# Future compressed hydrogen infrastructure for the domestic maritime sector

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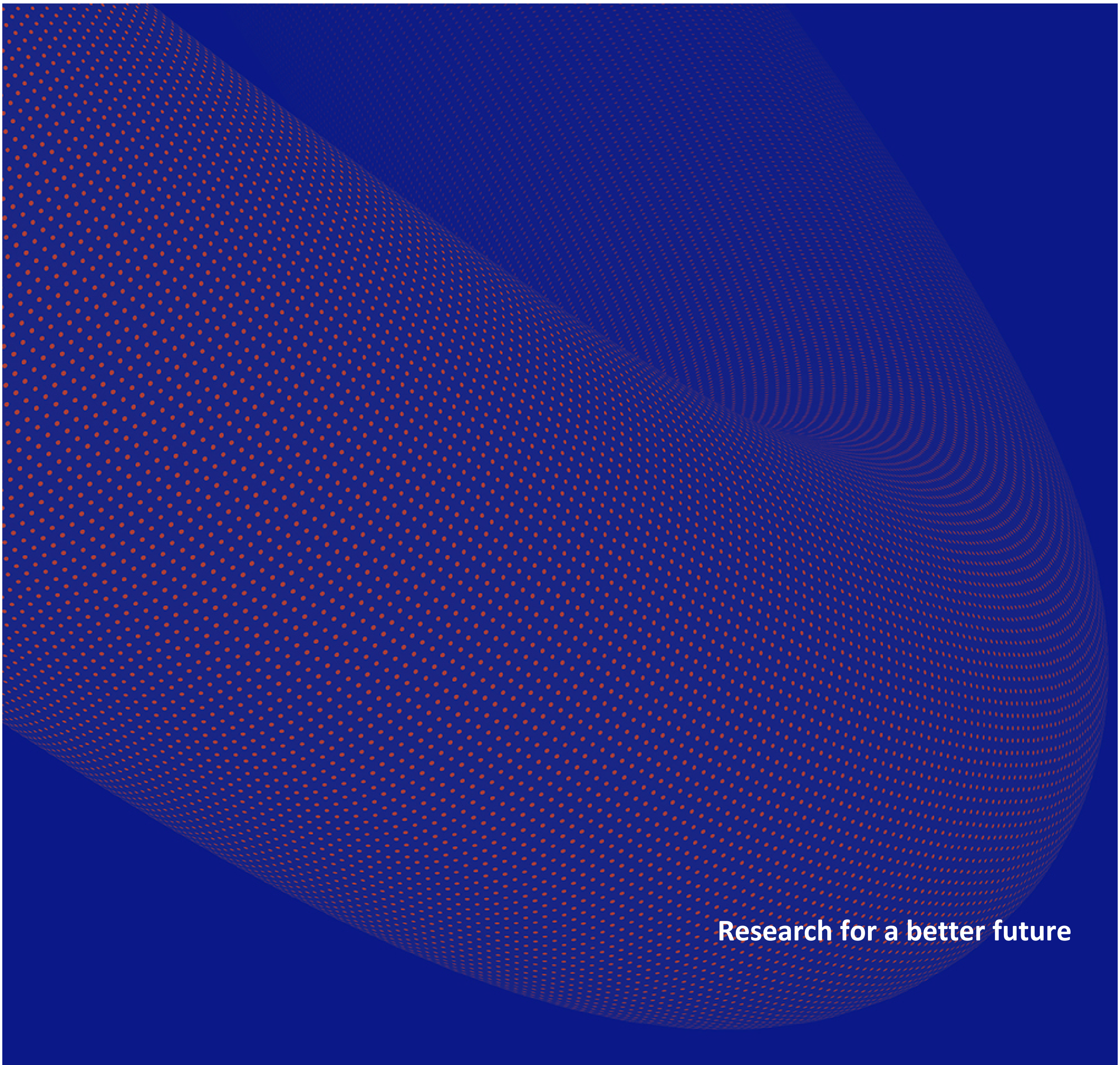

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<tr><td colspan="5">Summary:<br><br>This work is part of the HyInfra project lead by Arena Ocean Hyway Cluster and the user case on maritime transport in FME NTRANS. Previously, in HyInfra work package C, the potential demand for hydrogen in the domestic maritime sector was defined. This new work aims to estimate how the supply chain for compressed hydrogen could become based on the costs of the different steps in the supply chain calculated with the levelized cost of hydrogen (LCOH) methodology. The costs were gathered from both Arena Ocean Hyway Cluster members and literature studies. The analyses are based on expected cost levels by 2030.<br><br>SMR with CCS was identified as the cheapest production option, and costs for three different electrolyser sizes were used. Alkaline technology was used as the basis for electrolysis as it was identified as the cheapest option. By balancing cheaper hydrogen due to economies of scale and the additional cost of transport, the demand was clustered into feasible groups with common production units and some local production units. This clustering was done through two scenarios that either included or excluded already announced hydrogen production units. The results varied between the scenarios and are presented in both map and table format.<br><br>The demand size of the different clusters of compressed hydrogen varies between ~500 to ~6 000 kg hydrogen per day. When including the already planned hydrogen production locations, more local production sites were identified.</td></tr>
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# 1 Introduction

In 2019 the Norwegian greenhouse gas emissions from the maritime sector reached 3.0 million tonnes CO2 equivalents [1], which corresponds to 5.9% of the total national emissions. Hydrogen in compressed and liquid form, as well as e-fuels with hydrogen as a central component, is seen as a promising option to decarbonize the sector. Arena Ocean Hyway Cluster leads the HyInfra[1] project, with the overall goal to reduce uncertainty and risk related to hydrogen infrastructure for the maritime industry. The project involves the mapping of future hydrogen and ammonia demand, technical solutions and hydrogen value chains, technical uncertainty and project risk, safety and regulations, and other barriers.

Previously in the HyInfra project, potential national demand for compressed and liquid hydrogen, as well as ammonia, was mapped. This report is a continuation of the HyInfra project and aims to analyse the upstream production and distribution of compressed hydrogen. The cost of producing compressed hydrogen is known to decrease with increasing production volumes, and transportation of compressed hydrogen is known to be expensive. In this report, the benefits of scale versus high transport costs is the main issue being analysed. Similar reports covering liquid hydrogen and ammonia are being prepared in parallel by Ocean Highway Cluster and Amon Maritime.

This work has been co-developed with the user case study on hydrogen in the maritime sector conducted by the research centre for environmentally friendly energy NTRANS. The findings in this work provide a valuable basis for analysing how to unlock the potential of hydrogen and possible barriers to doing so.

[1] https://www.oceanhywaycluster.no/projectlist/hyinfra

# 2 Methodology

The demand was received as a printout of the dataset for compressed hydrogen used in the Ocean Highway Cluster (OHC) interactive map[2] consisting of 67 entries with GPS coordinates and a demand connected to each location. The initial work was to quality check the dataset and to merge nearby locations into a single demand to facilitate the main analysis.

The core question is how to satisfy the defined demand in the most cost-effective manner while considering two main aspects of the supply chain: i) the cost benefits of large-scale vs. local small-scale production and ii) the additional cost of hydrogen transport from large-scale production sites to the consumer.

To carry out this work, a techno-economic analysis of the production technologies was done based on the levelized cost of hydrogen (LCOH) defined by [2] as

$$LCOH = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + E_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{H_t}{(1+r)^t}} \tag{1}$$

where $I_t$ is the initial investment in year $t$, $M_t$ is the operations and maintenance costs, $E_t$ is the fuel costs, $H_t$ is the hydrogen produced in the year $t$, $r$ is the discount rate and $n$ defines the system lifetime.

The production cost by commercial electrolysers and steam methane reforming (SMR) was reviewed and differentiated based on size where relevant.

In this analysis, only road transport of hydrogen and its associated costs are considered based on hydrogen transport modules. Transport of compressed hydrogen by waterway is not included as it is still considered an immature method with unknown cost. The only exception is that trucks transporting hydrogen can use ferries, which are common along the Norwegian coast.

The LCOH for the different components is calculated for a 2030 case where some components are expected to cost less relative to today's levels (2020). This decision is based on the main demand growth's being expected between 2025 and 2035.

The main cost variables for the hydrogen supply chain were collected at a workshop with OHC members on 25 August 2020 where all participants discussed and agreed on a common dataset. This dataset was later also complemented by additional input and discussions with key partners and, where needed, additional data was gathered from the literature.

Based on the identified production and transport costs it is possible to determine the transport distance at which it becomes more feasible to build an additional local production facility.

[2] https://www.oceanhywaycluster.no/membersarea

The hydrogen production facilities in this work are divided in two groups: i) pre-defined sites and ii) compressed hydrogen demand-driven sites. The pre-defined sites are sites that have either been

- announced by the industry as hydrogen producing sites, no matter their main source of demand (industry, transport or other), or
- identified within HyInfra as covering demand for liquid hydrogen.

