Feasibility study for LNG on the Port of Skagen

Development of LNG facilities at the Port of Skagen

Conducted for the Port of Skagen as part of the Interreg North Sea Region project, DUAL Ports by GEMBA

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PREFACE

This feasibility study builds on the two reports, 'LNG market overview' and 'Business cases for LNG on the Port of Skagen' made as a part of the Interreg North Sea Region project DUAL Ports/Port of Skagen – LNG pilot.

The two first reports sets the scene and identify the potential; this feasibility study build on the most promising ideas and assess the feasibility of an LNG production at the Port of Skagen.

The feasibility of the LNG production in the Port of Skagen is described and assessed from the perspective of the current competition in the region. At this point some of the LNG providers in the region has made great investments in large bunker barges and has a large organisation to back their investments. Some of these competitors has entered the industry with a strategic purpose to be first movers and establish a dominant position in the market. Whether these operators run a profit in the short run or long run on their bunkering operations is not clear.

The backing of a large corporation and an acceptance of running an LNG fuelling operation with very low profit or by just covering the operational costs may also mean that such operators are willing to lower the LNG bunker price below a breakeven point if a threat of new entrants becomes high. This dynamics in the LNG market situation may have a great impact on the profitability and hence feasibility of the entire LNG production at the Port of Skagen.

This potential market dynamic may become a hindrance to the feasibility of LNG production at the Port of Skagen. This study takes some of these dynamics into account but acknowledge that the potentially fatal impact this may have on the project.

1 Definitions

In this study several definitions and abbreviations are used. The textboxes below gives an overview of the most used.

LBG - Liquified BioGas
LNG – Liquified Natural Gas
LSMGO – Low Sulphur Marine Gas Oil is Max 0.10% Sulphur
MGO – Marine Gas Oil, a Max 1.50% Sulphur "Clear and Bright"
MMBTU - Million British terminal units
NO_x - Nitrogen oxide
PTS – Port to Ship
SECA area/region - zones in the North Sea and the Baltic, where an a max 0.10 % SO_x is allowed
SO_x - Sulphur oxides
STS – Ship to Ship
ULSFO - Ultra-Low Sulphur Fuel Oil is Max 0.10% sulphur
ETF – GasPoint Nordic
TTF – Dutch Title Transfer Facility

Nano scale LNG system- a system/unit that can produce up to 15 metric tons of LNG per day
Small-scale LNG system - a production capacity of less than 500,000 tons per year
Medium scale LNG system – has an export capacity of approximately 4-6 million tons per year
Large scale LNG system - has an export capacity of approximately 16 million tons per year.

The gas quality used in this report is based on high quality gas that has a density of 0,83 kg/m3, and a GCV of 37,05 MJ/m3.

Table 1 below shows the different conversion ratios used in the calculations of this feasibility study regarding energy, density and currency.

Table 1: Conversion overview table for LNG, MGO and HFO

Energy		Density		Other conversions used	
1 ton	MWh	1 m^3	Ton	Unit	
LNG	13.72	LNG	0.461	1 ton of LNG	49.25 MMBTU
MGO	11.90	MGO	0.900	1 MWh LNG	96 Nm^3
HFO	11.25	HFO	0.900	1 EUR	7.46 DKK

2 Executive summery and recommendations

The table below summarize the findings done in the Feasibility study.

<u>Gas- price:</u>

The Danish natural gas prices are critical for the economic feasibility of LNG production in Skagen:

- With a 2019 average gas price at 0.20 €/Nm^3 an LNG production in Skagen will give a positive economic return.
- With gas prices at the 2018 average of 0.29 €/Nm^3 the economic feasibility would be lower.
- With gas prices at the 2013-2017 average at 0.23 €/Nm^3 the LNG production would give a positive economic outcome.

Due to this a variable LNG price-structure tied to ETF or TTF is recommended to a fixed price-structure.

<u>Production costs:</u>

It is viable to make nano-scale LNG liquefaction at the Port of Skagen based on the conditions below:

- Sales price from STS or directly picked up from a Generic PTS deliver varies between 36.00 and 38.80 €/MWh with a gas price at 0.23 €/Nm^3.
- With one Cryobox the LNG production costs level is 31.58 €/MWh at a gas price of 0.23 €/Nm^3.
- With three Cryoboxes the LNG production costs level is 27.50 €/MWh at a gas price of 0.23 €/Nm^3.
- A LNG production at the Port of Skagen will have a mark-up between 5.75 €/MWh (one Cryobox) and 9.90 €/MWh (three Cryobox) depending on gas price, electricity price etc.

A three Cryobox production unit in Skagen have the best competitiveness against generic STS and PTS.

<u>Other fuel types:</u>

The price of oil based SECA compliant fuels has increased while gas prices has decreased during 2019:

- The difference (in 2019) between sales price of MGO and the production costs of LNG (based on one Cryobox) at the Port of Skagen is 12.50 €/MWh in the favour of LNG
- The difference (in 2018) between sales price of MGO and the production costs of LNG (based on one Cryobox) at the Port of Skagen was 6.40 €/MWh in the favour of LNG

The mark-up in 2019 is measured to 42% in the favour of LNG with three Cryoboxes units compared to other SECA fuels.

<u>Risks:</u>

The main risks for a nano-scale LNG liquefaction solution at the port of Skagen are:

- Increasing gas prices in Denmark and/or increasing industry electricity prices in Denmark.
- Variation in the natural gas quality may lead to increased gas consumption in the process and may lead to a lower quality of LNG fuel.
- Low ability or non-ability to meet shippers' preferences for flexible supply of LNG and/or increased competition might lead to lower profit.
- LNG production is new in Denmark and public authorities may need long time to approve production.

<u>Recommendations:</u>

- ➢ An LNG Cryoboxes (three units) is price competitive to other LNG suppliers in the area of Skagerrak/Kattegat/North East North Sea, the current demand for LNG is raising and gas prices is low this indicate a solid case on initiating a production in Port of Skagen.

- ➢ It is recommended that a nano-scale LNG production with three Cryoboxes at the Port of Skagen focus on PTS rather than STS service due to better rentability.

- ➢ An analysis of the added value an STS bunker barge could bring to the operation at the Port of Skagen is needed.

3 Introduction and structure of the Feasibility study

Based on the Market Overview and Business Case Scenarios for the Port of Skagen, a Feasibility study is carried out to document a Cryobox solution at the Port of Skagen.

The Business Case operated with four scenarios/steps and it has in the previous analysis been decided to continue to work with step 3.

Step 3 constitute on-site liquefaction with storage aimed towards PTS operations.

The feasibility study will therefore analyse a solution containing a nano-scale LNG liquefaction plant and stationary tanks for storage placed at the port area and managed by a private operator.

The feasibility study is based on the predictions in scenario 2 (see table 2).

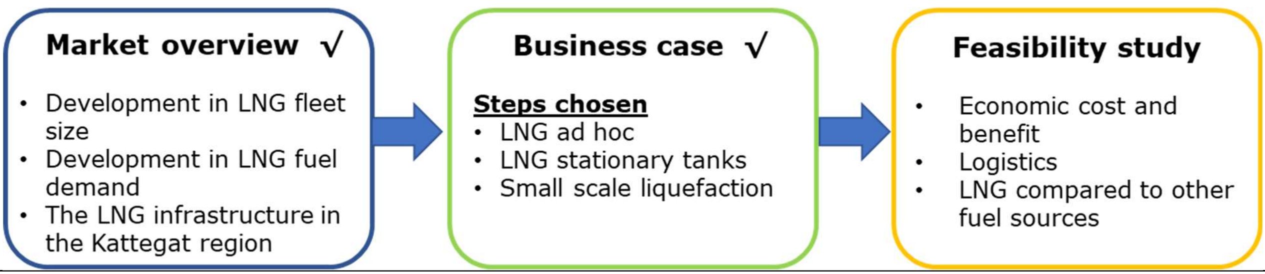
Table 2: Port of Skagen - LNG market assumptions, Scenario 2	
Number of refuels pr. vessel per year	24
Average volume pr. fuelling (m^3)	150
Annual growth rate scenario 2	20%
Market share Port of Skagen, Scenario 2	15%

A study of the cost between LNG and other low sulphur SECA compliant fuels will be conducted to document the advantages of on-site nano-scale LNG liquefaction.

The study will also detail which taxes and tariffs will impact the economics of an LNG production and distribution in Denmark.

Lastly the study examines the risks an operator might face with an LNG production in Denmark through a short SWOT analysis.

Figure 1: Overview of the process



The study will not discuss the production of liquid biogas (LBG) but recognizes that biogas may be of relevance to greening of ship fuel and something that an operator should include in their business development.

4 Tariffs, taxes and fees on natural gas for LNG production

An aspect of important for any LNG production is the tariffs, taxes and fees placed on acquiring and redistribution the gas. The following section will be based on the situation for gas in Denmark. Normally in Denmark, natural gas is subject to several tariffs and taxes.

According to Danish tariff and tax law on natural gas the entire production of LNG is subject to tariffs and taxes, **except for LNG that is sold as maritime fuel.**

In this case the following tariffs and taxes no longer become applicable for a production of LNG in Denmark:

- *Mineral oil tax*
- *Methane tax*
- *NOx and SOx taxes*
- *VAT on the sale of LNG to maritime vessels*

There is no CO_2-tax on other fuel types for maritime use.

In order to secure equal competitiveness between the fuel types, an argument for the CO_2-tax to not be applied to LNG for maritime use should be made. It's informed that the Danish Tax Agency are understanding of this position and open not applying the CO_2-tax to LNG. If the CO_2-tax is applied, it would add an additional 0,05 €/Nm^3.

Should the operator decide to sell the LNG to land-based operations, the taxes and tariffs becomes applicable to this transaction.

There will still be a distribution fee for the natural gas that needs to be paid the distribution company for the use of gas network in Denmark. The distribution fee varies based on distributors and the amount of gas needed but come for them all is that the higher volume purchased the lower the distribution fee is.

