Business case

Green hydrogen production at Vikan, Smøla, Norway

"The end depends on the beginning"

Project sponsor: Interrreg Northsea Region G-Patra and Møre and Romsdal County Council

Authors: Møre and Romsdal County Council, Smøla Business and culture center and the National wind energy center (NVES)

Møre og Romsdal fylkeskommune

NASJONALT VINDENERGISENTER

Smøla Nærings- og kultursenter KF

Photo: K2 Filmproductions AS

TINGH

The Wind Farm at Smøla Photo: Lina Vassdal

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1. Background

The purpose with this business case is to show the possibilities for a hydrogen plant at Smøla and the preconditions for a profitable business. This business case is based on the aim to decrease CO_2 emissions from transport on and around the island Smøla. The business case is based on the possibility to use green energy from wind power and use of an existing area planned for industry, and the availability of possible end-users both for hydrogen and the by-products, heat and oxygen in immediate distance. The business case is also based on the idea that it is possible to scale up and to make a profitable business case that can be transferred to other rural areas and island communities throughout Europe.

This business case is a part of the EU Interreg North-sea region project "Green Passenger Transport in Rural Areas". (See fact box on page 5). The aim of the G-PaTRA project is to find solutions to reduce CO_2 emissions from passenger transport in rural areas. Today there are very few green transport solutions outside city centers, while the main part of the population in Norway lives in smaller communities. Many people are dependent on using their own car in daily life due to lack of sufficient public transport solutions. The industry is also dependent on transport by trucks or ships. It is important to find transport solutions that can contribute to sustainable development also for rural transport. It is also crucial to find synergies between different transport segments to establish smart green solutions for the near future. This specific case is based on previous calculations around hydrogen use for a speed passenger ferry, in line with the concept of the main project.

Participants in the G-PaTRA project are private companies and public bodies like municipalities and County Councils that are into transport. Partners from Norway have been Møre og Romsdal County Council, The national wind energy center (NVES) and Smøla business and culture center. The rural municipality Smøla with its wind power production is chosen because of its possibility to produce green energy. At the same time Smøla is in the outskirts of the region, sparsely populated and with few transport alternatives. see facts about Smøla on page 8

There are significant CO_2 emissions from transport, businesses, and private/leisure activities on land and at sea around Smøla.
Smøla is connected to the mainland with the speed boat and car-ferries. There is no plan for building bridges or tunnels between the island and the mainland in the foreseeable future. It is crucial for Smøla to maintain a frequent and well-functioning connection to the mainland with speed boats and ferries, as it is one of the most important factors to receive goods, business development, access to hospital and other important services. It is also important for continuous societal enrichment, remain as a popular tourist attraction and provide positive results to surrounding areas.

There is still many aspects to be fulfilled before a hydrogen production at Smøla could be realized, but it is possible to make it profitable and it could be a large contribution for a better environment with less pollution – it is a zero emissions solution in both power production and the use of the power.

G-PaTRA fact box:

- G-PaTRA – Green Passenger Transport in Rural Areas – is a project with a consortium of 13 partners from across Europe who have been awarded funding by the Europe an Union Interreg North Sea Region programme to take forward a project on green transport in rural areas.

- The project, which will run until 2022, with an extension on Covid-19 impacts to 2023, is led by RGU (Robert Gordon University in Aberdeen) working in collaboration with partners from the UK, the Netherlands, Denmark, Germany, Norway, and Belgium. It will promote green transport and mobility by enhancing the capacity of authorities to reduce CO_2 from passenger transport in remote, rural and island areas. It will embed more zero emission vehicles in rural transport systems and improve available passenger transport resources.

- The participants are responsible for many different initiatives to achieve these goals, such as testing electric buses in rural areas, developing travel apps and testing out different mobility alternatives, especially for young and elderly people.

- The G-PaTRA Project Partners consist of Robert Gordon University, University of Groningen, Aalborg University, Office for Regional Development Leine and Weser Region, The Highlands and Islands Transport Partnership (HITRANS), Urban Foresight Limited, Mpact, Aberdeenshire Council, Province of Drenthe, Province of Groningen, National Wind Energy Centre, Møre and Romsdal County Council Administration, and Smøla Business and Culture Centre.

- Each partner contributes with diverse, valuable knowledge, as well as research and a widespread network. The project partners are endorsed within fields such as energy, innovation, academics, strategy, business development, and advisory, with the common goal of reducing CO_2 emissions by implementing innovative technologies in several segments. To read more complementary information about the respective partners: https://northsearegion.eu/g-patra/project-partners/.

Photo: Terje Rakke

The main challenges to develop a green sustainable hydrogen value chain

Severe CO_2 emissions from passenger transport in rural areas but few obvious solutions:

Today, most means of transport are using diesel as their main source of fuel, but more and more electric cars and busses are running on batteries. Battery technology alone is not sufficient to make transportation on land and at sea fossil-free. This is because today's batteries are too heavy and take too much space when the preferred distance of transport becomes longer as for example at routes for speed boats, cruise boats/ships, supply boats and long going trucks and busses. To be able to electrify transport on land and at sea, there is a need to increase power production and amplify the electricity grid. Increased power production and increased capacity of the electricity grid may also be necessary for coming green hydrogen production.

Supply and demand of hydrogen are mismatched in time:

This business case investigates the possibility of replacing diesel with hydrogen on the high-speed passenger ferry between Trondheim and Kristiansund. This option has been discussed widely and made different concept studies for several years, independent of this business case. However, so far it seems to be confirmed that the high-speed ferry between Trondheim and Kristiansund will continue to use diesel as their main source of fuel and will most likely not be running on hydrogen for the foreseeable future. Neither the development of hydrogen technology, having the necessary infrastructure nor feasible accessibility to hydrogen production, is at this point mature enough to be an independent fuel solution for these vessels. So, it's important to continue focusing on other potential consumers at sea and on land to find sufficient buyers of the hydrogen, produced at Smøla.
It is important to profilate Smøla as a possible refuelling place for hydrogen so that when the speed boat or other transport vessels and vehicles are ready to receive hydrogen, Smøla is ready to supply them.