The demand for hydrogen was provided as a list of locations and their daily and yearly hydrogen demand. With the help of a Python code that asks for distance using the Google Maps API, a distance matrix was created covering all locations. Based on this matrix and the previously identified thresholds of how far it is feasible to transport hydrogen vs. producing it locally, all the demands in the distance matrix were clustered to a production facility manually using the following design rules:

1. All demand which is feasible to connect to external hydrogen production facilities is assumed to be served by facilities that are already pre-defined.
2. The demand that cannot be connected to pre-defined hydrogen production facilities is clustered with a new production facility in the following manner:
    a. The largest demand of the demands not yet clustered is identified and a production unit at or nearby this point is assumed.
    b. All demands for which hydrogen transport is feasible considering the transport distance are added, thereby creating a new cluster of demands
    c. As long there are demands not yet clustered, the process is restarted from point a.

To show a diversity of how the supply chain can be structured, two scenarios are analysed: **Scenario 1,** which considers the announced locations for future hydrogen production plants by market actors and including the production locations for the LH2 set within HyInfra and **Scenario 2,** which looks at optimal location when considering only the demand of compressed hydrogen for maritime sector.

# 3 Demand for compressed hydrogen and pre-defined production sites

In this chapter, the main inputs of demand and possible production facilities are presented. The possible production facilities are either announced by industry actors or have been identified by the HyInfra project during analysis of liquid hydrogen supply chains.

## 3.1 Demand for compressed hydrogen

The demand for compressed hydrogen has previously been identified for car ferries and high-speed ferries as part of HyInfra work package C. The work done to estimate which high-speed ferries are eligible for hydrogen as energy carrier and the estimated energy demand is publicly available [3] while the methodology for car ferries is available through the Ocean Highway Cluster member area.

In total 67 connections where identified as feasible for hydrogen as an energy carrier, of which 17 are car ferries and 50 are high-speed ferries. The average daily demand for compressed hydrogen approaches 34 tonnes per day over the next decade, as shown in Figure 1. If all hydrogen would be produced with electrolysers at 66% efficiency, the annual electricity consumption for hydrogen production would be approximately 620 GWh of electricity by 2036.

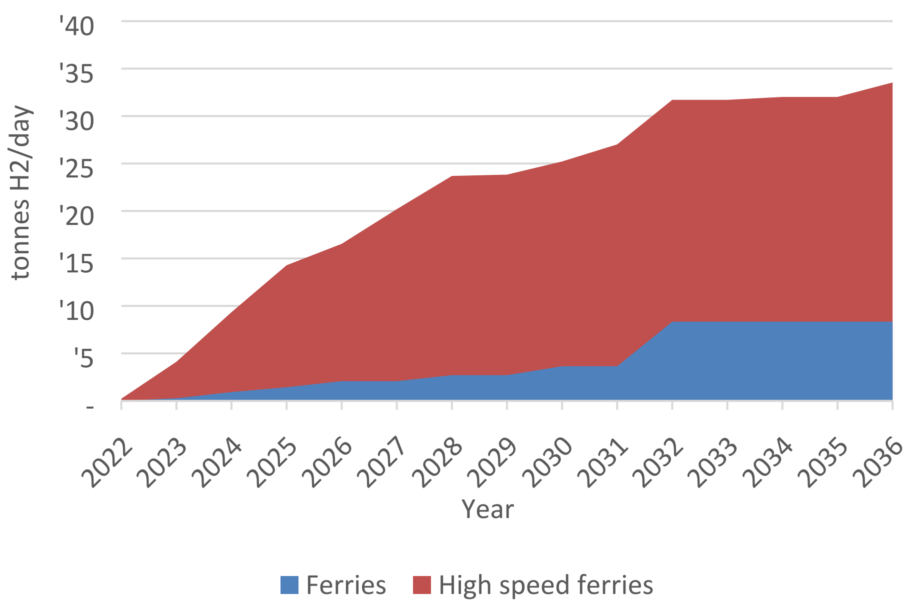


*Figure 1 Projected increase in the demand for compressed hydrogen over time*

The dataset for demand was reviewed in two steps. In the first step, all demand locations on islands were examined. In total, 23 of 67 demand locations were on islands. Of these locations, 14 were manually moved to the mainland or to the island with strongest grid and/or easiest access for delivering distributed hydrogen. When moving a demand (bunkering) location, the only alternative considered was another end-stop point on the route; however, feasibility with the existing route schedule was not assessed. From this analysis, local production was assumed as the only option for two routes, “Trænaruten”, and “Gåsvær-Hardbakke”, as they were located too far from mainland.

In the second step, the demands which lie within a 30 km radius of each other were merged into a single demand. This step was taken because it was assumed that the probability of two production facilities being placed so close to each other is low. This assumption is based on the fact that there will always be certain advantages of scale and administration to build and run a single plant instead of two separate plants, which might not be included in the simple methodology used in this work. It also facilitates further analysis as the number of locations is reduced.

After the process of merging locations, 50 unique locations remained. The demand in this dataset varies between 45 and 3135 $kg_{H2}$/day per site, while the average demand is 599 $kg_{H2}$/day. The daily demand is estimated by dividing annual demand by 365 days/year, while actual daily demand can vary depending on day of the week and season.

The original demand dataset is illustrated in Figure 2a. The modified dataset is illustrated in Figure 2b, with merging of demand and moving of bunkering locations indicated by separate colours. Also, the local fast-ferry route, “Trænaruten”, with limited grid capacity and assumed local production is shown in red in Figure 2b. The other route with limited grid and local production, “Gåsvær-Hardbakke”, is hard to identify in the figure due to its small hydrogen demand.

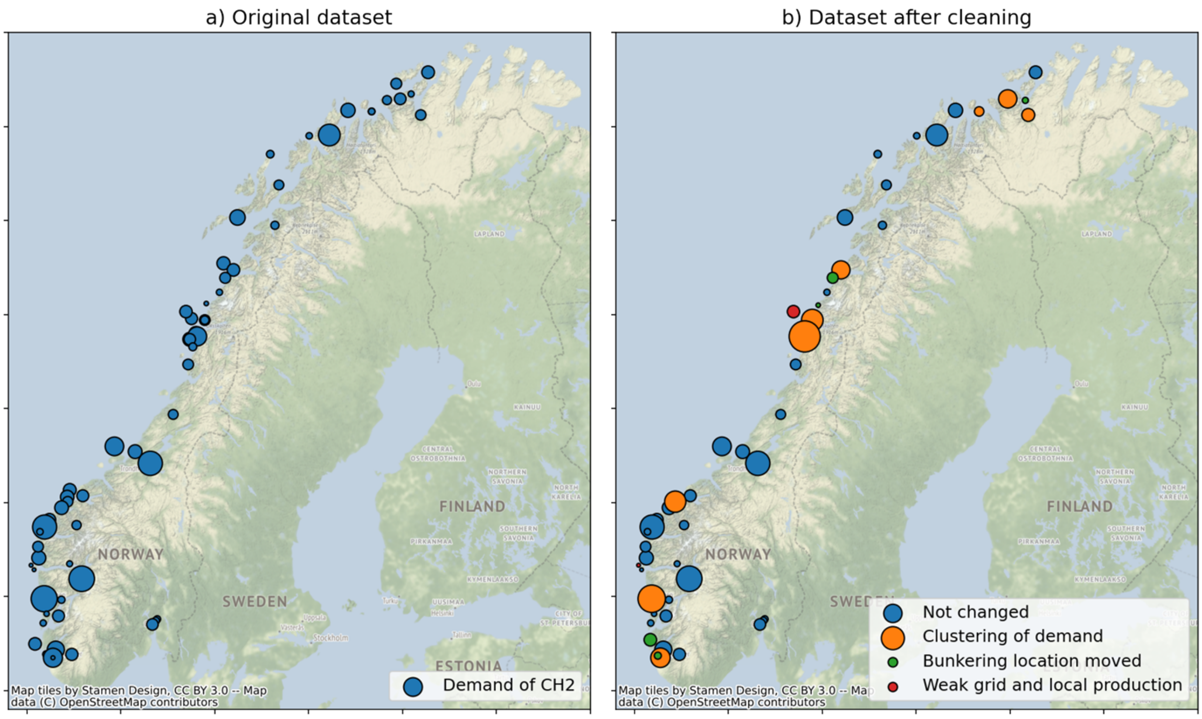


*Figure 2 Illustration of a) original $H_2$ demand dataset and b) $H_2$ demand dataset after cleaning and clustering*

## 3.2 Pre-defined production sites

Several companies have published press releases about their intentions to build hydrogen production facilities in Norway. In addition, through analysis of liquid hydrogen supply chains within the HyInfra initiative, additional production sites have been identified. Table 1 shows the overview of all the pre-defined production plants while Figure 3 displays them on the map.