For the LNG production covered in this study there would be a need for 10.000.000 m^3 of natural gas to produce the needed quantities of LNG. The distribution fee would in this instance be set to 0,02 €/Nm^3. Two other taxes aren't subtractable as well. These are a transmission/storage fee of 0,01 €/Nm^3 and an emergency supply fee of 0,004 €/Nm^3.

5 The Cryobox' economic cost and benefit

This section is a description of the economic costs and benefits of a Cryobox. The economic costs consist of both capital costs, i.e. CAPEX, connected to capital loan and operations costs, OPEX connected to the production of LNG. With a thorough description of costs, the section will calculate and describe the benefits associated to the costs.

5.1 Costs

The bunker fee is the profit of the operation and will in case depend on how competitors react to the introduction of LNG in Skagen. Due to this the Skagen produced LNG will be assessed in a sensitivity analysis with following variations:

- *A static comparative scenario with an LNG bunker barge and LNG from Generic*
- *A dynamic comparative scenario, where the competitors will lower their prices to compete with an LNG production in the Port of Skagen.*

The bunker price that a customer must pay may be described as the sum of:

Gas price + CAPEX + traders' margin + terminal fee + logistic + bunker fee.

The following assumptions are used to calculate the Gas price and traders' margin, Terminal fee and Logistic fee for the production.

Table 3: Assumptions are used to calculate the production prices for 1 ton and 1 MWh LNG			
Production and Gas characteristics	Density natural gas	0.83	kg/Nm3
	Density LNG	467	kg/LNGm3
	From compressed to LNG	560	Nm3/LNGm3
	Capacity Cryobox	550	LNGkg/h
	Production hours pr. Year	8,322	Hours
	Energy usage Cryobox	0.82	kWh/KG LNG
	Energy price pr. kWh incl. tariff and taxes	0.04	€/kWh
Gas price+ gas trader's margin	Natural gas price incl. Taxes	0.22	€/Nm^3
	Gas traders' margin	0.01	€/Nm^3
Capex	Cryobox investment	4,000,000	€/unit
	Storage Investment	400,000	€
	Establishment cost	300,000	€
	Depreciation span	30	Years
	Interest rate	0.5	%
Terminal fee & Logistic fee	Areal cost	2,022	€/year
	Service – six workers	267,110	€/year
	Maintenance	100,568	€/unit
	Storage cost	15,080	€/year
	Administration - billing, contact and marketing	107,273	€/year
	Service - LNG transfer fee (ship loading)	0.01	€/kg LNG
Demand	Demanded LNG in MWh	182,723	MWh/year
Source: Galileo, Kosan Crisplant (2015), DMA (2012), EP (2015) & TNO (2017) and Eniig.			

Based on the assumptions in table 3 the operation costs of producing 1 tonnes of LNG may be calculated.

Table 4 hence show the production costs of 1 tonnes of LNG when operating with one Cryobox. The costs are the production costs and hence exclude the bunker fee, i.e. the mark-up.

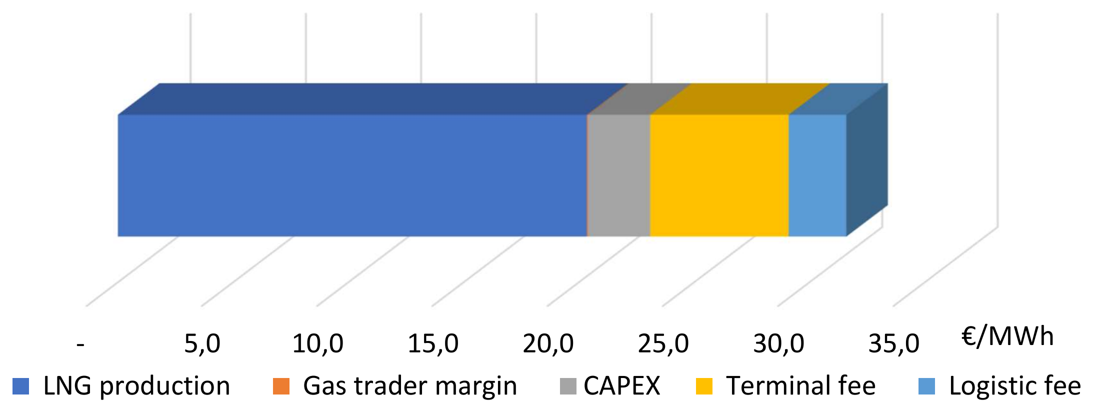
Table 4: The cost of producing 1 ton of LNG with one Cryobox unit, excl. bunker fee

		Value	Unit
Production price of LNG	Electricity consumption	163.061	€/year
	Natural gas consumption	1.258.110	€/year
	Total LNG production cost	1.279.961	€/year
Capex	Depreciation liner to 0	156.390	€/year
	Interest of investment	11.729	€/year
	Total Capex	168.119	€/year
Terminal fee and logistic fee	Service - LNG transfer fee (ship loading)	42.494	€/year
	Total Terminal and logistic fee	535.019	€/year
	Total cost	1.983.397	€/year
	Price pr. ton LNG	433	€/ton

Calculations by GEMBA.

The total production costs may also be illustrated as presented in figure 2, where the different cost lines are stacked to show the proportion of each.

Figure 2: Overview of the cost lines (€/MWh) of LNG production at a gas price of 0.23 €/Nm^3.



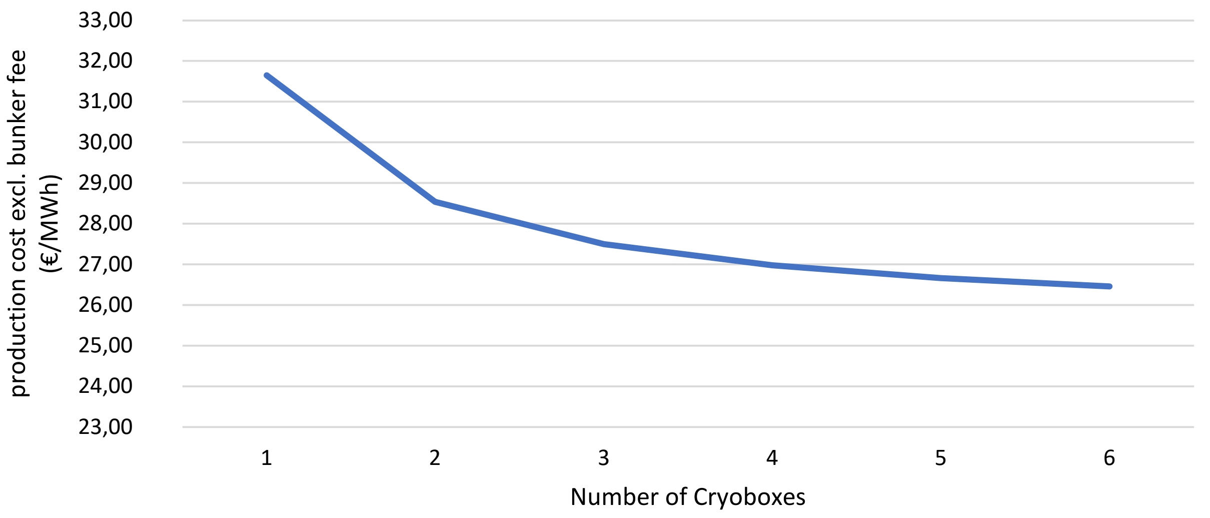
Calculations by GEMBA.

Based on the production costs before bunker fee and produced in a Cryobox, LNG may be produced at a cost of 433 €/ton which equals 31.58 €/MWh. The production cost without CAPEX, terminal and logistic fee and at a natural gas price of 0.23 €/Nm^3 equals 20.4 €/MWh.

As additional Cryobox units are added, the average cost of the produced LNG will start to decline due to no further need for additional workers to monitor the production or manage refuelling operation. In addition, given the demand no additional storage or areal for the production as well as administration is needed.

Production based on three Cryoboxes the cost would fall to 27.50 €/MWh. The economy of scale achieved by adding additional units is shown in figure 3.

Figure 3: The economics of scale of a Cryobox LNG price excl. bunker fee (€/MWh)



Source: GEMBA

5.2 Benefits

The monetary benefits of the investment in LNG production will take point of departure in the difference between sales price of LNG bunkering in Rotterdam and Generic, STS operations in the Kattegat, Skagerrak and North Sea and the price level of production at a Cryobox at the Port of Skagen.

The difference between production costs at Port of Skagen and the sales price hence indicates the **mark-up,** i.e. the potential room for profit from the LNG production.

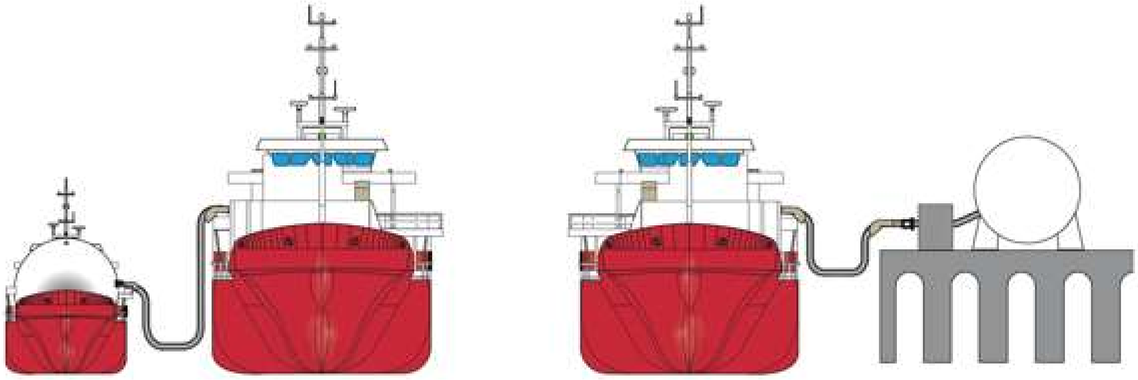
In April 2018 it was estimated that the price of LNG supplied by a generic LNG bunker barge from Rotterdam was approx. 40.60 €/MWh for STS operations.
The average cost of LNG excl. bunker fee with one Cryobox is 33.40 €/MWh in April 2018 and 29.24 €/MWh for three units if fixed raw gas prices are applied.

