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The program will begin soon.
You will not hear audio until we begin.

Status of H2 & CCS activities and technologies in Norway

27th January 2022

Eirik Melaaen

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Society of Petroleum Engineers
(SPE)

Agenda:

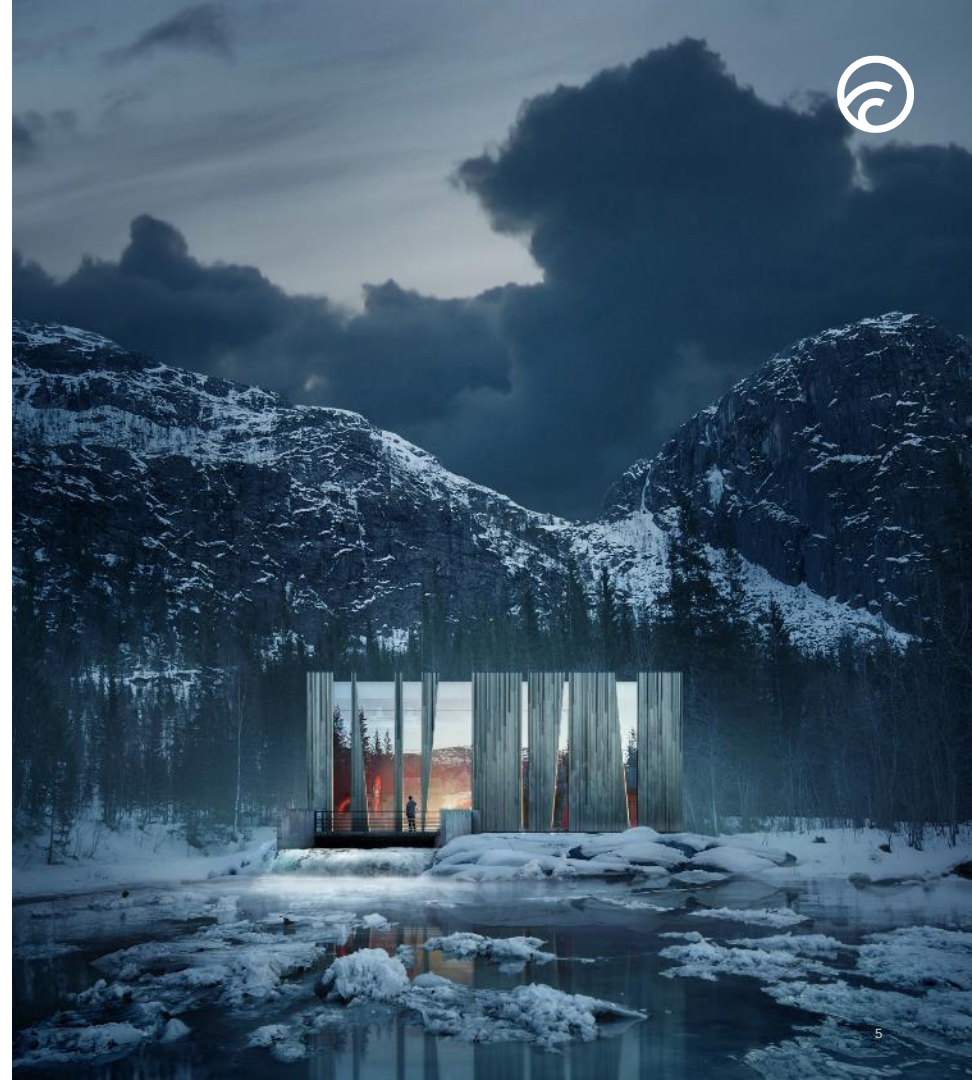
- NORWEP (norwep.com)
- Norwegian service and supply industry
- Hydrogen activities
- CCS activities
- Summary

This is Norwegian Energy Partners

Norway is a country with fantastic energy resources. For more than a century we have built our country on developing energy solutions in a sustainable way within a wide range of areas, from upstream and midstream oil & gas to energy systems, offshore wind, hydropower and solar energy.

We are promoting Norwegian energy capabilities in international markets.

Norwegian Energy Partners - providing solutions for global energy needs.

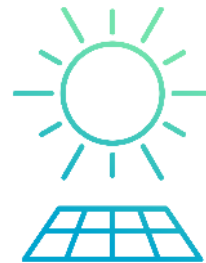
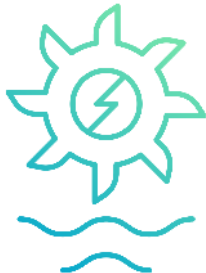
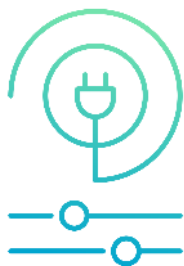




Technologies & Solutions

Making Norwegian competence, experience and technology available. Search and find world class innovative Norwegian technology and solutions for our future energy needs. Find your perfect energy match from more than 800 solutions.

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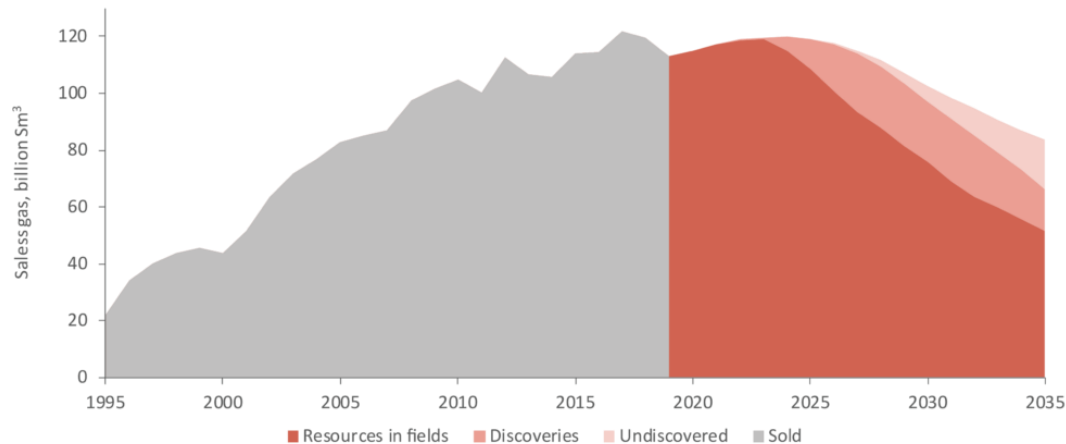


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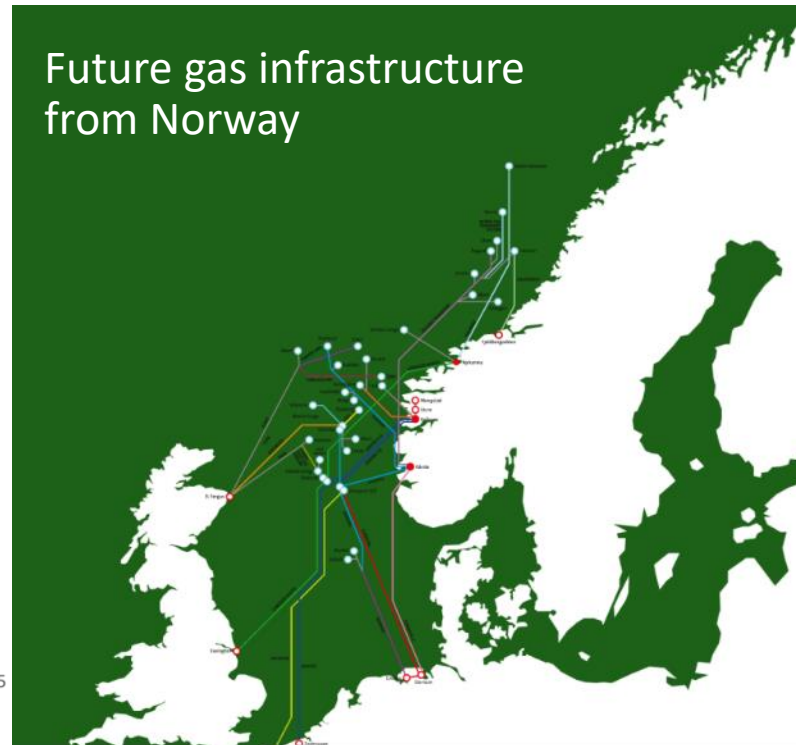