There has no official statement regarding an initiative to build a steam methane reforming (SMR) plant in connection with Equinor’s facilities in Mongstad, but the site is very relevant considering its ongoing carbon capture and storage (CCS) activities and is likely to be the location of a hydrogen liquefaction plant. Not far from Mongstad, in Kollsnes, Øygaarden, the companies CCB and ZEG Power have already received funding to demonstrate a small-scale hydrogen production plant based on ZEG Powers technology which utilizes Sorption Enhanced Reforming (SER). Carbon capture is an integral part of the SER process, making it an alternative to producing hydrogen from methane using SMR technology with CCS. It can be concluded that despite there being no announced plans to build large-scale SMR/SER plants based on natural gas as energy feedstock, there are ongoing activities with great potential for realizing such a plant in the vicinity of Bergen. This analysis is based only on an SMR plant in Mongstad. However, it is assumed that the changes in results would be marginal if the production facility were moved to Kollsnes (assuming production costs of SMR and SER are comparable).

As hydrogen production typically favours economies of scale, it is assumed that additional demand allocated to any of these sites will be a win-win situation both for producers and consumers of the hydrogen.

*Table 1 Overview of pre-defined production locations*

| Location | Initializer | Start year | Production type | Estimated GPS coordinates | Source |
|---|---|---|---|---|---|
| Glomfjord | Nel ASA, Greenstat AS and Meløy Energi AS (LH2 HyInfra) | 2024 | Electrolyser | 66.815933, 13.940030 | [4] |
| Mo i Rana | Statkraft, Celsa & Mo Industrial park | 2023 | Electrolyser | 66.310437, 14.167243 | [5] |
| Finnsnes | Statkraft & CRI | 2023 | Electrolyser | 69.221681, 18.082201 | [6] |
| Mongstad | BKK, Equinor & Air Liquide, and other (LH2 HyInfra) | 2024 | Electrolyser | 60.810344, 5.031334 | [7, 8] |
| Mongstad | A future SMR plant is assumed | | SMR | 60.810344, 5.031334 | |
| Kollsnes, Øygaarden | CCB & ZEG Power | 2022 | SER – demo | 60.550048, 4.838676 | [9] |
| Hellesylt | Hellesylt Hydrogen Hub | 2023 | Electrolyser | 62.086274, 6.870644 | [10] |
| Berlevåg | Varanger kraft (LH2 HyInfra) | 2020 | Electrolyser | 70.854403, 29.117184 | [11] |
| Florø | HyFuel | Construction starts 2021 | Electrolyser | 61.608586, 5.049001 | [12] |


*Figure 3 Location of announced future large-scale hydrogen production sites*

# 4 Cost analysis

To suggest a future national supply chain is very complicated as its formation will consist of many different aspects, many of which are not yet public or possible to foresee in this type of national analysis. Therefore, this analysis builds on a simplified methodology based on comparing the LCOH cost for different components in the supply chain and on the pre-determined geospatially spread demand to make a reasonable match between production and demand.

In all the calculations, a discount rate of 9% is assumed. This corresponds to the approximate yearly increase of the Oslo stock market index between 2010 and 2019. This value was selected to illustrate the opportunity cost an investor would face when investing in the hydrogen supply chain.

In the following subchapters, the LCOH is presented for different parts of the supply chain including both current and future costs.

## 4.1 Electrolyser

Only the electrolyser technologies commercially available today are considered in this work. This limits the technology alternatives to either alkaline or PEM type electrolysers. Their main assumed performance and cost variables for today and for 2030 are presented in Table 2.

*Table 2 Assumed performance and cost variables for alkaline and PEM electrolysers*

| | | 2020 | | | 2030 | | |
|---|---|---|---|---|---|---|---|
| | | **0.4 MWel** | **1 MWel** | **10 Mwel** | **0.4 MWel** | **1 MWel** | **10 Mwel** |
| **Alkaline** | | | | | | | |
| Investment cost | $kNOK/MW_{el}$ | 21,130 | 11,000 | 7,500 | 12,486 | 6,500 | 3,900 |
| Average energy efficiency | % | 63% | | 65% | 66% | | |
| Production capacity | $kg_{H2}/day$ | 181 | 454 | 4680 | 190 | 475 | 4,752 |
| Technical lifetime | hours | 75,000 | | | 95,000 | | |
| Electrolyser outlet pressure of H2 | bar | 5 | | | 15 | | |
| **PEM** | | **0,2 MWel** | | | **0,2 MWel** | | |
| Investment cost | $kNOK/MW_{el}$ | 34,044 | 19,780 | 10,221 | 25,240 | 14,665 | 7,577 |
| Average energy efficiency | % | 58% | | | 66% | | |
| Production capacity | $kg_{H2}/day$ | 84 | 418 | 4,176 | 95 | 475 | 4,752 |
| Technical lifetime | hours | 60,000 | | | 75,000 | | |
| Electrolyser outlet pressure of H2 | bar | 30 | | | 30 | | |

The main operational costs are connected to the electricity supply, which is comprised of the energy cost and grid connection fees. Future energy costs are very hard to predict, and in this work, they are assumed to be constant at 400 NOK/MWh both for today and for 2030. In addition to the energy price, the power consumer also needs to pay grid fees for operation and maintenance of the electrical grid. In this work, the grid fees are set at 50 NOK/MWh and 100 NOK/MWh for large (1 MWel) and small consumer (1, 0.4 and 0.2 MWel), respectively. This differentiation is made to illustrate that larger consumers might harvest some benefits through a strategic location or a more favourable connection to the grid or be co-located with an energy production or consumption site with the flexibility to ramp down at peak demand hours. The cost of the electrolyser is calculated based on a yearly capacity factor of 90%.

Based on the data provided above, the results of LCOH for both technology types, different sizes and years are calculated and shown in Table 3. Based on the data available today and the method used, an alkaline electrolyser will be the cheapest option in all cases and further analysis will be based on this technology. The importance of this comparison is to identify the different cost levels between the different sizes of electrolyser and not make a definite conclusion about preferred technology type.

*Table 3 LCOH for producing hydrogen by electrolysis in NOK/kg$_{H2}$*

| | | Size (MWe) | | | |
|---|---|---|---|---|---|
| | | **10** | **1** | **0.4** | **0.2** |
| **2020** | **Alkaline** | 32 | 41 | 53 | |
| | **PEM** | 42 | 61 | | 83 |
| **2030** | **Alkaline** | 27 | 32 | 39 | |
| | **PEM** | 32 | 43 | | 56 |

The results showing that alkaline is the cheapest option should be interpreted with caution as factors such as the cost of land area, the cost of hydrogen compression and additional income sources such as variable load operation as support for the grid have not been considered. In a more detailed analysis, these factors might lead to a different result.

## 4.2 Steam methane reforming

Data from IEA's Future of Hydrogen report were used for the costs of SMR technology and are presented in Table 4 together with the expected cost for transport and storage of sequestered carbon dioxide according to HyInfra members. In the analysis, an average cost of 750 NOK/ton is used for carbon transport and storage. An essential parameter for SMR is the cost of natural gas; a value of 200 NOK/MWh is used based on the average historic price between 2014 and 2019 at one of the main natural gas trading hubs in Europe, TTF Hub [13]. The calculation is simplified by assuming no $CO_2$ tax for the 10% of $CO_2$ that is not captured in the carbon capture process.

*Table 4 Input variables used to calculate cost of SMR with CCS*

| SMR w. CCS | | | Source: |
|---|---|---|---|
| Lifetime: | Years | 25 | [14] |
| Investment costs: | kNOK/(Nm3/h) | 35 | |
| Maintenance costs: | Share of CAPEX | 3% | |
| Efficiency: | | 69% | |
| Carbon transport and storage costs: | NOK/ton | 500-1000 | HyInfra workshop |

The costs and operation values presented in Table 4 are based on a reference plant with an hourly production of 100,000 Nm3H2 (~220,000 kg$_{H2}$/day). While the national demand for compressed hydrogen for maritime use is estimated by HyInfra to be ~35,000 $kg_{H2}$/day. One well-developed company within this field, Air Liquid, can offer modular plants down to 10,000 Nm3/h (~22,000 $kg_{H2}$/day) [15] which are assumed to have relatively similar production costs per kilogram produced hydrogen.

## 4.3 Compression

The compression of hydrogen depends on many different parameters and may look different depending on the design of the supply chain. Factors such as the output pressure of the electrolyser, the pressure level at the storage and dispenser sires, the choice of local production or distributed hydrogen and the type of hydrogen dispensing system are important. To keep the analysis manageable, only compression at the production site is included, based on assumptions for a "typical" compressor shown in Table 5, and is assumed to be constant towards 2030. Even if a top-up or high-pressure compressor will probably be required, it accounts for a smaller cost when considering 350 bar systems [16]. Based on the listed assumptions, the compressor would induce a LCOH of 5.6 NOK/$kg_{H2}$.

