Final report

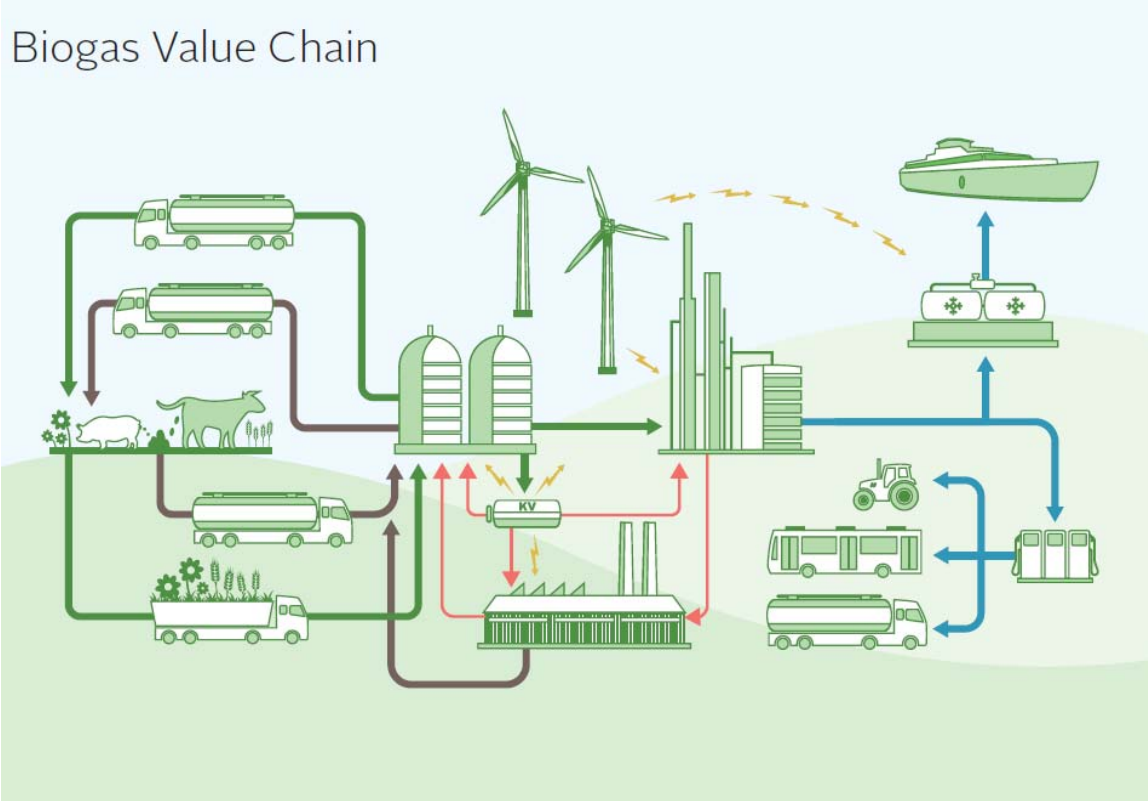
Project details

Project title	Biogas for transport
Project identification (program abbrev. and file)	Journalnr.: 64014-0173 - Biogas (biomethane)for Transport
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	Samsø Kommune Søtofte 10, 8305 Samsø
Project partners	Samsø Kommune PlanEnergi Aalborg University Minor Change Group Teknologisk Institute Nærenergi Energiakademiet Samsø Elektro
CVR (central business register)	23795515
Date for submission	30 November 2015

Short description of project objective and results

The aim of the EUDP-project is to carry out a 360 degree feasibility study of a value chain for local production of liquefied bio-methane (biogas) (LNBG) and compressed bio-methane (biogas) (CNBG) to provide both the Samsø ferries and vehicles on land with fossil free fuel. It will be the core element of a Smart Energy System, which can make Samsø a model for the national 2050 goal of a 100% fossil free society.
The results show that it is technically, financially, organizationally and legally possible to establish a biogas value chain on Samsø if there is equal access to support schemes.

Projektets formål er at gennemføre et 360 gr. feasibility study af en værdikæde for lokal produktion af flydende biogas (LNBG) og komprimeret biogas (CNBG) på Samsø til fossilfri drift af Samsøfærgerne og landtransport på øen. Den skal udgøre kernelementet i et Smart Energy System, der kan gøre Samsø til modelsamfund for den nationale 2050 målsætning om et 100% fossilfrit Danmark. Resultatet viser at det er teknisk, økonomisk, organisatorisk og juridisk muligt at etablere en biogas værdikæde på Samsø, hvis der er lige adgang til støttemuligheder.