Norwegian gas resources

The figure below shows the expected volume of sales gas from Norwegian fields, 1995-2035



Future gas infrastructure from Norway

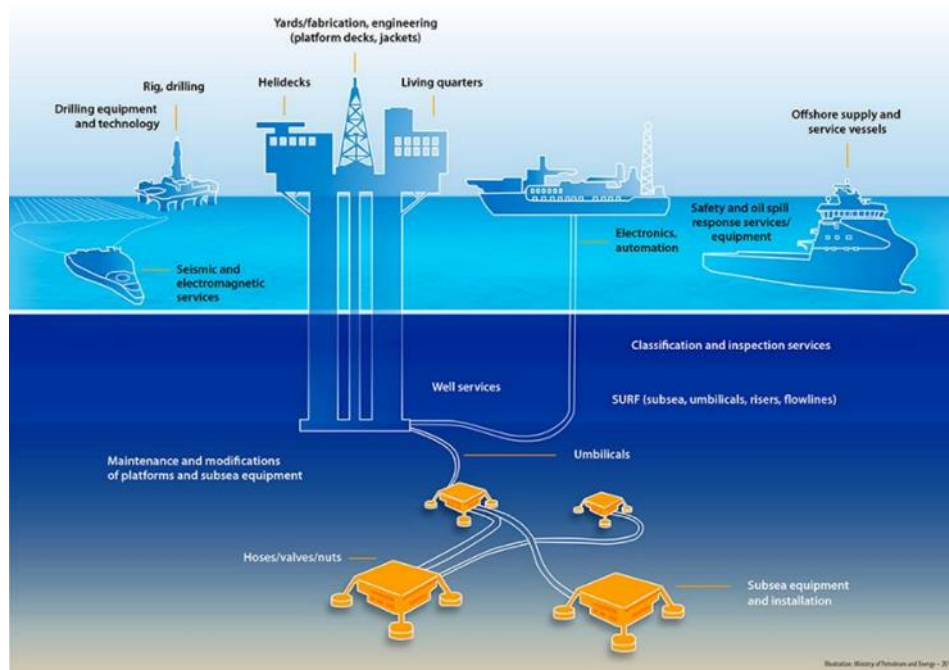




Norwegian service and supply industry - petroleum

Service and supply in Norway (2019):

- Second-largest industry in terms of turnover
- More than 1250 companies
- Total turnover of NOK 397 billion (USD 45 billion)
- 30% in international market
- 50 years of offshore petroleum activities





UN sustainable development goals



- **Norway has committed to cutting greenhouse gas emissions by 50-55 percent by 2030**
- **Norwegian Shipowners' Association** – cut climate emissions by 50% per unit by 2030, new ships zero-emission technology from 2030, climate-neutral fleet from 2050, international ban on non-climate-neutral fuels from 2050
- **Equinor** – The goal is to achieve carbon-neutral global operations by 2030 and reduce net carbon intensity in produced energy by at least 50% by 2050. **November 2020 - Net zero emission by 2050.**



Norway's ammonia and hydrogen history

Norsk Hydro (Yara)

- First fertilizer production 1905 - Notodden
- Ammonia produced from H₂ (electrolysers) 1929 – Notodden and Rjukan



Hydrogen strategy – Norwegian Government

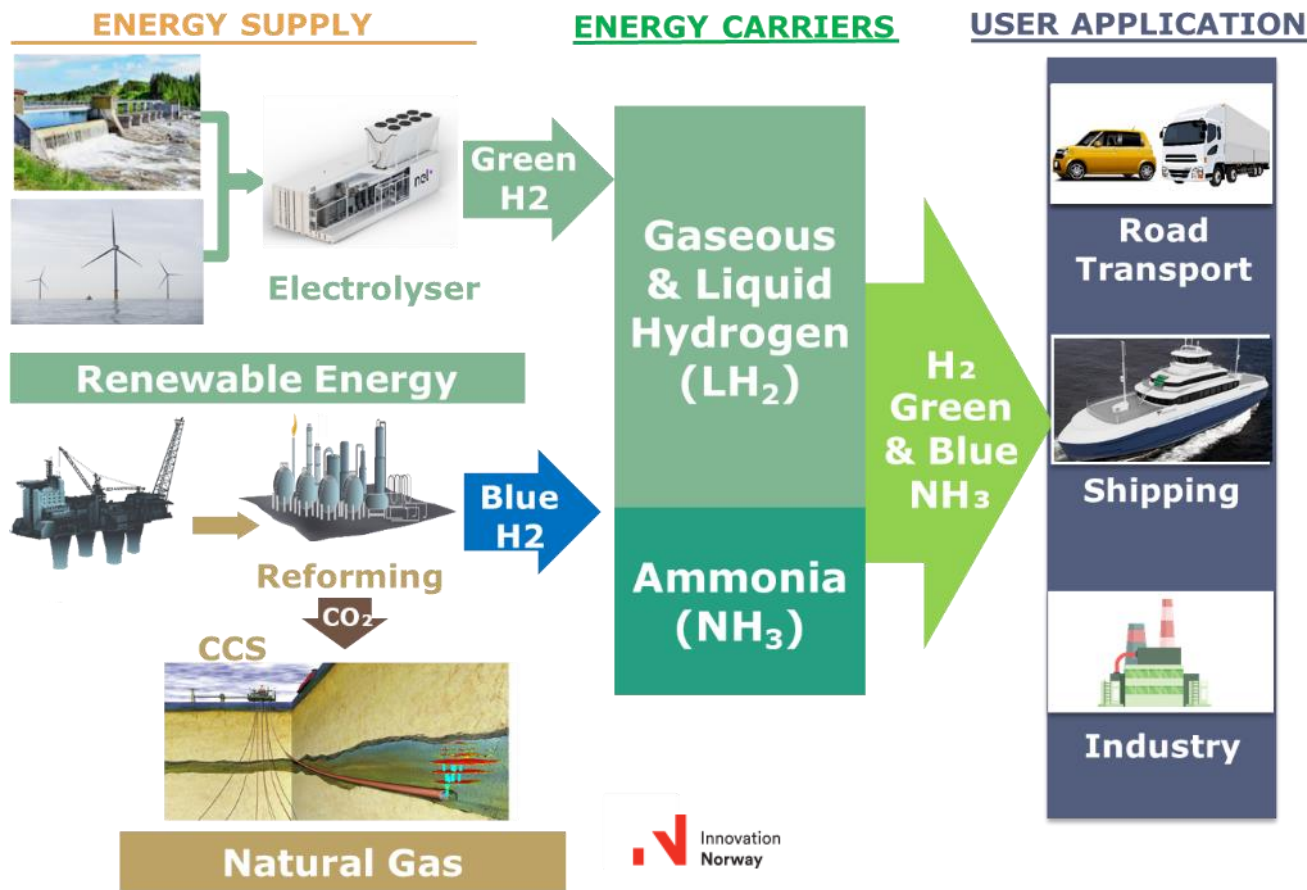
“On the Way to the Low-Emission Society”



