Feasibility study and Cost benefit analysis of the DUAL Ports Heat project.

- Feasibility of Hydrogen as maritime fuel at the Port of Hvide Sande

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

2021

Table of content

Executive summery

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

- Based on the general assumptions, the hydrogen as maritime fuel is not deemed economically viable compared to other maritime fuels.
  - Maritime fuels used for comparison in this study is MGO, LSMGO and ULSFO all trading at approx. 43 €/MWh.
  - One reason for the lack of economic feasibility is the low local and national demand for hydrogen as ship fuel.
  - The amount of downtime in production due to low demand is another main reason for the lack of economic feasibility.
- The cost of producing one MWh of hydrogen without any cost reductions is 215 €.
- Reduction to hydrogen production cost can be found in the following ways:
  - Reduced electricity prices by wind turbines at night-time.
  - Seeking economic aid for the projects CAPEX through national and international development founds.
  - Reducing the cost of hiring a new full-time employee by rotating exiting staff from the central heating system into the hydrogen production.
  - Reducing the allocated costs for unforeseen events in the budget.
- With reductions to CAPEX, the cost of producing hydrogen as fuel is 108 €/MWh.
- With reductions to CAPEX and OPEX, the cost of producing hydrogen as fuel is 56 €/MWh.
- The lack of local maritime consumption of Hydrogen is preventing the scaling of the production to achieve comparable prices to MGO.
- To reach a production price for Hydrogen that is comparable with MGO, LSMGO and ULSFO six A90 units would be needed for production scale with significant economic aid.
- The CO_2 reductions of producing and utilizing hydrogen as a maritime fuel is 100 % compared to MGO, LSMGO and ULSFO.

Introduction and structure of the Feasibility study

The concept for the energy infrastructure being introduced in this analysis is the expansion of the green transition in Hvide Sande district heating.

The project in Hvide Sande has introduced wind turbines and a solar park to reduce their reliance on fossil energy, i.e., natural gas that until 2018 was a stable source for heat production in Hvide Sande.

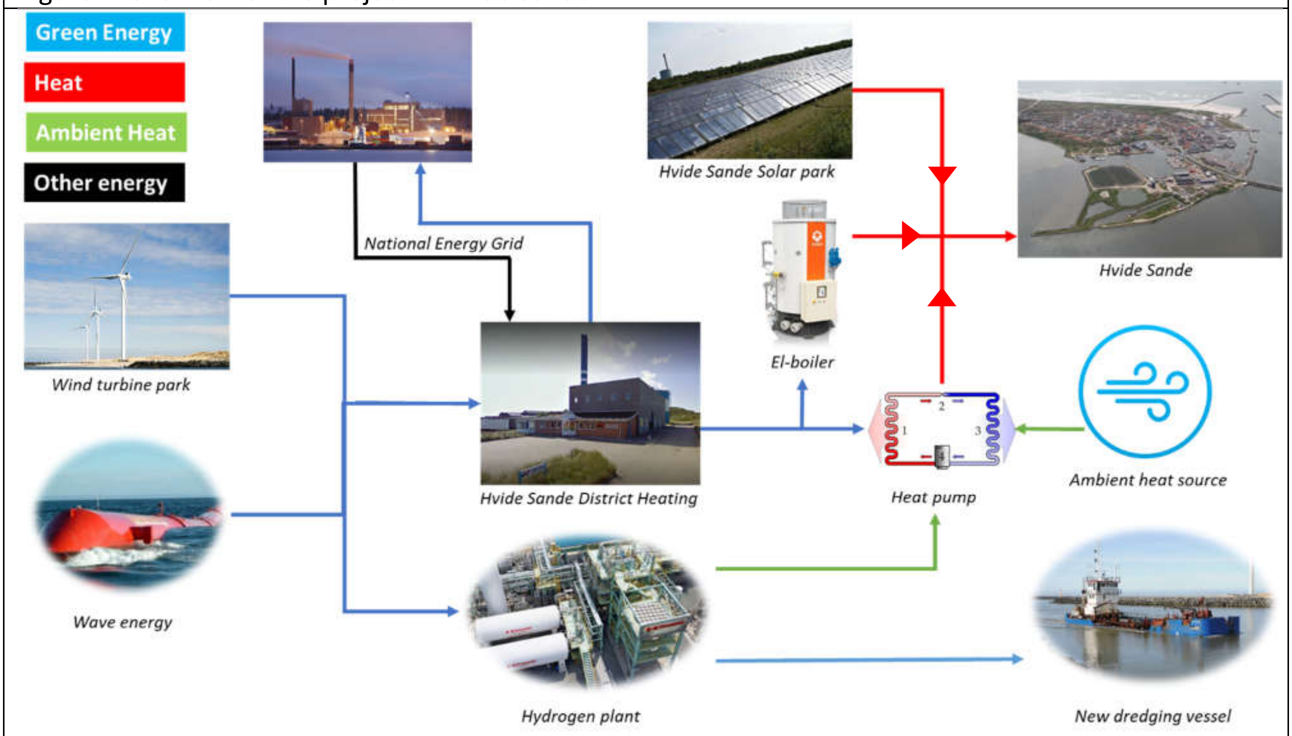
In 2018 the three wind turbines were added on to the district heating setup in addition to the establishment of a solar heating system, which enabled the heat production to reduce its dependence on natural gas by 85 %.