Facts about Smøla:

Geography: Smøla is an island located furthest out on the north-west coast of Norway. The island has no mainland connection aside from car ferries and high-speed passenger ferries.

Area: The main island is 214 km², in addition there are 5846 other smaller islands, islets and reefs.

Population: 2121 (2021)

- Smøla had Europes largest windfarm when the second phase with 48 wind turbines was commissioned in 2005, and the largest in Norway until 2017
- A larger industrial area near the sea is now under construction
- Smøla's business community has traditionally been involved in the primary industries such as agriculture and fishing, but this trend has changed, and the business community today consists of companies in many diverse sectors.
- The building of the wind farm led to several new and stable jobs and have contributed to development of Smøla's local businesses. Aquaculture has become a very important industry for Smøla, and Smøla continuously sees great synergies in business development that spring from these activities.
- Smøla is also well known for its tourism and rich cultural life
  (Smøla kommune, 2021)

Photo: Google Maps

Photo: Wigdis Wollan

The wind farm at Smøla

- 68 wind turbines with a total effect of 150 MW. Buildt in two steps, first phase opened in 2002 and the second in 2005.
- Energy production of 365 GWh/year.
- When the second phase of the wind park opened in 2005, it provided approximately 23.000 households (Bygg, 2005) with clean electricity annually. Per 2021 it is estimated to provide 17.800 households due to higher energy consumption among the population (!).
- The capacity of the electricity transmission cable to the mainland is limited.
- The wind park is situated 10-40 meter above sea level.
- Rotor diameter is between 76 to 82,4 meter and the height of the towers is 70 meter
- The wind park at Smøla was Europe's largest wind power site on land when it was started and was the largest wind park in Norway until 2017.
- Investment costs was approximately 130 million EUR, where 13,8 million EUR was investment support from the national government (ENOVA), converted from NOK with the exchange rate 10.
(Statkraft, 2011) and (Statkraft, 2021).

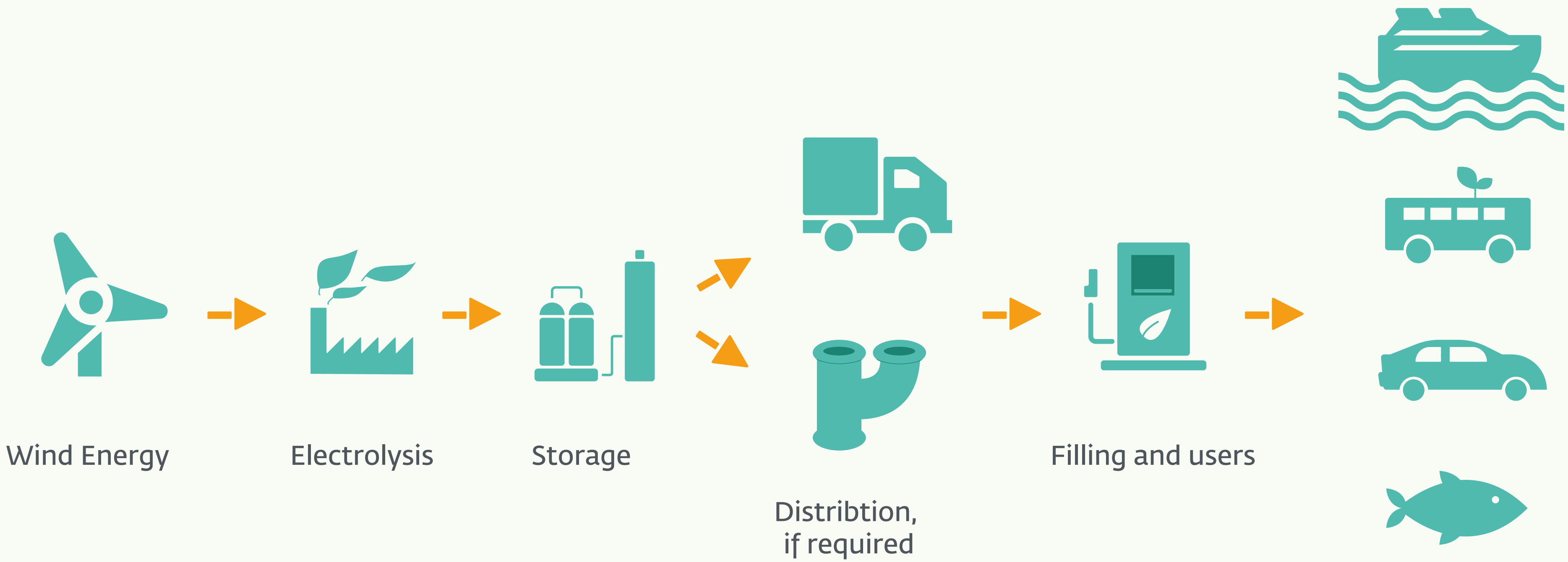
2. Business case

This business case is based on the conclusion that it is profitable to produce compressed hydrogen on Smøla. This assumption is obtained from the techno-economic study of possible hydrogen value chain concepts "Smøla Hydrogen Value Chain" written in 2019. (Vandenbussche, Rambech, Gjerløw, & Trondstad, 2019)

Found here:
https://mrfylke.no/naering-og-samfunn/energi

This business case is taken further with more detailed calculations. The business case aims to give clearer answers on the economic conditions for production and sale of hydrogen at Smøla. The calculations have been carried out with help from the hydrogen production company GreenH.

