Arena Ocean Hyway Cluster

HYINFRA

2030 Hydrogen Demand in the Norwegian Domestic Maritime Sector

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SUMMARY

This report summarizes the work that has been carried out as part of work package C in the project OHC HyInfra. The overall aim of the work has been to map and estimate the potential future hydrogen demand in the Norwegian domestic maritime sector, and thereby contribute to an overview of future possible bunkering locations and hydrogen infrastructure in Norway. The data presented in this report and the sub-reports C1, C2, C3 and C4 will be used as a basis for the work package B in the HyInfra project.

Focus has been on hydrogen and ammonia demand in the following sectors: offshore, domestic ferries and high-speed passenger ferries, as well as the Kystruten and other publicly known projects. Estimates are based on scenarios with varying uptake of hydrogen-based fuels depending on sector specific assumptions and data. The basis for the assumptions on fuels for different ship types are described in the report from work package A (maritime end users).

2030 has been used as a basis for scenarios, however in some sectors information about contract durations exceeding 2030 are available. Therefore, scenarios have been extended to include possible hydrogen projects until 2035 for the sectors Kystruten, car ferries and high-speed crafts. For the offshore sector estimates are based on 2030.

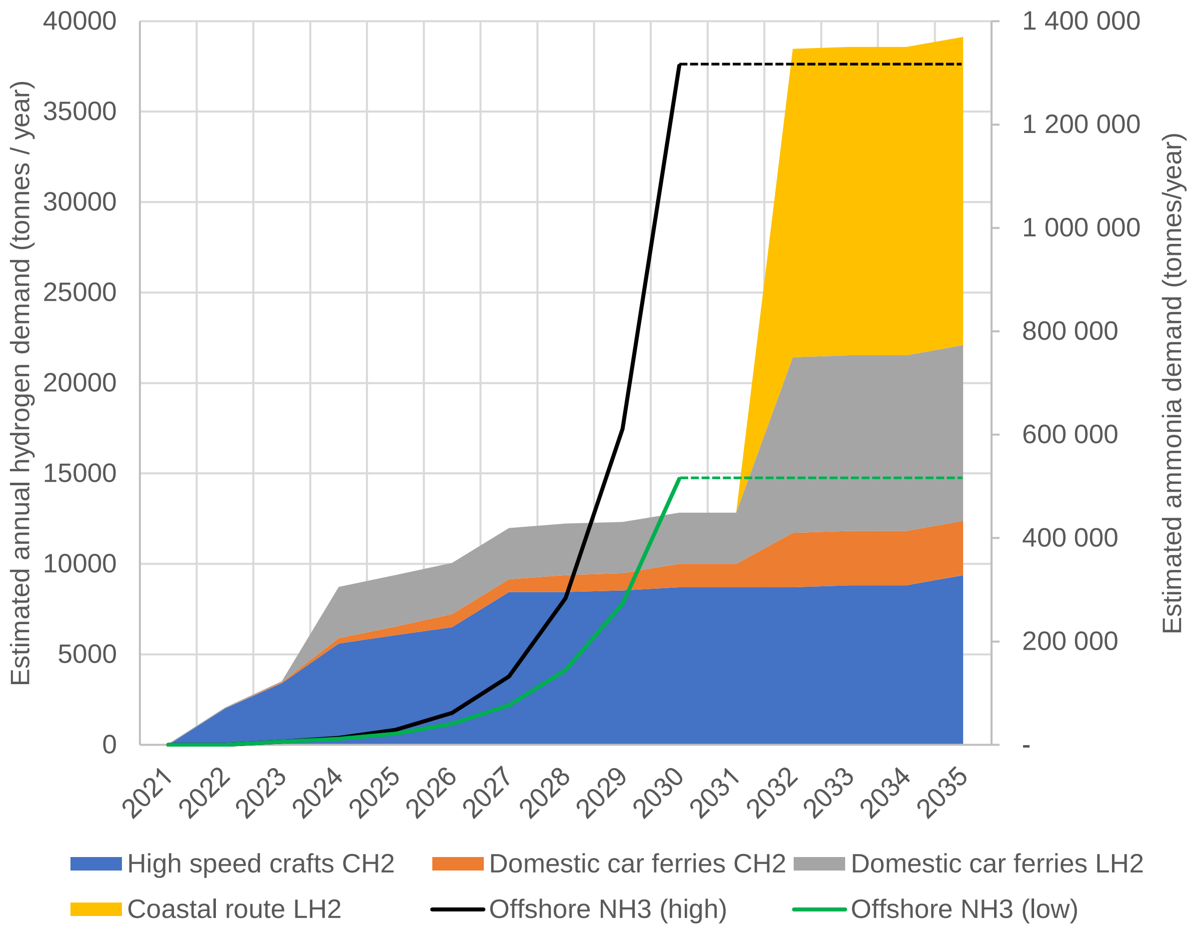
The figure “potential demand 2021-2035” on next page depicts the total estimated hydrogen and ammonia demand from 2021 to 2035, as well as the demand in each sector. **A total hydrogen demand of 39.000 tonnes (4,7 million gigajoules) has been found in 2035. The ammonia demand in the offshore sector been found to be in the range 0,5 to 1,3 million tonnes or 9,7 – 24,8 million gigajoules annually in 2030.**

Based on assessments as presented in work package A and findings from the current work, **a significant demand for ammonia (NH_3), liquid hydrogen (LH2) and compressed hydrogen (CH2) is expected in the domestic maritime sector in 2035**. Hydrogen demand is expected to increase gradually from 2022-24 until 2032. In 2032 a substantial increase in hydrogen demand is expected due to many contracts being renewed in the sectors subject to public tenders.