The next step of the green transition for Hvide Sande district heating is to explore the feasibility and integration of a wave energy component in order to create a greater independency from the national energy grid.

Furthermore, the integration of a small-scale hydrogen plant will also be examined in this study. The small-scale hydrogen plant will supply hydrogen of a new dredging vessel in Hvide Sande which will run on hydrogen. The heat from the hydrogen production will be channelled to a heat pump at Hvide Sande district heating and increase the heat production while reducing the cost of supplying district heating for the inhabitants of Hvide Sande.

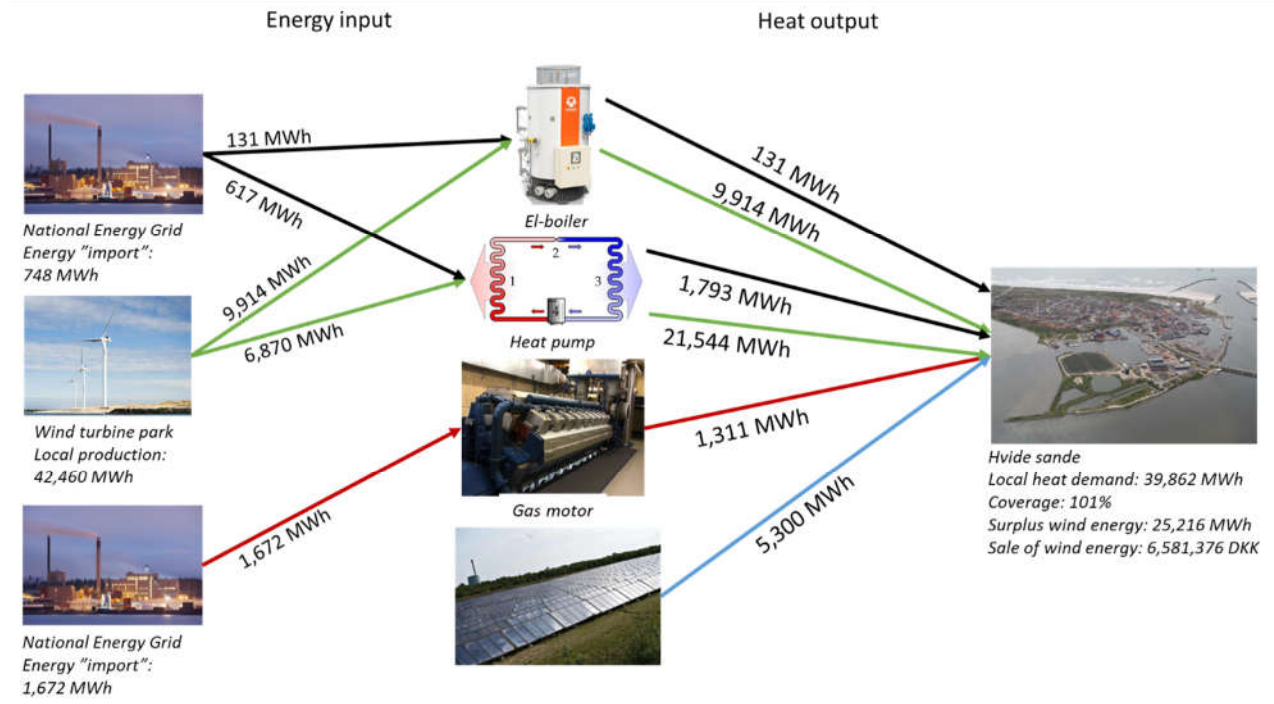
Figure 1 illustrates the ambitions in the entire energy system of Hvide Sande district heating.

Figure: 1 overview of the project in Hvide Sande



The heat demand in Hvide Sande is on average 39,860 MWh per year. The way this amount of heat is generated by Hvide Sande district heating is shown in figure 2.

Figure 2: The energy to heat setup in Hvide Sande district heating with the new heat pump.



This energy to heat setup in Hvide Sande is able to cover the city's heating needs and reduce the dependency of CO_2 loaded energy sources by 85 %. In addition, the setup with a new heat pump will reduced the need for wind energy in the heat production thereby creating a surplus of wind energy of 25,216 MWh.