This makes a difference of approx. 11.40 €/MWh, which enables a bunker fee of approx. 39% of the LNG production cost with operation from three Cryobox.

Table 5 below details this.

Table 5: Pricing and profit overview of Cryobox LNG compared to STS LNG. Three units at fixed gas price of 0.23 €/m³.			
Definition	Sales price (€/MWh)	Price difference to Cryobox production costs, three units (€/MWh)	Potential mark-up (bunker fee) for Cryobox produced LNG (%)
Generic STS operations 2018 average	40.60	11.36	39
Generic PTS operations 2018 average	36.10	6.86	23

Following this price difference, it is possible to estimate of the bunker fee and hence economic benefit of a Cryobox.



5.3 Cost benefits applied to estimated demand in Skagen

With information about the costs and potential benefits it is possible to establish a case-based calculation of the total profit and ROI.

In table 6, a profit example is calculated for the estimated demand in scenario 2 year 1 approx. 13,318 tons with a bunker fee that fits the mark-up to a generic STS operation.

Table 6: Profit overview of Cryobox LNG in scenario 2, year 1 prospected demand.	
LNG demand at the Port of Skagen - scenario 2, year 1. (tons)	13,318
Profit with one unit (€)	452,155
Number of units (Cryobox) needed to cover demand	3
Investment cost of the required units and storage (€)	12,700,000
Profit with the required units with six workers (€)	2,139,532
ROI (%)	16.8

The calculation in table 6 shows that in order to cover the demand three Cryoboxes are needed. There would be no need for additional storage, administration or workers as all three Cryoboxes would supply the same storage units and only need six workers to operate the units.

This would mean a total investment of 12.7 million € in Cryoboxes and storage.

The production profit would in this case be a approx. 2.1 million €, which equals a ROI of approx. 16.8%.

This is however the ROI in a static scenario, where neither the STS or the PTS competitors react to the new competition and allows the new operator a high mark-up.

This scenario might hence be connected to some uncertainty and requires a further investigation into the price structure of the competitors. This investigation may determine how much, and at which costs a competitor would be able to decrease. In the following sections the LNG price structures of the competition to an LNG operator in the Port of Skagen will be discussed to provide an estimation of the Cryobox productions economic viability.

6 Price structure of an LNG operator

The overall price setting method in the LNG supply industry is based on the LNG prices found on the Dutch gas exchange TTF_{M-1} (M-1 = spot price).

In theory this means that the price setting can be summed up in this formula:

$$P = TTF_{M-1} + \text{administration/service}$$

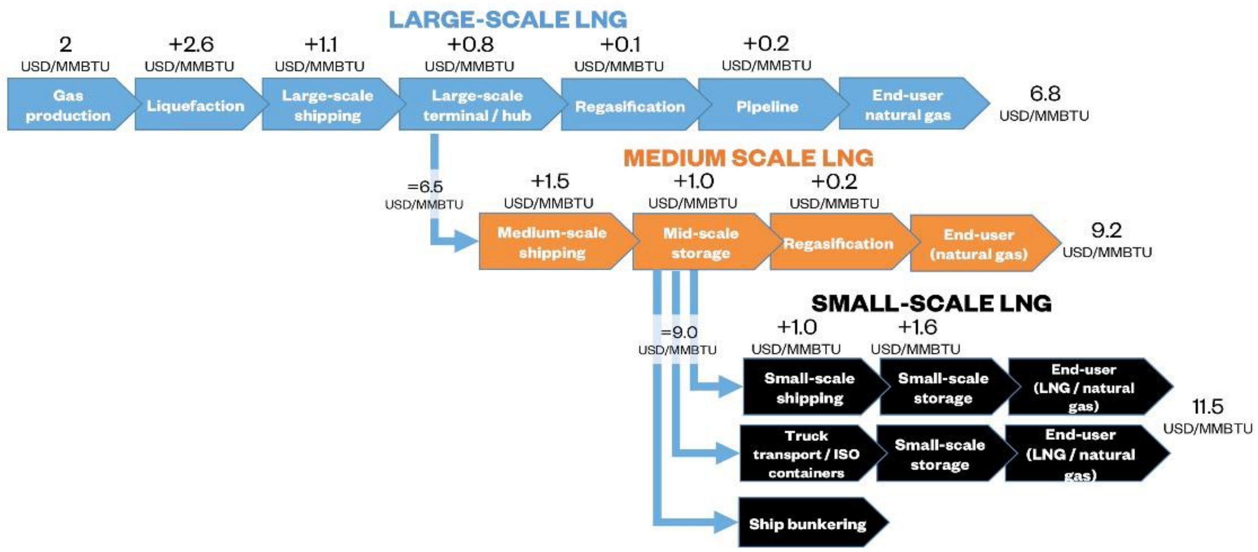
Research shows that this is also carried out in practice as LNG supply companies seemingly bases their price on TTF, with an added profit margin.

$$P = TTF_{M-1} * \text{profit margin} + \text{administration/service}$$

This 'profit margin' is assumed to be the operators bunker fee, while 'administration/service' is the operators terminal fees and logistic fees.

The primary unknown variable is the individual bunker fee an operator adds to the TTF LNG price and the service/administration fees they charge. The price formula indicates that the competitive LNG suppliers' gas prices are tied to the TTF developments. To exemplify the cost structure, figure 4 shows the generic LNG value chain with prices for April 2018. In the further analysis it is assumed that only the gas price is variable.

Figure 4: The generic LNG value chains from the production to the end user.



Source: Wärtsilä and Nauticor, based on TTF day price for LNG on the 10/04 2018

The Generic STS and PTS used in this Feasibility study based on LNG value chains observed in Northern Europe.

According to the generic LNG value chain, the LNG cost for an end-user on April 10th, 2018 would be 11.60 USD/MMBTU LNG = 37.07 €/MWh if the LNG is provided through truck transport or small-scale LNG distribution as PTS.

The value chain for ship bunkering however stops with PTS at 10 USD/MMBTU and the chain does not fully show the cost of STS operations. Based on interviews the general rule of thumb is to apply a 1 USD/MMBTU to STS operations after ship bunkering which brings the cost of LNG for an end-user on April 10th, 2018 choosing STS up to 11 USD/MMBTU = 35.10 €/MWh LNG excl. bunker fee.

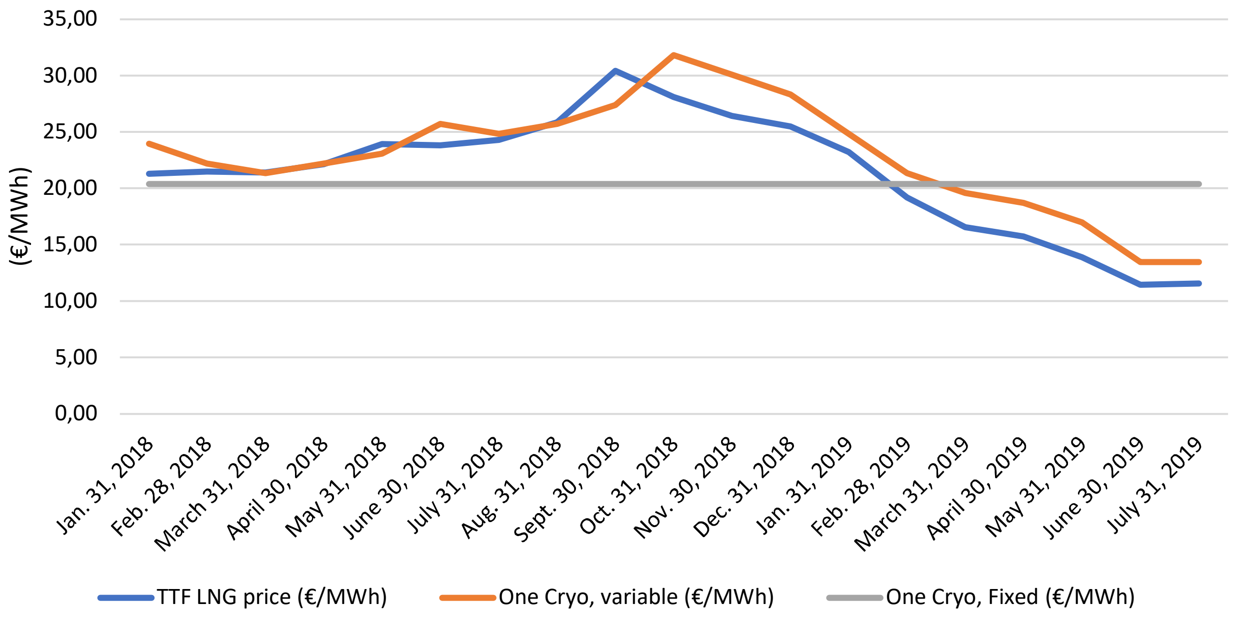
6.1 Competitors gas price

According to the price function, the gas price is tied to TTF.

This means that LNG competitors' prices are tied to the TTF development and that import of LNG from the Netherlands to supply their operations may be in effect. The increase in TTF LNG prices in 2018 was due to prospect of a cold winter in Europe. However, the winter in Europe was rather mild and it created a surplus situation of LNG in Zeebrugge and Rotterdam, but with lacking demand to keep the prices from declining.

The advantages for competitors to an on-site liquefaction is that they can achieve a better gas price than a local production based on a fixed gas price may. Figure 5 below show the monthly LNG price for LNG from TFF compared to a Cryobox at both a variable and fixed gas price for the natural gas.

Figure 5: The LNG price for LNG at TTF and one Cryobox from January 2018 to July 2019, monthly average. Tariffs and taxes included. Cryobox show both as based fixed and variable natural gas price.