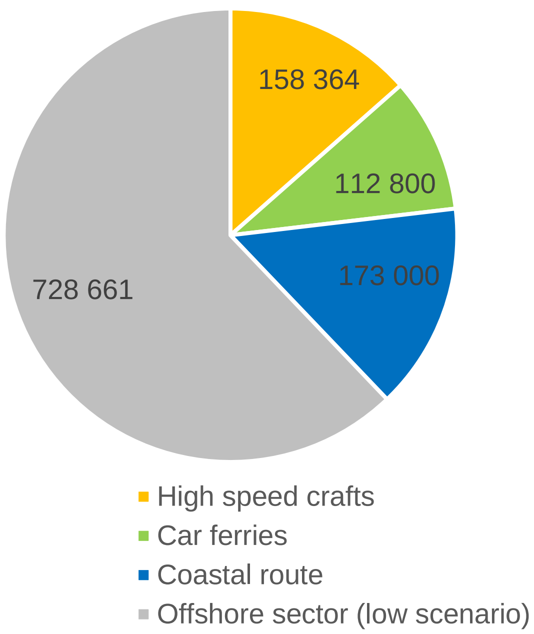
The potential carbon dioxide emission reductions for the relevant sectors are illustrated in the figure “CO_2 reduction potential” on next page. The given data is based on the high scenarios for the sectors car ferries, high speed ferries and the Kystruten, whereas low scenario estimates from the offshore sector has been used. **Switching to zero emission, hydrogen-based fuels, can potentially reduce annual CO_2 emissions by more than 1,17 million tonnes by 2035. This roughly corresponds to the annual carbon dioxide emissions from 780 000 Norwegian cars.**

As part of the HyInfra project a digital map on OHC webpage has been developed. The map shows vessels and routes that are included in the work package C and indicates bunkering locations for the different vessel categories. The map will be continuously updated when new projects are added or when new estimates becomes available. The map can be accessed in the members area on OHC webpage by clicking on the following link: https://www.oceanhywaycluster.no/membersarea

POTENTIAL DEMAND 2021 – 2035



CO_2 REDUCTION POTENTIAL (TONNES/YEAR)



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DOCUMENT HISTORY

The document will be updated when new or updated information becomes available, or when additional ship categories / sectors are added.

Revision	Date	Description	Sign
01	28.04.2020	Report covering domestic car ferries, high speed crafts, offshore and other known projects	SFK

1 INTRODUCTION

In the action plan for green shipping from 2019 by the Norwegian government it is clearly stated that Norway is to become a low emission society. In order to achieve this, large emission reductions and technology developments are required in all sectors. For the maritime sector alone DNV GL estimated that the total CO_2-emissions from domestic shipping in Norway was 4,8 million tonnes in 2017.

There is currently a widespread focus on climate gas reductions in many sectors and organizations. The International Maritime Organization (IMO) has set an ambitious goal of at least 50% reduction in greenhouse gas emissions (compared to 2008) by 2050 in the maritime sector alone. The same organization aims for a 40% reduction of carbon dioxide emissions per transport work by 2030.

In order to achieve the emission reduction targets as set forth by both Norwegian government, the IMO and other organizations, there is a need for zero-carbon fuels.

Ocean Hyway Cluster (OHC) is the Norwegian national cluster for maritime use of hydrogen. The cluster focuses on the entire hydrogen value chain, including production, storage and distribution and end users. OHC will contribute to making hydrogen available to the Norwegian maritime market. The main purpose of the work in clustering is to develop safe, reliable technical solutions for hydrogen-based energy systems to propel vessels. The goal is for Norwegian companies to take a leading position globally and that the development work that is taking place in the cluster will lead to increased exports from the maritime sector and associated supplier industry.

At OHC, we believe that hydrogen as a maritime fuel will play a key role in the future marine energy mix. We believe that in order to achieve the necessary emission targets, widespread use of liquid hydrogen, compressed hydrogen and ammonia (NH_3) will be needed in the maritime industry.

***Figure 1**: Træna ferry connection in Nordland. Photo by: Kari-Ann Dragland Stangen/Helgelands Blad.*

1.1 Objective and Scope

The purpose of the study is to highlight the potential future (2030) hydrogen and ammonia demand in the Norwegian domestic maritime sector. Estimates will be based on information available in OHC at the time of writing. The report will be updated with new public information, updated data from cluster members or when new estimates become available.

The overall goal of the work is to provide estimated data about future hydrogen demand. Presented figures and data should thereby only be used as a reference.

It was decided early to limit the scope of the work and initially focus on ship types and markets where it is expected zero or close to zero emission requirements by 2030. For the first version of the report the scope is therefore limited to the following categories:

- Domestic car ferries subject to public tenders
- Domestic high-speed ferries subject to public tenders
- The Kystruten which is subject to public tenders
- Offshore ships (PSV, AHTS and mobile drilling units) subject to contracts with oil & gas operators which has signalized significant greenhouse gas reductions by 2030
- Other known hydrogen projects

1.2 Project HyInfra

HyInfra is an Ocean Hyway Cluster (OHC) project aiming to reduce technical uncertainties related to future hydrogen infrastructure projects. The project is structured in work packages as indicated in the table below. The current report is part of work package C and aims on mapping the size and location of the future hydrogen demand in the maritime sector. The following sub-reports have been made as part of the work package C:

- C.1 Mapping 2030 hydrogen demand for high speed ferries (report by IFE)
- C.2 Mapping 2030 hydrogen demand for domestic car ferries (report by OHC/Multi-Maritime)
- C.3 Mapping 2030 hydrogen demand for the Kystruten (report by OHC)
- C.4 Mapping 2030 hydrogen and ammonia demand in the offshore sector (report by Amon Maritime)

As part of work package A, Sintef Ocean has prepared a report describing the fuel options and ship types relevant for zero carbon fuels. Information about the most suitable hydrogen-based fuels for different vessel types are presented in the report, and this input is used as basis for the assumptions in the current work (work package C).

The results of the work package A and C will be used as the basis for describing technology options and possible future value chains for maritime hydrogen and ammonia infrastructure in Norway (work package B).