This surplus of energy can be sold to the Danish national grid and present a value of approx. 885,674 € (2020 prices). However, it is expected that this source of revenue for the central heating district will be dismissed as new regulations and price adjustments are introduced to the Danish energy market for wind energy.

This has therefore created a need for finding new outlets for the wind turbine park in order to ensure maximum usage of the wind turbines every year.

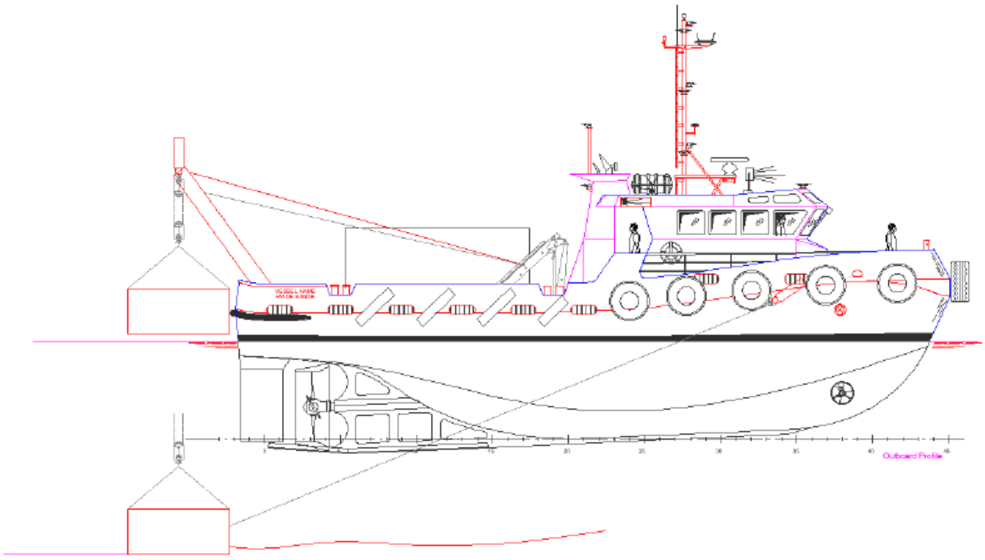
The new energy production idea of hydrogen is envisioned as a potential new demand point for the wind energy production. As previously mentioned, the hydrogen plant is expected to supply hydrogen for local maritime use and potentially supply hydrogen for land-based use as well.

In this study the economic viability of hydrogen as a maritime fuel will be considered for both wind turbine energy only and a combination of wind turbine and wave energy.

The demand situation

Currently there is no hydrogen vessels, vehicle, or industries in Hvide Sande that is dependent on hydrogen for their operation. There is however an opportunity for this as new hydrogen vessel is current being designed for operation in the Port of Hvide Sande. The new vessel will be able so substitute the existing dredging vessel that operate in the port, the new vessel will be called 'Træl II' and is depicted in figure 3.

Figure 3: Concept design for the dredging vessels 'Træl II'



Source: Hvide Sande Shipyard

The vessel is expected to be dredging the Port of Hvide Sande 200 days a year to keep the port and ship lanes in and out of the port free from sand.

The vessel will need 11,600 kWh for a full tank worth of energy to operate for one sailing day. Converted to kg hydrogen this is a need of 345 kg hydrogen for each sailing day. The needed amount of hydrogen would in this case be 69,000 kg each year for this vessel alone. These 69,000 kg of hydrogen will provide the foundation for the feasibility study.

The economic cost and benefit – hydrogen

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

Tariffs, taxes, and fees on hydrogen as maritime fuel

An aspect of importance for hydrogen production is the tariffs, taxes, and fees on acquiring and distribution water for the hydrogen production. The following section will be based on the situation for hydrogen in Denmark. Normally in Denmark, hydrogen would be subject to several tariffs and taxes.

According to Danish tariff and tax law on hydrogen the entire production of hydrogen is subject to tariffs and taxes, except for hydrogen when it is sold as maritime fuel.

When being sold as a maritime fuel the following tariffs and taxes are not applicable:

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

There is no CO_2-tax on other fuel types for maritime use either. In order to secure equal competitiveness between the fuel types, an argument for the CO_2-tax to not be applied to hydrogen for maritime use should be made. It is informed that the Danish Tax Agency understand this position and are open to not applying any CO_2-tax on hydrogen. If the CO_2-tax is applied, it would add an additional 0,05 €/Nm^3.

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

For the hydrogen production covered in this study there would be a need for 31,400 m^3 of water to produce the needed quantities of hydrogen. The distribution fee would in this instance be set to 9.46 €/m^3. The fee for disposal of wastewater is set to 7.20 €/m^3.

Cost

Table 1 shows the generic CAPEX associated with acquiring and installing a hydrogen production unit in Denmark. The costs are derived from the hydrogen case in Hobro Denmark.