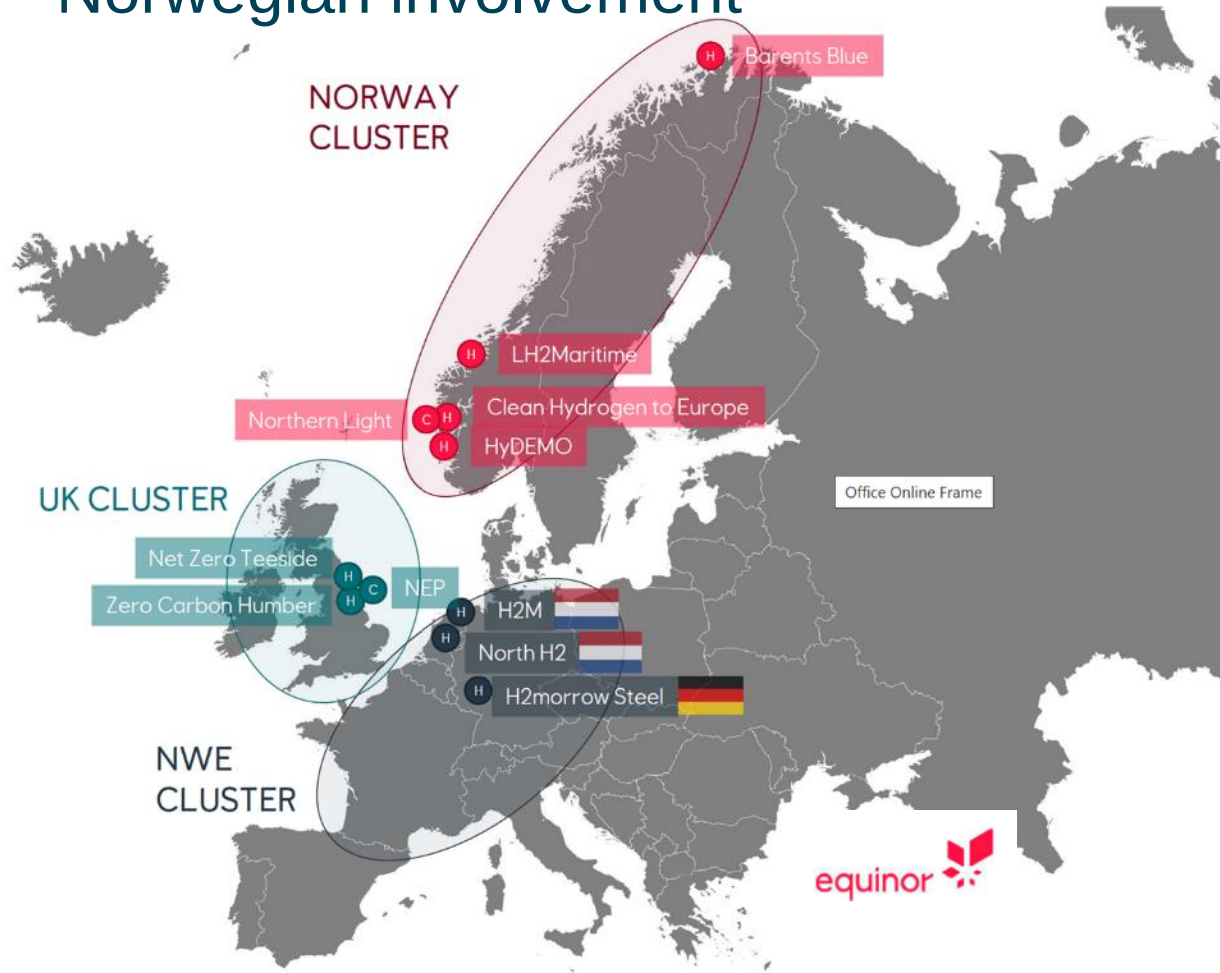
Focus areas in the report (June 2020)

1. Safe use and production of hydrogen with low emissions
 - Hydrogen with low emissions - from production to consumption
 - Safety and regulations
2. Hydrogen in Norway
 - Transportation (maritime, onshore, infrastructure)
 - Industry
 - Power sector
 - National R&D
3. Norway and Hydrogen Internationally
 - European ambitions
 - International cooperation

Norway – developing a comprehensive hydrogen value chain



Norwegian involvement



Project types:

- Renewable/H2 production
- Low-carbon H2 production/CCS
- Infrastructure/distribution
- EU open grid
- Ammonia
- Power to X/efuel
- End users (process industry, transport, maritime, power etc.)
- Value chain/Supply chain

Not only hydrogen/CCS competence/technology required for the green shift

Timeline for development



Torghatten Nord – Contract two H2 ferries
Operation: 2025



Viking Energy
supply vessel with
ammonia and SOFC
cells 2023

Ammonia

LNG

Hybrid

Electricity

2000
Glutra –
First LNG ferry

2015
Ampere/Norled
World's first electric car and
passenger ferry

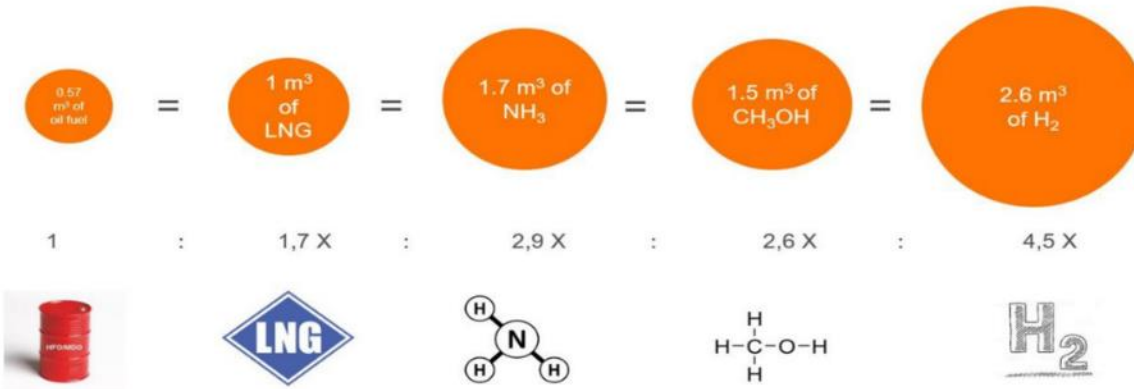
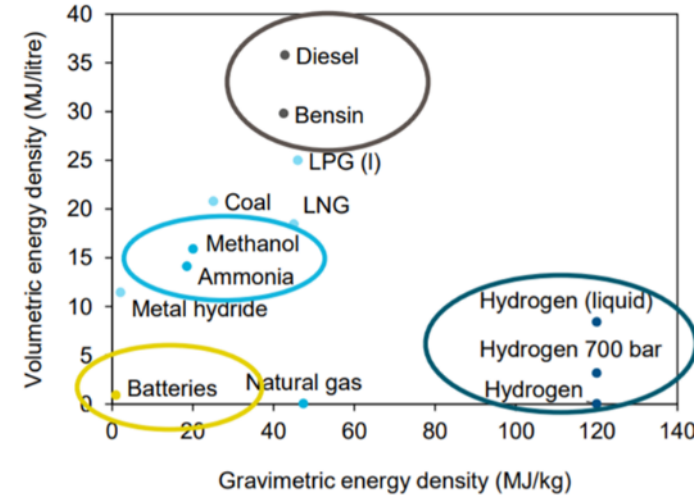
Ferry Norled/Finnøy
100% hydrogen and fuel
cells, CGH2
2021

2023
First LH2/fuel cell
cruise ship planned



Fuel and volume

- The different fuels compared to each other, energy wise.
- The maintenance space around the tanks etc. is not included.