Work package		Delivery
A	Ship types and relevant fuel types	Report
B	Future hydrogen value chain, technology and suppliers	Report, digital map and data
C	Mapping future hydrogen demand	Reports, digital map
D	Barriers (safety, politics, finance etc)	Reports
E	Uncertainty and project risk related to H_2 infrastructure projects	Report, risk registers
F	Financing and costs	Report. Price levels.

1.3 General assumptions and limitations

Estimating the maritime hydrogen and ammonia demand in 2030 involves a large degree of uncertainty relating to scenarios, applied data and end results. Therefore, the following general assumptions and limitations have been adopted:

- Zero emission technology in 2030 is defined as technology with no local emissions of carbon dioxide or other greenhouse gases. To estimate carbon dioxide emission reductions “tank to wake” emission factors are used.

- It is assumed that there will be a mix of energy carriers for different ship types. Expected fuel types for different ship categories are described in the work package A report by Sintef Ocean.

- Based on conclusions from work package A, it is assumed that the vessel types considered in the offshore sector will predominantly operate on ammonia in order to achieve zero emissions in a future scenario. Ammonia is not considered relevant for passenger vessels.

- Based on conclusions from work package A, it is assumed that liquid hydrogen is only relevant for vessels with hydrogen consumption above 1000kg between bunkering. Below 1000kg, compressed hydrogen is considered to be the best technical and economic solution.

- It is assumed that hydrogen and ammonia as marine fuels are developed and mature by 2030 with regards to bunkering, on board storage, conversion, integration and rules/regulations.

- Engine and fuel cell efficiencies based on 2020 technology is applied for calculations. Data used are depicted in the appendix

- Energy consumption and hull performance of future ship types are assumed to be the same level as modern vessels in 2020. No attempt is made on predicting future developments.

- It is assumed no major developments (more than 10% lower power demand at given speed) within ship performance the next 10 years. It is assumed that hydro foils and other “new” technology trends are not widespread by 2030

- For known routes and contracts, it is assumed that the same timetables and vessel capacities will apply for new contracts

- All future public tenders for car ferry, high-speed craft and Kystruten operation will require zero emissions, if technical feasible.

- For projects that are not yet initialized, it is assumed that the earliest start-up date for hydrogen operated vessels is 3 years from the time of writing.

1.4 Scenarios

Descriptions of scenarios and specific assumptions related to data and methods are given in the sub reports C.1-C.4. In general, the presented figures are based on 2030 scenarios where a certain level of hydrogen or ammonia use is assumed. For some sectors where contract details are known, scenarios and increase of demand prior to 2030 are based on available information from existing contracts. Also, some contracts relevant for hydrogen operation will be renewed after 2030. For this reason, the 2030 scenarios are extended to include potential hydrogen demand until 2035.

2 MAPPING OF FUTURE HYDROGEN DEMAND

Detailed descriptions of methods, scenarios and analysis for the different vessel categories are given in the sub-reports C.1-C.4. A short description of the vessel categories is given below, as well as a summary of methods and main findings.

2.1 HIGH-SPEED PASSENGER FERRIES (C.1)

High-speed passenger ferries play an important role in the Norwegian public transportation system, but is unfortunately the mode of transport with highest associated CO_2 emissions per passenger-km. Of the 100 high-speed passenger ferry routes in Norway, diesel is used as fuel for all vessels currently in operation. In total the high-speed passenger ferry sector consumes about 56 million litres of diesel per year, equivalent to approx. 0,7% off all the consumed fossil fuels in Norway.

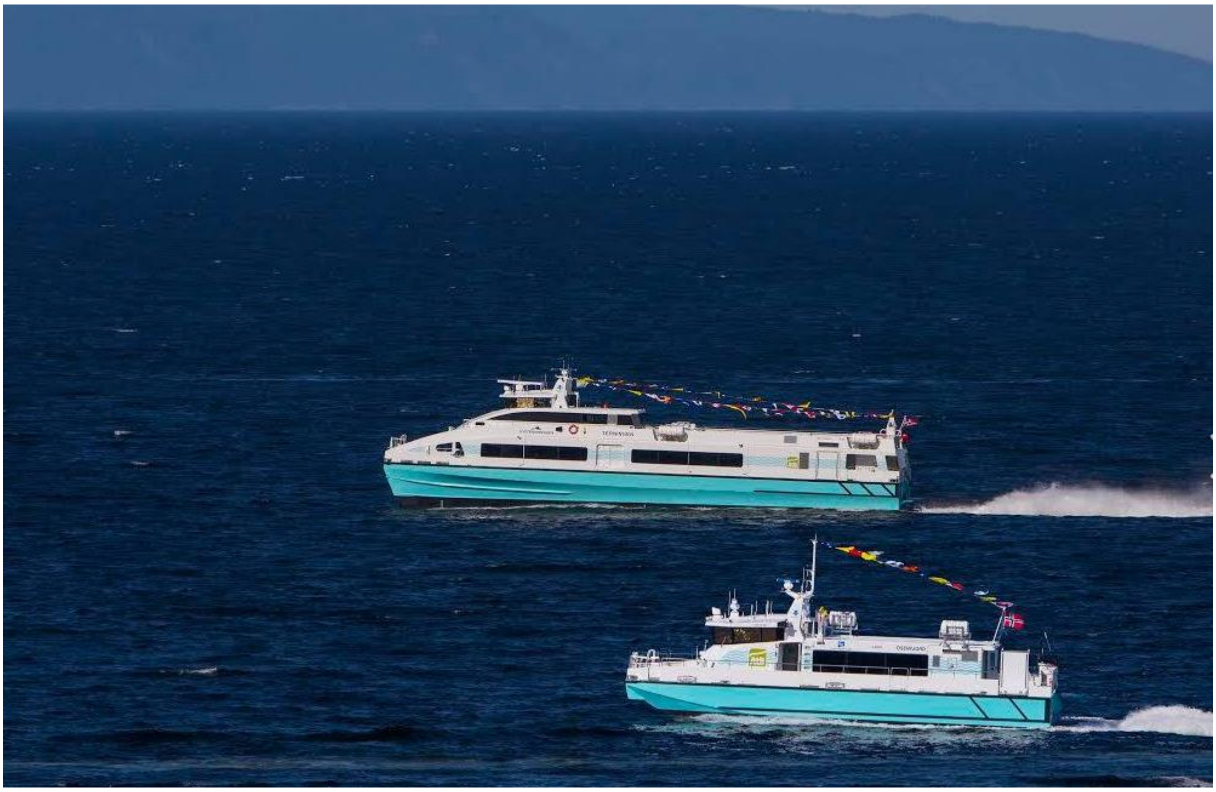


Figure 2*: High speed crafts MS Terningen and Osenfjord. Both vessels delivered by cluster member Brødrene Aa. Photo by: Jan Olav Storli*