Table 1: Investment cost - general	Value	Unit
Foundation + Fence	106.667	€
Container + installation in container	170.000	€
electrolyser (2xA90)	950.000	€
Compressor	400.000	€
Storage	414.000	€
"Tank station"	133.333	€
Electrical supply 3x400 V AC	33.333	€
Installation Hvide Sande	30.000	€
Heat pump + district heating pipe	80.000	€
Water installation	13.333	€
Nitrogen	13.333	€
IP Link	667	€
Various establishment cost	133.333	€

Table 2 shows the OPEX associated with operating a hydrogen production unit in Hvide Sande, Denmark.

Table 2: Fixed OPEX	Value	Unit
Rent of area at Port	2.789	€/year
One employee	80.000	€/year
Maintenance compressor	4.000	€/year
Calibration of gas detector	1.333	€/year
Maintenance electrolyser	1.333	€/year
Replacement of component	26.667	€/year
Other Maintenance	6.667	€/year
Unforeseen events	33.333	€/year
Energy price pr. kWh	0.038	€/kWh
Energy Tariffs pr. kWh	0,033	€/kWh
Water for hydrogen production	9.46	€/m^3
Disposal of wastewater	7.20	€/m^3
Compression of hydrogen	0.0067	€/kWh

Table 3 shows the different commercial options regarding hydrogen productions units. The alkaline technology is the most technological developed of the investigated electrolyze types but is limited in its productions output compared to the PEM technology.

Table 3: Definitions for hydrogen production	Green Hydrogen	Hybalance Hobro (Hydrogenics)	ITM Power	Nel Hydrogen
Product	A90	1.2 MW unit	2-Stack	MC250
Electrolyze type	Alkaline	PEM	PEM	PEM
Max effect kW	430	1,200	1,300	1,350
Max kg hydrogen pr. 24h	194.5	480	540	536
Max kg hydrogen pr. hour	8.1	20.0	22.5	22.3
kWh el/kg hydrogen	53,1	60.0	57.8	60.5
Price electrolyzes (€)	475,000	1,600,000	1,641,714	2,100,000
Effectiveness %	0.45	0.40	0.42	0.40

For this study it has been decided to explore the feasibility of the Green Hydrogen A90 alkaline model future. The reason for this is in part the electricity to hydrogen efficiency of the model but also the cost of the unit relative to the produced hydrogen pr. hour.

Table 4: Properties of the A90 electrolyzer	Green Hydrogen	Hybalance Hobro (Hydrogenics)	ITM Power	Nel Hydrogen
Product	A90	1.2 MW unit	2-Stack	MC250
Unit cost (€)	475,000	1,600,000	1,641,714	2,100,000
Max kg hydrogen pr. hour	8.1	20	22.5	22.3
Cost (€) pr. kg hydrogen pr. hour	58,641	80,000	72,965	94,170

Scaling the Green Hydrogen A90 does not increase the cost pr. kg hydrogen pr. hour or for any of the other models investigated. In addition to the cost differences there are also technological differences that needs to be accounted for. The drawback of the current PEM technology is that it is more expensive, has a shorter lifecycle and lacks the same level of commercialization as the Alkaline types. The advantages and disadvantages of both alkaline and PEM technologies are listed in table 5 below.

Table 5: Advantages and disadvantages of alkaline and PEM	
Alkaline electrolysis	PEM electrolysis
<u>Advantages</u> • Well-established technology • Non-noble catalysts • Long-term stability • Relative low cost • Stacks in the MW range • Cost effective	<u>Advantages</u> • High current densities • High voltage efficiency • Good partial-load range • Rapid system response • Compact system design • High gas purity • Dynamic operation
<u>Disadvantages</u> • Low current density • Crossover of gases, degree of purity • Low partial load range • Low dynamics • Low operational pressures • Corrosive liquid electrolyte	<u>Disadvantages</u> • High cost of components • Acidic corrosive environment • Possibly low durability • Commercialization • Stacks below MW range
Source: Carmo et al. 2013	

The cost of producing one MWh with two Green Hydrogen alkaline electrolysis with a runtime of 360 days/year 12 hours a day is detailed in table 6.

Table 6: The cost of producing 1 MWh with two Green Hydrogen alkaline electrolysis.