	Density	Energy density
	[kg/m ³]	MJ/kg
Gasoline	735	43,1
LNG	450	50
NH ₃	682	18,6
Methanol	792	19,9
LH ₂	71	119,9



Different concepts - Low and zero emission solutions for all type of vessels

- Combustion engines
- Fuel cells
- All electric
- LNG
- Hydrogen, ammonia, synthetic fuel
- Hybrids
 - Diesel and battery
 - LNG and battery
 - Hydrogen and battery

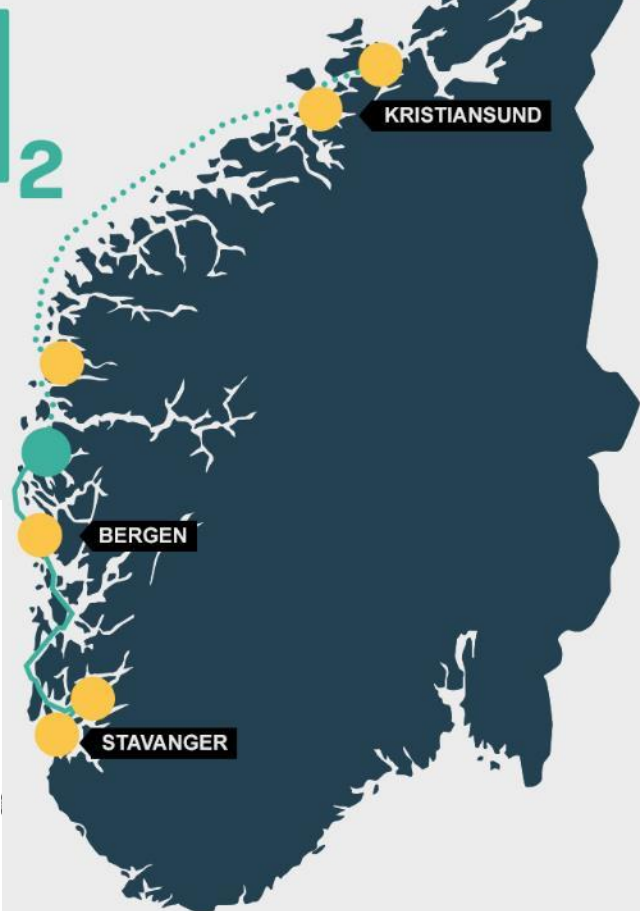


AURORA

Europe's first maritime value chain project for liquid hydrogen

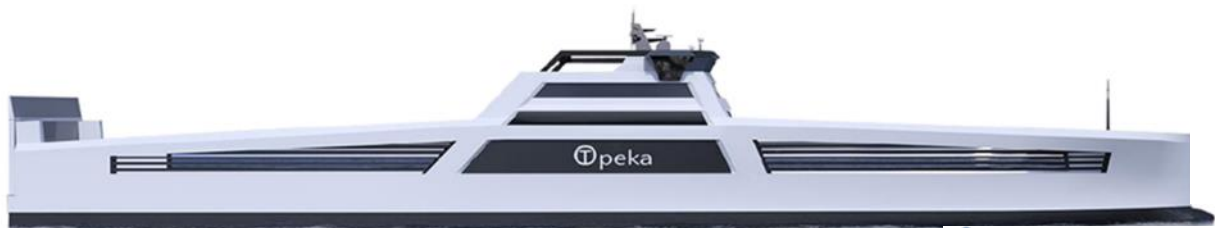


- The Aurora project will provide emission free LH2 to the maritime transport sector in Norway.
- The hydrogen will be produced by electrolysis based on hydropower.
- Partners are global industrial gas supplier Air Liquide, Norwegian energy major Equinor and regional hydropower company BKK.
- A production and liquefaction facility will be established at the Mongstad Industrial Park, close to a Equinor refinery and close to large seaports.
- Through cooperation with Wilhelmsen's planned liquid hydrogen-powered "Topeka" base-to-base vessels, the partners will distribute LH2 from Mongstad across Western Norway.
- The project also covers the development of a distribution network, multi-user terminals and ship bunkering stations.
- Aurora is a mature project ready to commence cooperation with new partners immediately.



Topeka base-to base vessel

The zero emission seaborne alternative



Supply and value chain for Hydrogen



Production

- **Equinor** – Clean hydrogen with CCUS, Northern lights project
- **Reinertsen** new energy/HYDROGEN Mem-Tech – Production of hydrogen with CCS
- **ZEG Power** – Hydrogen production
- **Siemens** - Hydrogen electrolysis, batteries and gas turbines
- **Statkraft** – Renewable solutions, energy management
- **NEL** – Hydrogen production, storage and refueling solutions
- **Aker, Aibel** – EPC, complete value chain

Transportation, distribution & storage

- **Moss Maritime** – Marine applications
- Equinor
- **UMOE Advanced Composites** - storage
- **TechnipFMC** – Deep purple project (hydrogen and wind)
- **Kongsberg** – Marine applications
- **Kongstein** - Engineering and consulting, propulsion solutions
- **LMG Marin** - Design, engineering and documentation
- Norwegian shipowners (**BW, Höegh, Golar, Knutsen OAS** etc.) – Transportation of H₂
- **Wärtsilä Gas Solutions**

End user & utilization

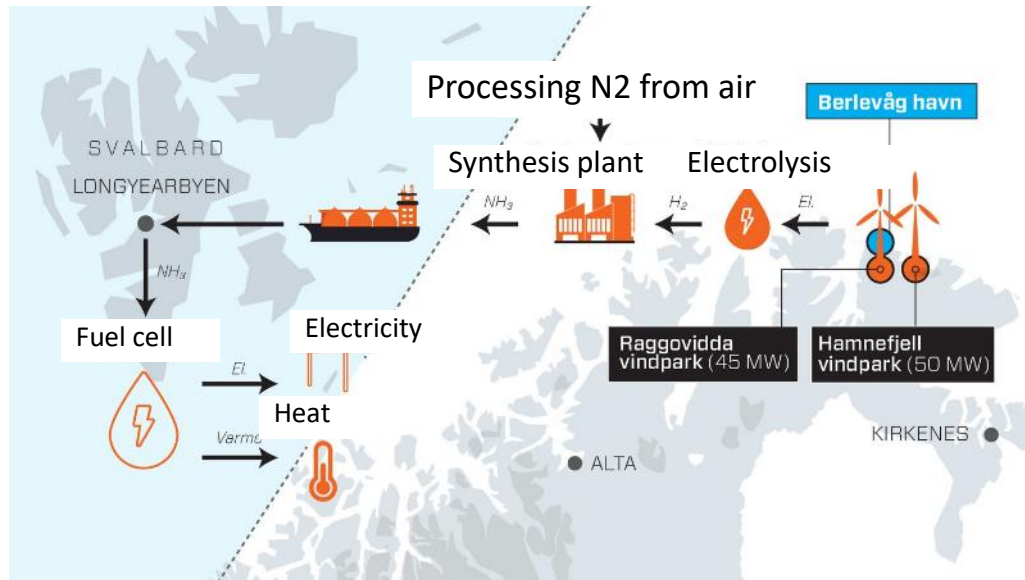
- **Equinor** – Green shipping/fuel on vessels
- **ABB** – hybrid power system, fuel cells
- **Siemens** - batteries and gas turbines
- **Sevan SSP** – SSP hull. offshore wind, hydrogen
- **Yard/Vessels** operating on Hydrogen
- Hydrogen in the process industry
- **Yara** – Fertilizer
- **Bergen engines**

Other companies; **DNV and Gexcon**(Risk management, safety, studies), **Multiconsult and Norconsult** (consulting), **Academia/R&D**,