The high-speed passenger ferry sector is to a large extent based on public contracts, and it is therefore considered likely that future tenders will require zero emissions. As high-speed passenger ferries have a high relative energy consumption compared to other vessel types, the sector is considered relevant with regards to using hydrogen as an energy carrier.

By using publicly available information about tenders and fuel consumption data, routes relevant for hydrogen is assessed. Out of 96 investigated routes, it is found that 51 routes will be hydrogen powered and 30 routes battery powered. Most of the fossil fuel consumption may be replaced by zero-emission solutions by 2027. It is estimated a total yearly energy consumption of 8710 tons of hydrogen, 44 GWh of electricity and 4.1 million litres of diesel in 2030. This represents a reduction of fossil fuels by 93%, based on an estimated diesel consumption of 56 million litres in 2021.

2.2 DOMESTIC CAR FERRIES (C.2)

The domestic car ferry sector includes more than 130 ferry connections from the county Agder in southern Norway all the way to Finnmark in Northern Norway. Annually the whole car ferry fleet in Norway transports approximately 20 million cars and 40 million passengers, thus being a critical part of the Norwegian transport infrastructure.

With many short fjord crossings, plug in electric operation is a reasonable solution to achieve zero emissions in many cases. This however is not necessarily the case for long crossings, several island connections and routes in remote areas with poor grid capacity.

Figure 3*: The ferry connection Anda-Lote. Both ferries operating the route are designed by Multi-Maritime and operated by Fjord1 ASA. Photo by: Tor Arne Aasen/Samferdselsfoto*

To estimate the potential hydrogen demand in the domestic car ferry sector, assessments are done of the routes given in the ferry market overview by the Norwegian public roads administration (NPRA). For the routes identified as relevant for hydrogen operation, energy and hydrogen consumption for three scenarios is estimated.

16 ferry connections with a total of 27 ferries are considered challenging or not possible with plug in battery operation, thus requiring hydrogen in order to achieve zero emissions. For these connections, findings suggest a total annual consumption of 12 611 tonnes in 2032, corresponding to potential CO_2 emission reductions (tank to wake) of 111 000 tonnes annually.

A second scenario with 12 routes and 21 ferries operated on hydrogen is considered due to high uncertainty related to battery electric operation on 4 of the identified routes. For this scenario the annual estimated consumption is 11 620 tonnes hydrogen.

Based on the given assumptions, liquid hydrogen is considered relevant only for the most energy demanding routes Halhjem-Sandvikvåg, Bodø-Moskenes (Ytre Vestfjorden) and Bognes-Lødingen (Indre Vestfjorden). For the remaining routes compressed hydrogen is considered more relevant, as the daily consumption of hydrogen per vessel for most routes is in the range 300-750kg.

2.3 The Kystruten Bergen- Kirkenes (C.3)

The Kystruten is a popular tourist cruise and cargo route transporting passengers, cars and cargo between Bergen and Kirkenes. Since the Kystruten is subject to tenders by the ministry of transport, emission requirements are strict compared to the commercial cruise and tourist sector.

In the contract starting in 2021 there is an upper limit on annual carbon dioxide emissions. To meet these requirements the vessels that are part of the new contract will run on LNG or liquefied biogas for main propulsion or in hybrid mode with batteries. For the next contract starting latest in 2032, stricter emission requirements are expected. Therefore, liquid hydrogen is considered highly relevant as an energy carrier for the 2030 Kystruten hydrogen scenario.

Figure 4: *Illustration of Havila Kystruten Kystruten vessel. The vessels are designed by cluster member Havyard design & solutions. Illustration by: Havila Kystruten*

As described in report C.3, a simplified approach based on the 2017 tender documentation has been used to estimate the liquid hydrogen demand for the Kystruten contract from 2032. For the scenarios considered, 335 – 1638 tonnes of annual hydrogen consumption per vessel have been estimated. This corresponds to annual total carbon dioxide reductions of 43.000 – 173.000 tonnes for all 11 vessels.

2.4 OFFSHORE SECTOR (C.4)

The offshore sector is the largest market for marine fuel in Norway and has historically been an early adopter and originator of maritime technical innovations. The industry is currently in search of technical solutions for power generation with low- or zero carbon emissions.

***Figure 5**: The integrated production, drilling and quarters unit Snorre A in the Norwegian North Sea. Photo by: Harald Pettersen*

For reasons described in the report C.4, the zero-carbon fuel of choice for the offshore market is assumed to be NH_3 due to energy storage requirements and practical factors.

To estimate future ammonia demand, data is collected through conversation and cooperation with leading E&P companies, rig- and shipowners, as well as shipbrokers, and other market players on the NCS. In addition, public sources are used to collect vessel technical specifications, and AIS data has been used to verify regional distribution of the fleet.

It was decided to focus exclusively on fuel demand from the four largest vessel segments: PSV, AHTS and MODU (Semi-sub and Jackup).

Current diesel-equivalent fuel consumption for each of the four vessel segments were estimated, and the age distribution in the current fleets were mapped in order to estimate a split between replacement- and conversion candidates.

