the green profile will be strengthened.

A third value proposition is perhaps a local sense of pride: we take care of our own development, we care about the environment, the local jobs etc. Biogas delivers (parts of the) solution to 9 out of the 17 United Nations Sustainability goals – this can make a local community proud. This will be expressed clearly at the Bioeconomical visitors center. In addition, the biogas feasibility has calculated additional 13 local jobs.

4. Key Activities

The solution for Samsø is to replace the fossil fuel with locally produced green fuel, produced from a biogas plant with two separate lines, to keep the societal wastes apart from the agricultural wastes. For the farmers the treatment of their manure and wastes will give them an attractive fertilizer and their products an improved reputation.

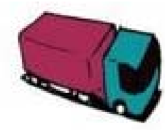
For the municipality and the Samsø Energy Academy, the overall goal of becoming fossil free island is largely centered around the Field to Ferry achievement. Without this, we cannot reach the goal of becoming free of fossil fuels by 2030. In addition to this, the expected job creation and the generally improved reputation of the Island of brave green activism is a secondary rural development aspect to attract new inhabitants,

In order to establish the value chain, the main activities are to reply seriously to the four basic questions (inspired by Mikkelsen, Pers. Comm.):

1. **Do we like it?** Is it in the interest of the local society as such to establish this value chain? At Samsø this has been in the public debate for a couple of years now, and we have had a dozen public meetings discussing the issue. There is some opposition, but the local politicians support the idea as illustrated by 10-1 in the final vote in favor of the plans.
2. **Can we get the legal permissions** to operate? The work has focused on the environmental impact assessment which is a comprehensive investigation in any environmental aspect of the biogas plant, including pollution of soil, air, waters, nature etc. based on a detailed technical description. In addition, the local planning requires work and this process involves further public hearings and discussions, too.
3. **Is it technically possible** to establish the value chain? Most of the basic technology is standard, but introducing the double loop concept of nutrient recycling is innovation, but probably not technically challenging. However, the Nano-scale liquefaction of the biomethane is technically and financially tricky under Danish subsidy system.
4. **Can we make a living from it?** If the business model *sensu stricto* is not profitable, the biogas plant will not be established. We need to find investors for around 10 mio € for the whole value chain and they should see a positive return on Investment to join. Apart from this, calculations show that the local economic effect is around 2,7 mio. € annually, creating 13 jobs on the island. In additions to this, the circular economic calculations can create additional side-businesses due to better waste handling.

5. Channels

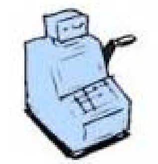
If the biomethane is liquefied and sold to the ferry, a contract for sale over a considerable timespan would be ideal with some regulations according to the variation in the parallel world market prices, including Green ticket values. If the costumer for the gas would be the national gas grid, the value of the gas would have to be regulated according to gas market prices and the achieved value of the Green ticket, followed by documentation/certification of the quality and sustainability of the produced biogas.



The fertilizer market will be regulated through delivery and return delivery of specified criteria for the in- and outcoming fertilizer. The costumers for the bioeconomical visitors center will be reached through a website and/or the Samsø Energy Academy network.

6. Revenue streams

The basic revenues streams are the following



- Sale of gas to the ferry/the gas grid, perhaps with an intermediate/a brooker to ensure a fair price for both the buyer and the gas producer
- Potential sale of raw biogas for the pickling factory – and the purchase of the process heat for the biogas process
- Depending on the choice of gas handling, there could be a potential sale of liquid CO_2, too
- The fertilizers will be traded possibly in a mutual contract with the livestock farmers, but also specific prices for incoming straw/silages and sale of specialized fertilizers, such as post-digestion fibers for potato cultivators.
- For some biomass types there will be a gate fee for treatment, such as waste water and municipal solid wastes
- Entrance fee from guests at the visitor center.

7. Cost structure

Major costs in the business plan are

- The capital expenditure and the salaries for the personnel. Both are steady and primary cost-drivers.
- The cost of biomass purchase/delivery, storage and the transport of the biomass is a rather stable cost, but can be changed over time
- Gas handling is a major cost of around half of the production price for the raw biogas. Can only be avoided for the gas stream sold to the pickling factory
- Gas transport is expected to be via existing LNG carriers –one for filling/storage, one for transport and bunkering
- Costs of power and heat can be considerable, but many solutions are available including the potential industrial symbiosis. Taxes and subsidies are susceptible to changes and backup systems are needed
- Insurances needed
- Marketing of the visitor's center

8. Key resources

The keys to this investment and the focus for solution are the following

- Liquid Natural Gas price dropped significantly on the world marked in 2013-15, and the tendency is that the price will remain low as shale gas and shipping of LNG has made LNG available worldwide. One possible solution is the sale of Bio-tickets for other customers in need of such.

- Liquefaction technology is expensive in nano-scale and innovative. Is it possible to ensure the service and to have the right competences for this technology on an island?
- The environmental permit is susceptible for political approval in an election period.
- Based on the above, the consortium of (patient) investors have to be found
- In addition, (non-commercial) funding for the visitor's center has to be found
- The national feed-in tariffs are quite determining and only guaranteed until 2023

9. Customer relationships

Using the Lean Canvas model for start-ups, this is called the Unfair Advantage to be able to establish this value chain. Samsø has a very strong brand in Denmark (energy knowledge, food, gastronomy, tourism and the 'spirit to transform') and internationally (energy transition and cooperation). Samsø has shown in numerous cases that we can make wise and brave decisions and make things happen, e.g. as the Renewable Energy Island. This can be called the unfair advantage of the Island making the whole business model interesting for external investors

In addition to this, the gas customers expect stable delivery of high quality fuel at a competitive price first and foremost. Furthermore, a green label on the gas should give our customers a competitive advantage on their market, and some technology companies are highly interested in the exposure of/becoming part of the Renewable Energy Island with some 4-5000 business tourists annually from all over the world. This exposure alone could attract co-investors, e.g. on the innovative liquefaction technology.