Source: Ycharts and Timera Energy and GEMBA

Basing a Cryobox production on a fixed gas price is therefore risky, in that competitors can exploit if the variable TTF LNG prices are lower than the fixed cost. By basing their production on the TTF LNG prices a competitor will be able to achieve a better MES-point for their operations, which can be used to outcompete a Cryobox LNG production based on a fixed gas price.

It should be noted that the gas prices in table 7 are the raw LNG price without other fees such terminal fee, logistic fee and bunker fee. The generic LNG value chain does not include a specific post for the gas trader's margin. It is estimated that this margin already is included in the cost of 1.5 USD/MMBTU for reselling the LNG to another operator.

> *Based on this, it would not be advisable to base an LNG production on a fixed natural gas price given this inherent risk. It would therefore be advisable to base an LNG production on variable gas prices that are either tied to the ETF or TTF prices to minimize this risk.*

6.2 Terminal fee + Logistic fee

According to the generic value chain the terminal fee and logistic fee for a medium scale LNG operator importing LNG from a large-scale operator is 2.5 USD/MMBTU. Further based on the generic value chain the terminal fee and logistic fee is increased to 3.5 USD/MMBTU when the medium operator sells the LNG to PTS and 4.5 when it is sold as STS. In periods of high TTF LNG prices such as in October to December 2018, the generic operators can reduce their Terminal fee and Logistic fees to 10.90 €/MWh and 13.00 €/MWh for STS operations in order to keep cost of receiving LNG low for the customer. The discount in terminal and logistic fees are almost covered by the higher bunker fee. In some cases, an additional fee to the terminal and logistic cost is added in some of the LNG operators PTS operations

Table 7: Overview of terminal and logistic fee for generic STS and PTS LNG operators

Definition	Terminal fee and logistics fee (€/MWh)	Terminal fee and logistics fee difference to Cryobox (€/MWh)
Generic STS	14.4	5.9
Generic PTS	11.2	2.7

This is a general difference in terminal and logistic fee of 2.70 €/MWh in PTS and 5.90 €/MWh in STS as shown in table 7.

> *Given the generic value chain there is little economic room for an LNG operator to decrease their terminal fee and logistic fees without it hurting their profit from the bunker fee.*
>
> *The terminal fee and logistic fees for the generic value chain are higher than the terminal fee and logistic fees for the Cryobox production, which has been estimated to be 8.50 €/MWh.*

6.3 Bunker fee and competition

The bunker fee for the competitors is expected to be a function of the TTF LNG gas price times a margin. Recipes from the Generic LNG plant shows that the bunker fee is based on a factor of 11 % of the TTF LNG gas price at a spot price for natural gas based of the average gas price the previous month.

An example of this would be for the month of April 2018. The bunker fee would be 2.10 €/MWh based on the TTF price which is listed as TTF_{DA} meaning that this is the spot price on the day for LNG at TTF. In periods of high TTF LNG prices such as in October to December 2018 the Bunker fee factor remains unchanged, which helps offset the discount given in Terminal fee and Logistic fees in these situations. If it is assumed that this is a general bunker fee structure, the bunker fee for Cryobox LNG should be calculated the same way. In this case the bunker fee from an TTF LNG price of 20.40 €/MWh would be 2.24 €/MWh

In case of competition the operator might be interested in decrease the bunker fee. It is expected that an operator that would like to increase the competition on the customer base would, for a shorter period, be able to lower its bunker fee towards zero and relying only on its breakeven of the operation.

Given that the amount of LNG vessels is expected to increase which will give an increase in the demand for LNG in the area. It is also uncertain if an operator would start sacrificing their profit to outcompete their competitors.

During the high TTF LNG prices in October to December 2018 the pricing behaviour by the operator in Generic indicates that it is the terminal fee and logistic fee which is lowered first before any reduction in the bunker fee is made.

In a more extreme sense, large LNG operators like Shell could outcompete most and if not all medium to small-scale operators in the market by lowering their prices even further and covering any losses to their terminal or logical fee through the profit generated in other divisions.

A decrease in bunker fee would be a rather drastic behaviour by a medium scale competitor in order to outcompete a new entrance given the cost structure for their operation.

In an already saturated market with the aim of consolidating the market and secure a long-term profit generation without or with minimal competition on prices a *decrease in bunker fee would therefore be an effort to outcompete competitors.*

6.4 Sum-up of price structure

Based on the review of a generic LNG operators and Generic's price structure for LNG the following can be concluded:

- *Gas prices are rather volatile and if a Cryobox operator's price structure is based on a fixed gas price only, the variations in the gas price will be a major risk to the operator.*
- *In the case of Generic there is only little economic room to lower the prices for the end-user. The practice is to remove surplus on terminal fee and logistical fee before adjustments to the bunker fee is made.*
- *The bunker fee is a function of the TTF LNG prices times a margin. In the case of Generic the margin is set to 11 %. For further analysis it is assumed that this is the generic bunker fee rate used in the market.*

7 Sensitivity analysis of income level

The following is an account of the income for an operator with an LNG liquefaction solution at the Port of Skagen. The LNG liquefaction solution will be based on the economics of a Cryobox with LNG ISOcontainer solutions as detailed in the previous section.

This will be done through four scenarios that vary over five dimensions:

1. *Terminal fee and logistic fee*
2. *Additional terminal fee*
3. *Reduction in terminal and Logistic fee*
4. *Bunker fee for STS and PTS*
5. *Number of Cryoboxes*

The variations of the four scenarios over the five dimensions is shown in table 8

Table 8: Description of scenarios and the variation among five dimensions.

Scenario/Dimension	Terminal fee and logistic fee (€/MWh)	Additional terminal fee (€/MWh)	Reduction in terminal and Logistic fee (€/MWh)	Bunker fee for STS and PTS (%)	Number of Cryoboxes
Scenario 1					
Generic STS	14.4	0	0	11	1
Generic PTS	11.2	0.4	0	11	
Scenario 2					
Generic STS	14.4	0	0	11	3
Generic PTS	11.2	0.4	0	11	
Scenario 3					
Generic STS	14.4	0	- 1	0	1
Generic PTS	11.2	0	0	0	
Scenario 4					
Generic STS	14.4	0	- 1	0	3
Generic PTS	11.2	0	0	0	

Each scenario will be subject to a sensibility analysis where variations in Natural gas prices for the Cryobox production and TTF LNG prices that the STS and PTS buy at will give an indication of the performance of Cryobox produced LNG compared to generic STS and Generic PTS. In these scenarios the pilot fee and time for deviating from the course by the shippers has not been factored in. These are factors that the shippers will factor into their planning, which means that a 100 % mark-up in bunker fee compared to generic STS will not be possible.

It is therefore advised that the LNG operator factors these concerns into their possible bunker fee, by having a flat discount in their bunker fee of 0.8-1.2 €/MWh, to compensate for the pilot fee and time for deviating from the course

7.1 Scenario 1 & 2

In scenario 1 and 2, the competitors are not changing LNG prices.

Figure 6 shows the results of changes in the natural gas prices on the production costs of Cryobox produced LNG (using one unit) compared to the prices of generic STS and Generic PTS.

Figure 6: Scenario 1 Overview of the sensitivity in changes in gas prices incl. taxes and tariffs (€/Nm³) for the Cryobox LNG (one unit) and generic STS and Generic PTS, one unit.

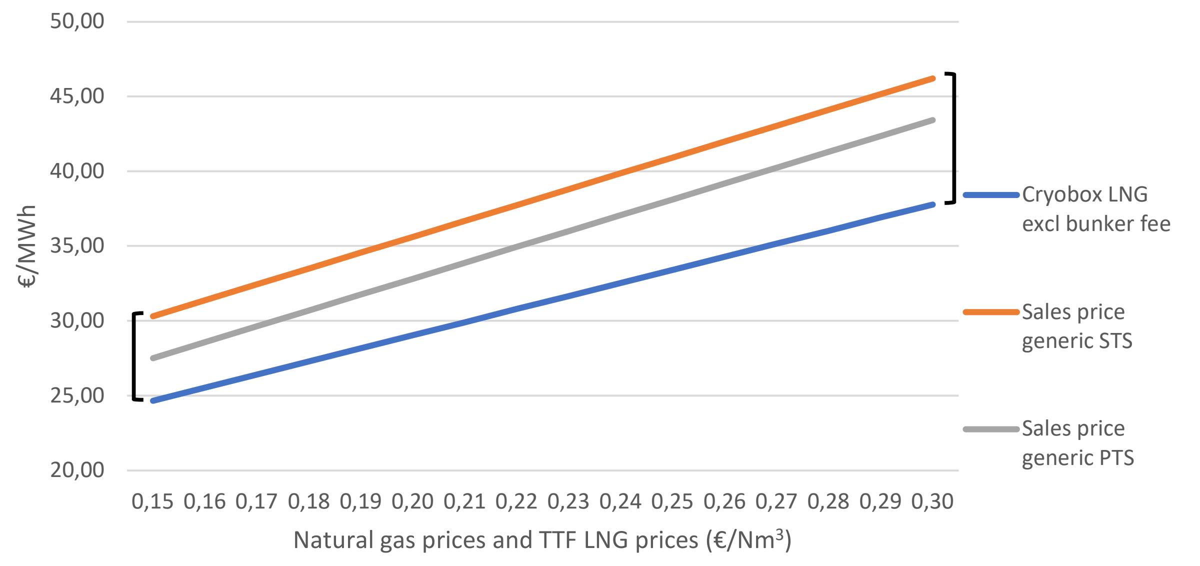
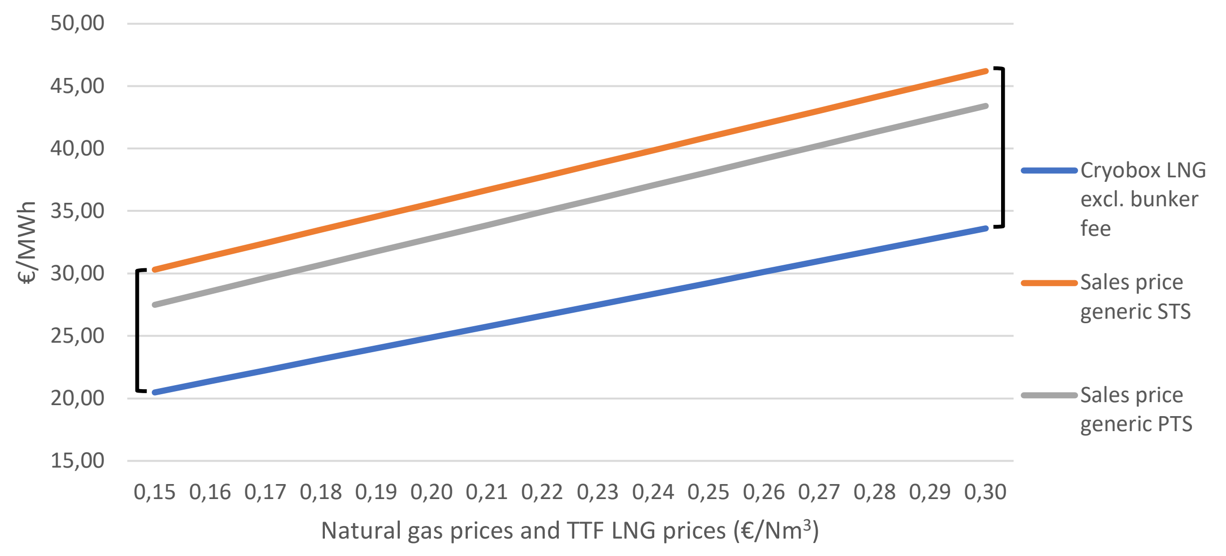