Figur 1 System integration:

From biomass to LBNG and CBNG together with fluctuating electricity.

Executive summary

Samsø municipality wishes to carry out a 360 degree feasibility study of a proposed biogas value chain to ensure fossil free operation of the island ferries and transport on the island using locally produced liquefied biogas (LNBG) and compressed biogas (CNBG). Samsø embarked on the transition to the fossil free society very early on and has for several years obtained a gross 100% self-sufficiency of renewable energy. Now Samsø wants to take the next step and make the island 100% fossil free by establishing a 'Smart Energy System', in which the production and consumption of power, heat and energy for transportation are fully integrated. Hereby it is the ambition to become a model society for the national 2050 climate 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.

Hence it is the natural focal point in a transition process. Samsø Municipality wants this to happen by making the ferries run on locally produced biogas. Therefore, they have invested in a new gas turbine ferry sailing between the main land and Samsø. Though it at first will have to be fuelled by imported liquefied natural gas (LNG), it will create a demand for locally produced biogas and hence the basis for establishing the biogas value chain on Samsø. However it is a very comprehensive and complex process with a lot of unknowns.

Therefore Samsø Municipality wants to carry out a feasibility study of the value chain, which can shed light on both the technical, organizational, legal and business side the chain it self, and its socio economical impact on Samsø – and Denmark. It has been carried out in collaboration with a number of private and public partners, which now have a strategic and/or commercial interest in realizing the biogas value chain.

The main conclusion of the feasibility study is that there is a basis for establishing the planned biogas chain on Samsø for the production of fossil-free fuel for the ferry and land transport on the island. But it should be integrated with the development of other energy infrastructure, so that Samsø can become 100% self-sufficient in renewable energy by 2030 and thus effectively be fossil-free.
This requires the expansion of renewable energy capacity in step with the replacement of existing facilities and that Samsø is able to use as much of its own renewable energy as possible, including the installation of heat pumps on the island and converting the light transport to electricity. By doing so, biomass can be reserved for the production of fossil-free fuels for the heavy transport – including the ferries. The proposed developments and conversions of renewable energy infrastructure in the heating sector should therefore be undertaken. It is cost neutral from a socio-economic viewpoint and can be implemented independently of the biogas chain.

The feasibility study started in June 2014 and ended November 2015. The objective has been to draw such a comprehensive picture of the potentials and risks that it can be decided afterwards whether or not to realize the biogas chain, and if so to provide the basis for rising the necessary funding and forming the right partnership behind.

Because of the positive progress and findings within the study, Samsø Municipality has already hired a new employee. He will, along with other stakeholders, continue the work with the objective to implement biogas facilities etc. Therefore the expectation to the projects academic content has been fulfilled.

The project has evolved successfully regarding the objective of projects. The most critical finding, which has also been surprisingly, is that the support scheme for upgraded biogas is not legally possible on Samsø. The reason for this is that there is no existing gas grid on Samsø. This market failure, regarding access to grid compared to access to support schemes, will be the biggest risk for the project.
Regarding the project process there has been one main change. One of the companies within the partnership declared bankruptcy petition in spring 2015. This lead to a reconstructed budget and the assignment was conducted by other partners. Subsequently the project was exposed.

The project's final report can be found on the website of Samsoe Municipality: http://www.samsoe.dk/site.aspx?MenuID=174&Langref=1&Area=&topID=&ArticleID=9151&expandID=2151&moduleID=.

This final report has also been published in a printed version. By following the link above the background reports of the projects for each work package and a legal investigation can be found. Work Package 4 *Smart Energy System* is available in English.

During the project there has been held 2 workshops for the potential biomass supplier's e.g. local farmers and local industries. Besides this, there has been held a seminar for invited companies. These 25 companies, who are all suppliers within different aspect of the biogas value chain, visited the potential location for the biogas facilities and the LNG-ferry etc. During the project there has also been send out 3 press releases. Finally an "energy safari" was held where comparable biogas facilities was inspected and findings from the EUDP-project was disseminated to potential stakeholders.

The study consists of 5 elements, each with a special focus:

- Production of biogas: prerequisites and potentials – technologically, biologically and economically
- Production of LNBG – optimal technological solution, capacity vs. consumption, integration with existing energy systems – e.g. use of surplus wind power
- Biogas for transport – technological feasibility of using LBG for ferries and vehicles and market potential for biogas compared with other fuels
- Smart Energy System – the biogas chain as an integrated smart energy system and the potential of Samsø becoming a simulator/test centre of such systems
- 2050 Model Society – the secondary effect of Samsø as a 2050 model society, both regarding business development, demography and environmental issues.