Gas-grid liquefaction of biogas blend

As mentioned, the nano-scale liquefaction and direct Field to Ferry concept has some communicative advantages, but indeed also some scaling disadvantages. Two other potential cases under development will be briefly described to showcase another interesting approach.

The case is briefly described for inspiration based on presentations by HMN/Eniig, Kosan Crisplant and Nature Energy. At the time of writing the two concepts are relatively similar and competing for the same space in an emerging market. Still however, the concept can give some indications of another way of heading towards more BSR liquefaction cases, where a gas grid is available.

The shipping route that passes the northern part of Denmark is one of the most trafficked routes in the world. With more than 100,000 ships passing the strait every year this could become a prime location to supply LNG and LBG. Today Fjordline is bunkering LNG in Hirtshals for its two LNG ferries MS Stavangerfjord og MS Bergensfjord, and the number of LNG/LBG costumers is expected to increase http://energibyen.dk/sites/default/files/lng_nordjylland_information.pdf

Presently, two liquefaction projects are being planned for in Denmark in the size of around 150 tons pr. day ('small-scale') using the existing gas grid with a blend of biomethane and natural gas for a blended liquefied methane (Rousing 2017, Frej 2017). The marketing of the liquefied product can be followed by bio-tickets to document the green value of the gas. Probably only one of the two projects can be realised.

We can only briefly describe the concepts based on presentations and press releases from the two consortia.

The Hirtshals case

HMN, Fjordline and Scangas are the companies behind the idea, where it is planned to establish a Liquefaction plant next to existing LNG bunker facility for Fjordline on the harbour in Hirtshals.

- The capacity is planned to be 160 ton LNG/day corresponding to 56.000 tPA
- Price estimate 50 mio €
- Time plan: Environmental and gas security permissions Q1-2018

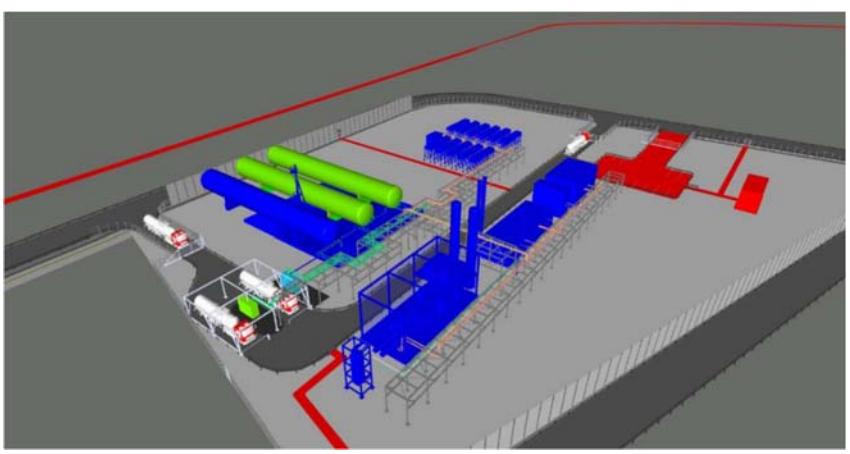


Figure 8. The Planned Hirtshals bunkering facility (from Rousing 2017)

The Frederikshavn case - Nordliq

Nature Energy, Bunker Holding, Kosan Crisplant and Frederikshavn Havn are partners in the consortium behind Nordliq - a similar project planned for Frederikshavn Harbour. The project has received Ten-T support from EU Commission.

The liquefaction plant can operate 24/7 with a production capacity of 50, 100 or 150 t/LNG/day. LNG can be supplied from the process tanks by tank trucks trough loading points. The potential customers are both the shipping sector and heavy load trucks.

Figure 9. MS Stavangerfjord powered by LNG

In project Blue INNO ship the development of a new liquefaction methodology has been developed by Kosan Crisplant and Danish Technical University by optimizing the refrigerant blend, reducing the energy efficiency by up to 40% compared to similar technologies. The technology is developed for this specific purpose, however, the prototype is yet to be scaled up and installed in real conditions. The first results indicate the optimization potentials – also when scaling up from nano- to small scale liquefaction.

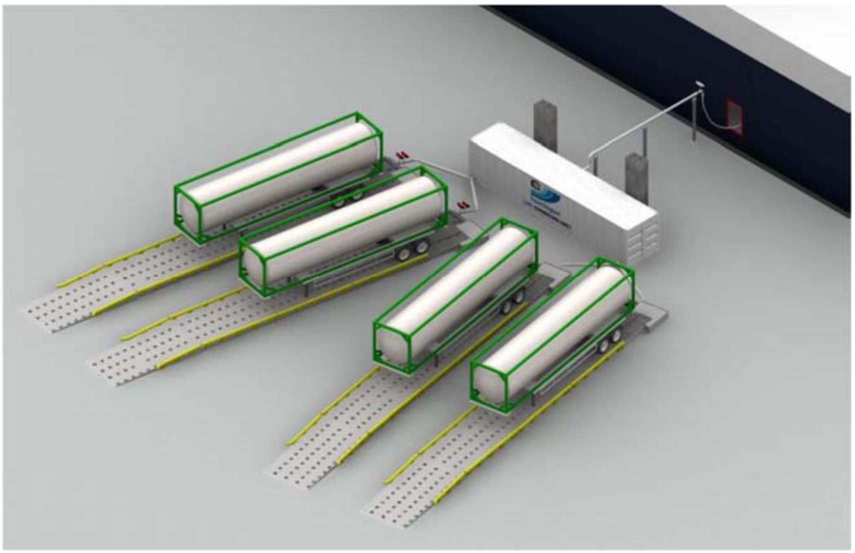


Figure 10. Potential bunkering concept by Kosan Crisplant

The business concept behind

The reasoning behind the two competing projects is the growing market for LNG in the marine sector and a potential for LBG in the future. However, also the fact that due to strong increase in biogas grid injection in the gas grid north of Aalborg in Denmark, there is a 'surplus' of biogas in the distribution grid during the summer. In 2017 the biogas injection in Northern Jutland exceeded the total gas grid consumption during summertime and from 2020 the biogas production is expected to exceed total annual gas consumption in this grid part. Thus, another economic reason for the liquefaction is to save costs of compression of the biogas into the 80 bar main gas transmission grid in Jutland.