	Definition	Value	Unit
Production and Hydrogen characteristics	Max effect	860	Kw
	Max kg hydrogen pr. 24h	389	KG/day
	Max kg hydrogen pr. hour	16	Kg/hour
	kWh/kg hydrogen	33.30	KWh/kg
	Energy tariff pr. kWh	0,028	€/kWh
Hydrogen energy price	Energy price pr. kWh	0.038	€/kWh
	Production hours pr. year	4,320	Hours
	Water for hydrogen production	9.46	€/m^3
	Disposal of wastewater	7.20	€/m^3
	Compression of hydrogen	0.0067	€/kWh
	Energy production	2,330,467	Kwh
	Hydrogen price	0.071	€/kWh
	Hydrogen energy price incl. Taxes	0.099	€/kWh
	Total Hydrogen energy cost	128.507	€
CAPEX	Hydrogen investment - 2xA90	950,000	€
	Installation of 2xA90 unit and storage	624,000	€
	Storage unit investment	547,333	€
	Depreciation	20	Year
	Rent on loan %	0.5 %	
	Depreciation liner to 0	106,067	€/year
	Rent on loan	10,607	€/year
OPEX	Areal cost	2,789	€/year
	Service - workers and maintenance	118,667	€/year
	Administration	33,333	€/year
	Total cost	502,215	€/year
	Price pr. unit	215.7	€/MWh

Based on the calculation, two A90 alkaline units can produce approximately 2,330 MWh/year, at a cost of 215 €/MWh.

Since the primary purpose of the hydrogen plant is to supply a new dredging vessel with hydrogen, it becomes relevant to compare the cost of producing hydrogen with traditional maritime fuel sources such as MGO, LSMGO or ULSFO.

Figure 4 below illustrates the price development for MGO, LSMGO or ULSFO between 2018 and 2019.

Compared to other maritime fuel sources such as MGO, LSMGO or ULSFO, the hydrogen cost is a high per unit of MWh as shown in figure 4.

Figure 4: The price development of ULSFO, LSMGO and MGO

Source: Shipandbunker.com

Compared to other maritime fuels such as MGO, LSMGO or ULSFO, hydrogen produced in Hvide Sande would have a high MWh cost per unit of and be approx. 5 times more expensive per MWh than traditional maritime fuel.

The current hydrogen technology is therefore not deemed economically feasible as an implementation for the heat project in Hvide Sande unless significant economic aid is provided by the government to compensate for the high production cost.

Opportunities for economic support and cost reductions

In order for Hydrogen production to become economically viable compared to MGO, a series of cost reductions and economic support from the government is needed. This section will look into different opportunities for cost reductions in the hydrogen production for both CAPEX and OPEX.

CAPEX reductions

Economic aid to the hydrogen production plant and storage.

Support for hydrogen development project in Europe and Denmark is common. In 2015 the EU project Hydrogen Mobility Europe (H2ME) received 32 million EUR in aid (approx. 51 % of the total budget) and the EU project Hydrogen Mobility Europe 2 (H2ME 2) received 35 million EUR in aid (approx. 34 % of the total budget).

In Denmark national aid is also given to hydrogen project. In 2018 the Danish government agency 'Vejdirektoratet' provided a total of 10 million DKK in aid to three projects and in 2019 the Danish project H2RES received 34.6 million DKK in aid from the national Danish agency EUDP.

There are therefore opportunities for economic aid to establish a hydrogen production plant on both a national and EU level. In the following calculations the economic aid is expected to only be applied to CAPEX expenses of acquiring a hydrogen production plant. The rate for economic support is set to 50% in a scenario 2 and 75 % in a scenario 3 for the acquisition for the production unit and establishment. There will be no cost reduction for the storage unit in scenario, but in scenario 3 a 50 % reduction will be implemented.

Reduction to loan rate

In the initial scenario the loan rate is set to 1.0 %. In scenario 2 the rate will be kept the same, but in scenario 3 the loan rate will be set of 0.5%. The loan length will still be set to 20 years.