A possible hydrogen value chain at Smøla



There are several prerequisites that have to be fulfilled to make the business case become profitable:

Available area for the production site

Vikan industry park are under construction and have area available. The Smøla municipality is completing the site at Vikan for industrial activities. The site represents approximately 54 600 m^2. The total required area at the hydrogen production site is estimated to be approximately 1 400 m^2. The infrastructure needs to be ready at Vikan before building a hydrogen production facility. The time perspective estimated for upgrading the power grid at Vikan is set to be between 2-3 years. Smøla municipality is working simultaneously to expand the water supply down to Vikan, so that more water-intensive business activities can be established, for example fish hatcheries.

Access to green energy

Smøla Wind park - a 100% zero emission energy source that could produce 100% zero emission fuel, both in the production and use. But the power grid to Vikan must be upgraded, as is set to between 2-3 years as mentioned earlier.

Potential users of hydrogen

Per today there is no users of hydrogen for the near future but the potential are huge, for more information have a look at page 27. It is expected that maritime activity at Vikan port will grow when the infrastructure of power and water etc. is in place.

Fulfilled

Partly fulfilled

Potential users of the by-products oxygen and heat

Per today there is no industry yet on place at Vikan, but the potential and the fish-farm locations nearby are enough to be able to make use of all the planned amounts of by-products. The by-products heat and oxygen from the hydrogen production are assumed to be used by coming local industry at Vikan port for fish farming, salmon hatchery and salmon slaughterhouse. .

Technically mature enough

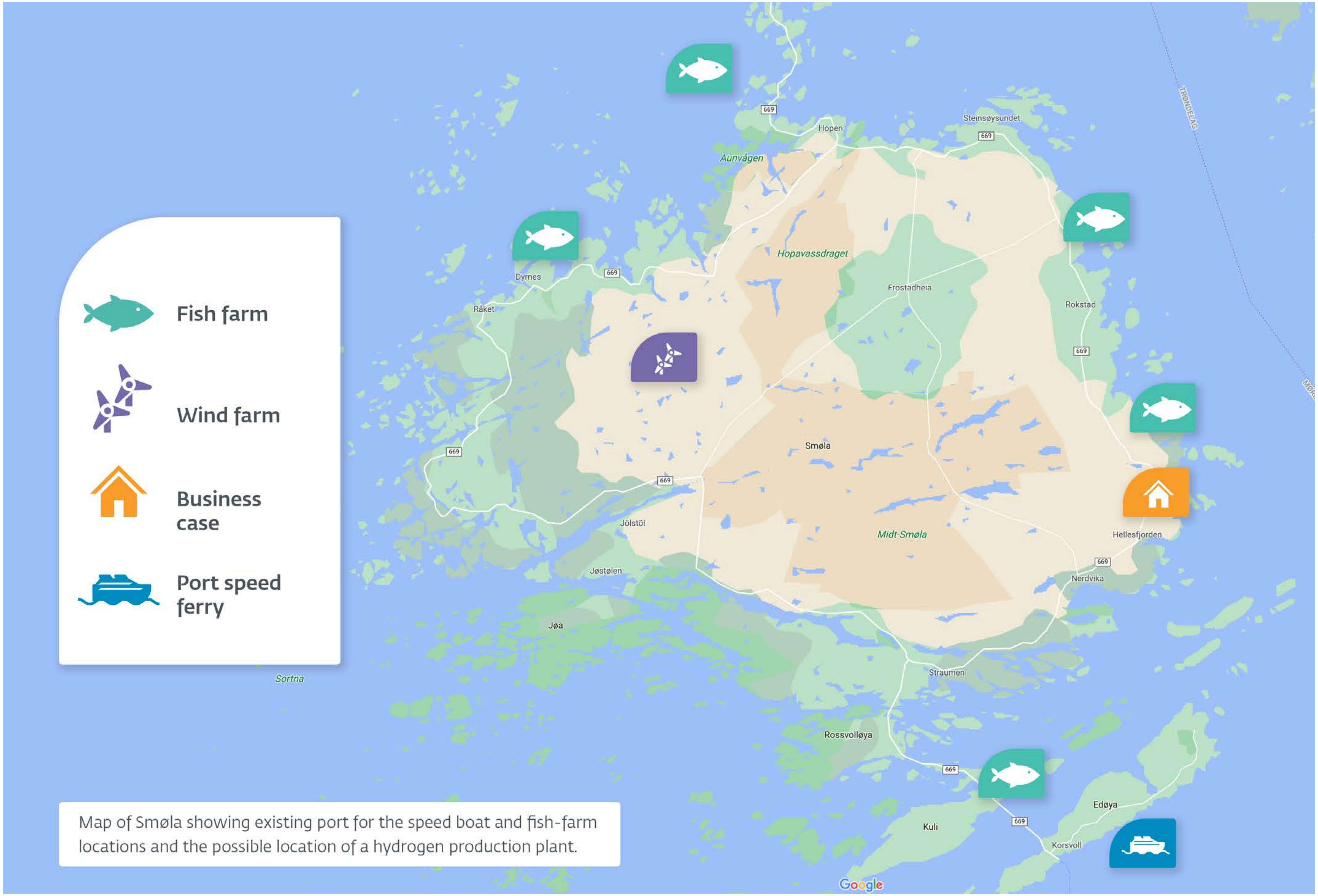
It is already today technically possible for ships, boats and busses/trucks to use hydrogen, but not so many are built yet both due to financing and to uncertainties with regulations and technical solutions.

Attractive price

It is important that the price is attractive enough for the buyers and with the setup presented, where all the by-products are sold, it would be possible to fulfill that goal. To place the production plant at Vikan is important due to reach an attractive price. It is a short detour to drive the passenger speed boat to Vikan port instead of staying at Edøy for bunkering, but this is assumed as possible regarding staff shift, time and not making it more expensive.