This will enable the delivery to be associated with bio-tickets documenting the sustainable origin of the gas to be used for marketing of a green profile.

As it is today, the marine sector has no mandatory blending of biofuels, but an increasing awareness and pressure to take responsibility could change this in the future. In the present drafts of Renewable Energy Directive II to be implemented from 2021, there is a stimulation to increase the use of biofuel in the marine sector. The basic concept of liquefaction of a blend of biogas and natural (fossil) gas can unlock a market, enabling a shipping company in purchasing 5, 10, 25 or 50% LBG on the bland, depending of the price and the marketing value.

However, the bio-ticket market still needs a land transport company to buy the bio-tickets as only the land transport has been included in the EU Renewable Energy Directive to have mandatory biofuel blending. The expected price for LBG is expected to be as LNG + biogas fee, which will be driven by demand and the value of the exact GHG-savings on the specific biomass input.

The political agreement as of June 2018 on RED II has stipulated that a minimum of 3,5% of transport fuel in 2030 should be advanced (waste-based) biofuels, including waste based biogas. If the Bioticket market can develop, the competitiveness of biogas will increase.

A potential Baltic Sea Region case

One basic idea and purpose of this report is to describe the above cases and to give some key points of focus for developing a model inspired by this for any coastal community in the Baltic Sea region. We have now added a LBG blending model as another option for inspiration, if the 'pure' Field to Ferry value chain is not possible.

We have held workshops between WP 3 and 6 in GO-LNG to develop this business model and the concept to be discussed. The following is a drafted version of the preliminary conclusions of this work.

Preconditions

A basic precondition to start with will typically be the proximity of a farming system and a ferry. Both these have to be judged in the early feasibility to fit each other in terms on energy production and energy consumption. Biogas production is stable all year round and therefore a summer tourist ferry is not a good match, unless another energy consumer is available during winter – e.g. district heating. The biogas plant has to consider alternative markets for the gas for a 20 year investment.

On the other hand, the ferry also has to make strategic decisions. Security of supply can be translated into dual fuel engine (e.g. gas and Marine Diesel oil) or back up suppliers to keep down the price of the fuel. A contract with a gas intermediate could ensure the stable delivery of CBG or LBM.

The availability of a gas grid can also be a determining factor – typically absent on small islands, but if present on the mainland side, this can be a key asset, see the biogas blend-case in the previous chapter.

Flexibility and competition are 'normal' market factors, but for this specific case Field to Ferry, the strong dependency may reduce the competition significantly. The competition has to be included in the procurement procedure and flexible criteria for price fixing. Total flexibility and competition on an open and raw marked can significantly reduce the option of this beneficial solution for the local community.

The local supply and demand of energy and fertilizers have to be analyzed to fit into this market. This includes also for instance the farmers view and knowledge on digestate as a fertilizer. Do they have the storage capacity, the spreading equipment and the skills to use the digestate in the right way?

Local Support Schemes

The national support scheme for biogas varies between countries in the Baltic Sea Region. The support schemes (if any) can open doors, but it is unlikely that the system is designed to support the Field to Ferry concept. In some countries the support has stimulated for establishment of small biogas plants others for lager industrial productions. It can be an idea to initiate a dialogue with the relevant ministries at a very early stage to understand the implication of the existing support schemes for the specific project – and to explore opportunities for having a special pilot case outside of normal procedure.