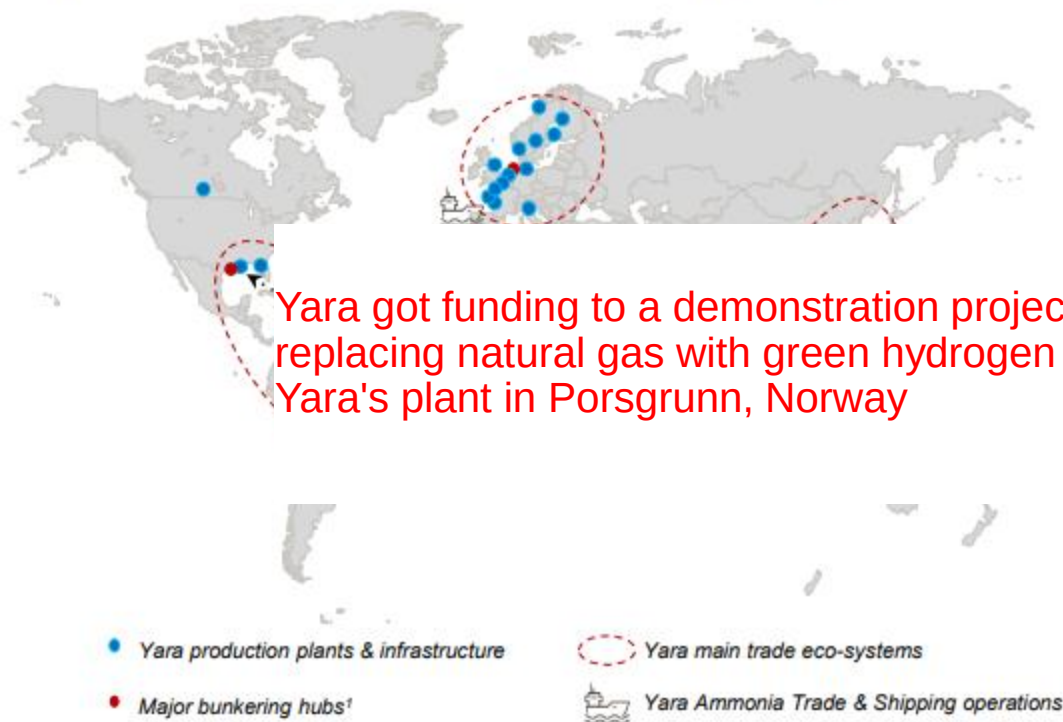


Ammonia as energy carrier

- Equinor, Eidesvik to test ammonia fuel on LNG-fueled PSV
- Propulsion: 2MW fuel cell system.
- In operation from 2023



Yara's ammonia position is unique, with leading positions across production, trade and shipping



Production

- 8.5 mt capacity across 17 units
- Proximity to major bunkering sites
- Electrolysis can replace SMR step; rest of infrastructure can be utilized
- Three green ammonia pilots, start-ups scheduled for 2023-25

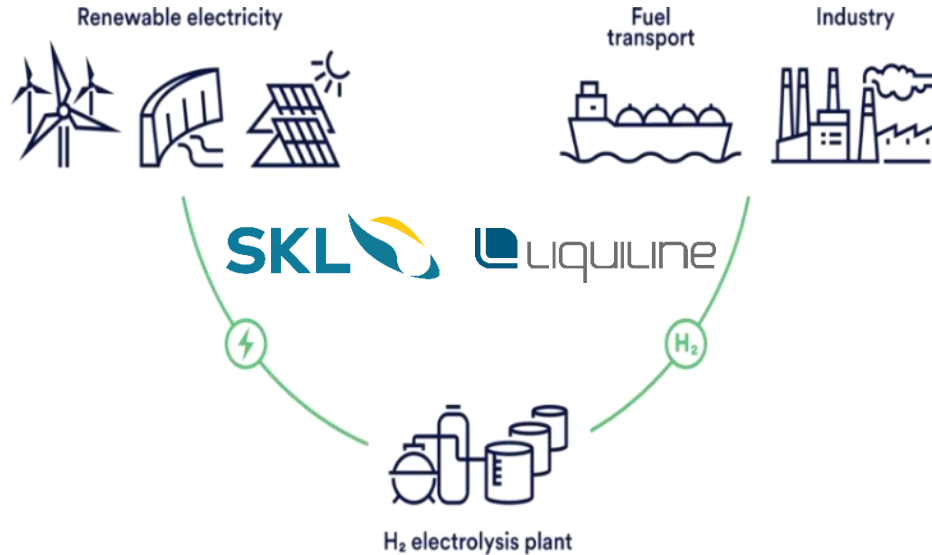
Trade

- Global trader with > 20% market share
- ~3.7 mt of global export capacity with multiple downstream outlets
- Industrial solutions land logistics expertise

Shipping & storage

- +200 kt maritime transport (11 ships)
- 580 kt ammonia storage capacity
- 18 marine ammonia terminals
- Connecting green supply and demand

Hydrogen Solutions



HYDROMAR – Energy Terminal
- a unique marine solution for production, storage and bunkering in city-close locations

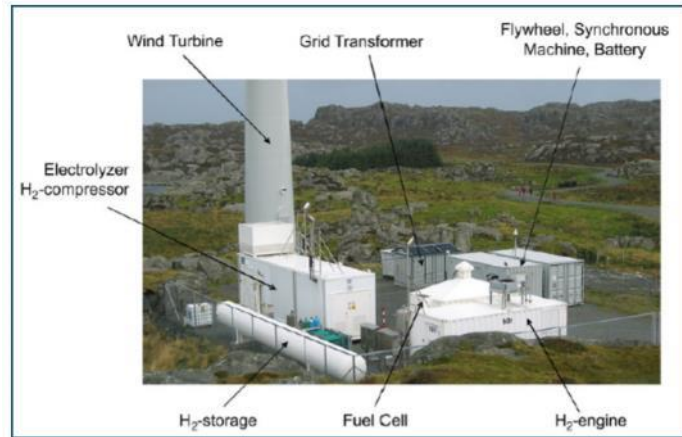
- Provider of Hydrogen Solutions – maritime focus
- Safe, feasible and cost-effective solutions
- Scalable and locally produced green hydrogen – proven technology
- Projects in pipeline and under development



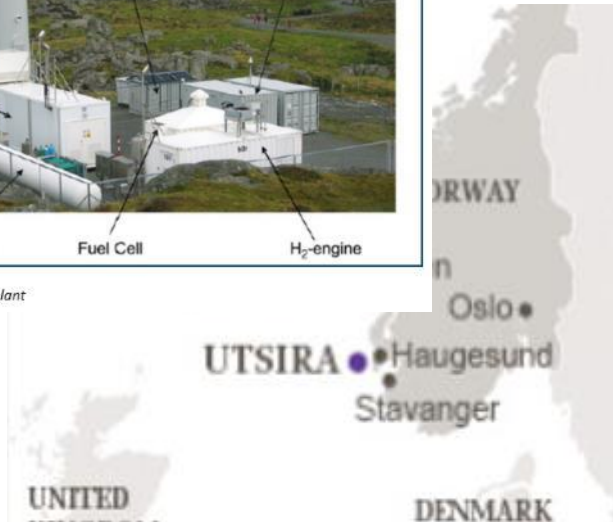


Wind power and hydrogen plant

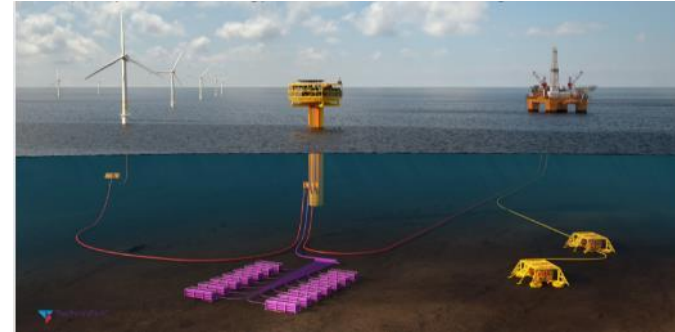
In 2004, the small island of Utsira, Norway, became home to the world's first, full-scale combined wind power and hydrogen plant



Utsira wind/hydrogen demonstration plant



- Deep Purple project (TechnipFMC)
- Offshore hydrogen technologies for CO₂-free energy production



- 23 % of total CO₂ emissions from Norway come from the gas turbines on Norwegian platforms.
- Hydrogen from offshore wind can offer stable zero emission energy deliveries

Hydrogen bunkering & ship transport

- In 2018 Moss developed an LH₂ carrier with bunkering capability
- Collaboration with Equinor, Viking Cruises, DNV and ship operator Wilhelmsen
- Cylindrical vacuum insulated tanks – 2 x 4500m³
- Suitable for short/medium distance transport and providing LH₂ fuel to other ships





FLEXIBLE FUEL APPROACH

By partner able to provide full or partial turnkey projects



Compressed hydrogen (CH_2)

Can operate on pressure ranges up to 700 bar



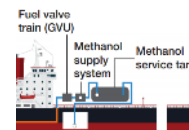
Liquid hydrogen (LH_2)

Maintains high efficiency with low H_2 input pressure



Liquid organic hydrogen carriers (LOHC)

Eliminates the need for compression and makes it safer



Methanol / Ammonia

Pre-treatment

Active research on pre-treatment



Metal Hydride hydrogen storage

Unique fuel tank-fuel cell heat regulation system



Hydrogen replacing coal

- To be climate neutral by 2050, TiZir Titanium & Iron (TTI) will replace coal with hydrogen at the smelter in Tyssedal.
- Developed technology for a full-scale plant where they replace 85 percent of coal consumption with hydrogen
- CO2 emissions reduced by approx. 235,000 tons of CO2 per year - a reduction of more than 82 percent.