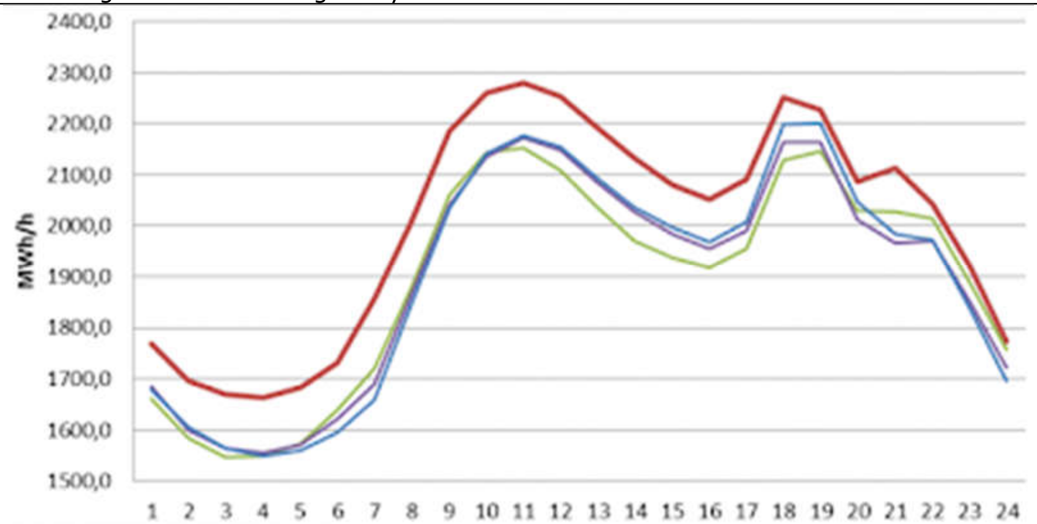
OPEX reductions

Reducing electricity prices

Currently the wind power turbines in Hvide Sande are producing an annual surplus of energy. This surplus energy is sold to the Danish national electricity grid and is a major source of income for the central district heating system.

Given this dynamic it would not be prudent to divert energy from this income source to the hydrogen production as it would mean a loss of income. Instead, another dynamic with the on-site wind power turbines could potentially be exploited. During night-time (22 pm to 7 am), the wind power turbines are not producing any electricity due to the low demand from both the local and national grid. Figure 5 shows the variation in power consumption in Eastern Jutland.

Figure 5: the usage variation during a day in Eastern Jutland.



This means that during this period the wind power turbines could be used to produce energy for the hydrogen production. Given that this is surplus energy used in a vertical value chain setting it would mean that the Hydrogen production facility could receive the energy for free and with no tariffs. For this to be possible though, the central heating district in Hvide Sande would need a permit to produce hydrogen otherwise they will not be allowed to use this setup.

In the following calculations for scenario 2 and 3 it is assumed that the central heating district in Hvide Sande has achieve permission to produce hydrogen. The downside to this concept is the limited timeframe to produce hydrogen. With a production scheduled for the night-time operation, overall output of the plant will be lower than a production that occurs in the daytime. It is estimated that this will result in 600 fewer production hours pr. year.

Reducing the cost of employees

The estimated cost of hiring a new employee to oversee the hydrogen operation is set 80,000 € in the initial scenario. In scenario 2 the cost of the employee will remain the same, but in scenario 3 it is assumed that existing employees from Hvide Sande district heating can be rotated in and out of the hydrogen production. This will reduce the employee cost by 75 %, with the remaining 25 % being the night-time adage for the employees.

Reducing unforeseen costs

The financial post unforeseen covers events that might occur during a production year in relation to the employees. This can be events such as child sickness, sick leave etc. In scenario 3 the allocated amount is reduced by 75 % compared to the initial scenario.

Based on these cost reductions to CAPEX and OPEX the new production scenarios (2 & 3) will result in the following production costs for hydrogen as shown in table 7.

With cost reductions and economic aid to hydrogen production the production cost may be reduced to approx. 108 €/MWh in scenario 2 and 56 €/MWh in scenario 3. The benchmark for the hydrogen production would still be 43 €/MWh for the MGO, LSMGO and ULSFO, which the Hydrogen are not able to compete with in production price yet.

If the hydrogen production is to be economically feasible compared to MGO etc. scaling the production with the cost reductions would be needed. The A90 electrolyze units can be stacked to increase energy output linearly and thereby reduce the production cost. If the number of A90's in scenario 3 is increased to 3 unit the cost would be approx. 43 €/MWh, which is comparable to MGO.

Table 7: Hydrogen production cost after reductions to CAPEX and OPEX.

	Scenario 1	Scenario 2	Scenario 3	Benchmark - MGO
Hydrogen production cost	**No reductions**	**Reduction to cost** Electricity price: 100 % Electricity taxes: 100 %	**Reduction to cost** Electricity price: 100 % Electricity taxes: 100 %	**None**
CAPEX	**No reductions**	**Reduction to cost** A90 investment: 50 % Installation cost: 50 % Storage cost: 0 %	**Reduction to cost** Unit investment: 75 % Installation cost: 75 % Storage cost: 50 %	**None**
OPEX	**No reductions**	**No reductions**	**Reduction to cost** Employee: 75 % Unforseens: 75 %	**None**
Production at night-time only.	**No**	**Yes**	**Yes**	**-**
Price pr. unit	**215** /MWh	**108** €/MWh	**56** €/MWh	43 €/MWh

However, the hydrogen output of this production would most likely be higher than the estimated local demand, thereby creating a surplus of hydrogen. The issue would now be that more maritime or land-based customers would be needed in order to justify producing with 3 units to achieve economic of scale.

If the surplus hydrogen cannot be sold to additional maritime customers, then land-based customers would be the next outlet for the production. The issue with selling the hydrogen to land based use, would be the added cost in the form of energy taxes that will be applied, thus increasing the price of the hydrogen.