*Table 5 Input parameters for calculating a representative compressor.*

| Item | Value |
|---|---|
| Capacity (kg/day) | 1000 |
| Max pressure (bar) | 300 |
| Investment cost incl. redundancy (NOK) | 6,000,000 |
| O&M excl. electricity (NOK/year) | 500,000 |
| Lifetime (years) | 10 |
| Energy intensity (kWh/$kg_{H2}$) | 3.25 |

## 4.4 Transport and storage

The modelling of storage is greatly simplified in this analysis. The main technical and economic assumptions are listed in Table 6 and are partly inspired by hydrogen transport modules as shown in Figure 4. In discussion with the company Hexagon, which produces hydrogen transport modules, a 20-25% reduction in costs was estimated as possible towards 2030. This reduction was argued to be achieved mainly with more precise safety margins and to some extent economies of scale [17]. It should be noted that because Hexagon products are made of carbon fibre, their costs for hydrogen transport modules are probably above 5000 NOK/$kg_{H2}$. In this work, a slightly optimistic approach is taken to hydrogen storage cost in 2030 as a 20% reduction is estimated from the previously mentioned costs from 2020. Lifetime is another factor which is hard to estimate, therefore a fixed lifetime is set regardless of how often it is cycled.


*Figure 4 Transport solution of hydrogen by truck in a 20- and 40-foot hydrogen transport module [18, 19]*

*Table 6 Estimated values of a hydrogen transport module*

| Parameter | Value |
|---|---|
| Cost 2020 | 5000 NOK/$kg_{H2}$ |
| Cost 2030 | 4000 NOK/$kg_{H2}$ |
| Storage pressure | 300 bar |
| Capacity for mobile unit | 800 kgH2/unit |
| Storage density<br>(kg hydrogen/total weight) | 4% |
| Lifetime | 25 years |

If the hydrogen needs to be distributed, it will imply higher volumes for buffer storage at the production and the refuelling sites, as well as for transport. This leads to less frequent cycling of the storage and thus smaller volumes of hydrogen among which the costs can be divided. This difference is modelled by assuming that at a local production site, the hydrogen storage tanks will by cycled on average once per day, while if hydrogen is distributed from a larger production site to a marine hydrogen refuelling station, the storage will be cycled once every second day.

The costs for transport of hydrogen are central to this analysis and are based on the cost function for dangerous goods ($C_{transp}$ in NOK) and can be expressed as [20]

$$C_{transp} = 549 * t + 6{,}93 * d + 11 * w + 136 \qquad (2)$$

where *t* is time for the trip (h), *d* is the distance (km) and *w* the weight of the payload (ton). The payload will include the weight of the hydrogen, the storage tanks and accessories for the storage solution. As the truck will need to both deliver the full hydrogen transport module to the hydrogen refueling station and bring back an empty transport module, the transport cost needs to be doubled to represent a single hydrogen delivery. This cost is assumed to be constant until 2030.

## 4.5 Hydrogen refuelling system

Information regarding hydrogen refuelling systems for ships is very sparse as there are basically no hydrogen vessels built to be served by such infrastructure. An estimated cost of 5 million NOK was set after discussion with Ocean Highway Cluster members. This cost is assumed to only provide the dispenser itself without compression, storage or cooling. Approximate costs for compression and storage of a supply chain are included separately, while it is assumed that no pre-cooling of hydrogen will be needed.

A lifetime of 15 years is assumed, as well as that several vessels can bunker from the same dispenser.

If it is assumed that a dispenser is serving only one ship and that daily demand corresponds to the average demand from the vessels assumed to operate with compressed hydrogen (599kg/day), the dispenser is inducing a cost of 2.8 NOK/$kg_{H2}$.

Due to the sparse information on dispenser systems, there is a great deal of uncertainty connected to the technical and economical input parameters for the hydrogen refueling system. However, this uncertainty will have no impact on this analysis as this equipment is involved at the end of the supply chain and in a general analysis like this does not affect the upstream steps. On the other hand, the cost of the hydrogen refueling system will affect the final supplied hydrogen cost and its design might affect suitable location at the harbour considering factors such as space requirements and safety distances.

# 5 Results

Based on data provided in the previous chapters, the levelized cost of hydrogen (LCOH) for the different components and different value chain solutions is presented. These findings will then be used in a national analysis based on pre-defined demand.

## 5.1 Levelized cost of hydrogen

Table 7 summarises the different steps included in the value chain and the cost they induce to the total LCOH in a 2030 scenario. It can also be seen that regardless of set-up, the cost of compression and dispensing is fixed while the other costs vary based on production method and for an eventual distribution step. The cost of transport is presented separately as it is dependent on distance travelled and is shown in Table 8.

*Table 7 The induced LCOH of the different steps in the supply chain*

| **Supply chain step** | Production | Compression | Storage | Transport | Dispensing |
|---|---|---|---|---|---|
| **LCOH (NOK/kg$_{H2}$)** | 22–39 | 5.6 | 1.1–2.2 | See table below | 2.8 |

*Table 8 LCOH induced by transport depending on distance for a 2030 case where 1000 kg are transported at 300 bar in a 40-foot container*

| **Distance (km)** | 5 | 10 | 50 | 100 | 200 | 400 | 800 |
|---|---|---|---|---|---|---|---|
| **LCOH (NOK/kgH2)** | 0.89 | 1.07 | 2.49 | 4.26 | 7.79 | 14.87 | 29.03 |

Based on the different production technologies, including distinct sizes of electrolysers, the cost of delivered hydrogen can be compared between different supply chain alternatives as a function of distance and is depicted in Figure 5. The stippled horizontal line shows the maximum transport distance to reach a price parity between a 1 MWel electrolyser and the 10 MWel or SMR hydrogen supply alternatives. Based on this figure, a matrix of price parity points was elaborated and is shown in Table 9. This matrix is used as decision base to cluster demands.

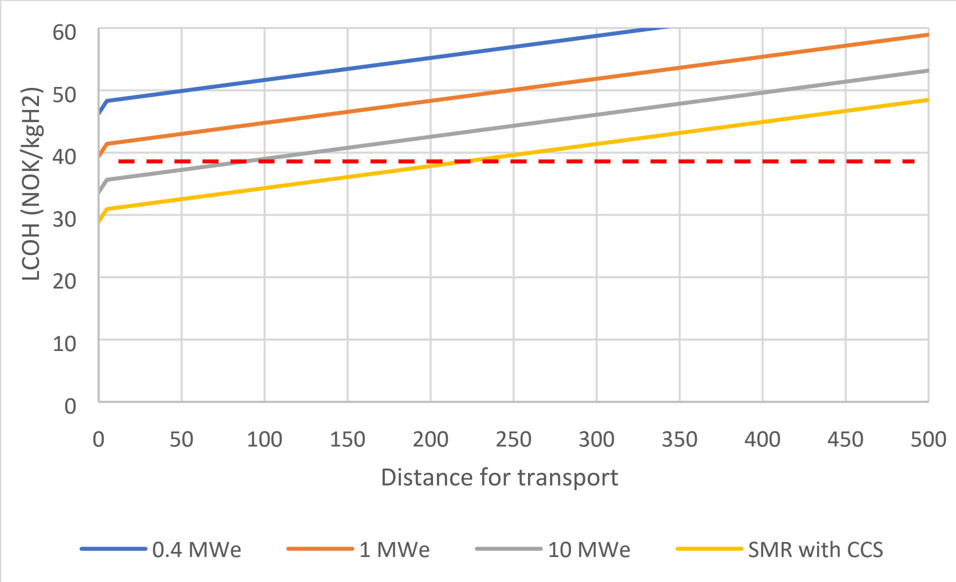


*Figure 5 Variable cost of hydrogen supply chain depending on production technology and distance of transport*

*Table 9 Identified feasible transport distances in km when selecting between local and distributed production*

| | | Local production alternative (electrolyser) | | |
|---|---|---|---|---|
| | | 0.4 $MW_{el}$ | 1 $MW_{el}$ | 10 $MW_{el}$ |
| Source of distributed hydrogen | Electrolyser 0.4 $MW_{el}$ | - | - | - |
| | Electrolyser 1 $MW_{el}$ | 150 | - | - |
| | Electrolyser 10 $MW_{el}$ | 330 | 110 | - |
| | SMR with CCS | 470 | 250 | 70 |

## 5.2 Geographical distribution

Based on the identified price parity distances, suitable demands were clustered through two scenarios with **scenario 1** considering the announced locations for hydrogen production plants by market actors and including the production locations for LH2 set within HyInfra and **Scenario 2** considering the optimal location based soley on the demand for compressed hydrogen from the maritime sector. The clustering was done manually based on the decision rules set in the methodology chapter. The identified production locations and sizes are listed in Table 10 and Table 11 for scenarios 1 and 2 respectively. In addition, both production sites and demand are illustrated for both scenarios and divided between northern and southern Norway in Figure 6 and Figure 7 respectively. A detailed overview of both production sites and demand are shown in tables in Appendices A & B.