Expertise in Hydrogen safety

TO UNDERSTAND CAUSES

Increase Knowledge & Understanding Of The Physical Phenomena Which Result In Occupational Accidents



TO MITIGATE CONSEQUENCES

Limit The Impacts Or Damage To Plant And Environment Due To Incidents Occurring



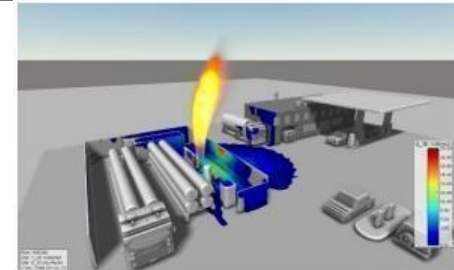
TO PREVENT

Procedures, Material Properties, Correct Choice of Equipment To Prevent Accidents From Occurring



TO PROTECT HUMAN LIFE

Develop Standard of Safety Practice To Prevent Any OSH Accident To Happen



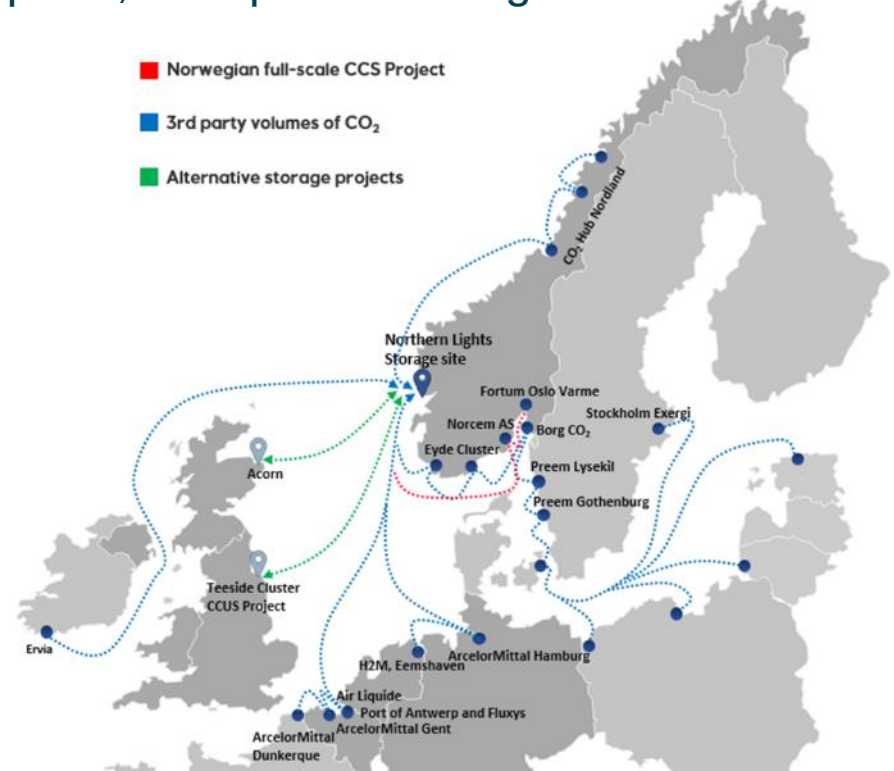
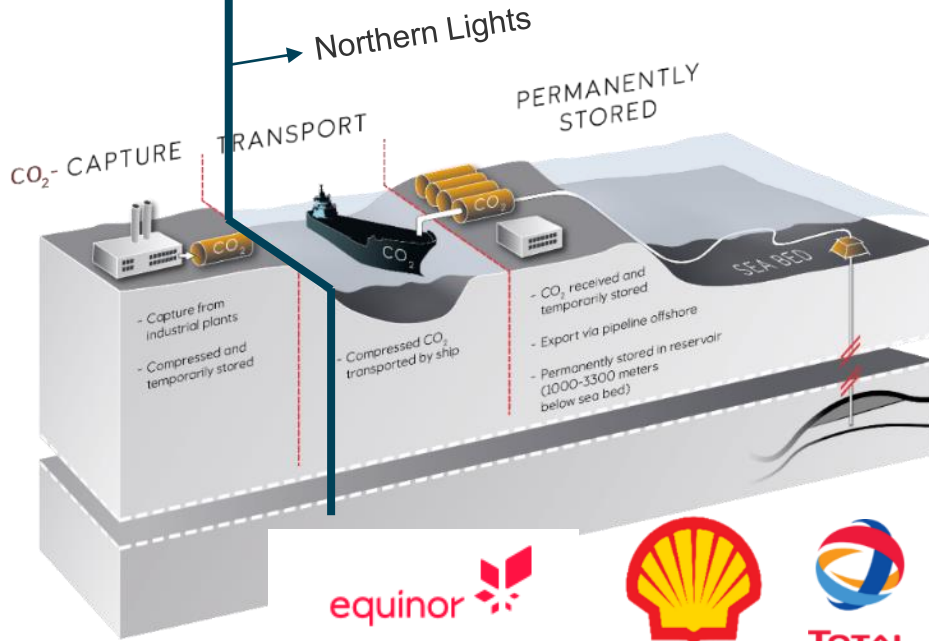
Northern Lights project/Longship - CCUS



The carbon dioxide value chain from capture, transport to storage or utilization

Phase 1: 1.5 mtpa CO₂

Phase 2: Additional 3,5 mtpa CO₂



Cooperation between Equinor, Shell and Total and the Norwegian Government

Equinor, Total and Shell ('Northern Lights')

Transportation and storage of CO₂ in the North Sea.



- Onshore terminal with storage buffer, pump and heating of CO₂.
- 110 km pipeline, 12 inches
- One injection well



Reception Terminal for CO₂ at Øygarden, Hordaland.