Therefore, while increasing the number of A90 units to achieve lower production cost is operationally possible, it is not economically feasible due to the existing low local demand and no additional maritime outlet for any surplus hydrogen. However, the future demand of renewable energy and hydrogen especially may change this situation very soon.

SWOT of hydrogen production

The strengths and weakness of the hydrogen production has been covered in the previous sections and is in this section summarized in the table below. The opportunities and threats to a hydrogen production will be covered in this section.

<u>Strengths</u> • CO_2 neutral propulsion fuel • Heat from production can be utilized in the district heat production • Scale-able hydrogen production	<u>Weakness</u> • Poor energy conversion (electricity to hydrogen) • High production cost for the hydrogen • Low hydrogen production compared to the total cost • Highly dependent on free electricity in the production scenarios • Dependency on excess wind energy
<u>Opportunities</u> • Options for methanol production • Options for Carbon capture techniques • The current national and EU aid programs for hydrogen • Transitions in the shipping industry to Hydrogen vessels – expansion of the maritime market • Transitions in the shipping industry to Hydrogen trucks – expansion of the land-based market	<u>Threats</u> • Lack of economic aid • Lack of demand beyond Hvide Sande • Up-scaling in battery technology • Existing green energy technologies • New green energy technologies. • Lack of innovation to make small scale hydrogen plants more efficient • Lack of transition in the shipping industry to Hydrogen vessels • Lack of transition in the shipping industry to hydrogen trucks • Changes to the weather and wind turbine output

Opportunities

The current national and EU aid programs for hydrogen

Following the EU and National Danish focus on a green transition, Hydrogen has been highlighted as one of the main technologies for this transition. There are therefore different opportunities for founding through EU and National programs such as:

- Horizon2020
- Clean Hydrogen for Europe
- European Green Deal
- EUDP
- FCH-JU (Fuel Cells and Hydrogen Joint Undertaking)

Transitions in the shipping industry to hydrogen vessels – expansion of the maritime market

As the SECA regulations in the North Sea and Baltic is being implemented and set to increase in the coming years a transition in the maritime market regarding fuel technologies are also underway. While the use of HFO and MGO is still usable with the scrubber technology it is not a long-term solution, as further regulations in the SECA areas will make this technological solution less viable.

This is creating a push for new fuel technologies on vessels. Here LNG has been the primary focus, but hydrogen as fuel is gaining more interests from maritime shipping companies. Hydrogen on large ocean-going vessels is still far from being a reality and even on fixed international routes in the EU, hydrogen vessels is a rarity.

However, the increased attention to hydrogen as a maritime fuel will most likely see it become a reality as in the case of the new ocean-going vessels that are operating on LNG. The case of LNG vessels shows that although a fuel type is considered uneconomic or impractical to use as a fuel type, technological development, and investments into this will drive these costs down and make the technology viable as a fuel source.

It took 15-20 years for LNG vessels to reach this state of market readiness and the development of hydrogen vessels, will still in the early stages, may follow a similar route as LNG as on-board storage is improved and hydrogen infrastructures are established.

Transitions to hydrogen trucks – expansion of the land-based market

Similar to the focus on hydrogen as fuel in the maritime shipping industry, there is also an increased focus on Hydrogen as fuel for land-based vehicles. This development is primarily driven in the USA where hydrogen trucks are starting to enter the shipping fleets, but also in Europe and in Denmark is hydrogen trucks and other vehicles starting to appear.

It is therefore likely that as the land-based hydrogen fleets in Denmark increases, the need for wide hydrogen infrastructure becomes more necessary to enable flexible routes rather than only enable fixed routes.

Threats

Lack of economic aid

In order to be economically viable compared to MGO, LSMGO and ULSFO, then project would need significant economic aid as shown in scenario 3. While both the national Danish government and the EU has made it clear that investments and development in hydrogen infrastructure is a cornerstone in their climate and energy policies it is not certain to what place small scale facilities has in this outlook.

While economic aid is begin granted to projects with a large scope is being made, there is yet to have been a grant to a small-scale production for local consumption only. The focus on producing hydrogen for local consumption only may work against an application for economic aid to the project.

A way to circumvent this potential threat is to expand the scope of the production to either included supplying the municipality or the more of the West Jutland region. Issue with this is however that there is no actual land-based demand in Denmark.

Lack of demand beyond the Port of Hvide Sande

The demand for hydrogen is currently minimal in Denmark, with very few industry vehicles and fewer private cars. The same is observed in the maritime industry, where the primary category of vessels sailing on hydrogen is ferries and other short-range vessels, the population of which isn’t very large.

The demand situation for hydrogen as a fuel is therefore limited. The next option for the hydrogen would then be storage and distribution to cities or factories which might need it is also unlikely to be the case. The lack of demand therefore brings on a classic “chicken and the egg” metaphor similar to that of LNG in the early 2010’s. Hydrogen infrastructure will have to be built for demand to increase, but this increase in demand can take a long time to mature.