*Table 10 Production locations and volumes for Scenario 1*

| Production site | Connection | Location | Daily production volume of compressed H2 (kg) |
|---|---|---|---|
| Local (0) | Andenes-Gryllefjord | 69,3268078, 16,133813 | 186 |
| Local (0) | SørøysundXpressen | 70,6646675, 23,6833834 | 520 |
| Local (0) | Bodø-Svolvær | 68,231487, 14,566642 | 768 |
| Local (0) | Trænaruten | 66,501698, 12,102514 | 494 |
| Local (0) | Dyrøy-Øyrekken | 63,7986987, 8,6814705 | 1118 |
| Local (0) | Gåsvær-Hardbakke | 61,1766807, 4,6945631 | 47 |
| 1 | Glomfjord | 66,815933, 13,94003 | 1637 |
| 2 | Mo i Rana | 66,310437, 14,167243 | 5210 |
| 3 | Finnsnes | 69,221681, 18,082201 | 3118 |
| 4 | Mongstad | 60,810344, 5,031334 | 6160 |
| 4 | Kollsnes, Øygaarden | 60,550048, 4,838676 | |
| 5 | Hellesylt | 62,086274, 6,870644 | 5171 |
| 6 | Berlevåg | 70,854403, 29,117184 | 0 |
| 7 | Florø | 61,608586, 5,049001 | 502 |
| 8 | Trondheim-Kristiansund | 63,438221, 10,39716 | 2816 |
| 9 | Stavanger-Ryfylke | 58,9725825, 5,7402974 | 3311 |
| 10 | Skoleruta i Rognsundet Kvalfjord-Pollen | 70,215343, 23,191892 | 1735 |
| 11 | Aker Brygge-Slemmestad | 59,7824773, 10,4980692 | 749 |

*Table 11 Production locations and volumes for Scenario 2*

| Production site | In connection to the route for | Location | Daily production volume of compressed H2 (kg) |
|---|---|---|---|
| Local (0) | SørøysundXpressen | 69,3268078, 16,133813 | 520 |
| Local (0) | Trænaruten | 62,607904, 6,4488837 | 494 |
| Local (0) | Dyrøy-Øyrekken | 62,2067555, 5,5691984 | 1118 |
| Local (0) | Gåsvær-Hardbakke | 62,087436, 6,870432 | 47 |
| 1 | Sandnessjøen-Bodø and other | 69,977934, 23,331312 | 5275 |
| 2 | Sunnhordaland-Austevoll-Bergen | 63,6867782, 9,6708975 | 3260 |
| 3 | Bergen-Sogn-Flåm | 63,7986987, 8,6814705 | 2225 |
| 4 | Trondheim-Kristiansund | 59,8709668, 10,657193 | 2816 |
| 5 | Bergen-Nordfjord | 60,395307, 5,321904 | 2523 |
| 6 | Brattvåg-Dryna-Fjørtofta-Harøya | 61,6017458, 5,0285202 | 2785 |
| 7 | Tromsø-Harstad | 67,283743, 14,373536 | 2308 |
| 8 | Stavanger-Ryfylke | 59,023752, 5,613677 | 3311 |
| 9 | LoppaXpressen and other | 60,810344, 5,031334 | 2024 |
| 10 | Bodø-Væran | 59,412112, 5,255994 | 1572 |
| 11 | Bodø-Svolvær | 66,3393778, 13,0023048 | 1475 |
| 12 | Askvoll-Fure-Værlandet | 65,821969, 12,430263 | 1040 |
| 13 | Aker Brygge-Slemmestad | 62,086274, 6,870644 | 749 |

Scenario 1 - Considering other hydrogen production facilities

Scenario 2 - Not considering other hydrogen production facilities

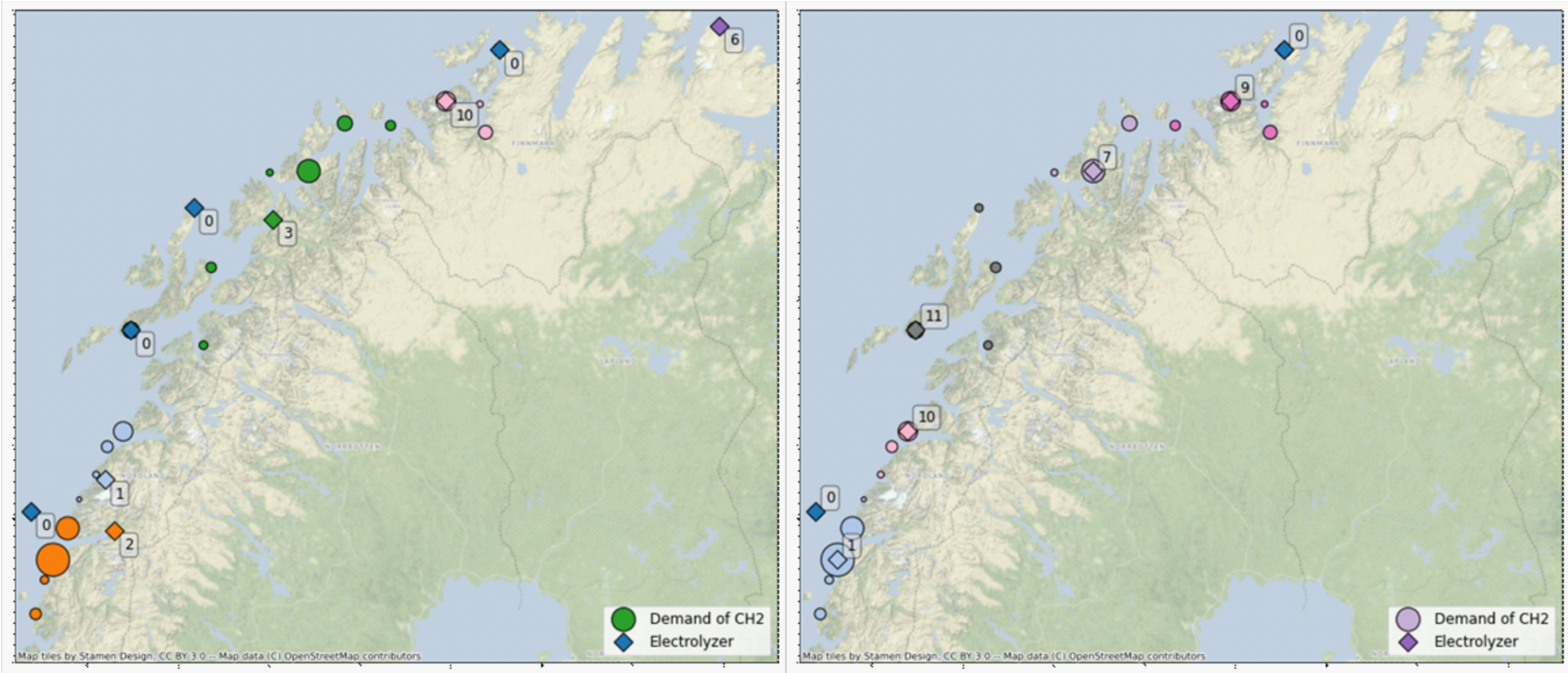


*Figure 6 Assumed demand and its relative size and identified production facilities in northern Norway shown for both scenario 1 (left) and scenario 2 (right). The production and identified demand sites for distribution are color matched. Production sites numbered with 0 represent local production.*