Based on the above, three scenarios for NH3 fuel market penetration in 2030 were developed: Low, Medium and High penetration. Applying the scenarios on the consumption data, the annual estimated ammonia demand is 514 259 – 1 314 138 tons in the offshore sector, corresponding to potential CO_2 emission reductions of 0,7-1,9 million tons per year.

2.5 OTHER KNOWN PROJECTS (C.5)

In this section publicly known maritime hydrogen projects and initiatives that are ongoing or planned, will be briefly discussed. Table 1 summarizes the data and indicates the status of each project with regards to hydrogen operation. The estimated demand for the following projects is included in the mapping for the 2030 "high scenarios" as presented in chapter 3.

On the ferry route Hjelmeland-Nesvik-Skipavik, Norled will from 2021 operate an 80PCU double ended ferry that will be fuelled partly on liquid hydrogen. 50% of the vessel energy consumption will come from hydrogen fuel cells. As this connection is considered ideal for battery electric operation, it is expected that hydrogen operation will only be required until the end of the contract (2031). Due to no LH2 production facilities in Norway, it is expected that hydrogen will be produced in Germany or France, and transported to Hjelmeland/Nesvik by truck. Publicly available data is used to estimate annual hydrogen demand for this route.

In Hellesylt there is an initiative by the Hellesylt Hydrogen Hub (Nowegian Hydrogen Company), working towards producing and delivering hydrogen to the cruise/tourist ferry connection Hellesylt-Geiranger, in addition to other potential maritime end users. At the time of writing there is an ongoing tender for commercial operation of the connection with zero emission requirements from end of 2023. Hydrogen is considered a relevant fuel alternative for zero emission operation on this connection. As the tender is open with regards to timetable, ship size, number of vessels etc, the provided estimates are based on the current timetable operated by two double ended 40PCU ferries. Estimates are based on the same approach as described in report C.2.

***Table 1**: Publicly known maritime hydrogen initiatives and estimated future demand*

Connection	Type of vessel	Number of vessels	Total daily consumption (tonnes)	Annual consumption (tonnes)	Fuel type	Date, H2-operation	Status
Hjelmeland-Nesvik	Ferry	1	0,14-0,16	52	LH2	2021	Confirmed from 2021
Geiranger-Hellesylt	Ferry	2	0,25-0,7	100	CH2	2023/24	Potential from 2023

3 POTENTIAL DEMAND 2021-2035

The main findings for each vessel category are presented in detail in the sub-reports C.1, C.2, C.3 and C.4. In addition, the results are presented in the online map tool as described below.

3.1 ONLINE MAP TOOL ON OHC WEBPAGE

As part of OHC project HyInfra, work package C, an online map tool has been developed to visualize and present the results. The map includes routes, bunkering locations, fuel types, estimated daily and annual consumption data and more. The map will be continuously updated when new data are added, existing estimates corrected/ removed etc.

For the first version of the map, the following data is included:

- High speed passenger ferry routes operated on hydrogen as presented in report C.1
- The high consumption scenario for domestic car ferries as presented in report C.2
- The high consumption scenario for the Kystruten as presented in report C.3
- The low scenario for the offshore sector as presented in report C.4

The online map can be accessed by clicking on the map below.

***Figure 6**: Illustration and link to OHC hydrogen map tool*

3.2 COMPRESSED HYDROGEN (CH2)

Compressed hydrogen is deemed the best technical and economic alternative in cases where ship design and other technical constraints allow installing necessary equipment and bunkering of CH2. For this study CH2 is assumed to be the solution for vessels using below 1000kg hydrogen between bunkering operations.

Based on the given assumptions and analysis as given in the reports C.1-C.2, the total compressed hydrogen demand in the period 2021 – 2035 is estimated as shown in figure 7. The presented data is based on the "high scenario" where it is assumed widespread use of hydrogen in future contracts. A total of 12 423 tons of hydrogen is predicted annually for high-speed passenger and car ferry routes in 7 different counties. Bunkering locations and routes are given in the relevant reports and in the online map tool.