Figure 7 shows the sensitivity of Cryobox produced LNG using three units, i.e. the necessary capacity to cover the projected demand at the Port of Skagen.

Figure 7: Scenario 2 overview of the sensitivity in changes in gas prices incl. taxes and tariffs (€/Nm³) for the Cryobox LNG (three units) and generic STS and Generic PTS, one unit.



Both figure 7 and 8 shows that the Cryobox LNG production remains well below the sales price of STS and PTS.

The one of the drivers for the increasing difference in prices shown in the two figures is the lower terminal fee and logistic fee for the Cryobox production compared to the STS and PTS operation. Another a more significant driver is the bunker fee of 11% that is added to the TTF LNG price.

While locally produced Cryobox LNG has a higher gas price than STS and PTS, it has a lower transportation costs compared to LNG that needs to be transported from Zeebrugge or Rotterdam to the end-user. This enables the Cryobox to gain mitigate the higher production cost of the raw LNG through their terminal and logistic fee. On average this benefit amounts to an additive 0.2 €/MWh pr. 0.01 €/Nm^3 increase in scenario 1 & 2.

Production with three Cryoboxes show the possibility to achieve economies to scale as additional units are added. It is within these positive differences that the potential bunker fee for the Cryobox can be found. The potential bunker fee intervals for the Cryobox production are shown in table A in the appendix.

7.2 Scenario 3 & 4

In scenario 3 and 4, the competitors are changing LNG prices.

Seeing that the market for LNG is growing and new suppliers are entering the market, it is uncertain what type of response the current suppliers would take towards the new entrances and how they would reconfigure their pricing.

In the following it is assumed that current LNG suppliers will lower their prices through reduction in their fees.

The assumptions are as followed:

- The bunker fee for generic STS and Generic PTS is reduced from 11 % to 0 %
- The additional terminal fee to both STS and PTS is reduced to zero.
- The terminal fee for STS is reduced by a further 1 €/MWh.

Figure 8 shows the results of changes in the natural gas prices on the production costs of Cryobox produced LNG (using one unit) compared to the prices of generic STS and Generic PTS and where the terminal, logistic and bunker fee is reduced to zero.

Figure 8: Scenario 3 Overview of the price difference by Cryobox solution based on different gas price incl. tariffs and taxes levels (€/Nm³) in Denmark to generic STS and Generic PTS, one unit.

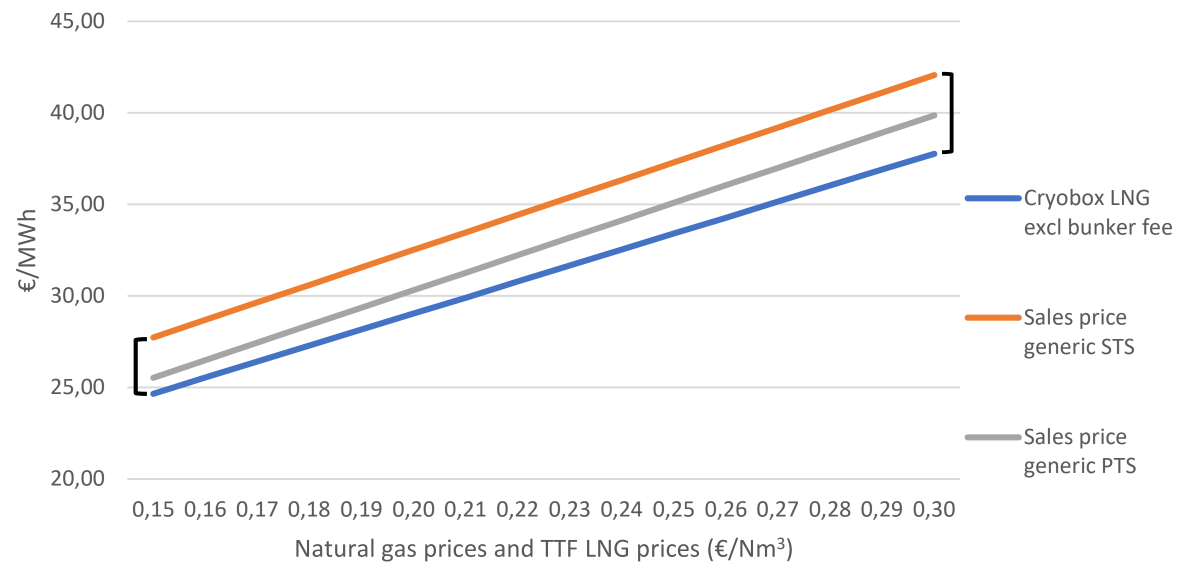
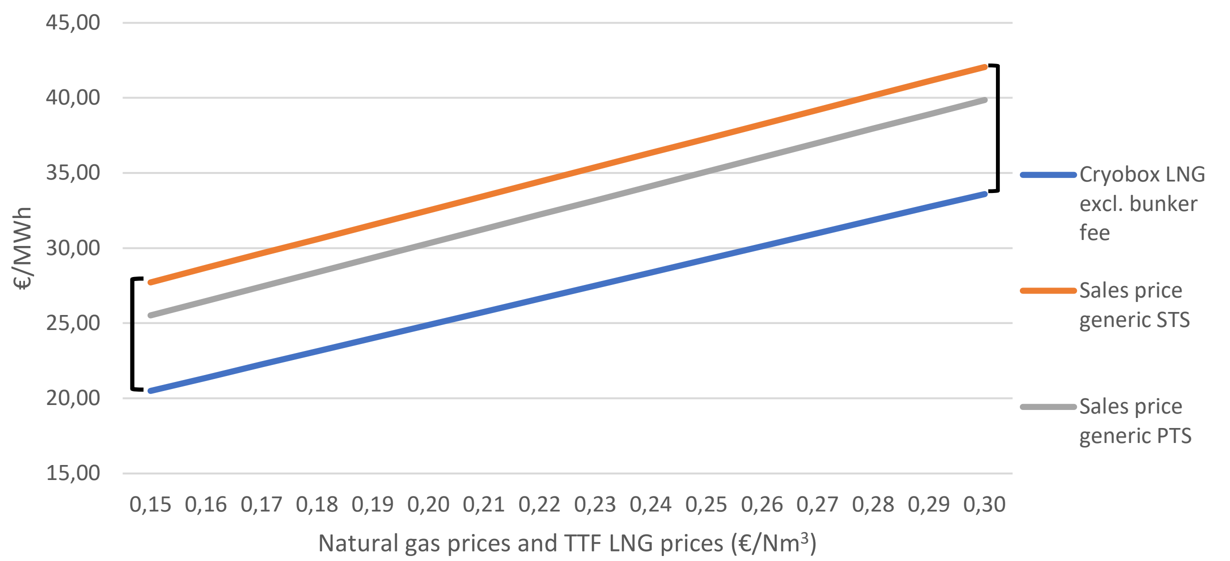


Figure 9 shows the sensitivity of Cryobox produced LNG using three units, i.e. the necessary capacity to cover the projected demand at the Port of Skagen, and still with fees reduced to zero.

Figure 9: Scenario 4 Overview of the price difference by Cryobox solution based on different gas price incl. tariffs and taxes levels (€/Nm³) in Denmark to generic STS and Generic PTS, three unit.



The two figures show that there is an increasing gap between the sales prices of PTS and STS to that of the Cryobox production cost. The difference compared to scenario 1 & 2 is less and this is mainly due to the reduction in the bunker fee to 0%.

The reduction in terminal and logistic fee also has an impact, but this is less significant compared to the reduction in bunker fee. In average the additive difference due to an increase in gas price of is 0.08 €/MWh pr. 0.1 €/Nm^3 in scenario 3 & 4.

With one Cryobox unit the production cost (i.e. cost excl. bunker fee) remains below the price of the Generic PTS and generic STS sales price. With one Cryobox unit compared to Generic PTS the difference is in favour of the single Cryobox at all gas prices. The difference is however rather small, and it would be difficult to achieve any profit from the Cryobox operation.

With three Cryoboxes however the difference in price compared to Generic PTS is further increased in favour of the Cryobox production.

Here the main driver is the economies of scale in the LNG production that three Cryoboxes enables.

For the comparison with generic STS the difference is further increased but much lower than in the previous scenario where prices remained somewhat static regarding bunker fee and terminal and logistic fee. In this scenario the STS operation would however be trading at a deficit as their have reduced their sales an additional 1 €/MWh below their estimated breakeven point. The Bunker fee for the Cryobox production would in this scenario be within the different intervals shown in table B in the appendix.