This threat is an issue because it would severely diminish the scaling for a hydrogen production.

Up-scaling in battery technology

One of the main reasons for the uptake in hydrogen interest on a national and EU level is the opportunity it brings for storing excess energy. While the storing element of Hydrogen is a major positive for the technology, the battery technology is evolving rapidly and do have the potential to out scale energy storage compared to hydrogen.

Examples of the increases in energy storage with batteries would be the Tesla Virtual Power Plant system, which is proving early stages of success in South Australia. A virtual power plant broadly refers to an aggregation of resources (such as decentralized generation, storage, and controllable loads) coordinated to deliver services for power system operation and electricity markets.

Another component that makes the scaling of battery capacity a treat to hydrogen is that the storage of hydrogen versus the storage of wind or solar energy in batteries are not a 1:1 comparison. Storing of hydrogen takes approx. 13 % of the energy in the process, while storage into to batteries takes approx. 5 % of the energy in the process. While storage of hydrogen still has the natural advantage of higher energy density, the potential economic advantage of batteries cannot be overlooked in this regard.

Lack of innovation to make small scale hydrogen plants more efficient

While there has been technological progress in regard to hydrogen production, there is still issues regarding scaling and economy. In regard to small scale hydrogen production the energy consumption is an issue, which hurts the business case.

If innovation in small scale production plants is being postponed in favour of innovation to large-scale production plants, the business case of small-scale production plants becomes more reliant on economic aid and the availability of excess heat to present a plausible business case for other contexts.

Lack of transition in the shipping industry to Hydrogen vessels and trucks

The current storage issues relating to Hydrogen and the lack of a Hydrogen refuelling infrastructure is slowing down the transition in the shipping industry. While hydrogen on ferries and busses are becoming a reality in Denmark, it is only a concept that works because these modes of transportation are operating on fixed routes where refuelling stations with electrolyzes can be planned in advance.

For the shipping industry fixed routes are not a guarantee and here flexible routes are more common. This creates a logistical issue that will most likely delay the transition to hydrogen, since shipping companies that operates on flexible routes will factor the availability of a fuel source when planning their future shipping fleet.

A similar issue is observed in the slow transition to LNG in the Maritime sector. Here the lack of an LNG refuelling infrastructure in advance was one of the factors that lead to a slower than expected transition to LNG and a continuation of using either HFO or MGO with scrubber technology.

The threat to a hydrogen production would therefore be the lack of customers with hydrogen needing trucks or vessels, due to an underdeveloped hydrogen refuelling network.

Changes to the weather and wind turbine output.

Given that the production in the cost reductions scenarios draws on excess wind energy to reduce production costs it becomes vulnerable to fluctuations in wind. If there is no wind to power the wind turbines in Hvide Sande for the 12 hours production days, the output of hydrogen would be decreased unless energy from the national grid is used during periods of lulls in the wind.

The issue of this would be that the hydrogen production would be subject to increased costs from buying the electricity from the grid. Both scenario 2 and 3 demonstrate the impact electricity price has on the hydrogen price, making it one of the more impactful cost positions. If it becomes the case that non excess electricity would be needed to power the production, then the production in Hvide Sande would not be able to achieve economic feasibility without subsidies to the electricity.

Conclusion

The study shows that there are great opportunities for the Port of Hvide Sande to continue its focus on renewable energy and a transition towards zero emissions. Production of hydrogen could very well be one of the necessary steps that could lead the port further in that direction. With the opportunity to fuel the dredger with local produced hydrogen, the business case should be carefully considered.

Production and utilization of hydrogen is not profitable without some support on both the capital expense (CAPEX) and operational expenses (OPEX). There are several research and development funds that can be supportive of such a development, but effort and focus should be targeted the development if it should be achieved.

Maritime fuel (MGO, LSMGO and ULSFO) are all trading at approx. 43 €/MWh while the cost of hydrogen production is 215 €/MWh and hence five times as high per MWh. There are ways to reduce the hydrogen production costs by utilizing low electricity prices and hence production during night-time, achieving economic aid for the projects CAPEX through national and international development founds and through increasing the scale of production including savings on e.g., personal.

With reductions in CAPEX and the prerequisites that has been established in this study, the cost of producing hydrogen could be brought down to 108 €/MWh while a reduction in the OPEX on the terms that is described in this study, the cost could be brought down to 56 €/MWh, and hence be much more competitive to traditional maritime fuels.

Further development in the hydrogen production technology, market demand and changes in the emission taxation would be in favour of the production cost of hydrogen and mean that the business case would become more positive. It is therefore recommended that the Port of Hvide Sande continue to monitor the development of the technology, potential demand from new and existing customers and be ready to support the development of hydrogen production when it is needed.