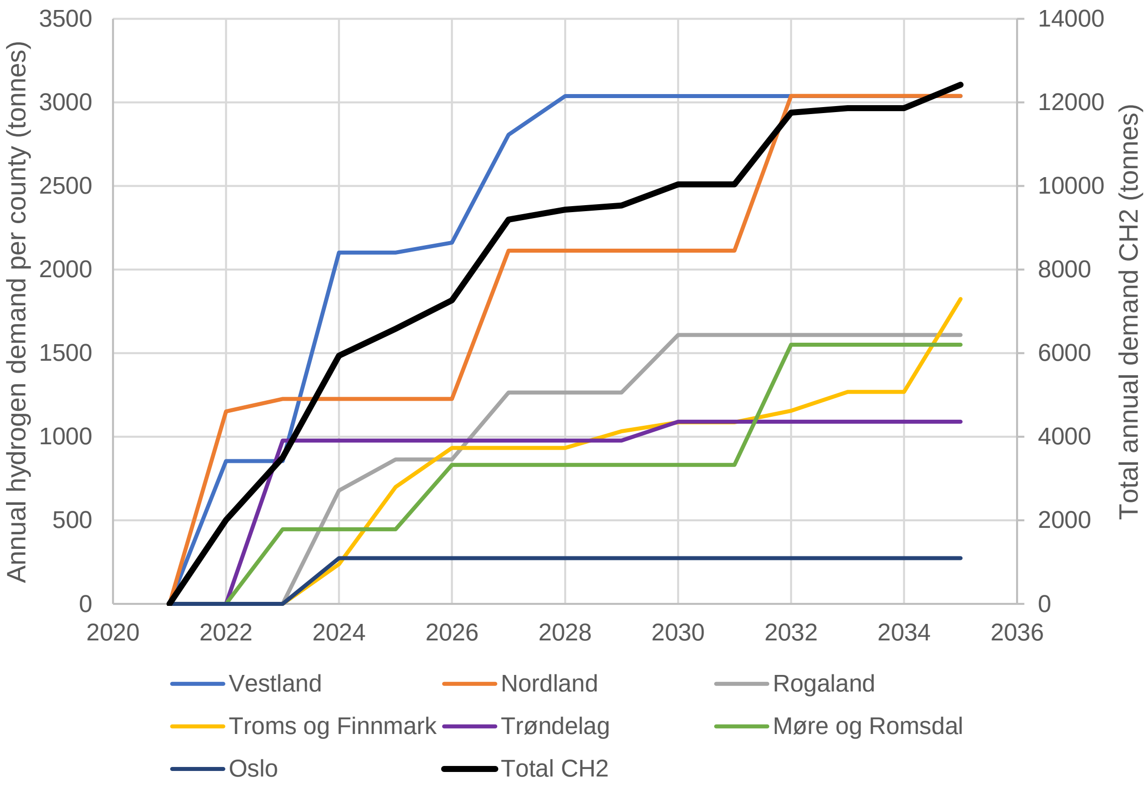


***Figure 7**: Estimated compressed hydrogen demand development from 2021-2035*

3.3 Liquid hydrogen (LH2)

Liquid hydrogen is considered necessary when zero emission requirements apply in cases where compressed hydrogen is not technical feasible due to space limitations, limited bunkering time or other technical constraints. For the sectors and ship types assessed in this study, only 3 car ferry connections and the Kystruten is deemed relevant for liquid hydrogen.

The total liquid hydrogen demand in the "high consumption" scenario is estimated as shown in figure 8. A total of 26 703 tons of hydrogen is predicted, with operation and bunkering locations in the counties Vestland, Nordland, Troms & Finnmark and Rogaland. The latter includes the Hjelmeland-Nesvik connection, however this route is expected to be solved by plug in electric operation after the contract ends in 2031.

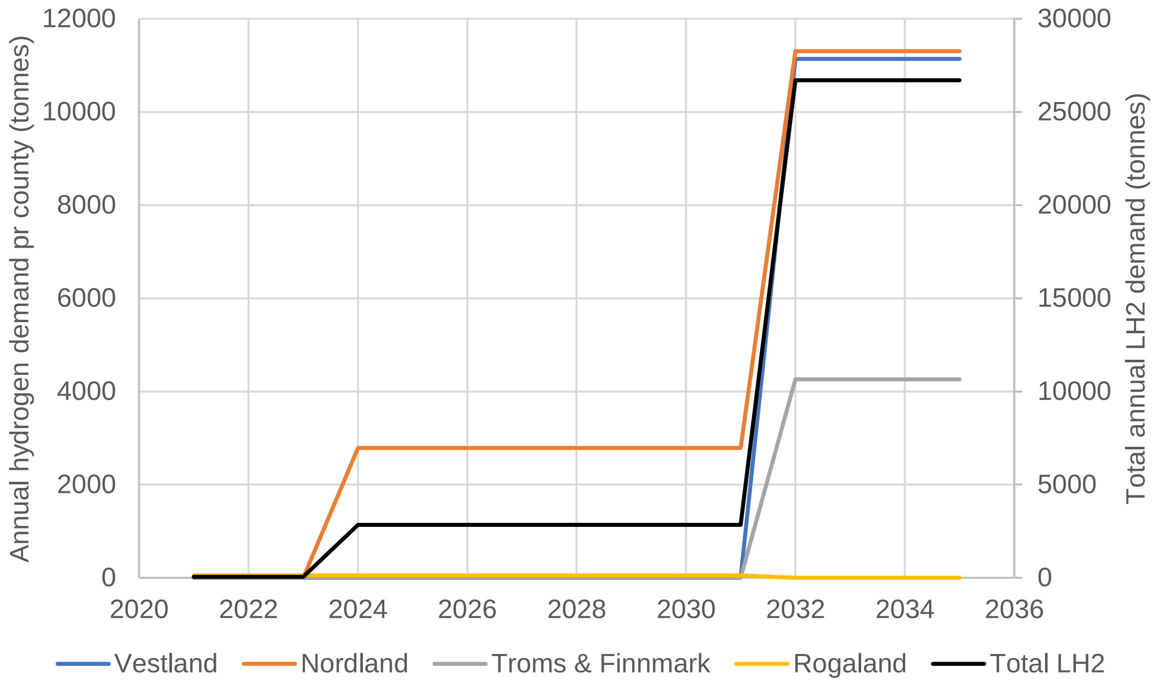


Figure 8*: Estimated liquid hydrogen demand development 2021-2035*

The assumed bunkering locations in the 2032 “high consumption” scenario is depicted in figure 9. Due to the ferry connection Bodø-Moskenes and the Kystruten with assumed bunkering in Bodø both in northbound and soutboun direction, Bodø is expected to be the location in Norway with the highest hydrogen demand.