Sufficient biomass resources on Samsø

There is sufficient biomass resources available on Samsø to produce the amount of biofuels required to convert the transportation sector to fossil-free operation. However, if this is done with biogas production, it will require that 15% of the area under grain be used for growing energy crops. Before the final decision on the establishment of the biogas facility is made, there needs to be clarity about the possibilities for making this conversion, and farmers must prepare sustainable business plans for cultivating it.

Recommended biomass mix	Amount / year in tons	Amount / day in tons	Biogas potential x 1000 / year	
			Nm3 biogas	Nm3 CH4
Pig manure	33.000	27	234	152
Cattle manure	10.000	90	581	378
Solid manure	3.000	8	207	135
Aftercrop	2.000	5	236	153
Energy crops (clover/lucerne etc.)	17.500	48	2.748	1.786
Meadow grass	2.000	5	226	147
Surplus straw	700	2	217	141
Industrial waste	1.400	4	115	75
Industrial sewage	35.000	96	319	207
Horticultural waste	3.245	9	276	180
Household waste	580	2	108	70
Total	108.425	296	5.267	3.424

Figure 2 Conclusion: Recommended types of biomass and amount per year. (Lucerne=alfalfa)

Carbon accumulating and nitrogen-fixing energy crops instead of corn

To get a better accumulation of carbon in the crop rotation and more nitrogen into the biomass cycle to replace commercial fertilizer, perennial nitrogen-fixing crops like clover and alfalfa or other leguminous crops would be preferable as energy crops instead of corn which, from a purely economic standpoint, would otherwise be the most obvious choice.

Biogas –the realistic choice

As a process for converting biomass into fuel, traditional biogas production will be the most realistic choice in a Samsø context. Gasification could also be a possibility, where straw and wood chips in particular could be exploited more efficiently than in biogas production. But the process would not take advantage of two other large biomass resources on Samsø: manure and wastewater from Industries. These also need to be treated in a biogas facility to better utilize the nutrients and minimize emissions of methane and ammonia into the atmosphere and discharges of nitrogen and phosphorus into the aquatic environment. Furthermore, biogas facilities – as opposed to gasification facilities – can be established and operated profitably on a Samsø scale.

Robust design – possibly 2 lines from the start

The biogas facility must be designed with certain robustness in order to be able to handle different combinations and amounts of biomass and thus be less sensitive to changes in the biomass that is available.

It should be considered to make two lines from the start to provide better opportunity:

- To support the development of organic farming on Samsø.
- To expand biogas production in step with the conversion of transport to gas operation.
- And to create an increased reliability and security of supply for the ferry.

Location in proximity to Industrie in Kolby

The biogas facility should be located in proximity to Industries in Kolby in order to take advantage of the wastewater and vegetable waste from the canning factory without transportation costs and to limit the transportation of slurry and deep litter from the island's livestock, which are primarily located south of Tranebjerg.

Upgrading, cooling and compression - Upgrading with an AMINE-Scrubber – located at the biogas facility to utilize excess heat

The technology for upgrading the biogas to bio-methane (100% methane) that has proven most suitable both in terms of capacity, cleaning requirements and economics is a so-called AMINE-Scrubber. The upgrading facility should be located in proximity to the biogas facility in order to utilize waste heat from the upgrading process in the production of biogas and conversely, to supply electricity and heat from the combined heat and power (CHP) motor to be constructed at the biogas facility and operated with raw biogas.

Later expansion with methanation technology

Later, when the technology is mature, it will be appropriate to expand the upgrading facility with methanation. In this way, Samsø's fluctuating production of renewable electricity can be balanced and utilized locally to increase methane production by approximately70% - and thus get much more energy out of the available biomass and avoid C02 emission with the upgrade.

Process heat symbiosis with Industries and other companies

Process heat symbiosis between the biogas facility and the upgrading facility can be developed with Industries. The biogas combined heat and power (CHP) motor at the biogas facility can also supply heat for the canning production and the heat from there can be recycled for use in the biogas facility, either directly via wastewater or indirectly via a heat exchanger or a heat pump. If methanation is later connected to the upgrading facility, this symbiosis will be even more suitable, since the high temperature heat generated by the electrolysis process could be used directly in production at Industries and in other companies that need high heat and/or steam in production and could therefore be interested in establishing themselves in this bioindustry symbiosis.