Business Canvas model case for BSR

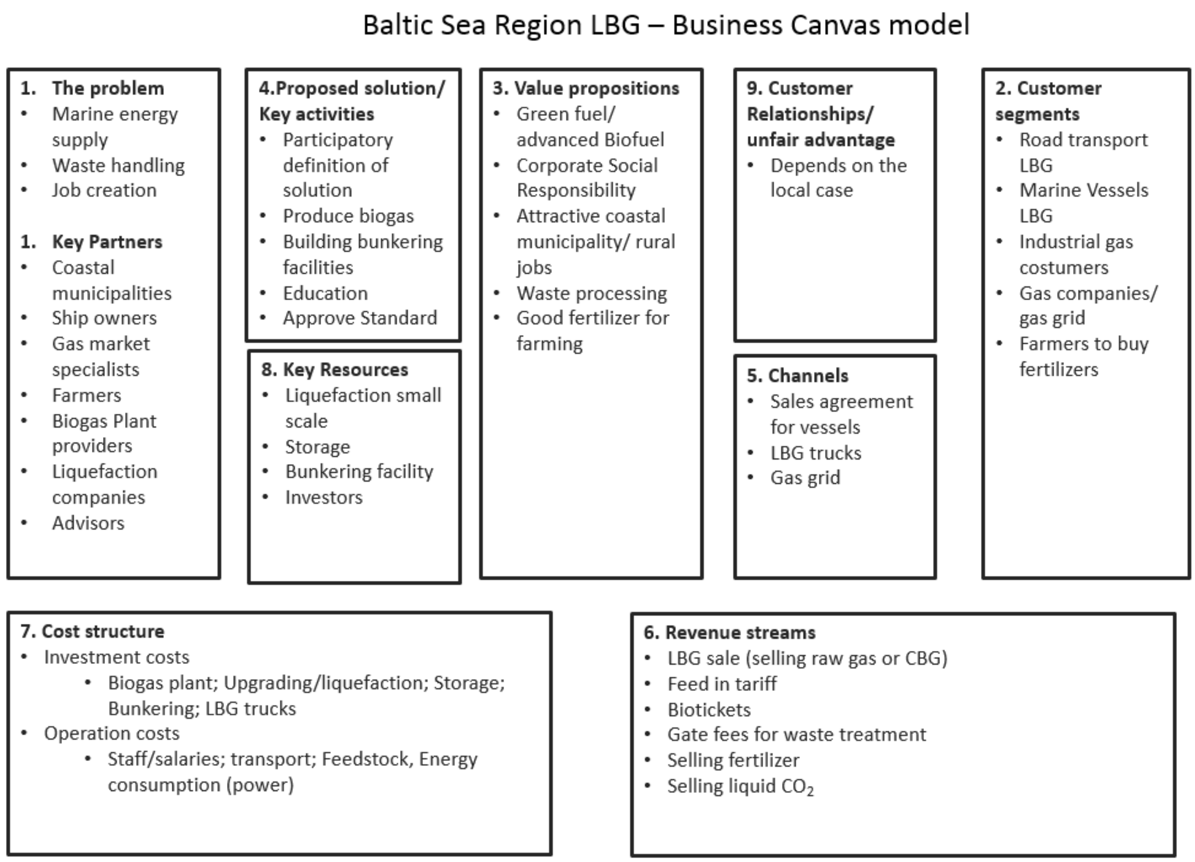


Figure 11. Business model concept for Baltic Sea Region coastal communities

The preliminary description of the business model concept is derived from the initial project discussions interpreted in combination with the Danish Manual for Biogas Planning and the Samsø Business Canvas model.

1. Key partners

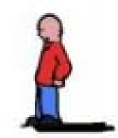
In the early process stage, the definition of the problem or the challenge to solve it can be very good starting point to find the right actors and partners. Is the challenge the IMO regulations for the ferry fuel or is it primarily a challenge for the farming community to handle their manure and other wastes? Maybe it is a rural development challenge to create local jobs and innovation or to become independent from a single energy distributor?

The feasibility study will identify the key relevant stakeholders. The municipal authorities at both harbors should be contacted as well as the relevant public or private ferry. In addition, a representative of the agricultural organization should be invited for the first meeting. The initial dialogue will reveal a list of other stakeholders to work on the idea. The gross list of stakeholders to consider is the following

- Farmers association/representative and other potential biomass delivers
- Municipality(-ies)
- Ship owner/shipping company

- Gas grid/gas market specialists
- Relevant gas liquefaction companies
- Shipping classification society (IACS) covering maritime safety and regulation
- Alternative gas customers in the area
- Biogas plant producers
- Relevant engineering and environmental advice

2. Customer segments



The concept of 'Field to Ferry' is only relevant where there is a potential ferry as costumer and a biogas plant to deliver. However, for the ferry on traditional fuel, a new potential deliverer of locally produced green gas can be interesting, if the ferry owners have a goal of contributing to local rural development in their coastal communities as well as a green profile. If the ferry is presently considering LNG or CNG as future fuel, the opportunity should be thoroughly investigated.

If a relevant size biogas plant already exists, this could be easy, if surplus gas is available. If a new biogas plant is to be established, a feasibility study will also reveal alternative costumers for the gas. This could be raw gas for industrial process heat or for district heating; it could be CBG for road and maritime transport or LBM for heavy duty vehicles and ferry. A larger gas company could also be the main costumer for the biogas plant to take care of the gas processing and sale, including the green certificates and the documentation of the biogas produced.

3. Value proposition

The values proposed to the costumers vary along the value chain – or where in the Business Model Ecosystem we are looking. In the 'maritime end', the value proposition is - or should be - a green and sustainable fuel fulfilling all known and expected demands for shipping industry in the coming decades – including potentially coming CO_2 emission reductions. Usually a green fuel should be expected to be more expensive than a fossil fuel, but it depends on the coming regulations and implementation of the revised Renewable Energy Directive. Therefore, the tradeable bio-ticket value can become the most valuable asset for either gas costumer.

In the 'field-end' of the value chain, the value proposition is the improved handling of the manure and other wastes from agriculture and from the society. For private actors this 'waste turned into resource' can be a strong asset in marketing – and the treatment could even become cheaper. For a public entity, such as the municipality, the sustainable handling of waste and sewage sludge and reduced total greenhouse gas emissions can attract new inhabitants, and thereby stimulate rural development.

For the farmers, receiving digestate as fertilizer, this could also - if local market conditions are suitable - result in a better and/or a cheaper fertilizer for their crops and in turn give added value to their production. Furthermore, the society may profit from reduced nitrate leaching and less smell from agriculture, if the digestate is used appropriately.

Finally, the job creation associated with this value chain should not be underestimated for coastal communities.

4. Key Activities

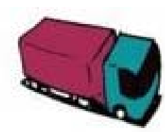
The proposed solution should initially be clarified – and would be an integrated part of the feasibility study. When the solutions are defined together with the stakeholders (including the local community and green NGOs), the start of the specific activities to achieve the goals are often rather straightforward to define.

The ferry will initially often know the energy needs and the technical requirements for fuel for the existing Vessel, but if the situation is to insert/procure new ferry operators, the feasibility work will increase in complexity. For the ‘Field-end’ of the value chain a realistic fodder plan for the biogas plant, preferable including a mapping of all livestock manure within e.g. 20 km distance from the proposed localization is a key. Often these statistical data are available, but a specific analysis is needed: do we have enough fodder to produce the gas expected?