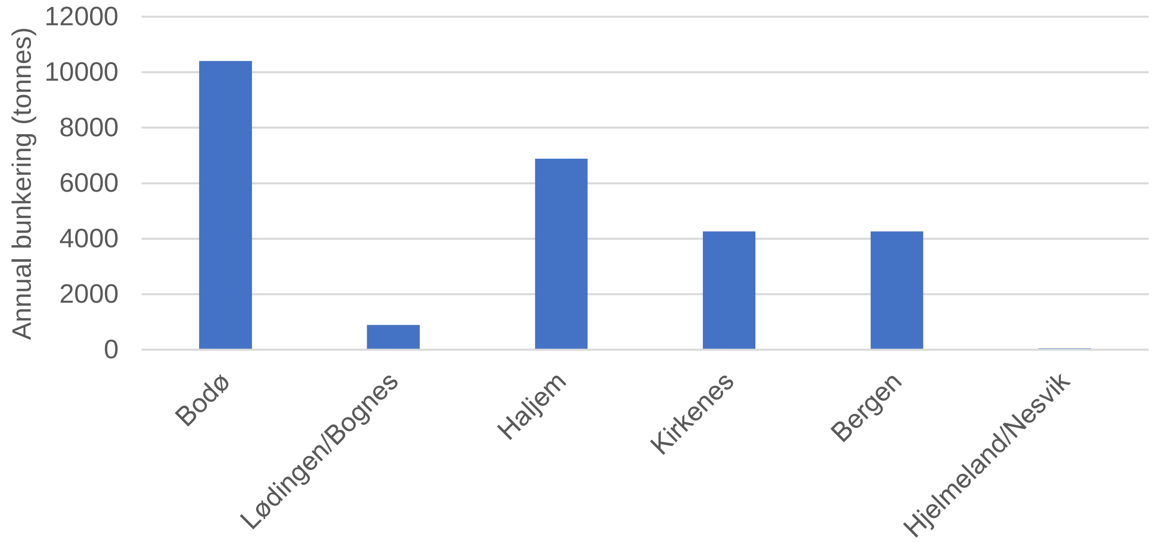


Figure 9: *LH2 bunkering locations for 2032 scenario*

3.4 Ammonia (NH_3)

Ammonia as a zero-carbon fuel is in this report only considered for the offshore sector. It is however expected that ammonia is relevant for several other ship categories within deep sea shipping that are currently not included in this report.

The estimated development in ammonia demand from 2021 to 2030 is given in figure 10, indicating a high scenario and a low scenario. The potential annual demand in 2030 is estimated in the range 0,51 – 1,31 million tonnes, with bunkering on the different supply bases along the Norwegian coast. Figure 11 indicates the estimated bunkering volumes in the different operational areas, which gives an indication of where future demand will take place.

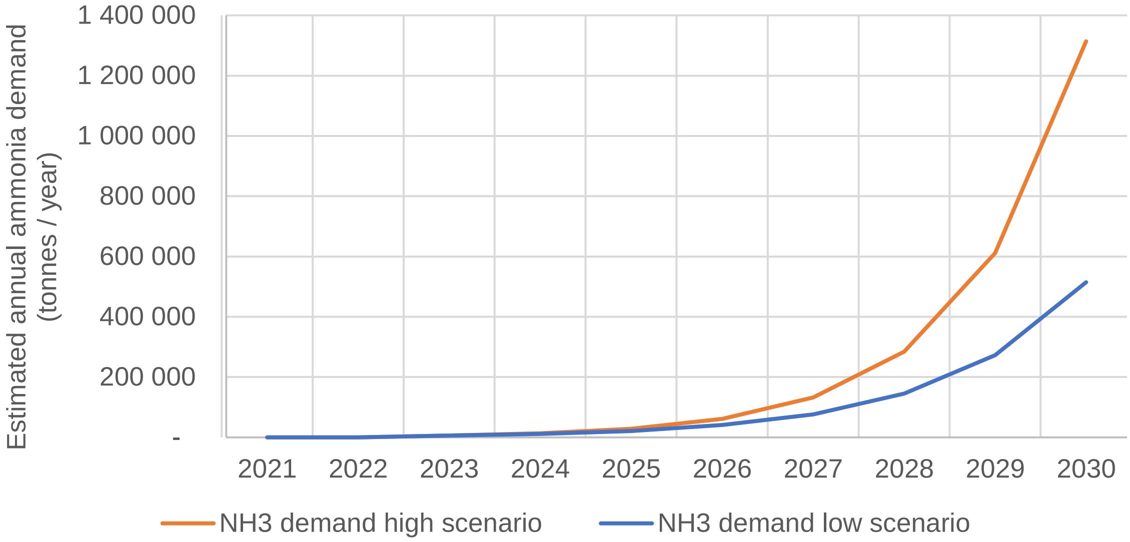
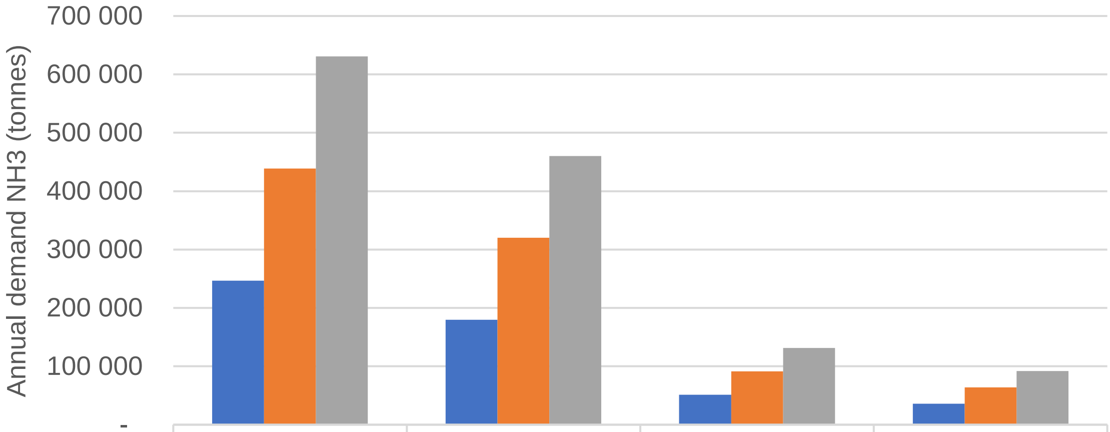


***Figure 10**: Estimated development in ammonia demand 2021-2030*



	South West	North West	Mid	North
Low	246 844	179 990	51 426	35 998
Medium	438 815	319 969	91 420	63 994
High	630 786	459 948	131 414	91 990

***Figure 11**: Estimated ammonia demand in the different operational areas along the Norwegian coast*

3.5 Carbon dioxide emission reductions

The carbon dioxide reduction potential has been estimated based on CO_2 emission factors for tank to wake, meaning that emissions from production and distribution of fuels have been neglected. Reduction potential are thus calculated based on known factors for fuels being used in current contracts and by assuming zero emissions when operating on hydrogen. Other greenhouse gas emissions such as methane slip from gas engines have also been neglected.