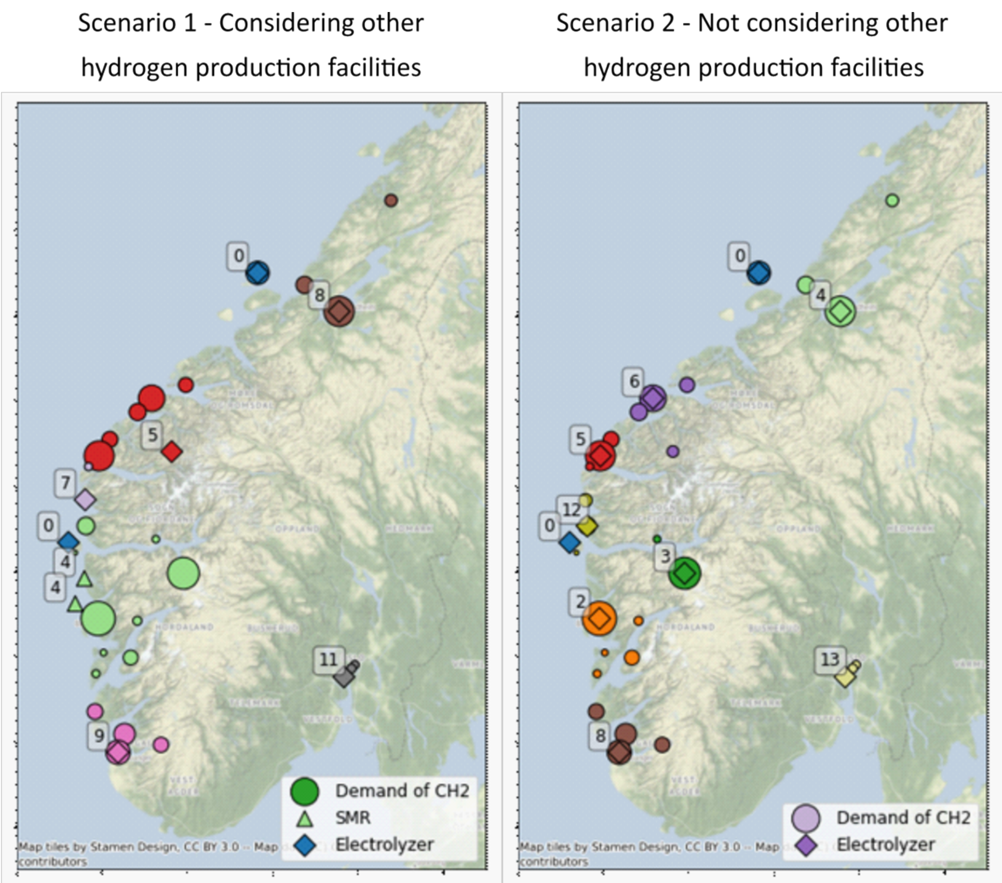


*Figure 7 Assumed demand and its relative size and identified production facilities in northern Norway shown for both scenario 1 (left) and scenario 2 (right). The production and identified demand sites for distribution are color matched. Production sites numbered with 0 represent local production.*

The demand, as shown in Figure 1, is assumed to increase gradually until 2036. How this affects the demand on the production sites identified in this chapter is illustrated in Figure 8 and Figure 9 for scenarios 1 and 2 respectively.

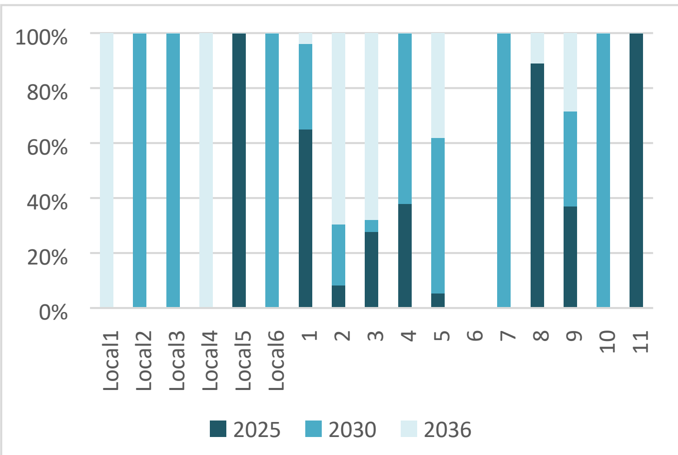


*Figure 8 Overview of when the demand is estimated to appear for the local and clustered production facilities in Scenario 1*

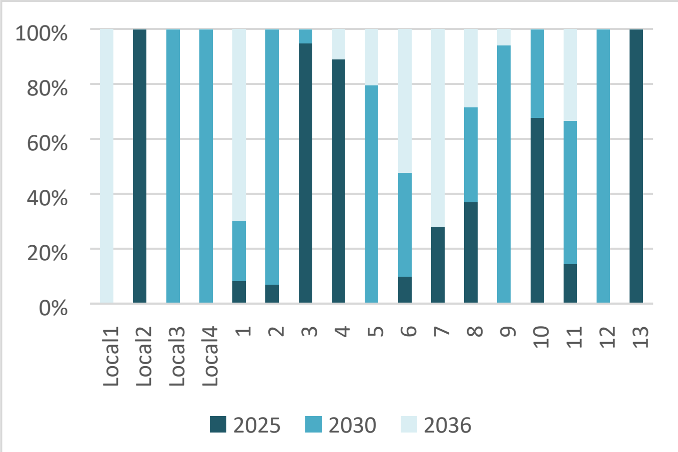


*Figure 9 Overview of when the demand is estimated to appear for the local and clustered production facilities in Scenario 2*

# 6 Discussion and conclusion

This work presents a suggestion of how the expected demand for compressed hydrogen for ferries and high-speed ferries can be satisfied in an efficient manner considering the costs of the different steps in the supply chain. The results show that, with expected 2030 cost levels, local supply chains will develop with cost of transport playing a central role. For the cheapest production alternative, SMR with CCS, it is worth it to distribute the hydrogen up to 470 km in a 2030 cost scenario if the demand is approx. 200 kg hydrogen per day while from a large electrolyser, the feasible distribution distance is up to 330 km to satisfy the same volume of demand. With larger demand, local production becomes more feasible and the distribution distances decrease.

The difference between scenarios 1 and 2 shows that there is great flexibility in terms of where the production facilities can be located. In addition, it shows that what the supply of compressed hydrogen looks like can depend on developments in where hydrogen is produced based on demand in other sectors. As the demand for compressed hydrogen in general is relatively small in terms of volume per location, those locations that are closest to large hydrogen production facilities mainly facing demand for hydrogen from other sectors will be able to enjoy lower production costs and thus become more competitive in comparison with other zero-emission technologies. On the other hand, it was observed that when the supply chain relies on production initiated by other sources of demand, local production became the most feasible option for more demands for maritime compressed hydrogen. This translates to smaller production units with more expensive fuel. It enforces the idea that the competitiveness of compressed hydrogen is dependent on other hydrogen projects.

This work shows how all the expected demand can be covered in the most efficient manner; however, the demand will increase stepwise until 2036. Due to the incremental nature of demand and necessary investments in production facilities, the supply chain might look different as the first investments are made to satisfy the first demand, thereby creating some lock-in effects for supply chain development. It could have similar effects to the already announced hydrogen production facilities and result in more local production, as the location of the first plants might be sub-optimal.

Another finding of this work has been that compressed hydrogen for the maritime sector is not geographically concentrated enough to motivate an SMR plant on its own as it is assumed to need a demand of at least ~20,000 $nm^3_{H2}$/h (~20,000 $kg_{H2}$/day).

The location of hydrogen production will depend on more factors than just where the demand is, for example access to grid capacity, access to land, and the possibility to offset biproducts of oxygen and heat might play an important role. It can be concluded that even if this work gives an idea of what an effective supply chain might look like considering the expected demand in 2036, there are many more parameters that will affect the actual investment decisions regarding where and how the hydrogen production will be realized.

As already mentioned, the transport cost of compressed hydrogen is a main design parameter of the supply chain. Therefore, if new ways of transporting hydrogen were to be introduced, a more concentrated hydrogen production could be enabled. For example, sea transport of compressed hydrogen could provide shorter transport distances along the geographically challenging Norwegian coastline.

The main analysis of this work is based on a set of decision rules which are implemented through a manual decision-making process for each location. For each location, different options needed to be evaluated and weighted against each other; this is demanding work with many numbers to keep in mind. Due to the large amount of manual decisions, some irrelevant results are to be expected. The largest manual errors were noted and corrected when the production and demand sites where plotted on a map; however, some inconsequent decisions might be present, biased by a desire to cluster the demand. Another shortcoming has been that the demand is variable while the costs for production are based on three fixed electrolyser sizes, which required further simplifications in the analysis.

## 6.1 Future work

Several things can be done to improve the quality of this work, a central one of which is to create a code which could optimise the value chain to replace current manual methods. Another would be to identify the supply chain through time-steps so that it expands together with the demand. This would represent better how the actual development will occur.

The model could be expanded to also include possible demand from other sectors, such as forecasts of hydrogen demand for heavy-duty road transport. Again, this could better represent reality.

In addition, there is a great potential for more detailed analysis of the electrolyser locations, including assessment of access to grid, land and offset of biproducts (oxygen and heat). Such analysis could provide more reliable information regarding the most feasible location for the electrolyser.

Finally, the development of compressed hydrogen transport will have a considerable effect on the supply chain, so innovation in both road and sea transport might create a large impact on the supply chain of compressed hydrogen.

# 7 Acknowledgment

This report is part of the HyInfra project organised and partly financed by Ocean Hyway Cluster. Acknowledgement goes to Steinar Kostøl and Mark Purkis at Ocean Hyway Cluster to and its members for providing valuable feedback and technological insight for this report.

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MoZEES – Mobility Zero Emission Energy Systems, cosponsored by the Research Council of Norway (project number 257653) and 40 partners from research, industry and the public sector.