Fortum Oslo Varme AS
Energy recovery plant



Norcem AS, Brevik
Cement factory

Full-scale CCS project in Norway



- Transport: 1 or 2 ships
- Distance: 700 km
- Level: Liquid (15 barg, -26°C)

- Capture 400 kt CO₂/year from Norcem and Fortum Oslo Varme respectively.
- Amino technology
- Includes CO₂ cleaning, condensation and storage buffer (4 days)



The Norwegian full-scale project



Third party volumes of CO₂



Alternative storage projects



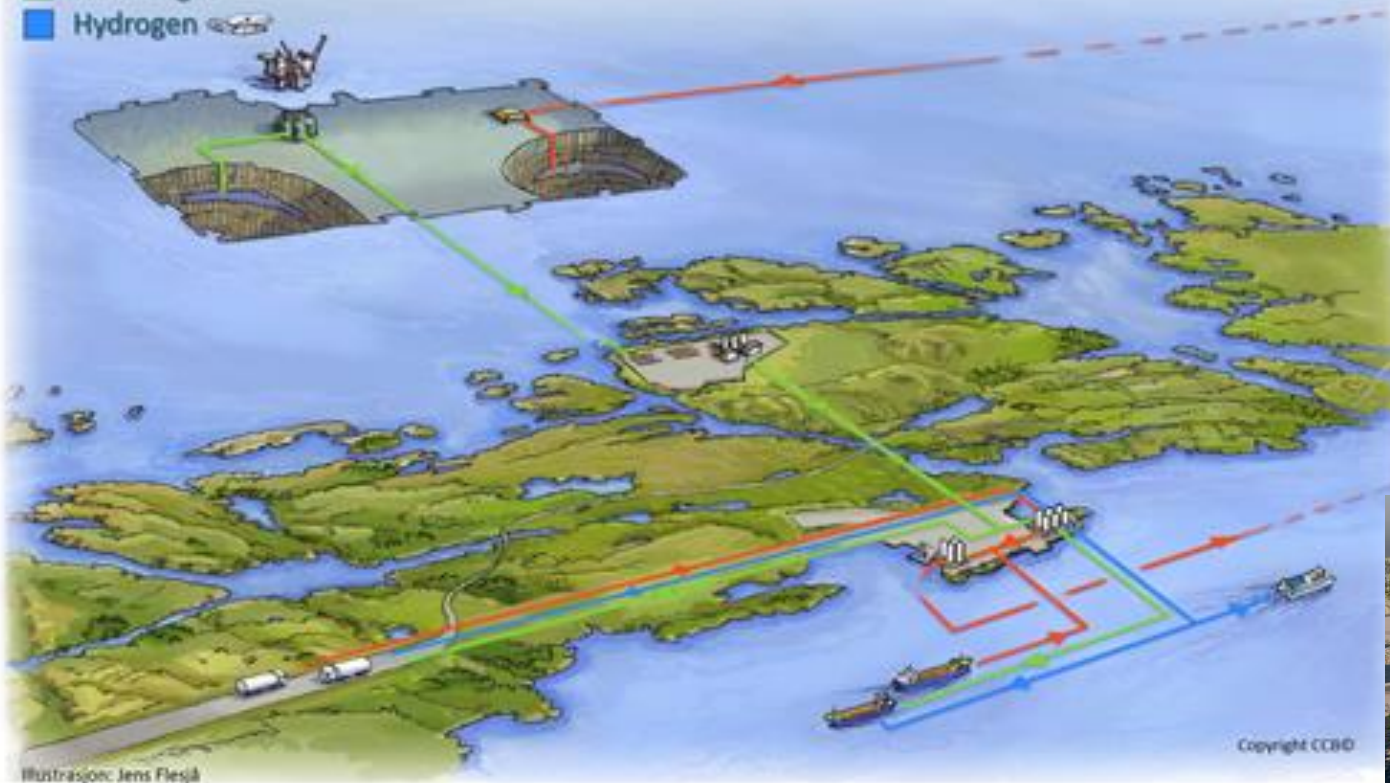
Ambition:
An open infrastructure

CCB Energy Park - Øygarden



- CO2 return
- Natural gas
- Hydrogen

CCB Energy Park



The planned facility at CCB Energy Park will be able to store huge amounts of CO2 under the seabed.

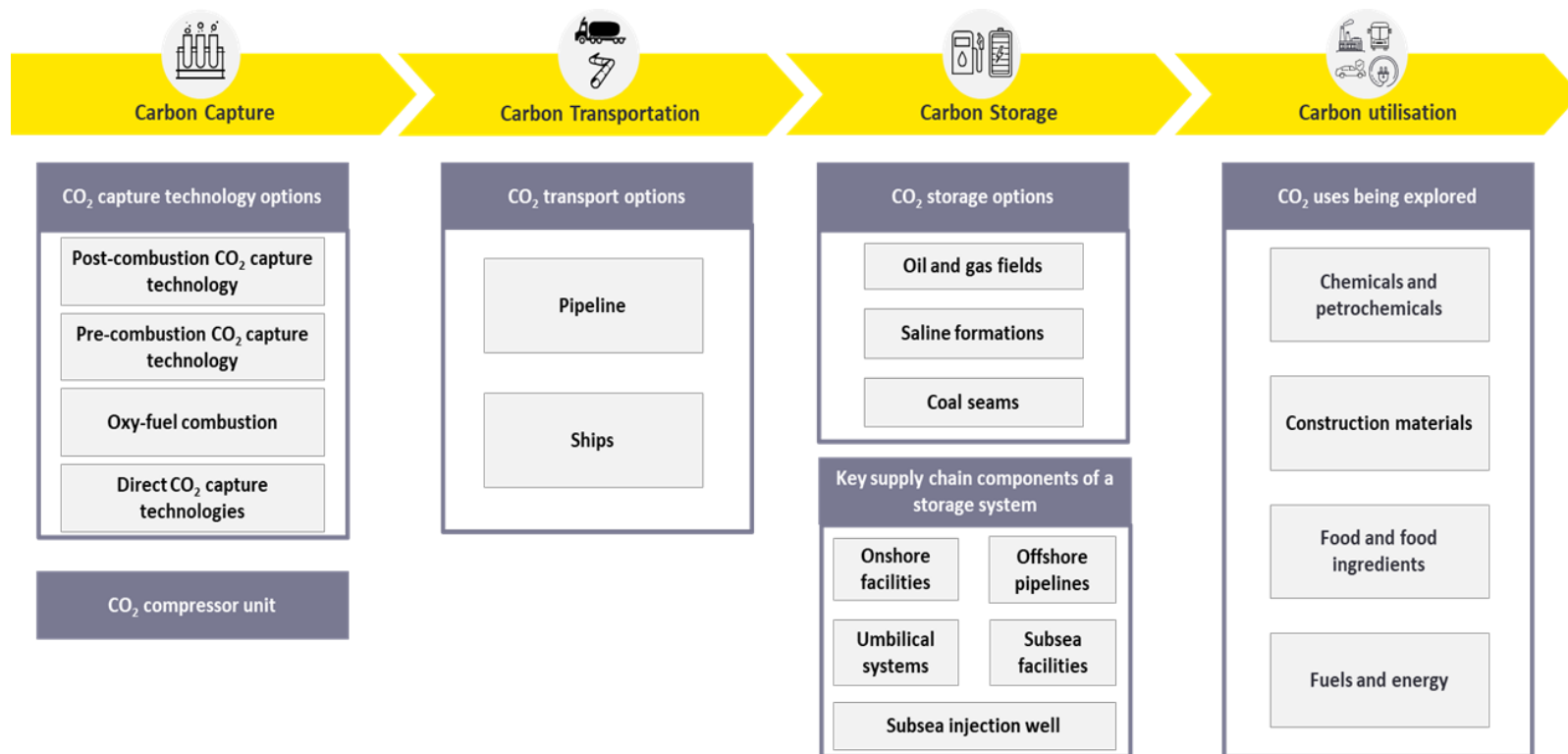
Kollsnes is also home to a natural gas processing plant, and the area could be used to produce hydrogen in future.