Profitable

If the production plant produces and sell at least 1 000 kg/day, to a price of 5 EUR/kg and in addition also sell the by-products, it seems to be possible to make profit, see chapter “Economy in the Business case” at page 17.



Map of Smøla showing existing port for the speed boat and fish-farm locations and the possible location of a hydrogen production plant.

Economy in the business case

The hydrogen plant in this business case is a small unit, but big enough to be able to make profit. The plant could produce around 1000kg Hydrogen/day. It is calculated that the plant could be served by one single person. In addition it is expected to need a part time employee to take care of economic and administrative tasks. Beside the production unit one will need storage tanks for both hydrogen and oxygen, pipelines for water, hydrogen and oxygen and a building shell around the electrolyser. The area needed for all installations is calculated to 1 400 m^2. To save expenditure and transport cost it is suggested to transport the oxygen within pipes and to supply ships with hydrogen through a container swap solution instead of a filling station. Heat sale is also suggested to be in proximity to the electrolyser, considered in the costs as heat exchanger or equivalent. This business case examines calculations both with and without the sale of by-products.

Profit/NPV is calculated for an operating time of around 20 years, with a refund time of the total CAPEX of 10 years. Costs are calculated from NOK to EUR with exchange rate 10.

HYDROGEN PLANT, CAPEX (EUR)		DESCRIPTION
EPCM	600 000	incl. Safety assessment report 50 000 EUR
Project management	300 000	
Power infrastructure	6 00 000	128 A, 400V
Infrastructure and preparation of plot	3 00 000	Incl. Water and oxygen pipeline
Controll, electricity, ventilation meassurment system	8 00 000	Incl. Firesystem
H_2 Production unit and compressor 350 bar	2 6 00 000	1 ton hydrogen/day
Building shell around electrolyser	1 00 000	1 600 EUR per m^2
Reach Stacker (container swap)	5 00 000	Other filling solution will come in addition
Mechanical system intergration/set up	6 00 000	
Facilitation for heat sale	3 00 000	
H_2 storage containers	8 00 000	
Sum: H_2 plant with storage	**7 5 00 000**	

HYDROGEN PLANT, OPEX (EUR)		
Rent of area	323 106	7% of total 219 800 EUR
Staff cost engineer	3 039 853	Full time
Staff cost admin.	2 164 749	Part time. Incl. accounting
Estimated electricity costs	19 533 268	0,035 EUR/kWh
Water costs	137 970	
Maintanance costs	3 867 498	2% of CAPEX pluss inflation 2%
Insurance	290 062	0,15% of CAPEX
Sum: Operations, transport and input factors	**29 356 506**	

TOTAL COST: CAPEX + OPEX (EUR)	36 856 506

EPCM = Engineering, Procurement and Construction Management

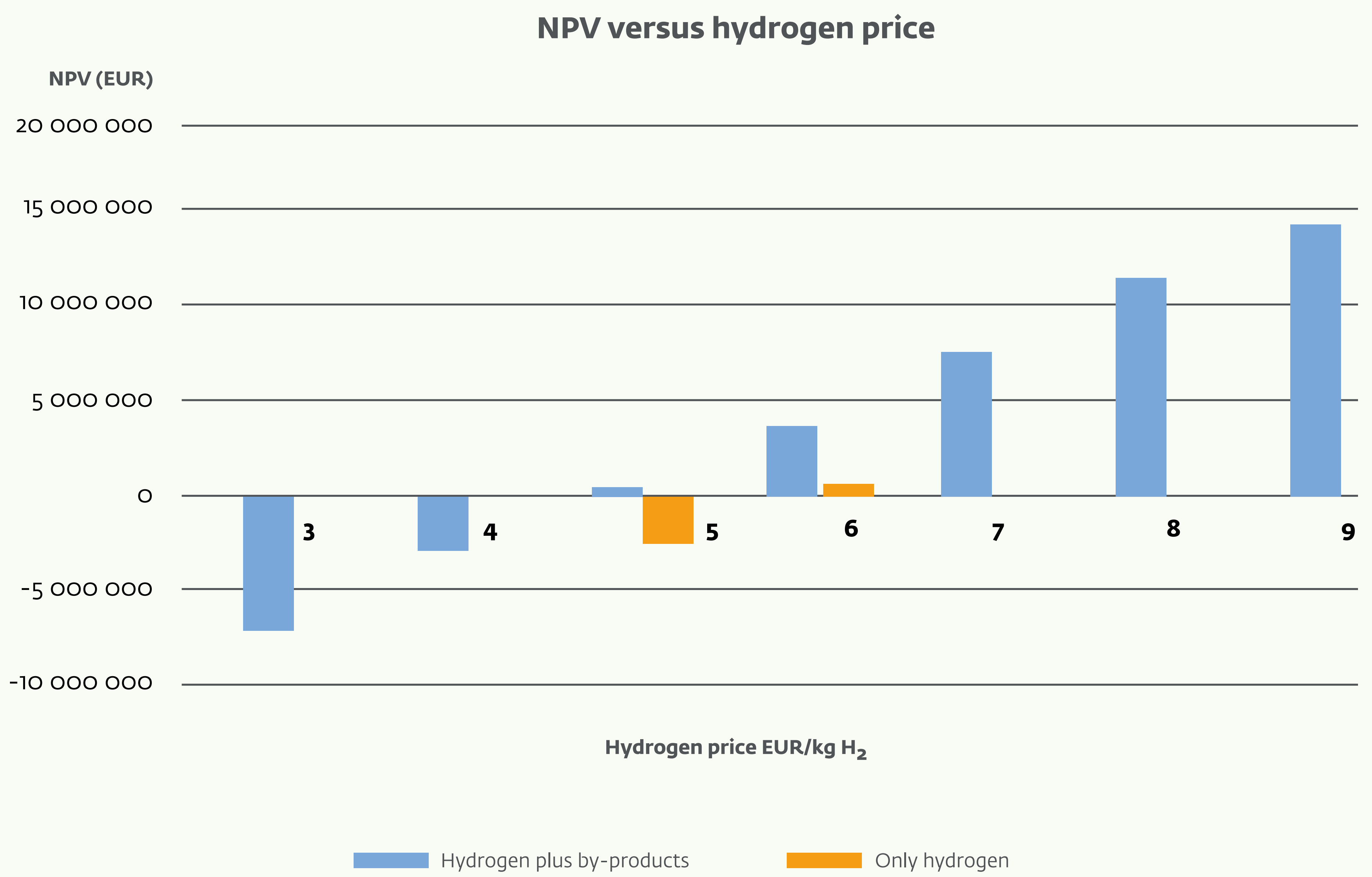
The profit will variate with the market price for hydrogen. Today hydrogen in Norway is sold for 9 EUR/kg, (90 NOK/kg) in filling stations for personal cars but this is not the case for hydrogen sold to maritime transport with special agreements on fuel and it is assumed that the price must be down to 5 EUR/kg to make it attractive. It is not possible to go further down than 5 EUR/kg hydrogen with this setup. From the table below it is also shown that the profit change very quickly depending on only very small differences in price of the hydrogen. In the future it is possible to scale up the production and then make a larger profit. If the production doubles in year 2025 to 2000kgH_2/day (buying an extra electrolyser and adding around 800 000 EUR in other costs) the profit will rise significantly allowing a lower hydrogen price to around 4 EUR/kg.