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## Appendix A - Overview of production and demand sites for Scenario 1

| Index | prod_ index | Connection | Location | Vessel type | Average daily demand (kg) | Distribution site | Production site | Distance | Daily production volume (kg) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | Andenes-Gryllefjord | 69,3268078, 16,133813 | Ferry | 186 | 0 | Local | | 186 |
| **9** | 9 | SørøysundXpressen | 70,6646675, 23,6833834 | High-speed ferry | 520 | 0 | Local | | 520 |
| **17** | 17 | Bodø-Svolvær | 68,231487, 14,566642 | High-speed ferry | 768 | 0 | Local | | 768 |
| **23** | 23 | Trænaruten | 66,501698, 12,102514 | High-speed ferry | 494 | 0 | Local | | 494 |
| **28** | 28 | Dyrøy-Øyrekken | 63,7986987, 8,6814705 | High-speed ferry | 1118 | 0 | Local | | 1118 |
| **37** | 37 | Gåsvær-Hardbakke | 61,1766807, 4,6945631 | High-speed ferry | 47 | 0 | Local | | 47 |
| **51** | 51 | Glomfjord | 66,815933, 13,94003 | Electrolyser | | 1 | 1 | | 1637 |
| **19** | 51 | Bodø-Væran | 67,283743, 14,373536 | Cluster | 1063 | 1 | | 136 | |
| **20** | 51 | Bodø-Ytre Gildeskål | 67,1372797, 13,9795494 | High-speed ferry | 384 | 1 | | 76 | |
| **21** | 51 | Meløy | 66,8672878, 13,7038281 | High-speed ferry | 125 | 1 | | 18 | |
| **22** | 51 | Rødøy-Melfjordbotn | 66,624259, 13,2852 | High-speed ferry | 64 | 1 | | 69 | |
| **52** | 52 | Mo i Rana | 66,310437, 14,167243 | Electrolyser | | 2 | 2 | | 5210 |
| **2** | 52 | Stokkvågen-Onøy-Sleneset-Lovund and other | 66,3393778, 13,0023048 | Cluster | 1510 | 2 | | 74 | |
| **24** | 52 | Sandnessjøen-Bodø and other | 66,024375, 12,639482 | Cluster | 3135 | 2 | | 110 | |
| **25** | 52 | Forvik-Vistensteder og Tjøtta-Husvika | 65,821969, 12,430263 | High-speed ferry | 202 | 2 | | 146 | |
| **26** | 52 | Brønnøysund-Sandnessjøen + Brønnøysund-Rørøy (Vega) | 65,4740329, 12,2092223 | High-speed ferry | 364 | 2 | | 243 | |
| **53** | 53 | Finnsnes | 69,221681, 18,082201 | Electrolyser | | 3 | 3 | | 3118 |
| **0** | 53 | Hansnes-Vannøy | 70,053535, 19,8528594 | Ferry | 649 | 3 | | 229 | |
| **12** | 53 | Tromsø-Skjervøy and other | 70,0353393, 20,9829403 | Cluster | 289 | 3 | | 254 | |
| **14** | 53 | Tromsø-Harstad | 69,646943, 18,959549 | High-speed ferry | 1525 | 3 | | 153 | |
| **15** | 53 | Sommarøy-Tussøy-Sandneshamn | 69,6340507, 17,9971567 | High-speed ferry | 133 | 3 | | 165 | |
| **16** | 53 | Harstad-Flakstadvåg | 68,8008765, 16,5478639 | High-speed ferry | 307 | 3 | | 122 | |
| **18** | 53 | Tysfjord | 68,0930686, 16,3580214 | High-speed ferry | 214 | 3 | | 233 | |
| **54** | 54 | Mongstad | 60,810344, 5,031334 | Electrolyser/SMR | | 4 | 4 | | 6160 |

| Index | prod_ index | Connection | Location | Vessel type | Average daily demand (kg) | Distribution site | Production site | Distance | Daily production volume (kg) |
|---|---|---|---|---|---|---|---|---|---|
| **55** | 54 | Kollsnes, Øygaarden | 60,550048, 4,838676 | SER – demo | | 4 | 4 | 115 | |
| **6** | 54 | Askvoll-Fure-Værlandet | 61,3453005, 5,0644085 | Ferry | 630 | 4 | | 121 | |
| **36** | 54 | Flåm-Balestrand | 61,2101118, 6,5379471 | High-speed ferry | 113 | 4 | | 161 | |
| **38** | 54 | Hardbakke-Utvær | 61,0722132, 4,8375079 | High-speed ferry | 45 | 4 | | 81 | |
| **39** | 54 | Bergen-Sogn-Flåm | 60,8630605, 7,1169918 | High-speed ferry | 2111 | 4 | | 205 | |
| **40** | 54 | Sunnhordaland-Austevoll-Bergen | 60,395307, 5,321904 | Cluster | 2422 | 4 | | 68 | |
| **41** | 54 | Norheimsund-Herand-Utne-Kinarsvik-Loftshus-Ulvik-Eidfjord | 60,371531, 6,146505 | High-speed ferry | 166 | 4 | | 115 | |
| **42** | 54 | Reksteren-Våge-Os | 60,0381559, 5,4359447 | High-speed ferry | 90 | 4 | | 136 | |
| **43** | 54 | Rosendal-Bergen | 59,9860597, 6,0072091 | High-speed ferry | 453 | 4 | | 156 | |
| **46** | 54 | Austevoll ruten | 59,8162548, 5,2757573 | High-speed ferry | 128 | 4 | | 174 | |
| **56** | 56 | Hellesylt | 62,086274, 6,870644 | Electrolyser | | 5 | 5 | | 5171 |
| **3** | 56 | Brattvåg-Dryna-Fjørtofta-Harøya | 62,607904, 6,4488837 | Cluster | 1455 | 5 | | 103 | |
| **4** | 56 | Larsnes-Voksa-Åram-Kvamsøya | 62,2067555, 5,5691984 | Ferry | 518 | 5 | | 106 | |
| **5** | 56 | Geiranger-Hellesylt | 62,087436, 6,870432 | Ferry | 274 | 5 | | 0 | |
| **31** | 56 | Molde-Helland-Vikebuktsekken | 62,7368539, 7,1689301 | High-speed ferry | 454 | 5 | | 106 | |
| **32** | 56 | Ålesund-Valderøya-Nordøyane | 62,4742543, 6,1532936 | High-speed ferry | 602 | 5 | | 87 | |
| **33** | 56 | Bergen-Nordfjord | 62,0445606, 5,3432954 | High-speed ferry | 1869 | 5 | | 127 | |
| **57** | 57 | Berlevåg | 70,854403, 29,117184 | Electrolyser | | 6 | 6 | | 0 |
| **58** | 58 | Florø | 61,608586, 5,049001 | Electrolyser | | 7 | 7 | | 502 |
| **34** | 58 | Florø-Måløy | 61,938035, 5,118909 | High-speed ferry | 137 | 7 | | 99 | |
| **35** | 58 | Florø-Svanøy-Askrova | 61,6017458, 5,0285202 | High-speed ferry | 365 | 7 | | 2 | |
| **30** | 30 | Trondheim-Kristiansund | 63,438221, 10,39716 | High-speed ferry | 1896 | 8 | 8 | | 2816 |
| **27** | 30 | Namsos-Leka og Rørvik | 64,464085, 11,492235 | High-speed ferry | 310 | 8 | | 192 | |
| **29** | 30 | Trondheim-Brekstad | 63,6867782, 9,6708975 | High-speed ferry | 610 | 8 | | 109 | |
| **50** | 50 | Stavanger-Ryfylke | 58,9725825, 5,7402974 | Cluster | 1223 | 9 | 9 | | 3311 |
| **7** | 50 | Haugesund-Utsira | 59,412112, 5,255994 | Ferry | 510 | 9 | | 122 | |

| Index | prod_ index | Connection | Location | Vessel type | Average daily demand (kg) | Distribution site | Production site | Distance | Daily production volume (kg) |
|---|---|---|---|---|---|---|---|---|---|
| **8** | 50 | Finnøysambandet | 59,1701176, 5,8775741 | Ferry | 942 | 9 | | 81 | |
| **48** | 50 | Stavanger-Kvitsøy | 59,023752, 5,613677 | High-speed ferry | 160 | 9 | | 51 | |
| **49** | 50 | Stavanger-Lysebotn | 59,0545822, 6,6452997 | High-speed ferry | 476 | 9 | | 84 | |
| **10** | 10 | Skoleruta i Rognsundet Kvalfjord-Pollen | 70,215343, 23,191892 | High-speed ferry | 120 | 10 | 10 | | 1735 |
| **11** | 10 | LoppaXpressen and other | 70,2395601, 22,350474 | Cluster | 1074 | 10 | | 165 | |
| **13** | 10 | Alta-Hammerfest and other | 69,977934, 23,331312 | Cluster | 541 | 10 | | 53 | |
| **47** | 47 | Aker Brygge-Slemmestad | 59,7824773, 10,4980692 | High-speed ferry | 425 | 11 | 11 | | 749 |
| **44** | 47 | Aker Brygge - Drøbak | 59,9104764, 10,7299428 | High-speed ferry | 149 | 11 | | 31 | |
| **45** | 47 | Nesodden-Lysaker | 59,8709668, 10,657193 | High-speed ferry | 175 | 11 | | 51 | |