Flexible LBNG production with modular Stirling Cryogenic technology

For cooling the upgraded bio natural gas (BNG) to liquid form (LBNG) for use by the Jutland Ferry, Stirling Cryogenic technology is recommended because it is modular, making it reliable and easy to tailor to the Jutland Ferry's requirements and to expand with extra modules, if the Zealand Ferry is eventually equipped for LBNG. On the same land register and under the same ownership as the LBNG facility, renewable energy production units should be established that could deliver renewable energy directly to the cooling process, which can be produced without the PSO-tariff.

Location of the CBNG filling station and the LBNG cooling facility in Tranebjerg

The CBNG filling station for supplying gas vehicles on Samsø should be located in the island's capital and transportation hub, Tranebjerg. A 3.5 km gas pipeline should therefore be established from Kolby to Tranebjerg for the transport of the upgraded bio-methan. The LBNG cooling facility should also be placed in Tranebjerg and the LBNG should be transported in containers to the harbour in Sælvig by truck. This also provides greater flexibility to later deliver LBNG to the Zealand Ferry, which puts in at Ballen harbour.

Conversion of the transport sector to fossil-free operation - Gradual conversion of transport on Samsø in step with the development of biogas production

Aside from supplying the Jutland Ferry (Sælvig) with gas, focus should be placed entirely on converting the heavy transport on Samsø to gas operation.

1. In order to begin conversion and create the economic basis for the establishment and operation of the CBNG filling station, Samsø Municipality should take the lead and convert their heavy driving work to gas. Combined this will create sufficient consumption to establish the CBNG filling station.

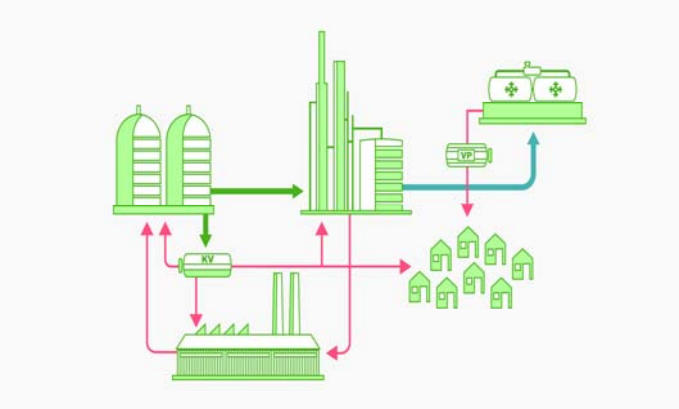
2. At the same time, continue to convert the island's personal and freight transport to electricity –this can possibly be accelerated by seeking funding for the conversion.

3. The Jutland Ferry should be converted to hybrid operation so that its gas consumption can be brought down to the original estimate. If the production capacity of the biogas facility is optimized at the same time, there will thus be enough biogas for the conversion of all the heavy transport on Samsø.

4. Tractors and agricultural and construction machinery are the most difficult to convert to gas and they can be omitted if necessary and instead be supplied with DME or biodiesel imported to the island, either in direct exchange for biomass (straw and wood chips for gasification and DME production) or offset by exports of renewable electricity.

5. If it proves possible to also convert the Zealand Ferry to LBNG operation, Samsø's biogas should be prioritized for it. It would be realistic from the moment methanation is coupled to the biogas chain and all transport to, from and on Samsø will thus be able to be fossil-free.

Integration of the biogas chain and the district heating system- Integration of the biogas chain with the district heating system – and parallel development
Until all the heavy transport and the Zealand Ferry are converted, there will be a surplus production of biogas, for which a market will need to be found – and imbalances will probably also emerge later on between production and consumption, so there will be a need for a buffer to offset this. Much of the surplus production would probably be used for the production of process heat for Industries.
But it could also be used for district heating. If the first stage of the proposed district heating expansion went to Kolby and Kolby Kås, the combined heat and power (CHP) motor at the biogas facility and Industries could be connected to the district heating network, and thus it would be possible to utilize any excess biogas for district heating production. If it is done in connection with the establishment of the gas pipeline to Tranebjerg, capital expenditures could even be saved.



Figur 3: Conclusion: System integration of Heat pumpts (vp) for individual households.

Likewise, there could conceivably be synergies between the production of LBNG and district heating in Tranebjerg. If the LBNG cooling facility was placed adjacent to the Tranebjerg heating plant and if a large heat pump was installed here first, the excess heat from the cooling process could be recovered for district heating and could be sent out onto the grid. By developing the district heating system in this way, parallel with the establishment of the biogas chain, they can be integrated and the synergies between them can be utilized.