The oxygen and heat price also needs to be quite low to make it attractive, here assuming an oxygen price down to 0.1 EUR/kg and a sales price for heat at 0.02 EUR/kWh. Without selling the by-products the price for hydrogen needs to be 5,9 EUR/kg to make profit.

See also visualiziation of the different prices at page 20.

Hydrogen Price, EUR/kg	NET Present Value (NPV) calculations	EUR	Prerequisites
5, 893	Total NPV, sold hydrogen and all by-products	0	Loan 60% of total CAPEX (10% depreciation 10 year), Weighted Average Cost of Capital (Wacc) 6,5%, Taxes 22 %, Internal Rate of Return (IRR) 14, 79% at Hydrogen price 5 EUR/kg
4,900	Total NPV, sold hydrogen and all by-products	25 454	
5,000	**Total NPV, sold hydrogen and all by-products**	**379 576**	
5,900	Total NPV, sold hydrogen and all by-products	3 566 671	
9,000	Total NPV, sold hydrogen and all by-products	14 544 446	
5,000	Total NPV, sold only hydrogen	-2 762 182	
5,900	Total NPV, sold only hydrogen	424 914	
4,000	Total NPV, Double the production in 2025, 2000 kg/day	747 192	
5,000	Total NPV, Double the production in 2025, 2000 kg/day	7 107 972	

By - products: 1000kg Hydrogen/day, 57kWh/kgH_2, where heat makes up 30 % - sold 65% of that with a price of 0,02 EUR/kWh. Oxygen price 0,1 EUR/kg - sold 90 %


NPV versus hydrogen price
NPV (EUR)
20 000 000
15 000 000
10 000 000
5 000 000
0
-5 000 000
-10 000 000
3
4
5
6
7
8
9
Hydrogen price EUR/kg H2
Hydrogen plus by-products
Only hydrogen

Special advantages for hydrogen production on Smøla

At Smøla there is a comprehensive aquaculture industry, and Smøla municipality has put in a lot of work to stimulate this industry to keep growing in the coming years. The aquaculture industry needs both heating and significant amounts of oxygen. By producing hydrogen, it would be possible to enhance the industry by using the excess oxygen and heat coming from the production itself and adapting it to Smøla's local aquaculture companies. This makes it possible to create a sustainable value chain, as the industry needs the by-products coming from hydrogen production, which is essential to ensure a financially profitable production.

In order to sell by-products from hydrogen production, the assumption is that the by-products will have to be easily accessible to the companies. It is not reasonable to transport by-products, such as heat and oxygen, when they can be used locally. In this business case we have chosen to localize the production of hydrogen to a port with great area size, named Vikan Havn. The port have enough available area, is facilitated for new business development and corresponds to the premises of larger and smaller boats approaching the port. Vikan Havn will function as a hub for activity both at sea and on land, and there are prerequisites for being able to use oxygen and heat coming from the hydrogen production in connection with establishments of future aquaculture industry.

In this business case we have emphasized the need for hydrogen to the speedboat travelling between Trondheim and Kristiansund, as Smøla is one of six ports of call to the end destination in both directions. As for today, this speedboat requires large quantities of diesel, and by replacing diesel with hydrogen, it would result in a considerable positive environmental impact for this passage. Development of technology still prevents a concrete plan to replace the diesel boat with a boat powered by hydrogen, but we assume that it will be of great interest to implement this change as soon as technological challenges are fully overcome. For more information in regard to this, we refer to the Endrava report. (Vandenbussche, Rambech, Gjerløw, & Trondstad, 2019). Note that the expectation of a hydrogen-powered boat from 2024 as outlined in the Endrava report was in hindsight seen as not realistic, and that there is a lot of research remaining before a speedboat powered by hydrogen, travelling over such a long distance - approximately 170 km, is put into operation.

Production of hydrogen at the wind farm may be more profitable if the power is sold directly from the production site. As for now, our experience is that there is no formal solution to this, and that the cost is therefore not guaranteed to be any less. The surplus production is not high enough to provide a stable supply of power. Production of hydrogen in the wind farm would also involve transportation of by-products, and this is considered both inappropriate and cost-driving.