7.3 Possible bunker fee for a Cryobox

It is assumed that the LNG production has three units and is receiving their Natural gas at a fixed gas price of 0,15 €/Nm^3 with tariffs and taxes applied.

The generic STS is not making any reduction in their sales prices through decreasing fees and is buying their LNG from TFF at an LNG price of 0,15 €/Nm^3 with tariffs and taxes applied.

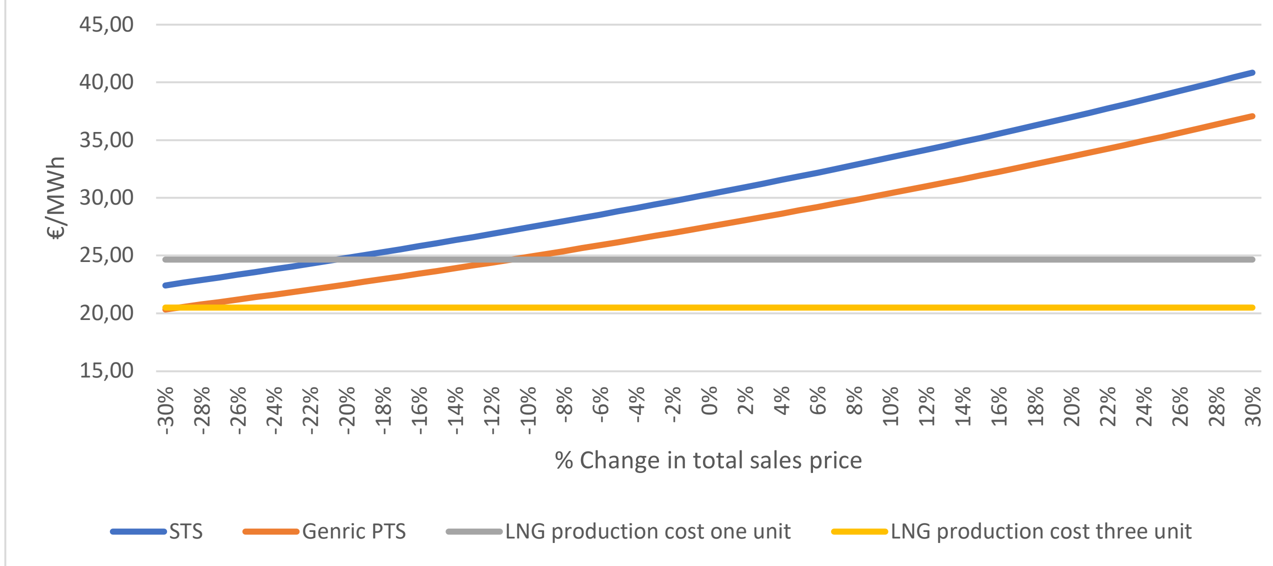
Table 9 outline the pricing and possible bunker fee for the Cryobox LNG.

Table 9: Pricing and profit overview of Cryobox LNG compared to STS LNG sales prices and Generic at gas price of 0,15 €/Nm^3. Scenario 1-4.

Definition	Sales price STS and PTS (€/MWh)	Price difference to Cryobox production price (€/MWh).	Possible bunker fee for produced LNG from Cryobox, Mark-up (%)	ROI at mark-up bunker fee (%)
Scenario 1				
Generic STS	30.31	5.7	22.9	7.5
Generic PTS	27.51	2.9	11.6	3.8
Scenario 2				
Generic STS	30.31	9.8	47.8	14.7
Generic PTS	27.51	7.0	34.2	10.4
Scenario 3				
Generic STS	27.73	3.1	12.5	4.1
Generic PTS	25.53	0.9	3.5	1.2
Scenario 4				
Generic STS	27.73	7.2	35.2	10.7
Generic PTS	25.53	5.0	24.5	7.4

Figure 10 shows Cryobox LNG (one and three units) compared to STS LNG sales prices and Generic at gas price of 0,15 €/Nm^3 at different increases and decreases in the total sales price for generic STS and Generic PTS.

Figure 10: Cryobox LNG (one and three units) compared to STS LNG sales prices and Generic at gas price of 0,15 €/Nm^3 at different increases and decreases in the total sales price for generic STS and Generic PTS.



7.4 Sum-up sensitivity analysis

Based on the review of a generic LNG operators and Generic's price structure for LNG the following can be concluded:

- *Due to the lower the terminal fee and logistic cost for Cryobox LNG, the Cryobox increases in competitive performs against generic STS and PTS as the gas prices increases.*
- *The Cryobox production costs are below the costs (i.e. excluding terminal, logistics and bunker fees) STS and PTS LNG.*
- *The Cryobox production cost is cheaper than the sales price of STS and PTS in all scenarios to the sales prices of the STS and PTS. The difference between Cryobox LNG and STS/PTS increases as more Cryoboxes are added as this creates economy of scale.*
- *Factors such as pilot fee and time for deviating from the course is not factored into the scenarios. It is advised to provide shipping companies with a discount due to these factors and thereby to improve the competitiveness of the operation.*

8 Operator risks at Port of Skagen

The following is an overview of the different risks that an LNG operator would need to consider with production and distribution of LNG at the Port of Skagen. The risks will be summed up in a SWOT framework at the end of this section.

8.1 Gas prices

The gas grid that stretches out to the Port of Skagen and on-site liquefaction is a strength due to the increased access to industry gas which ensures a lower OPEX for a Cryobox solution. There is however a threat of a lower gas production in Denmark from late 2019 to early 2022 due to renovations carried out at the Tyra gas fields. The lower gas production could lead to higher than average gas prices in Denmark, which can put the LNG production under economic pressure. Based on the Cryobox economics an increase in gas prices of 0.01 €/Nm^3 leads to a production cost increase of 0.87 €/MWh.

8.2 Electricity prices

Another variable cost for the production is the electricity price. The Danish industry electricity price has increased the last years and it is uncertain if the price will continue to increase. Like the gas prices, an increase in the electricity price will lead to an increase in LNG production cost, but with less impact. Based on the electricity consumption, an increase in electricity prices of 0.01 €/kWh leads to a production cost increase of 0.08 €/MWh. In a market where the profit is found through small margins, any increases in the industry electricity price will see a decrease in the possible profit of the operator.

8.3 Variation in the quality of natural gas supplied

In the feasibility study, the calculations are based on gas with a density of 0.83 kg/Nm^3. This density is what is supplied now and is considered to be of high quality. The higher the gas quality is the less natural gas is needed to create an amount of LNG. Based on interviews with Danish natural gas suppliers it was stated that gas with that quality cannot be guaranteed at all time. It is expected that when the Tyra field reopens the gas quality will be around 0.77 kg/Nm^3. If the natural gas is below the characteristics used in the feasibility study, it would result in a need for more gas at a lower quality to produce the same amount of LNG.

This is a risk that an operator should seek to mitigate with the natural gas supplier in order to ensure the production cost against fluctuations. A model could be to divide the risk evenly between the LNG producer and the gas supplier. The operator and supplier should agree to a set amount and quality of the supplied natural gas that meets the production demand – in the scenario approx. 16 million m^3 natural gas.

If the natural gas is of low quality and 17 million m^3 natural gas is needed to meet the needs, the supplier would accept the risk and not charge the operator for the additional 1 million m^3. In return, if the natural gas is of higher quality and only 15 million m^3 gas is needed, the operator should not seek reimbursement for the 1 million m^3.

Another risk tied to the variation in natural gas quality is the burn-value of the gas supplied. While the risk regarding the production can be mitigated, the quality of produced LNG could be lower and cause issues for users that use the LNG in mainly four-stroke engines. The end-users generally need LNG with a specific minimum energy content and burn-value to ensure that the engines operate properly.

8.4 Existing LNG infrastructure and bunkering opportunities in the area

Another threat to the operator will be the existing LNG infrastructure in the area, which is centred around the Port of Gothenburg and the STS operations around it. The first issue for the operator will be to make the presence of the new LNG offer known to the shipper's through marketing in order to secure a customer base as no LNG vessels are currently entering the Port of Skagen. The other LNG operators in the area is expected to respond to the new LNG operator in one of two ways – price competition or ignoring the competition. As detailed in the comparison section the LNG production with Cryoboxes will be able to compete with the STS operations favourably. But the LNG logistic at the Port of Skagen is landlocked and thus shipper's will have to deviate from their course in order to bunker LNG.

This is a logistic issue for the shipper's and one they do not have to factor in when choosing an STS operator. Interviews indicated that despite STS being more expensive, the flexible logistic service that the STS provides, is a great strength and preference of the shippers. While the Port of Skagen does not charge any harbour fees for vessels that are bunkering, there is a pilot fee and the time for deviating from the course would be factors that could deter a shipper from choosing PTS from Skagen over STS. The operator would therefore have to either compensate through a lower bunker fee, or if the Port of Skagen would promote green shipping discount like those found in e.g. Port of Gothenburg. In addition, the exception of harbour fee in the Port of Skagen also extends to STS operators.

8.5 Development in Cruise calls

There is an increasing focus on cruise activities in Skagen and a concern about the potential impacts it may have on air quality and environment due to the increasing numbers of port calls – see table 10.

Table 10: Number of cruise calls at the Port of Skagen

	2014	2015	2016	2017	2018	2019
Port of Skagen	5	14	17	31	43	45

The foundation of an LNG production in the Port of Skagen must therefore be found in the year-round maritime traffic in the SECA area, where there are several LNG vessels in operation as disclosed in the market overview. The inland ferry route to the Island of Samsø today operates on LNG that is trucked from Rotterdam – the operator could, in collaboration with the ferry company provide LNG or any mixture of this to this route. This would require the operator to win the supply contact in 2021, when it is next in public tender. The threat is again that other STS oriented suppliers can challenge the Port of Skagen on LNG price but more importantly, in terms of service options. The LNG vessel owners generally prefers receiving their LNG in start or end ports, and if this is not possible, in open sea via STS operations.