Finance and business models for the biogas chain - The total investment costs of the biogas chain are 75 million kr.
These are distributed as follows:

Investment Cost	Technology	Mio. kr
Biogas plant		43,5
Upgradering	Amin Schrubber	16
LBNG production	Stirling Cryogenic	12,3
CBNG Station	Nano-Box	3,6
Total		75,4

Figure 4: Conclusion: Estimated investment cost for all facilities

(Except transport investments.)

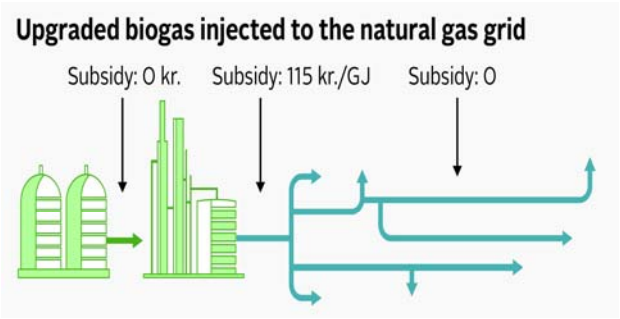
Production of LBNG and CBNG at market prices – with upgrading subsidies

With the proposed technology in the biogas chain it is possible to produce biogas, LBNG and CBNG at market prices.

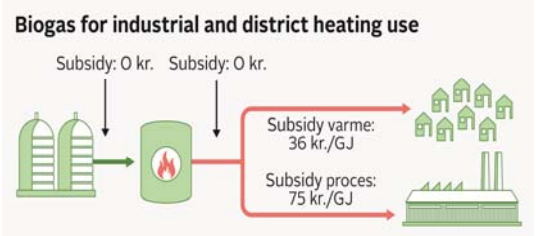
Economic	kr. /kg LBNG	kr./Nm3 CBNG
Biogas production	7,00	5,50
Upgradering (4 bar)	1,19	0,93
Transport 3,5 km	0,06	0,04
Gascromatografi	0,02	0,01
LBNG cooling incl. O&M and power	1,31	
Transport LBNG 4,5 km	0,25	
Fuel tax		2,93
Electricity cost CNBG station		0,14
O&M CNBG station		0,25
Total production cost	9,83	9,81
Upgradering subsidy	4,90	3,50
Total pro. Cost after subsidy	4,93	6,31
Proposed sale price	5,00	8,00

Figure 5: Conclusion: Estimated gas price.

This assumes, however, that it is possible to obtain upgrading subsidies*. Without this it will not be economically feasible to produce LBNG and CBNG on commercial terms. Samsø should request that the transmission line from Kolby to Tranebjerg be given the status of a public natural gas network or can be treated as a town gas network and can thus have access to subsidies for the upgrading of biogas with a view to injecting it into the natural gas network. Alternatively, the upgraded biogas can be shipped to Hov to be injected into the natural gas grid. This difficult and costly manoeuvre could have the advantage that it will provide both greater marketing collateral for the biogas that can be produced on Samsø and greater security of supply for the ferry and other transport that is converted to gas.



*Support scheme for upgraded biogas**



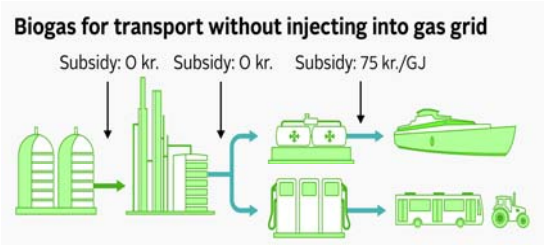


Figure 6 Support schemes for biogas 2015 in Denmark

Biogas facility and the upgrading facility owned and operated by a private biogas consortium
The biogas facility and the upgrading facility should be brought together in an organizational unit to take advantage of the many synergies in production. And they should be owned and operated by a private consortium – with the participation of local actors and stakeholders, including farmers who supply biomass and have a vested interest in integrating energy crops in their rotations. Samsø Municipality neither can nor should be involved in the ownership and operation – not even with a municipal guarantee, as it would put too many business constraints on the operation of the facility. The production of the biogas will balance out at a price of 3.18 kr./ Nm3 methane and with an asking price of 3.50 kr. there will be a payback period of 7.5 years on the biogas facility and a reasonable return to investors.