Vikan Industry Park at present stage (2021)

Photo: Tom Reidar Høibjerg

Vikan Industry Park visualized for future activities

Illustration: Hobøl Consulting / Kristiansund og Nordmøre Havn

3. Market situation

The market situation for hydrogen production is predicted to go from nearly nonexistent to a much higher demand in the years to come. Hydrogen can become a good solution for longer travels with higher speed, where batteries are not suited today, mostly due to range, efficiency, and weight.

There are several forums, clusters, and conferences on hydrogen for transport in Norway. The market is up-and coming and the government has set a strategy for the use of hydrogen and joined IPCEI (Important Projects of Common European Interest) in December 2020, with a goal to reduce CO_2 emissions further by implementing hydrogen solutions. Since 2016 the national research funding, Pilot-E, has have the aim to find new, competitive technologies and solutions for environment friendly energy technology. Pilot – E has supported stakeholders to come faster and more accurate from idea to market. Hydrogen projects have been an impotrant part of the supported projects (Enova, 2020). The world's first commercial ferry is expected to be up and running with hydrogen within 2022 and the technology is based on a combination of (liquid) hydrogen and batteries, for now. (Førde, 2021).

Currently there is no hydrogen demand or supply at Smøla or the rest of the County. But there is a local interest for hydrogen supply- and work boats in the future. Smøla, as an island, is especially interesting when it comes to focus on the aquaculture industry and use of by-products from the hydrogen production.

There is a need for more generalized technical regulation, guidelines, and standardization for hydrogen so that the cost of building and operating work boats can be easier to implement. Both for the local shipyard Promek AS, producing 10-11 boats for the aquaculture industry annually, but also for the consumers. This to indicate a more concrete cost overview over the cost of building and operating the boats, which will make it more interesting for the local industry to consider. It is also necessary to map out the necessary infrastructure needed on a national basis, in order to have sufficient re-fueling stations along the coast as the number of boats running on hydrogen is expected to increase significantly in the future.

In "Teknisk ukeblad" (Stensvold 2021) it was stated that there are 50 hydrogen projects (within Norway, Scotland, EU, and USA) that are waiting for a hydrogen infrastructure before they can start up. On the other hand it was also mentioned that hydrogen producers are waiting on a big enough demand before they are able to start the production in terms to make profit.

In the Fit for 55 Proposal (COMMISSION, 2021), Article 6 it is stated that:

> *"Member States shall ensure that, in their territory, a minimum number of publicly accessible hydrogen refuelling stations are put in place by 31 December 2030. To that end Member States shall ensure that by 31 December 2030 publicly accessible hydrogen refuelling stations with a minimum capacity of 2 t/day and equipped with at least a 700 bars dispenser are deployed with a maximum distance of 150 km in-between them along the TEN-T core and the TEN-T comprehensive network. Liquid hydrogen shall be made available at publicly accessible refuelling stations with a maximum distance of 450 km in-between them. They shall ensure that by 31 December 2030, at least one publicly accessible hydrogen refuelling station is deployed in each urban node."*

Smøla is outside The TEN- T comprehensive network but close to the Comprehensive network port in Kristiansund and could indirectly be part of this Proposal as hydrogen supplier or complementary refuelling station.

Working boats in action at a fish hatchery on Smøla — Photo: Nekton V/ K2 Filmproductions, Kristoffer Strand

Supply

Today there are not many producers of hydrogen from wind in Norway. Production at Smøla can therefore be crucial to fasten the implementation, and create solutions using surplus energy from wind to produce hydrogen, that also may be utilized in other locations with nearby wind parks.

The Haeolos project Varanger kraft in Finnmark county is going to produce hydrogen from wind power at Raggovidda. This project is a pilot for producing hydrogen where the grid is limited or no grid at all. The pilot project has already been established and did its first operational tests on 15th of June 2021. (Haeolus, 2021)
"Sandøy energi" has looked at producing hydrogen from five wind turbines at the Island Harøy. They got national funding through "Klimasats" (Miljødirektoratet, 2021) for doing the research. This case is quite similar to the case at Smøla. The pre-project showed that they could produce 400 kg hydrogen per day.

Norwegian Hydrogen is a newly started company with the aim to start hydrogen production at Hellesylt (southern part of Møre and Romsdal) with electricity from small scale hydro power plants. Today there is a diesel driven car-ferry going from Hellesylt to Geiranger, a trip that takes about one hour, which is too far to be served by batteries with today's technology. The aim is to supply the ferry, cruises, and others with hydrogen from that hydrogen plant. The project has got national funding and the plan is to start hydrogen production within 2023. (FuelCellsWorks, 2021) and (BlueMaritimeCluster, 2021)

Another producer that may be important for end-users in Møre and Romsdal, is Meråker Hydrogen. The company located in Trøndelag County was established in 2020 and aims to produce hydrogen for consumers within transport and industry operating in mid-Norway. Construction start is set to 2023, and the factory is expected to produce 10 tons of green hydrogen per day by the start of production in 2024. (Parr, 2021)

There are two landing sites for natural gas in Møre and Romsdal County, at both places (Tjeldbergodden where Europe's largest methanol plant is situated and Nyhamna where natural gas is processed and further delivered to UK through the pipeline Langeled) they are now looking into the possibilities for producing blue hydrogen (with Carbon Capture and Storage (CCS)).
This business case is looking at the possibility of facilitating a plant at Vikan, Smøla, with the intention of producing one ton of green hydrogen per day from 2026.

Demand

Ferries and speed boats are operating between Smøla and the mainland. The ferries are now electrified but the speed boat, which operates between Trondheim and Kristiansund are still diesel driven with high emissions. If replaced with hydrogen the CO_2 emissions could be reduced with 5,171 tonnesCO_2e/year according to the Endrava report, page 26. (Vandenbussche, Rambech, Gjerløw, & Trondstad, 2019). The high-speed ferry and local busses can together account for more than 1,000 kg of hydrogen demand daily according to the Endrava report.