8.6 Lacking political understanding of LNG production

LNG is a new fuel type in Denmark and there is currently no LNG production in Denmark. LNG production is therefore a new political and regulatory issue that is missing a clear national benchmark, which could make local authorities in Denmark hesitant with greenlighting a nano-scale LNG production at the Port of Skagen. Being a partly municipality owned port, the Port of Skagen should aid a potential operator with informing the local authorities of the prospects and safety issues of producing and conducting bunkering operations with LNG.

SWOT sum-up of the feasibility and market overview study

The following SWOT is a sum-up of the points made in this feasibility study and in the market overview study.

Figure 11: SWOT of an LNG production at the Port of Skagen

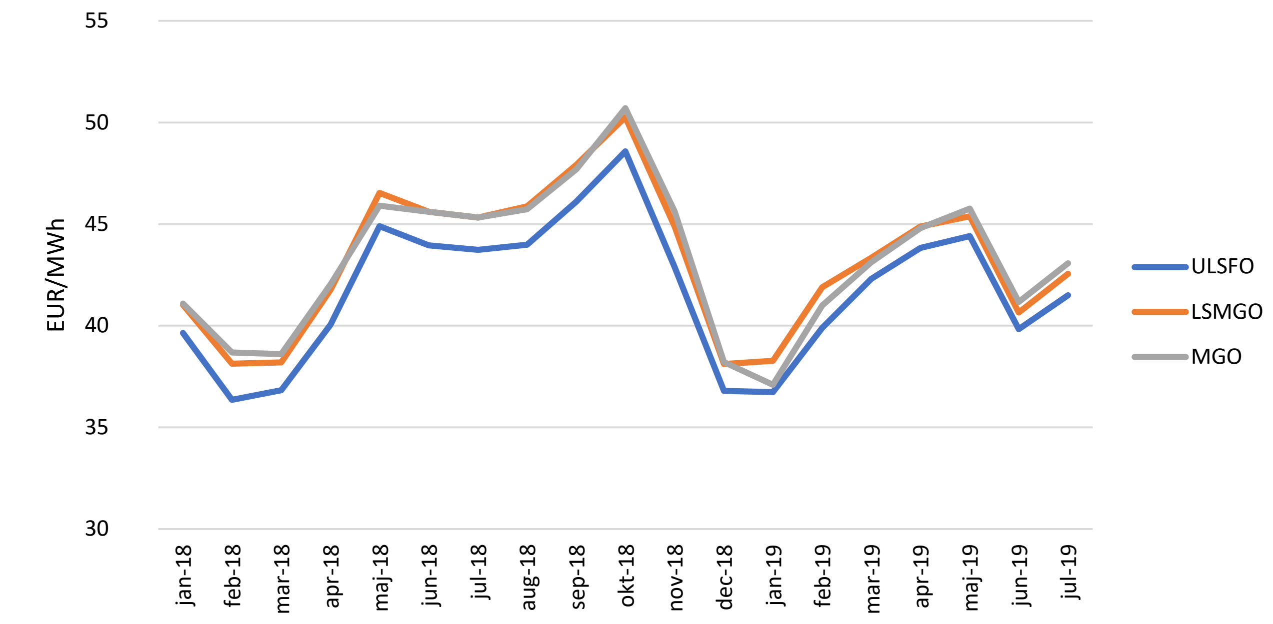
Strengths	**Weaknesses**
• Connected to the gas grid • Growth in cruise calls • Close to the Skaw Road – attract other segments • Several bunkering companies • Developing new port area at which the bunkering system could be implemented	• No LNG bunkering operations today • No LNG vessels are currently entering the port
Opportunities	**Threats**
• Existing demand for the ferry route to and from Samsø • Political strategies for growth in bio-based gas and fuel • Located inside the SECA area • Existing LNG demand from shipping companies operating inside the SECA area. • Selling LNG to STS operators in the Baltic Sea and the North Sea. • Producing LBG from the Danish National grid • The possibility of producing LBG in and differentiating the operation from conventional LNG with BIO tickets.	• Decrease in Danish natural gas production • Increases in gas and electricity price • Varying natural gas quality supply for the production • Lacking political support • Existing LNG infrastructure and bunkering opportunities in the area: Port of Gothenburg and the bunkering vessels (Coralius and Cardissa) • Current port regulations allow for STS operations to be conducted free of harbour fees for the seller and buyers of LNG. • Other ports are promoting discounts and incentives for green shipping.

9 Comparative analysis – LNG and SECA compliant fuels

It is of relevance to compare LNG to other SECA compliant fuels such as MGO and associated fuel types (ULSFO and LSMGO). The following sections will present the price development of MGO, LSMGO and ULSFO and compare this data to LNG produced from a Cryobox.

The following prices for ULSFO, MGO and LSMGO is derived from the Port of Rotterdam. The produced LNG price is based on the production costs for using <u>one unit</u> only. Figure 12 shows the price development from January 2018 to July 2019.

Figure 12: The price development of ULSFO, LSMGO and MGO



Source: Shipandbunker.com

As seen from figure 12, the different fuel type shows a similar pattern with obvious correlation between the fuel prices. The fuel prices top in October 2018 with prices up to 51 EUR/MWh which was an increase of 28% compared to January 2018. One of the main reasons for the large increase towards October 2018 is the increase in demand for Sulfur Emission Control Areas (SECA) compliant fuels where a cap of sulphur content of 0.5% came into force.

Comparing the production cost of LNG from one Cryobox to the other fuel types shows that on average over 2018. LNG was approx. 6.4 €/MWh cheaper than the other fuels.

Table 11: Price difference between Cryobox LNG and other SECA compliant fuels (averages, 2018)

	Price (€/ton)	Difference to Cryobox (€/ton)	Difference to Cryobox (€/MWh)
MGO 2018	521	17	7.1
ULSFO 2018	500	- 4	5.3
LSMGO 2018	517	13	6.8
LNG Cryobox	504	0	-
Average difference		9	6.4

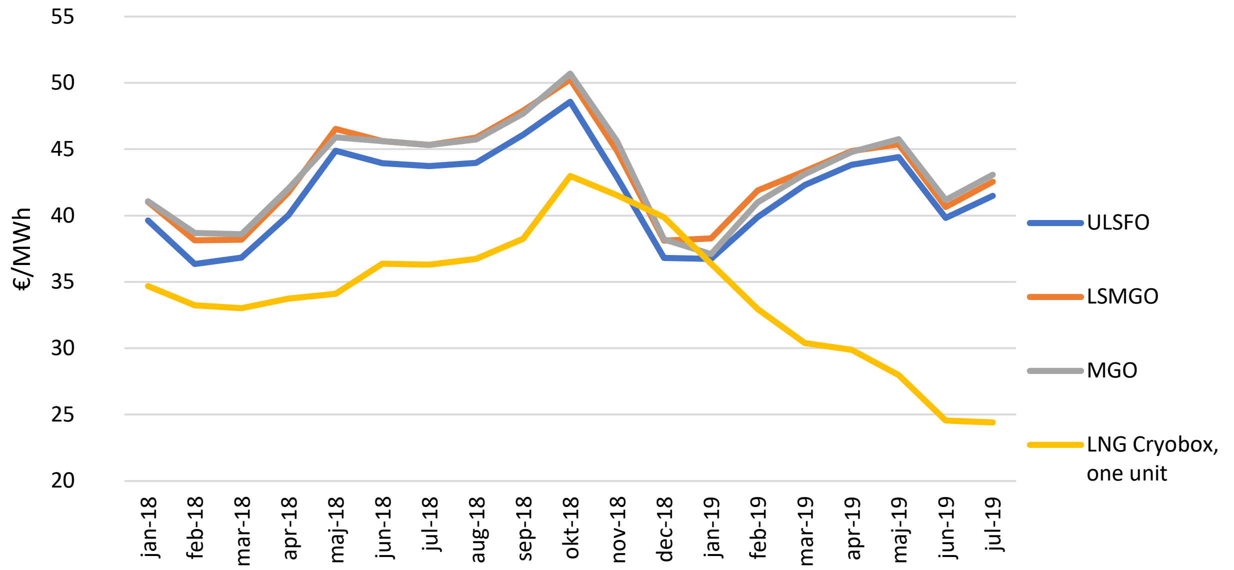
In 2019 the Danish natural gas prices has dropped significantly which creates a new price situation. Comparing the production cost of LNG from a Cryobox to the other fuel types shows that on average over 2019, LNG is approx. 12.5 €/MWh cheaper than the other fuel sources, as shown in table 12.

Table 12: Price difference between Cryobox LNG and other low Sulphur fuels (averages as of July 2019)

	Price (€/ton)	Difference to Cryobox (€/ton)	Difference to Cryobox (€/MWh)
MGO 2019	503	98	12.8
ULSFO 2019	490	85	11.7
LSMGO 2019	505	100	12.9
LNG Cryobox	417	0	0
Average difference		94	12.5

Currently, all low sulphur fuels in Rotterdam are traded above the price of Cryobox LNG as shown in figure 13 below.

Figure 13: The price development of ULSFO, LSMGO and MGO, with Cryobox production cost for one unit as a compassion – €/MWh. 2018-July 2019



Source: Shipandbunker.com and GEMBA

Figure 13 shows that there is a connection between the energy prices from January 2018 and until December 2018 where the prices of SECA compliant fuels and Cryobox produced LNG shows a similar pattern.

From January 2019 the LNG prices continues downward because of lower gas prices.

10 Conclusion

The nano-scale LNG production at the Port of Skagen can be considered as feasible for the following reasons:

- Based on the parameters set in the study and with the concerns raised in the preface, the potential for a positive ROI at a wide interval of different natural gas prices is possible.

- The LNG production at the Port of Skagen can provide LNG fuel for shippers at a lower price than MGO, ULSFO and LSMGO at approx. 17 % in 2018 and 42 % in 2019 before bunker fee.