LBNG cooling facility and the CBNG filling station owned and operated by Samsø Shipping/Samsø Municipality
As the owner of the largest customer for the upgraded biogas, Samsø Rederi, it is obvious that Samsø Municipality goes in and operates the LBNG cooling facility and buys the upgraded biogas from the biogas consortium on long-term contracts, which can ensure the operating economy of the biogas facility and provide security for the investments of the consortium partners. Samsø Municipality should also initially invest in the CBNG filling station to supply biogas for the municipality's own heavy transport work and to a lesser extent the private transport sector. But the moment the private sales exceed the public and the economy of the filling station is sustainable on a commercial basis, the municipality should sell it to a private operator so as not to overstep it powers in regard to the rules governing municipal government.

Gas pipeline probably owned and operated by the public sector
The gas pipeline between Kolby and Tranebjerg can in principle be operated in both the private and public sector, but the most realistic scenario would be if Samsø Municipality owned it. Thus there would be a very clear organizational separation of the biogas chain where the production facility for upgrading biogas is owned and operated by the private sector, while the distribution infrastructure, which will ensure sales, is owned and operated by the public sector.

2050 Model Community – The biogas chain's local economic potential

Purely in terms of energy and economically, it overall makes good sense to establish the proposed biogas chain on Samsø and make the island 100% fossil-free. It also makes sense for other reasons: the community development that such a significant investment in infrastructure may give rise to in a small and limited local economy as the one on Samsø. A development, which especially can be propelled by Samsø branding itself as a Model Community for the 2050 vision of a fossil-free Denmark. – 20 years early. Specifically, the biogas chain can in the short term:

• Support continued animal production on Samsø.
• Provide better fertilizer use – improved crop rotations – better soil quality – and thus higher yields and greater profitability from cultivating land on Samsø.
• Create better conditions for conversion to organic farming, which can increase the value of agricultural products from Samsø.
• Allow for more environmentally friendly use of marginal land, not the least to create economic yield from the care of natural areas, and thus greater incentives to take marginal land out of rotation and to create greater and more continuous natural areas on the island.
• And create increased employment in the production of bioenergy, both in the agriculture, energy and service sectors.

In the long term, the 2050 Model Community strategy can:

- Create the basis for the development of a circular bioeconomy on Samsø – with the production of high-value food, bioproducts and gastronomy and nature experiences.
- Provide the opportunity to further develop Samsø's strong brand as a pioneering island, not just for being fossil-free, but also for a forward-looking circular bioeconomy which has a far greater commercial potential in that it can be linked directly to products from Samsø.
- Make Samsø a test and demonstration island for new biotechnological solutions that can attract knowledge resources from home and abroad.
- Lay the foundation for Samsø to become one of the world's first local communities to convert to an entirely circular economy and become known as *The Full Circle Island*.
- Counter a negative demographic development and/or mitigate the socio-economic consequences of it.

Additional effect on local economi in mio. kr./year	Salary	Local tax* from salary	Multiplication effect**	Local economic effect in total
Direct effects	12,1	3,2	7,3	19,4
Indirect effect	18,1	4,3	10,9	29,1
Total / year	30,2	7,5	18,2	48,5

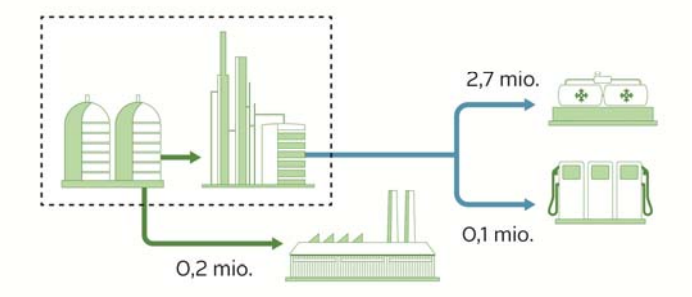
*Figur 7: Conclusion: Estimeted additional effect on the local economic on Samsø. *Municipality tax =26% ** Multiplication effect =1,6 (60% of income is used again on Samsø). The biogas plant, upgrading facilitie and transport of biomass will create app. 5 full time jobs. The estimated tax to the municipality is 317.000 kr/year.*