Basically the activities in an ideal case should analyze the four basic questions for participatory planning

- **Do we like it?** Is there a consensus in the local society that this proposed solutions is acceptable or even needed? Preferable a bottom-up process asking for solutions to the general challenges of the community could reveal this challenge and the proposed solution. Step 3 of the biogas planning manual.
- **Can we get the permissions?** Environmental impact assessment is a lengthy process, only for the biogas plant, and is we include further aspects such as liquefaction and ferry harbor the matter complicates further. Step 7 of the planning manual.
- **Is it technically feasible?** Can we define any technical bottleneck for the biogas plant and the gas handling to be obstructed or problematic? Do we have any need of innovation support to take some of the risk?
- **Can we make a living of it?** The whole business plan tries to persuade potential investors about this. Again we have to focus on CAPEX, OPEX and Return on Investment, but here also the societal economic benefits should be part of it, such as job creation and side-businesses.

5. Channels



The Field to Ferry concept is expected to have a rather close relationship to one or a few key main costumers. The channels to regulate the hard-core streams of goods and payment are crucial for any business to reduce the risk. We could reach a considerable number of contracts regulating the farmer’s delivery and return of digestate, the gas quality and amount the prices, the service contracts, the banks etc.

Being innovative, it is recommended to make marketing to profit from the situation in the local community. Farmers should use the new value chain for their product marketing and the same accounts for the ferry company. They will reach their ‘secondary costumers’ of the Field to Ferry concept using traditional marketing tools, such as websites, brands etc.

IN addition, the development of the idea, but indeed also during further development of side-businesses many other channels for new cooperation exist, such as EU-financed development and innovation projects adding international dimensions and possibly further development to the concept.

6. Revenue Streams

The basic revenues streams are quite similar to the Samsø Case, but local adaptation will probably alter the following points

- Sale of gas to the ferry/the gas grid, perhaps with an intermediate/a brooker to ensure a fair price for both the buyer and the gas producer
- Potential sale of raw biogas for other local costumers – and if an industrial symbiosis is possible - the purchase of the process heat for the biogas process
- Depending on the choice of gas handling, there could be a potential sale of liquid CO_2, too

- The fertilizers will be traded possibly in a mutual contract with the livestock farmers, but also specific prices for incoming straw/silages and sale of standard digestate for main crops and in some cases perhaps specialized fertilizers, such as post-digestion fibers for other crops.
- For some biomass types there will be a gate fee for treatment, such as waste water and municipal solid wastes

7. Cost structure

Major costs in the business plan are

- The capital expenditure and the salaries for the personnel. Both are steady and primary cost-drivers.
- The cost of biomass purchase/delivery, storage and the transport of the biomass is a rather stable cost, but can be changed over time
- Gas handling is a major cost of around half of the production price for the raw biogas. Can only be avoided if a certain gas stream could be sold to other local industry
- Gas transport – either gas carriers (compressed or liquefied) or grid expenditure
- Costs of power and heat can be considerable, but many solutions are available including the potential industrial symbiosis. Taxes and subsidies are susceptible to changes and back-up systems are needed
- Insurances needed

8. Key resources

The keys to this investment and the focus for solution differs from one community/one country to the other and the following list is mainly for inspiration

- Liquid Natural Gas price dropped significantly on the world marked in 2013-15, and the tendency is that the price will remain low as shale gas and shipping of LNG has made LNG available worldwide.
- One possible solution is the sale of Green Certificates/ tickets for other customers in need of such. The national feed-in tariffs can be quite determining
- Liquefaction technology is expensive in nano-scale and innovative. Is it possible to ensure the service and to have the right competences for this technology on an island?
- CNG ferry should be considered. If constructed for the purpose and slow fill bunkering during night is possible, it could be an interesting option.
- The environmental permit can be susceptible for political approval.
- Based on the above, a consortium of visionary investors has to be found

9. Customer relationships

In the Lean Canvas model for start-up value chains this is called the Unfair Advantage. Why should we do this precisely here? What are the local advantages that could make this happen?

It could be as simple as 'we are part of an Interreg project enabling us to develop this idea', but hopefully more profound reasons are present, such as a profound interest in becoming a green shipping company or the farmers and the local municipality are looking into sustainable solutions for waste and manure treatment.

Expected Samsø financial model

The Samsø value chain have contact to interested investors and we are working towards a mixed financial model. The total investment costs have been calculated to be around 10 mio. €, depending on detailed technical planning and decisions of the consortium. At the time of writing (June 2018) no decisions have been made on these conceptual models

Basically we expect the investor partnership to consist of

- Consortium of biogas companies to deliver the full technical setup (50-60%)
- A 'Bio-cooperative' consisting of local farmers and small industries to deliver biomass and to receive digestate fertilizer in return (20-40%)
- Private or other interested business/NGO investments via crowdfunding (5-15%)
- Green investment funds (5-15%)

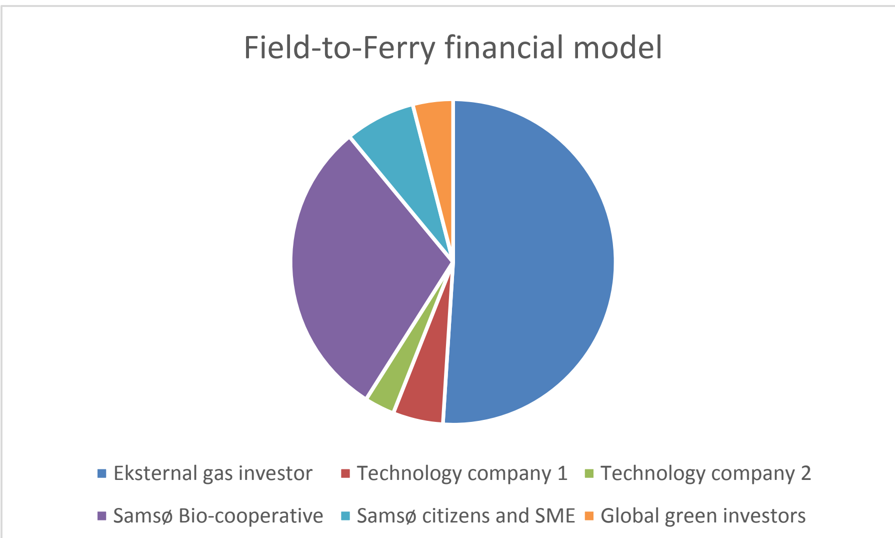


Figure 12 Conceptual model for financing the Samsø Case

In this context we will briefly describe the ideas about an innovative biogas value chain for crowdfunding. This could probably become the first in the world, but the Samsø reputation and the Field to Ferry case has a strong appeal to certain segments of investors.