The annual estimated CO_2 emission reduction for each sector is depicted in figure 12. In the figure the high consumption scenarios have been used for all sectors except the offshore sector. CO_2 reductions in the offshore sector is based on the "low scenario" to better illustrate the reduction potential in the different sectors and due to higher uncertainty related to future demand in this sector.

The total estimated CO_2 reduction potential for the considered scenarios and vessels are approximately 1,172 million tonnes.

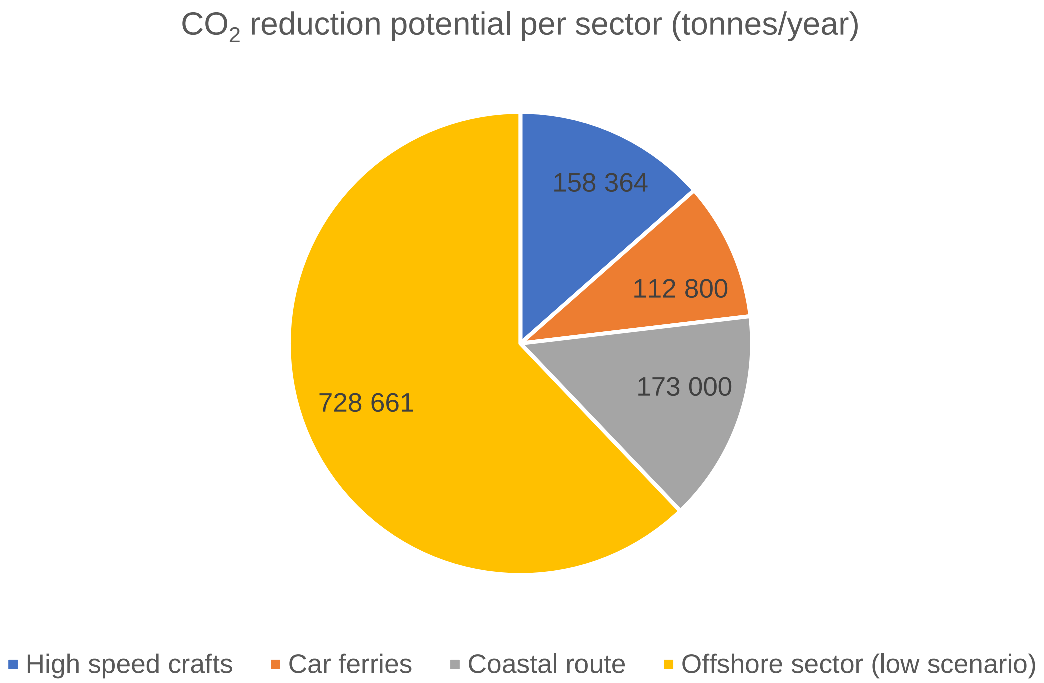


***Figure 12**: Estimated CO2 reduction potential*

4 Further work

The goal of OHC HyInfra project, work package C, has been to establish a database with future potential maritime hydrogen projects and estimates of future demand. Further work will therefore include improving the estimates and update reports and map tools accordingly. In addition, further work will include mapping potential hydrogen and ammonia demand in other sectors, including among others:

- Cargo vessels
- Bulk (dry/wet) vessels
- Cruise and tourist vessels
- Etc.

5 Acknowledgements

OHC administration thanks all cluster members that have participated directly or indirectly in the project. A special thanks to the following:

Institutt for energiteknikk (IFE). Responsible for mapping, analysis and the report C.1 (high speed crafts). In addition IFE contributed with valuable insights and information related to approach and information for other parts of OHC HyInfra.

Multi-Maritime AS. For sharing information about energy demand, enabling estimates in the ferry sector

Sintef Ocean. Responsible for work package A in the HyInfra project. Sintef also contributed with valuable information and insights on technical matters throughout the work

Amon Maritime AS. Responsible for mapping, analysis, and the report C.1 (offshore sector). Contributed as a technical resource in discussions related to use of ammonia and hydrogen as marine fuel

6 APPENDIX

6.1 COMMON DATA USED FOR CALCULATIONS

#	Description	Unit	MGO	LNG	HVO	LH2	CH2 (250bar)	LNH3
1	Density	kg/m3	890	450	780	71	17,6	670
2a	LHV	MJ/kg	42,7	49	44,1	120	120	18,9
2b	LHV	kWh/kg	11,9	13,6	12,3	33,3	33,3	5,3
2c	LHV volumetric	kWh/l	10,6	6,1	9,6	2,4	0,6	3,5
3a	Efficiency FC (PEM)	%	-	-	-	50 %	50 %	45 %
3b	Efficiency FC (SOFC)	%	-	-	-	65 %	65 %	60 %
4a	Efficiency 4s (medium speed)	%	42,5 %	42,5 %	42,5 %	-	-	42,5 %
4b	Eq. SFC	g/kWh	198	173	192	-	-	448
5a	Efficiency 4s (high speed)	%	37,5 %	37,5 %	37,5 %	-	-	-
5b	Eq. SFC		225	196	218	-	-	-
6a	Efficiency 2s (low speed)	%	50,0 %	50,0 %	50,0 %	-	-	50,0 %
6b	Eq. SFC		169	147	163	-	-	381
7	CO2 emission factor ("tank to wake")	kg/kg	3,20	2,75	3,20	0	0	0

Abbreviations:

LHV: Lower heating value

PEM: Proton exchange membrane

FC: Fuel cell

SFC: Specific fuel consumption

CO2: Carbon dioxide

SOFC: Solid oxide fuel cell

MGO: Marine gas oil

LNG: Liquiefied natural gas

CH2: Compressed hydrogen

LH2: Liquid hydrogen

LNH3: Liquid ammonia

HVO: Hydrotreated Vegetable Oil (biodiesel)