Learning Platform for the 2050 Model Community

To create a resilient local community with a facility for the production of biofuels as a focal point will be a relevant strategy for many other communities in peripheral areas. In order for those outside of Samsø to get knowledge and inspiration to create fossil-free communities and a bioeconomy, a learning platform should be established for the 2050 Model Community, which can gradually be developed and unfolded as the biogas chain is realized. It should be an open platform where anyone who finds what is going on interesting and/or has something interesting to offer is welcome to participate. And along the way, learning materials and curriculum can be developed for schools and universities and educational facilities and activities can be established on Samsø (including the Energy Academy), which can create the foundation for new green business and educational tourism on the island. The direct local economic effects of the construction and operation of the biogas chain is positive when the total employment potential is added up and translated in potential economic revenue for Samsø. It is however the secondary effects of the biogas chain that is likely to generate the greatest economic benefit for Samsø. On the other hand, they are difficult to calculate and depend on a number of factors. If this long-term potential is to be realized, it will require further investment, clear strategic priorities and a great readiness for change by the inhabitants of Samsø. The renewable energy island effort has demonstrated that the latter is present and decision makers and key players on Samsø have also previously shown that they have the courage to make visionary decisions that can ensure the island community's survival in the future.

Recommendations for a business model

Overall, there are good reasons to establish a biogas chain on Samsø. However, it is not clear which business model would be the most appropriate. The deciding factor is whether it is possible to obtain upgrading subsidies for the biogas or not.



Marketing of methan	Nm3 methan (mio.)	Price (kr.)	Turnover (mio.kr.)
LBNG cooling system	2,7	2,75	7,43
CBNG station	0,1	4,25	0,43
Proces/heating	0,2	5,5	1,1
Revenues			
Annual revenue -gas sale	3,0		8,95
Upgradering subsidy	3,0	3,5	9,8
Revenue electricity sale			1,5
Revenue biomass sale			0,0
Turnover			20,25
Result 1. year of operation			0,79
Simpel payback time			9,5

Figure 8: Conclusion: The most likely scenario. The biomethane is converted to LBNG, CBNG and a small amount is used as raw biogas (65% CH_4) and distributed as above. This distribution will have the index number showen.

Model A: Commercial facility

Provided that it is possible to obtain the upgrading subsidy one way or another, an attempt should be made to establish the biogas chain on a commercial basis. A biogas facility and upgrading under the auspices of a private consortium and a LBNG cooling facility and CBNG filling station owned by the municipality. Here, two parameters in particular will be critical for the operation and the economy:

• To secure the delivery of sufficient quantities of biomass, in particular to establish agreements with farmers about the cultivation of energy crops.

• And to ensure a market for the biogas that the ferry cannot take until the heavy transport on Samsø is converted to fossil-free operation.

If it is not possible to obtain the upgrading subsidy, it should be studied whether there is a sufficient market for biogas in a raw form for processing/heating, which would thus provide an economic basis for the establishment of just the biogas facility.

Model B: Test and demonstration facility

If it is not possible to obtain upgrading subsidies and/or it proves not to be possible to establish the biogas facility/upgrading in the private sector, the biogas chain should be thought of as a test and demonstration facility for future biotechnologies. This could open up alternative sources of funding for building and operation, and the economy would be supported by activities beyond just energy production. It could also open up the establishment of other small-scale facilities for the conversion of biomass into energy, for example, a mini-gasification facility, whereby several biomass sections on Samsø could be utilized optimally, and it could open up the development of test facilities for the production of a mini-biorefinery for the production of high-value bioproducts.

Model C: Combination model

The two models do not preclude each other and can be combined to build a commercial facility with test and demonstration facilities.

Model D: Fossil-free just by the export of renewable electricity

Finally, Samsø can choose the simple solution to just continue the expansion of renewable electricity facilities on the island, converting as much of the island's energy use to electricity as possible and to export renewable electricity in exchange for biofuels for the heavy transport on the island. However, it will mean that Samsø's desire for self-sufficiency would not be met, just as the additional economic development of setting up a biogas facility on Samsø will not happen.

The recommendation from the parties behind the feasibility study is therefore to proceed with exploring the possibilities for establishing the biogas chain on a commercial basis, but at the same time studying the potential for making the facility a test and demonstration facility and be ready to shift the main focus to this business model if the purely commercial model proves to not be realistic.

Efforts should be made to supply gas for both ferries, land transport and processing/heating, to have as many distribution channels as possible and the municipality should help support these channels with long-term contracts so that the economy of the private biogas operating company is stable.

In all cases, the economy of each part and the total biogas chain should be calculated and assessed continuously as the framework around it is finalized, as it is ultimately small margins that will determine whether economic equilibrium is achieved.