Crowdfunding

Crowdfunding is a method of collecting many small contributions, by means of an online funding platform, to finance or capitalize a popular enterprise. Crowdfunding is, however, not a new innovation, as it has been used in historical time for instance in crowdfunding of books, e.g. by subscription. The book would be written and published if enough subscribers signaled their readiness to buy the book, once it was out (Fredman & Nutting 2015).

Recently, crowdfunding via the internet has opened up new opportunities to crowdfund other creative businesses like music, film and arts. In this sense crowdfunding is 'just' an internet based way to find sponsors. The business model has matured since around 2005 and now numerous platforms exist to crowdfund other societal projects and business ideas within for instance education, environment, politics and technical developments.

To our knowledge biogas and crowdfunding has not yet been realized anywhere in the world, but we believe that the Samsø case *From Field to Ferry* has the needed elements to make a crowdfunding case successful, such as

- Local dedication to take hand of own situation (community empowerment)
- Long term goals developed in cooperation between the local stakeholders and approved politically
- The communicative force of the model to inspire the world
- The potential – but yet unsecure – good green business case via bio-tickets
- The structure to invite local, national and global investors whether idealistic and/or commercial to join the crowd

Basically there are several ways to use crowdfunding, but we will focus on the three most relevant here:

Donation based crowdfunding

The donation based crowdfunding is money from the goodhearted donor, basically because the donor feels good about it. It may increase the donor's social capital telling about this donation, but no other rewards are given. A proof of the donation in terms of a 'donation poster' for the office could be given: *I supported this purpose financially.*

Since around 2010, new donation-based crowdfunding sites have allowed small organizations and individuals to solicit donations from the crowd in more efficient ways than to meet with every single sponsor asking for sponsorships. In principle, the donation based crowdfunding is just a platform to tell a good story about the product/the case and to open an account for – typically - small donations.

Reward-based crowdfunding

In the case of reward-based Crowdfunding the donor will get something in return – a reward. This could be a number in a lottery with a nice and relevant premium, or it could be a sponsor-name on the investment or specific PR-articles on the relationship between the donor and the specific investment.

A number of platforms for reward based crowdfunding are available, such as Indiegogo since 2008 and Kickstarter since 2009. The options are typically all-or-nothing, i.e. your credit card will not be charged if the goal is not reached. However, also 'keep-it-all' campaigns exist, so that the donor's money will be given to the project in all cases. This could be the case, if an intermediate support association (e.g. as a biogas NGO) makes the crowdfunding, and the funds will then support this organization instead, if the specific project is not realized.

Equity based crowdfunding

Equity crowdfunding is real investments with real risks and real opportunities. The investor become the owner of a share – a shareholder. In principle all can invest in this way instead of only accredited investors on the stock markets.

This model requires most of the investor, the company asking the funding and the crowdfunding platform itself. Because equity crowdfunding involves investment into a commercial enterprise, it is often subject to securities and financial regulation.

Samsø Crowdfunding case

This model will be developed during 2018-19, but in this specific context we will briefly describe how we intend to develop the crowdfunding model for the case. We will describe the idea of combining hard-core business investment with local idealistic ownership of the production means and local side effects on environment and job creation.

Samsø Biogas is fully aware that crowdfunding of biogas and the full value chain is a complex matter for the crowdfunding tool. Usually the crowdfunding is used for more simple cases, but equity based crowdfunding require more detailed explanation and knowledge – not 'just' a good feeling. However, the communication to each crowdfunding type has to be adopted to the specific target group. In the following, we present the 'raw elements' for this differentiated target groups that will have to be elaborated further.

The 'Field-to-Ferry' crowdfunding business case in a nutshell.

Samsø is a 'Renewable Energy Island' producing more renewable energy than the total energy consumption. Still, however, Samsø consume some fossil fuels for transportation. The next step is to become an Island free of fossil fuels by 2030 – and for this the ferries are the focus point, as they are the largest single fossil fuel consumers.

Prinsesse Isabella is a ferry inaugurated in 2015 fueled partly by Liquid Natural Gas in order to comply with shipping emission regulations for the Baltic Sea and North Sea areas. Another reason was to enable the Island to produce biogas on the island to replace the fossil gas imported from Rotterdam. The ferry is showing remarkable technical and economic performance, and the market for local biogas has been created.

Studies have shown that the island can provide the needed waste biomasses from agriculture, food industry and households to cover the energy needs of the ferry Prinsesse Isabella. Biogas is a key technology on the island to create a circular economy integrating the major biological cycles (Carbon, Water and Nutrients). This will create jobs, reduce Green House Gas emissions and open for more organic agriculture on the Island. In addition, the circular biogas plant can become a hub for further innovative solutions to be demonstrated in a visitor center.

Samsø Municipality has approved the environmental permits for the production eliminating many uncertainties for investors. The business prospect shows good opportunities as the market for bio-tickets for transportation is increasing. We have a major investor, but we seek to balance the partnership of investors in this innovative value chain. The total investment is approx. 10 mio. €.

You can become a part of this by supporting the Field to Ferry case:

Donation

If you already have Samsø in your heart as a model to inspire the g society to support the establishment of Samsø Circular.