- There is a market for LNG as ship fuel and the market is expected to increase and there is an interest from shipping companies in the North Sea and Baltic Sea region for more LNG infrastructure.

- The operator should structure their LNG production around either a variable gas prices based on the variable gas prices from ETF or through a TTF spot price model.

- If the bunker fee for the produced LNG from three Cryoboxes is set to a 20 % and is based on the current gas prices in 2019, the economic benefit in fuel prices for shippers would be 39 % compared to MGO, ULSFO and LSMGO.

- The economic viability of the LNG production <u>is sensitive to even small changes in gas and electricity prices</u>.
  - An increase in the gas price of 0.01 €/Nm^3 would lead to an increase in production cost of 0.83 €/MWh.
  - An increase in the electricity price of 0.01 €/kWh leads to an increase in production cost of 0.08 €/MWh.

- Other cost such as capital costs, maintenance cost, service cost etc. also has an impact on the feasibility.
  - A decrease of one employee in the production would decrease the cost by 0.71 €/MWh.

A production of LNG with a Cryobox and with a storage unit solution is deemed as economically feasible at the Port of Skagen in Denmark.

11 Carbon analysis

The CO2 reducing properties of LNG as a ship fuel, has been documented numerous times by different organizations over the years (see appendix). An average reduction of 25-30% in CO_2 levels is the current standard, which is expected to increase as LNG ship engines and propeller technology improves. New research into the CO_2 reduction properties of LNG suggest that the improvement in technology could increase the reduction of CO_2 emissions to 40-50% compared to other fuel sources.

It is therefore likely that as new LNG vessels are being constructed that they'll emit at least 25 % reduced CO_2 compared to a new MGO vessel. Having a small-scale LNG hub in the Port of Skagen will help catalyze this development, as the LNG infrastructure network in Northern Europe is currently underdeveloped regarding fixed LNG terminals and relies heavily on STS vessels for supplying the shipping industry.

Furthermore, when comparing LNG and MGO regarding how many tonnes CO_2 there is in 1 tonne of MGO and 1 tonne of LNG, the difference is 1,56 tonnes CO_2 or 42 % less CO_2 in favor of LNG. LNG also holds an advantage in the number of nautical miles per tonne compared to MGO. The difference is about 16 % more nautical miles per tonnes LNG than with MGO.

The drawback of LNG is however that the LNG as fuel takes more storage space than MGO as fuel, which in effect balances out the advantages that LNG brings as a ship fuel about CO_2 reduction and longer-range pr. tonne. The difference in MWh/m^3 is approx. 1.58 in favor of MGO. In practical terms this will means that an LNG vessel will need to refuel more often than an MGO vessel, which can limit its operational range on a single tank.

11.1 CBA and CA calculations

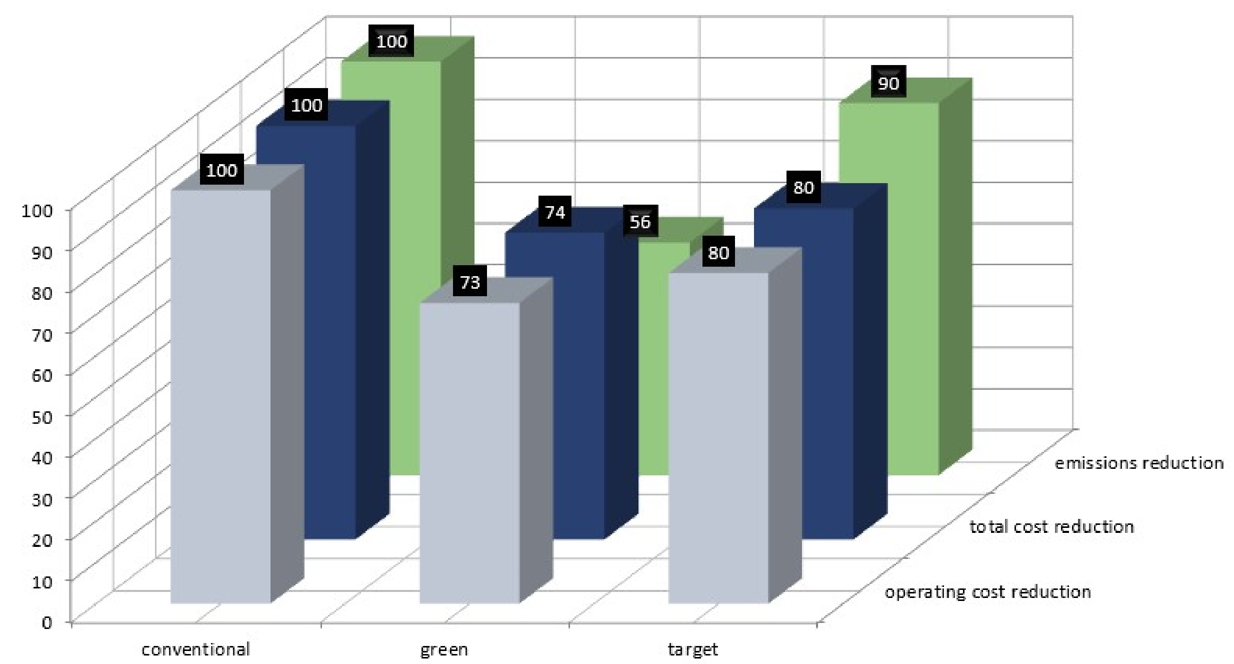
The following comparison is made between a small-scale MGO terminal and LNG terminal focused on PTS operations. The following assumptions are made regarding the conventional MGO terminal investment.

Assumptions taken in the CBA/CA calculation:

- *The MGO terminal will have a similar investment cost as the LNG terminal.*
- *MGO revenue is a function of the average Rotterdam bunkering prices for 2019 times the demand for 188,000 MWh. The average bunker price is 42 €/MWh.*
- *Operation cost is a function of the revenue times 0.9. The remaining 0.1 is the 10% bunker fee charged by the MGO operator.*
- *The LNG terminal is producing LNG with three Cryoboxes at a cost of 27,5 €/MWh at 0,23 €/Nm3.*
- *The LNG terminal is selling the LNG with a 20 % bunker fee.*
- *The MGO is brought in by a bunkering vessel four times a year. The bunker vessels are estimated to consume 18.000.000. kWh in Marine diesel during these trips.*
- *Both the MGO and LNG terminal has trucks to supply an inland demand on Samsø, Denmark. The trucks are estimated to consume 22.000.000 KWh in diesel a year.*
- *Both the MGO and LNG terminal will receive electricity from the national grid with 20 % green electricity.*

Based on these assumptions the following CBA and CA targets are meet as shown in figure 14.

Figure 14: The CBA and CA calculations between an MGO terminal (Conventional investment) and an LNG terminal with three Cryoboxes (Green investment)



Given the results it is estimated that it is possible to achieve the set goals for CBA and CA with at small-scale LNG terminal solution compared to a conventional MGO terminal investment.

DUAL Ports CBA/CA targets:

- *Target in reduction of operating cost was 20 %. The Green investment reach 27 % or 1.936.400 €.*
- *The target in reduction of total cost was 20 %. The Green investment will reach 26 % or 56.584.500 €.*
- *The target in CA reductions was 12 %. The Green investment will reach 44 % or 183.066 tonne CO_2.*

The assumptions are based on estimates derived from interviews and the real economic of a small scale MGO terminal may therefore differ from the CBA calculations. However, given the estimated difference in the CBA calculation it is certain that the CBA won't be less than 10%.

12 Appendix

Table A: Overview of the price difference between LNG Cryobox excl. bunker fee with references. Scenario 1 (light blue) and Scenario 2 (light orange).

Gas price (€/Nm^3)	Difference one Cryobox vs. Generic STS (€/MWh)	Difference One Cryobox vs. Generic PTS (€/MWh)	Difference three Cryobox vs. Generic STS (€/MWh)	Difference three Cryobox vs. Generic PTS (€/MWh)
0.15	5.65	2.85	9.81	7.01
0.16	5.84	3.04	10.01	7.21
0.17	6.02	3.22	10.18	7.38
0.18	6.21	3.41	10.36	7.56
0.19	6.39	3.59	10.55	7.75
0.20	6.58	3.78	10.74	7.94
0.21	6.77	3.97	10.92	8.12
0.22	6.95	4.15	11.11	8.31
0.23	7.14	4.34	11.29	8.49
0.24	7.32	4.52	11.48	8.68
0.25	7.51	4.71	11.67	8.87
0.26	7.70	4.90	11.85	9.05
0.27	7.88	5.08	12.04	9.24
0.28	8.07	5.27	12.22	9.42
0.29	8.25	5.45	12.41	9.61
0.30	8.44	5.64	12.60	9.80

Table B: The price difference between LNG Cryobox excl. bunker fee compared STS and PTS operation with zero terminal, logistic and bunker. Terminal fee for STS decreased by an additional -1 €/MWh. Scenario 3 (light blue) and scenario 4 (light orange).

Gas price (€/Nm^3)	Difference one Cryobox v. Generic STS (€/MWh)	Difference three Cryo v. Generic PTS (€/MWh)	Difference three Cryobox v. Generic STS (€/MWh)	Difference three Cryobox v. Generic PTS (€/MWh)
0.15	3.07	0.87	7.23	5.03
0.16	3.16	0.96	7.33	5.13
0.17	3.23	1.03	7.39	5.19
0.18	3.32	1.12	7.47	5.27
0.19	3.39	1.19	7.55	5.35
0.20	3.48	1.28	7.64	5.44
0.21	3.56	1.36	7.71	5.51
0.22	3.64	1.44	7.80	5.60
0.23	3.72	1.52	7.87	5.67
0.24	3.80	1.60	7.96	5.76
0.25	3.88	1.68	8.04	5.84
0.26	3.97	1.77	8.12	5.92
0.27	4.05	1.85	8.21	6.01
0.28	4.13	1.93	8.28	6.08
0.29	4.21	2.01	8.37	6.17
0.30	4.29	2.09	8.45	6.25

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