## Appendix B - Overview of production and demand sites for Scenario 2

| Index | prod_ index | Connection | Location | Vessel type | Average daily demand (kg) | Distribution site | Production site | Distance | Daily production volume (kg) |
|---|---|---|---|---|---|---|---|---|---|
| **9** | 9 | SørøysundXpressen | 69,3268078, 16,133813 | High-speed ferry | 520 | 0 | Local | | 520 |
| **23** | 23 | Trænaruten | 62,607904, 6,4488837 | High-speed ferry | 494 | 0 | Local | | 494 |
| **28** | 28 | Dyrøy-Øyrekken | 62,2067555, 5,5691984 | High-speed ferry | 1118 | 0 | Local | | 1118 |
| **37** | 37 | Gåsvær-Hardbakke | 62,087436, 6,870432 | High-speed ferry | 47 | 0 | Local | | 47 |
| **24** | 24 | Sandnessjøen-Bodø and other | 69,977934, 23,331312 | Cluster | 3135 | 1 | 1 | | 5275 |
| **2** | 24 | Stokkvågen-Onøy-Sleneset-Lovund and other | 70,0353393, 20,9829403 | Cluster | 1510 | 1 | | 108 | |
| **22** | 24 | Rødøy-Melfjordbotn | 70,215343, 23,191892 | High-speed ferry | 64 | 1 | | 150 | |
| **25** | 24 | Forvik-Vistensteder og Tjøtta-Husvika | 69,646943, 18,959549 | High-speed ferry | 202 | 1 | | 39 | |
| **26** | 24 | Brønnøysund-Sandnessjøen + Brønnøysund-Rørøy (Vega) | 69,6340507, 17,9971567 | High-speed ferry | 364 | 1 | | 91 | |
| **40** | 40 | Sunnhordaland-Austevoll-Bergen | 63,6867782, 9,6708975 | Cluster | 2422 | 2 | 2 | | 3260 |
| **41** | 40 | Norheimsund-Herand-Utne-Kinarsvik-Loftshus-Ulvik-Eidfjord | 63,438221, 10,39716 | High-speed ferry | 166 | 2 | | 78 | |
| **42** | 40 | Reksteren-Våge-Os | 62,7368539, 7,1689301 | High-speed ferry | 90 | 2 | | 73 | |
| **43** | 40 | Rosendal-Bergen | 62,4742543, 6,1532936 | High-speed ferry | 453 | 2 | | 120 | |
| **46** | 40 | Austevoll ruten | 62,0445606, 5,3432954 | High-speed ferry | 128 | 2 | | 111 | |
| **39** | 39 | Bergen-Sogn-Flåm | 63,7986987, 8,6814705 | High-speed ferry | 2111 | 3 | 3 | | 2225 |
| **36** | 39 | Flåm-Balestrand | 65,4740329, 12,2092223 | High-speed ferry | 113 | 3 | | 118 | |
| **30** | 30 | Trondheim-Kristiansund | 59,8709668, 10,657193 | High-speed ferry | 1896 | 4 | 4 | | 2816 |
| **27** | 30 | Namsos-Leka og Rørvik | 59,8162548, 5,2757573 | High-speed ferry | 310 | 4 | | 192 | |
| **29** | 30 | Trondheim-Brekstad | 59,7824773, 10,4980692 | High-speed ferry | 610 | 4 | | 109 | |
| **33** | 33 | Bergen-Nordfjord | 60,395307, 5,321904 | High-speed ferry | 1869 | 5 | 5 | | 2523 |
| **4** | 33 | Larsnes-Voksa-Åram-Kvamsøya | 61,2101118, 6,5379471 | Ferry | 518 | 5 | | 62 | |
| **34** | 33 | Florø-Måløy | 59,9860597, 6,0072091 | High-speed ferry | 137 | 5 | | 46 | |
| **3** | 3 | Brattvåg-Dryna-Fjørtofta-Harøya | 61,6017458, 5,0285202 | Cluster | 1455 | 6 | 6 | | 2785 |

| Index | prod_ index | Connection | Location | Vessel type | Average daily demand (kg) | Distribution site | Production site | Distance | Daily production volume (kg) |
|---|---|---|---|---|---|---|---|---|---|
| **5** | 3 | Geiranger-Hellesylt | 61,1766807, 4,6945631 | Ferry | 274 | 6 | | 103 | |
| **31** | 3 | Molde-Helland-Vikebuktsekken | 61,0722132, 4,8375079 | High-speed ferry | 454 | 6 | | 66 | |
| **32** | 3 | Ålesund-Valderøya-Nordøyane | 60,8630605, 7,1169918 | High-speed ferry | 602 | 6 | | 48 | |
| **14** | 14 | Tromsø-Harstad | 67,283743, 14,373536 | High-speed ferry | 1525 | 7 | 7 | | 2308 |
| **0** | 14 | Hansnes-Vannøy | 68,231487, 14,566642 | Ferry | 649 | 7 | | 77 | |
| **15** | 14 | Sommarøy-Tussøy-Sandneshamn | 67,1372797, 13,9795494 | High-speed ferry | 133 | 7 | | 58 | |
| **50** | 50 | Stavanger-Ryfylke | 59,023752, 5,613677 | Cluster | 1223 | 8 | 8 | | 3311 |
| **7** | 50 | Haugesund-Utsira | 59,0545822, 6,6452997 | Ferry | 510 | 8 | | 122 | |
| **8** | 50 | Finnøysambandet | 58,9725825, 5,7402974 | Ferry | 942 | 8 | | 81 | |
| **48** | 50 | Stavanger-Kvitsøy | 66,815933, 13,94003 | High-speed ferry | 160 | 8 | | 51 | |
| **49** | 50 | Stavanger-Lysebotn | 66,310437, 14,167243 | High-speed ferry | 476 | 8 | | 84 | |
| **11** | 11 | LoppaXpressen and other | 60,810344, 5,031334 | Cluster | 1074 | 9 | 9 | | 2024 |
| **10** | 11 | Skoleruta i Rognsundet Kvalfjord-Pollen | 69,221681, 18,082201 | High-speed ferry | 120 | 9 | | 165 | |
| **12** | 11 | Tromsø-Skjervøy and other | 68,0930686, 16,3580214 | Cluster | 289 | 9 | | 177 | |
| **13** | 11 | Alta-Hammerfest and other | 60,550048, 4,838676 | Cluster | 541 | 9 | | 113 | |
| **19** | 19 | Bodø-Væran | 59,412112, 5,255994 | Cluster | 1063 | 10 | 10 | | 1572 |
| **20** | 19 | Bodø-Ytre Gildeskål | 59,1701176, 5,8775741 | High-speed ferry | 384 | 10 | | 100 | |
| **21** | 19 | Meløy | 70,6646675, 23,6833834 | High-speed ferry | 125 | 10 | | 118 | |
| **17** | 17 | Bodø-Svolvær | 66,3393778, 13,0023048 | High-speed ferry | 768 | 11 | 11 | | 1475 |
| **1** | 17 | Andenes-Gryllefjord | 70,053535, 19,8528594 | Ferry | 186 | 11 | | 212 | |
| **16** | 17 | Harstad-Flakstadvåg | 66,8672878, 13,7038281 | High-speed ferry | 307 | 11 | | 169 | |
| **18** | 17 | Tysfjord | 66,624259, 13,2852 | High-speed ferry | 214 | 11 | | 117 | |
| **6** | 6 | Askvoll-Fure-Værlandet | 65,821969, 12,430263 | Ferry | 630 | 12 | 12 | | 1040 |
| **35** | 6 | Florø-Svanøy-Askrova | 59,9104764, 10,7299428 | High-speed ferry | 365 | 12 | | 117 | |
| **38** | 38 | Hardbakke-Utvær | 64,464085, 11,492235 | High-speed ferry | 45 | 12 | | 110 | |
| **47** | 47 | Aker Brygge-Slemmestad | 62,086274, 6,870644 | High-speed ferry | 425 | 13 | 13 | | 749 |

| Index | prod_ index | Connection | Location | Vessel type | Average daily demand (kg) | Distribution site | Production site | Distance | Daily production volume (kg) |
|---|---|---|---|---|---|---|---|---|---|
| **44** | 47 | Aker Brygge - Drøbak | 70,854403, 29,117184 | High-speed ferry | 149 | 13 | | 31 | |
| **45** | 47 | Nesodden-Lysaker | 61,608586, 5,049001 | High-speed ferry | 175 | 13 | | 51 | |

**Tittel: Future compressed hydrogen infrastructure for the domestic maritime sector**

**Dokumentklasse:**

**Signaturer:**

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