- You can donate from 100 € upwards.
  - You can win a weekend-stay at Samsø and meet with key actors in the transition to feel the spirit.
- We welcome citizens, second-home'er, tourists/guests, organizations, enterprises
- Funding goal 50.000 €

Reward - donation

If you want to be a part of the next step in the globally renowned Samsø story we can honor your input with different types of rewards, such as

- A donation > 1000 € will be rewarded with e.g.
  - a sign with your logo on the plant/in the visitor's center, or similar
- A donation > 10.000 € will be rewarded with e.g.
  - A public article and the right to refer to the cooperation in business materials for a period of time, or similar
- For Donations > 100.000 € the reward is negotiable
- Funding goal: 200.000 €

Equity investment

With venture capital we invite you to invest and become influential on the Samsø Case. Read the investment documents (Offering, Investment Agreement; Company summary).
Equity can be of different levels:

- Min. 5000 € investment
- Funding goal: 250.000€

Constraints and opportunities for implementation

In each country and each local coastal community there is a strong need to define the key constraints and opportunities for implementation of the value chain. Several of the elements in the value chain from Field to Ferry have typically been supported from governmental and/or local public bodies and these factors varies substantially between countries and regions. In the following we list a number of key incentive opportunities that should be investigated in each case.

Biogas incentive structures

Biogas incentives are carrying the market in EU in most countries, either supporting with nationally adapted feed-in tariffs and or investment support schemes. The reasoning behind is that biogas is still an emerging alternative fuel linking the power and gas-systems in many countries and is has a series of additional benefits on the environment and climate that the pure energy price cannot pay for (reduced green House Gas emission, fertilizer for agriculture, recycling of societal wastes etc.).

For this report, we will not go through all the different biogas incentive systems of the BSR countries, but see Luostarinen (2013). The national incentives are regularly adapted to new EU directive updates and basically many countries expect that the demand for biofuel blending and emerging market for bio-tickets for transportation will be able to create the market to cover the costs of biogas production.

Investment support incentives

Investment support for innovative technologies from EU or from national level is also an instrument often deployed. This can in its nature only be used for the first few examples of innovative technologies where the risk of investment is very high.

For the Field to Ferry value chain, we see the nano-scale liquefaction as a very relevant technology for support, and also biogas engines and/or hybrid ferry solutions could be a case for support. Typically, the support is between 10 and 50% of the investment with numerous requirements for documentation, reporting and communication, and there is still a risk at stake for the investors.

Ferry transport incentives

For most smaller islands the ferries are the life-line of the local society and in few case this can be run on purely commercial basis. A summer ferry for a touristic island can be profitable, but for the winter season and the needed service during evenings etc. a public support is usually needed. In some cases, the local municipality supports (e.g. based on general government subsidies to rural areas), and in other cases the region or the state is supporting the ferries, depending of the country and the local conditions.

Taxation and general frame conditions

In addition to the aforementioned incentives, the taxation systems in any country plays a significant role as well as the general frame conditions for new initiatives.

References

Allegue, L. B., & Hinge, J. (2012). Overview of biogas technologies for production of liquid transport fuels. Danish Technological Institute.

Andress, D. L. (1996). The Phillips optimized Cascade LNG process. A Quarter of a century of improvements. Retrieved from https://pdfs.semanticscholar.org/030d/d7dc93d849efd8533097dcfd2ec6300878ae.pdf

Arat, L. (2011). Corporate social responsibility in shipping companies in the Baltic Sea. Retrieved from http://www.merikotka.fi/julkaisut/CafeCSRraportti_LauraArat.pdf

Biogas2020. (2017). Nye Volvo-lastebiler på biogass. Retrieved November 6, 2017, from https://www.biogas2020.se/nye-volvo-lastebiler-pa-biogass/

Bouman E.A., Lindstad, E., Rialland, A., and Strømman, A.H. (2017). State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review. Transportation Research Part D, pp. 408–421

Charbagi. (2016). Personal communication. Air Liquide

Clean Marine Energy. (n.d.). SHIPPING EMISSIONS. Retrieved November 6, 2017, from http://www.cleanmarineenergy.com/mobile/shipping-emissions/

Cryonorm. (n.d.). LNG liquefaction plants. Retrieved from http://cryonorm.com/lng-liquefaction-plants

Danske Rederier. (n.d.). Nøgletal. Retrieved from https://www.danishshipping.dk/analyse/

DNV GL. (2016). DNV GL – LNG fueled vessels.

Energinet. (2016). ÅRSGENNEMSNIT FOR GASKVALITET. Retrieved November 6, 2016, from https://energinet.dk/Gas/Gaskvalitet/Aarsgennemsnit-for-gaskvalitet

European Biogas Association 2015. http://european-biogas.eu/biogas/

European Commission. (2017a). DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources (recast). Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0767R%2801%29

European Commission. (2017b). Reducing emissions from the shipping sector. Retrieved from https://ec.europa.eu/clima/policies/transport/shipping_en

Franzen, M. (2016). Volvos nye FM metan diesel.

Fredman & Nutting (2015) A Brief History of Crowdfunding http://www.freedman-chicago.com/ec4i/History-of-Crowdfunding.pdf

Gartner, J. (2016). Rail Looks to Move the LNG Market. Retrieved November 6, 2017, from https://www.navigantresearch.com/blog/rail-looks-to-move-the-lng-market

Global CCS Institute. (n.d.). 3.8 LNG Liquefaction. Retrieved from https://hub.globalccsinstitute.com/publications/ccs-learning-lng-sector-report-global-ccs-institute/38-lng-liquefaction

Implement. (n.d.). People and biogas. A manual on citizen involvement. Retrieved November 6, 2017, from https://peopleandbiogas.com/en/

International Gas Union. (2017). 2017 World LNG Report. Retrieved from https://www.igu.org/sites/default/files/103419-World_IGU_Report_no crops.pdf