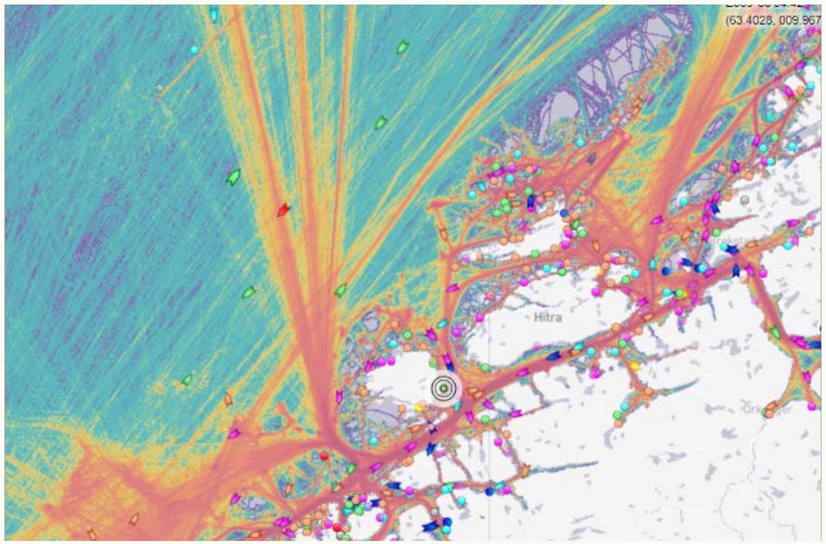
Today there are several projects on hydrogen for transport in Norway. The first hydrogen trucks were driven by ASKO with Trondheim as base (ASKO, 2020) , which had a handful of fuel cell trucks on trial from Scania. As of January 2021, Scania announced (Scania, 2021) that they believe batteries will meet the truck sector's needs, and that hydrogen fueled trucks will mostly serve stationary and niche applications. This assessment was based upon hydrogen technology as it is per today, and concerns regarding generation of the fuel as well as costs. In march however, automotive world (Holmes, 2021) stated that they still believe in hydrogen trucks. Thus, there are chances that hydrogen trucks will become end-users for hydrogen produced on Smøla in the future.
Ruter, the public transport company in Oslo and Akershus, has been operating 5 hydrogen buses since 2012 as part of the CHIC project, but did in 2019 decide to end the project without any further hydrogen bus investments due to costs, especially in correlation with refueling, operating and maintenance (Viseth, 2019). Sweden is thus starting to use hydrogen buses in the near future and other larger cities within EU are already using hydrogen busses.

Locally at Smøla, the transportation company Brødrene Sætran AS with 11 trucks could be relevant users of hydrogen in the future. Today, Brødrene Sætran AS consumes 3000-4000 liters of diesel per week. Other relevant hydrogen users at Smøla could be the agricultural industry, as well as trucks used for transporting fish and by-products from the aquaculture industry to and from the island.

There are many projects going on in Norway for hydrogen in maritime applications and we think that maritime transport will become a real alternative for use of hydrogen in the time to come.

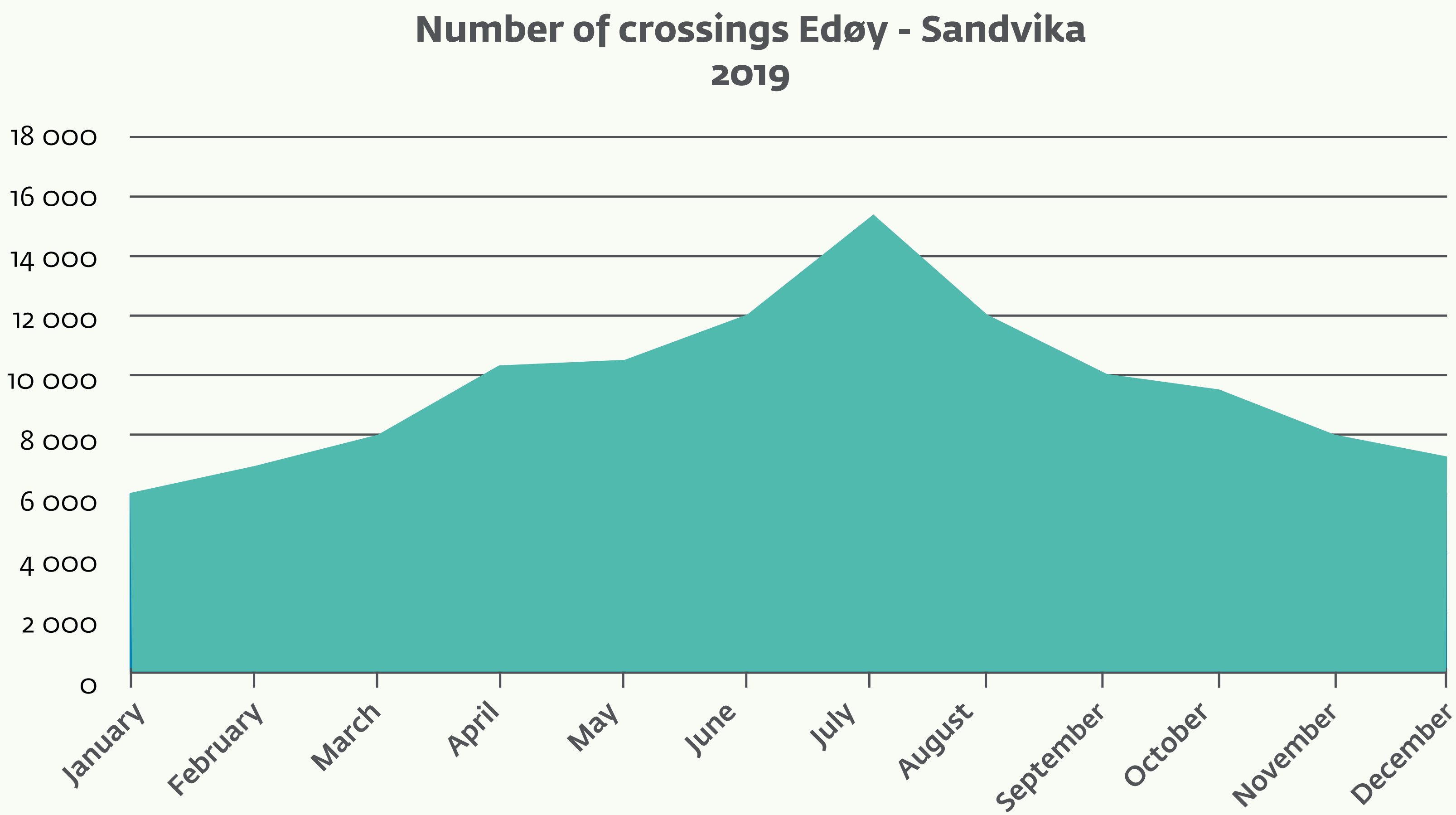
As per an article in Teknisk Ukeblad (Stensvold, 2021), 11 out of 15 maritime hydrogen vessels that are planned are in Norway, whereas France, Germany, The Netherlands and The USA have one project each in their portfolio. In order for these 11 vessels to be fully running on hydrogen by the end of construction, the necessary infrastructure for refueling stations along the coast needs to be operative. In addition, several pre-projects are looking at both speed passenger boats, cruise boats and transport ships running on hydrogen or ammonia.