Can Samsø be a model society for the rest of Denmark

In the project it was discussed whether the developments on Samsø can be used as a model society for the rest of Denmark. This discussion is complex as the energy system on Samsø is rather different from the national Danish energy system. The energy system demands on Samsø are almost negligible compared to the national system with electricity, heating and transport demands being around 0.1% of the national demands, see figure 9. The renewable electricity production share is larger with almost 1% of the national renewable electricity production in 2013.

Samsø vs. Danish system	Samsø 2013	Denmark 2013	Samsø Share of national
	GWh	TWh	%
Electricity demand	31	34.6	0.09%
Heating demand	62.5	49.9	0.13%
Transport demand	74.5	60.2	0.12%
Renewable Electricity production	106	11.5	0.92%
Biomass resources	67	66.7*	0.10%
Population	3,806**	5,602,628**	0.07%
Biomass resources/capita (kWh/capita)	17.6	11.9	

Figur 9: Conclusion: Comparison of the scale of the energy system on Samsø and in Denmark

In addition to the demand differences some of the key differences between the energy system on Samsø and in Denmark are that on Samsø there are no central electricity production plants as almost all the electricity demand can be covered by wind power production thereby reducing the need for backup capacity. Furthermore, the heating sector is simpler on Samsø as the district heating is produced to a large degree from boilers currently as there are no central or decentralized CHP plants. Moreover, the renewable electricity resources on Samsø are much larger compared to the demands in general in Denmark while the biomass resources are slightly higher per capita compared to an average Danish citizen.

Despite these differences some of the experiences by converting Samsø to a 100% renewable system can be transferred to other parts of Denmark. These experiences might be related to the development of a renewable transport system as these also on a larger scale could look quite similar to the systems analysed in this report. However, this also depends on the scenario followed as analysis for the national system has proven that electrofuels will be necessary.

Instead of using Samsø as a model society for the rest of Denmark this report suggests that it is more relevant to discuss what the role of Samsø can be in regards to the rest of Denmark. Samsø is located with favorable conditions for renewable electricity production when compared to the potentials for the rest of Denmark. Hence, Samsø should produce more renewable electricity than it consumes in order to feed into the national system as other parts of Denmark do not have the same renewable potentials. In the 2030 scenario analysed in this report the renewable electricity production is 140 GWh/year from wind and solar power meaning that they are 450% net exporter of electricity (Samsø produce 4.5 times their own demand). With this production the maximum electricity export in any hour of the year is 32 MW out of the maximum cable capacity of 50 MW. Hence, this means that Samsø could produce even more electricity and still use the existing interconnection capacity. In scenario *7e*, see back ground report WP4, which is the scenario with the highest electricity demand of 91 GWh/year, the maximum electricity export is 25 MW in any hour and so the electricity production could be even higher. The PV capacity could be increased by around 36 MW (total PV production of 41 GWh/year)
before the electricity interconnection would be fully utilized. All these considerations are however only reflections, but shows the potential of Samsø to be an even larger net exporter of electricity thereby benefitting other areas of Denmark with scarcer renewable electricity resources. When comparing the available renewable electricity resources and the demands it becomes clear that Samsø should prioritize integrating as much electricity as possible. On the other hand, the biomass resources are also larger per capita than an average Dane and even despite of this it will be difficult to achieve a 100% renewable energy system only utilizing local biomass potentials. Samsø has for a number of years had an image as a green island or a green laboratory inspiring other parts of Denmark or internationally to follow the same renewable

energy pathway. This role is important and Samsø should continue this image as a frontrunner within energy planning.

The results of the energy systems analyses proved that it is possible to create a 100% renewable energy system on Samsø depending on the transport technologies implemented and the biomass pathways followed. In order to reduce the use of the biomass resources, it was found that hydrogenation of the biomass enables lower biomass consumption for fuel production in comparison to scenarios that do not use this technology. The scenarios proved that the socio-economic costs in a 100% renewable energy system on Samsø are similar to the 2013 scenario with higher investments and reduced fuel costs. It is however not clear which of the transport scenarios should be preferred, as this depends on the availability of biomass resources in the future. Scenarios 2-6 about the heating sector are safe to start implementing with the exact levels of heat savings and the share of individual/district heating solutions still up for further research while the transport scenarios are more uncertain in regards to which technology to choose.

As mentioned, Samsø Municipality has already hired a new employee. He will, along with other stakeholders, continue the work with the objective to implement biogas facilities etc. The utilization of the project results will be done in the context of others plans and projects e.g. the master plan of Samsø as a fossil free Island by 2030.
For more information see:
http://www.samsoe.dk/site.aspx?MenuID=174&Langref=1&Area=&topID=&ArticleID=9151&expandID=2151&moduleID=.