International Maritime Organization. (2014). Third IMO Greenhouse Gas Study 2014. Retrieved from http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third Greenhouse Gas Study/GHG3 Executive Summary and Report.pdf

International Maritime Organization. (n.d.). Emission Standards International: IMO Marine Engine Regulations. Retrieved from https://www.dieselnet.com/standards/inter/imo.php

IRENA 2015. Renewable Energy Options for Shipping *http://www.irena.org/DocumentDownloads/Publications/IRENA_Tech_Brief_RE_for%20Shipping_2015.pdf*

IVECO. (2016). Neew Stralis NP. TCO2 Champion. Retrieved from http://www.iveco.com/uk/collections/catalogues/Documents/new-stralis/new-iveco-stralis-np-brochure.pdf

Lindgren, P. and Bandsholm, J. 2016. Business Model Innovation from a Business Model Ecosystem Perspective. Journal of Multi Business Model Innovation and Technology, Vol. 4 2, 51–70.

Luostarinen, S. (ed.) 2013. Energy Potential of Manure in the Baltic Sea Region: Biogas Potential & Incentives and Barriers for Implementation

Mikkelsen, N. (ed). 2015. Biogas til Transport. Gennemførlighedsstudie af biogaskæde på Samsø (in Danish). Available at www.Samsø.dk, search for biogas

Nguyen et al. 2017, Thermodynamic comparison of three small-scale gas liquefaction systems. Applied Thermal Engineering. Vol 128: 712-724

Norsk Gassforum, COWI, Østfoldforskning, & CargoNet. (2015). Gass som drivstoff for jernbane. Retrieved from http://gassforum.no/wp-content/uploads/2016/07/Nordlandsbanen_p__gass.pdf

Olesen, H. R., Winther, M., Ellermann, T., Christensen, J., & Plejdrup, M. (2009). Ship emissions and air pollution in Denmark. Present situation and future scenarios. Retrieved from http://mst.dk/service/publikationer/publikationsarkiv/2009/okt/ship-emissions-and-air-pollution-in-denmark/

Osterwalder, A. and Pigneur, Y. 2010. Business Model Generation

Roberts, M., Chen, F., & Saygi-Arslan, Ö. (2015). Special report: Small-scale processing solutions. Brayton refrigeration cycles for small-scale LNG. Allentown, Pennsylvania. Retrieved from http://www.airproducts.com/~/media/downloads/article/L/lng-braytonrefrig-cycle-article.pdf

Rousing, H. 2017, Pers. Comm. HMN/Eniig

Sall, L. 2017 Pers. Comm. Kosan Crisplant

Samsø Energy Academy, 2012. Samsø 2.0. Dokumentation af Open Space møde. http://energiakademiet.dk/2-0/

Samsø Kommune 2017. Environmental Impact Assessment (VVM rapport - in Danish) https://www.samsoe.dk/kommunen/nyhedsarkiv/tidligere-hoeringer/offentliggoerelse-af-planer-for-samsoe-biogas

Scania Norge. (2016). Lastebiler. Retrieved November 3, 2016, from https://www.scania.com/no/no/home/products-and-services/trucks.html

Siemens https://w3.siemens.dk/home/dk/dk/core_topics/intelligent-infrastructure/Documents/MOB_eferrystudy_1016UK_FINAL.pdf

Skagerak Naturgass AS. (2017). Transportgiganten Litra AS satser grønt med biogass på tanken. Retrieved October 6, 2017, from http://skageraknaturgass.no/eway/default.aspx?pid=324&trg=MainRight_11921&MainRight_11921=11871:246820::0:11988:1:::0:0

Smith, T., Raucci, C., Hosseinloo, S. H., Rojon, I., Calleya, J., Wu, S. S. D. L. F. P., & Palmer, K. (2016). CO2 Emissions from International Shipping Possible reduction targets and their associated pathways. Retrieved from http://www.lowcarbonshipping.co.uk/files/ucl_admin/DSA_2016_Co2_emissions_in_shipping.pdf

Stensvold, T. (2014). SIEMENS TRONDHEIM. Miljøvernerne jubler over denne ferga. Batterier erstatter 95 tonn motor. Retrieved January 10, 2017, from http://www.tu.no/artikler/miljovernerne-jubler-over-denne-ferga/222328

Tybirk K., Solberg, F.E., Wennerberg, P., Wiese, F. and Danielsen, C. G. 2018. Biogas Liquefaction and use of Liquid Biomethane. Status on the market and technologies available for LNG/LBG/LBM of relevance for biogas actors in 2017. https://www.biogas2020.se/projektet/aktivitetsrapporter/ http://www.golng.eu/en/news__/a-study-on-biogas-liquefaction-and-use-of-liquid-biomethane-17509.html

Tybirk, K. 2014. Manual for Establishment of Biogas (Manual for etablering af Biogasanlæg 2014) http://inbiom.dk/Files/Files/Publikationer/kogebog_for_etablering_af_biogasanlaeg_2014_web.pdf

Volvo Trucks. (2017). De nye Volvo-lastebilene som går på LNG, har samme ytelse som diesel, men 20–100 % lavere CO2-utslipp. Retrieved October 5, 2017, from http://www.volvotrucks.no/no-no/news/press-release.html?pubid=22400

Summary

The report analyses briefly the emerging market for both Liquefied BioMethane for marine transport and the corresponding market for coastal communities to produce biogas and to concentrate the biomethane in a liquid form either for heavy duty road traffic, for trains or for ferries.

The Samsø Field to Ferry *business concept is perhaps a one-of-a-kind case, but inspiration can be taken for other localities with similar aims and options.*

The report combines the biogas planning manual from Denmark with a generalized business concept model and ideas of crowdfunding into a conceptual model for other coastal communities.

GoLNG

Interreg Baltic Sea Region
EUROPEAN REGIONAL DEVELOPMENT FUND
EUROPEAN UNION
Go LNG

SAMSØ KOMMUNE