A future high-speed ferry will need 2,5 tons of hydrogen per day. Endrava (Vandenbussche, Rambech, Gjerløw, & Trondstad, 2019) has estimated in their report that a new built energy effective boat will bunker approximately 512 kg hydrogen a day at Edøy every day with some uncertainties, if the preferred fuel would be hydrogen for the new high-speed ferries. However so far, it seems to be confirmed that the high-speed ferry does not appear to be running on hydrogen in the near future.
There is large boat traffic around Smøla throughout the day as indicated at the picture at page 29 from Marine Traffic (Marine traffic, 2021). The picture shows boats above 15 meters, so in practice it is even more traffic. It is large activity in the fishing industry and aquaculture around the island in addition to ships going in both directions along the coast. In addition to this there is large traffic further out to oilfields and fishfields. The cruise-traffic is also relatively large. In the past few years 60-80 cruise boats is passing Smøla a year in addition to "hurtigruta" (Dybedal, 2018)



Logged marine traffic around Smøla

Locally, we have together with Nekton AS, Promek AS and FSV group at Smøla estimated that there are around 40 workboats working and bunkering at or around Smøla alone. However, Promek has stated that they will not be the first ones (Fenstad, 2021). Furthermore there is a lot of business activity on the nearby neighboring islands, such as Hitra and Frøya, where there also is a lot of aquaculture industry. With a hydrogen bunkering boat, one can expect to expand and reach a larger potential customer group.



3,7 % of the number of crossings are cars above 10 meters long.

Photo: K2 Filmproductions AS

4. Conclusion and discussion

The ends depends on the beginning. After a thorough review of essential aspects, it is reasonable to develop a hydrogen plant at Smøla. Though, the implementation of the plant will be demanding, as the consumers will demand hydrogen at lower cost as the use of hydrogen is more widespread in several markets in the long run. To be able to deliver hydrogen at a lower market price, it is necessary for the production to scale up significantly. Considering the geographic location of Smøla, it is a suitable placement for a hydrogen plant, as the harbor would be a hub for many vessels sailing along the Norwegian coastline. As the infrastructure and hydrogen technology gets developed and more widespread in the coming time, it is reasonable to believe that Vikan Havn would be a plausible harbor for both refueling and export of hydrogen.

Because hydrogen is quite modern in a fuel perspective, most numbers are from theoretical calculations instead of practical experience. They are given estimates, through meetings with relevant actors. «This case is based on the report from Endrava (Vandenbussche, Rambech, Gjerløw, & Trondstad, 2019), however we have focused on finding the most realistic cost and calculation estimate in today's market. Costs are very hard to predict, however Endrava shows in the sensitivity analysis that even with smaller volume the production is profitable. However, our calculation shows that the margins are narrower than Endrava predicted. As the technological development is moving forward, this may be cheaper in the future.

The production volume is tightly connected to the costs. One of the main uncertainties is the amount of hydrogen needed in the region in the future. We also see solutions and needs that have not yet been discussed locally. With additional funding, one can explore further solutions that yet have been uncovered

To increase chances of profitability, by-products need to be sold to generate income. The project needs to make deals with local industry to ensure this in the future. It would also be of interest to explore the possibility of having an electricity supplier, such as Statkraft, as a part owner of the hydrogen plant to ensure good and lasting electricity agreements in the long run.

There is an obvious question of timing. There are great risks in investing in a large plant that may not be used anyway, but if the hydrogen is not available when a high-speed ferry may be ready, Smøla may not be chosen as a main supplier. Smøla also needs to be ready when other boats will need hydrogen. The plant needs to be scalable, so it can produce more hydrogen in the future when needed.

The high cost of hydrogen production is challenging given the relatively low cost of fossil fuels/diesel in the transport industry. By looking at the utilization of both hydrogen and the by-products, the economic outlook will create a better basis for implementing the production of hydrogen at Smøla. Smøla as a location is also well suited for hydrogen production considering that sales of by-products to for example the maritime business, is the key to having a sustainable economy for this kind of production.

The development of vessels and vehicles that could use hydrogen has taken time. Technology, safety, and economy is premises that all have to be fulfilled before the development is accelerated.

Photo: Wigdis Wollan

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Møre og Romsdal fylkeskommune

NASJONALT VINDENERGISENTER

Smøla Nærings- og kultursenter KF