Photo © CCB EH





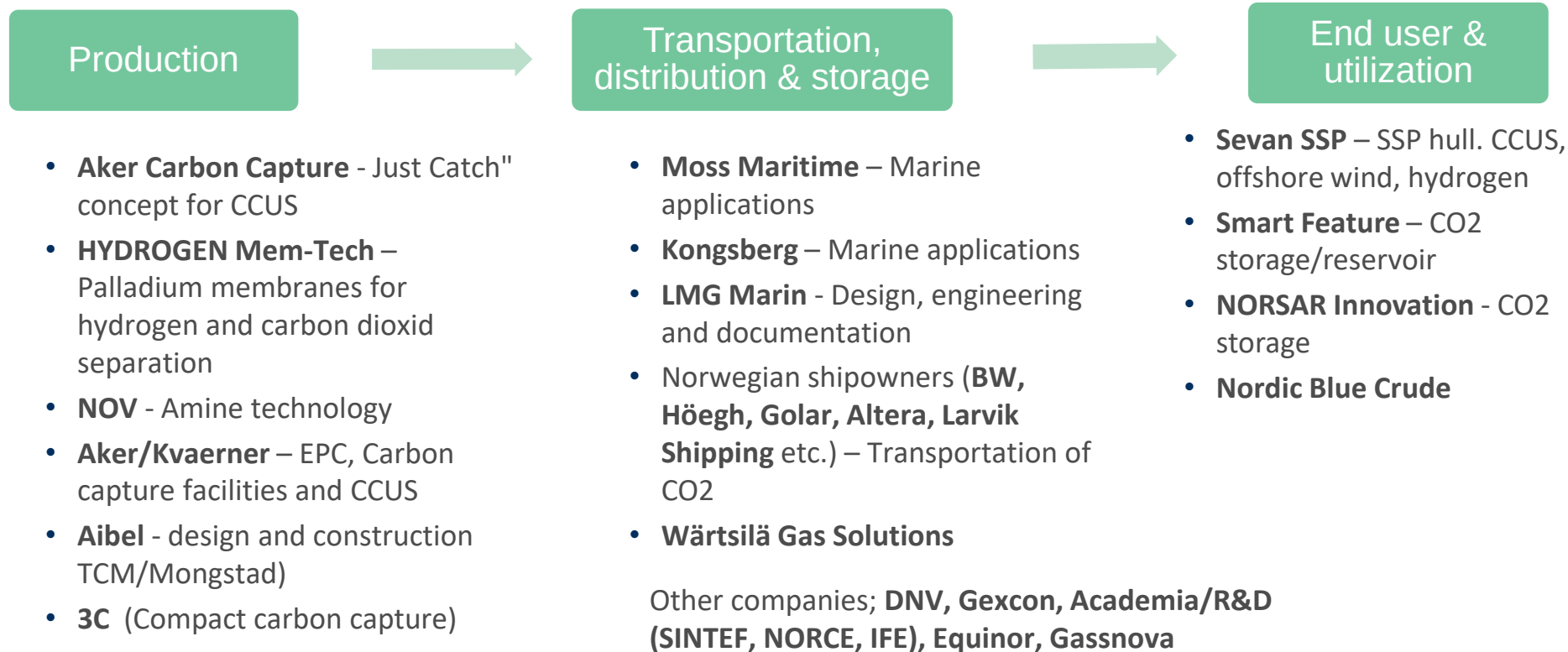
Value Chain – CCS/CCUS



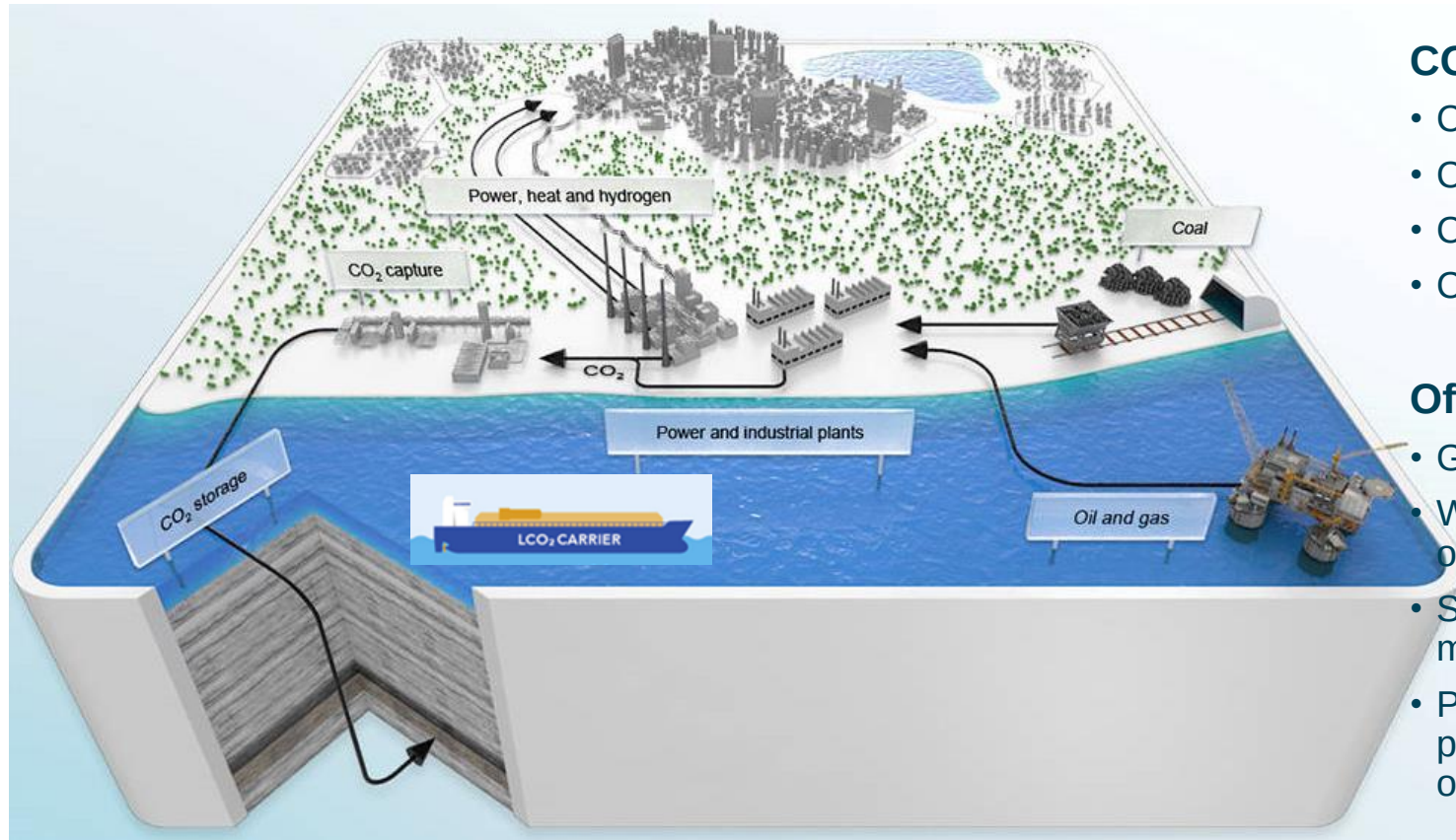
Note: The above-mentioned technologies/components/building blocks are only representative and are not exhaustive
Source: Global Status of CCS 2020, Global CCS Institute; IEA, EY Research



Value Chain – CCS/CCUS



Norwegian competence



CO2 Value chain

- Carbon capture
- Carbon transportation
- Carbon storage
- Carbon utilization

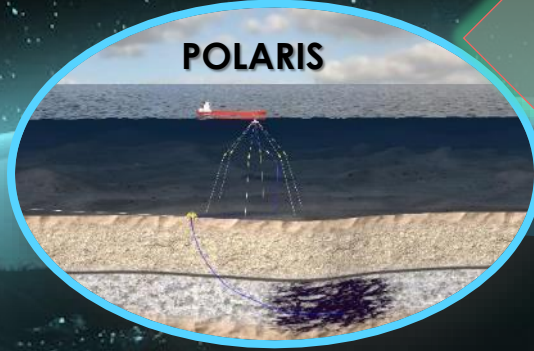
Offshore competence

- Geoscience & reservoir
- Well construction & operations
- Subsea systems & marine operations
- Platform, floating production systems & onshore plants

Barents Blue

World-scale production of clean ammonia

POLARIS



CO₂

Barents Sea

2.000.000t CO₂/year
*equivalent of annual
emissions of Norway's
aviation and ½ million cars

Gas

AMMONIA

1.000.000t NH₃/year



MARITIME FUEL

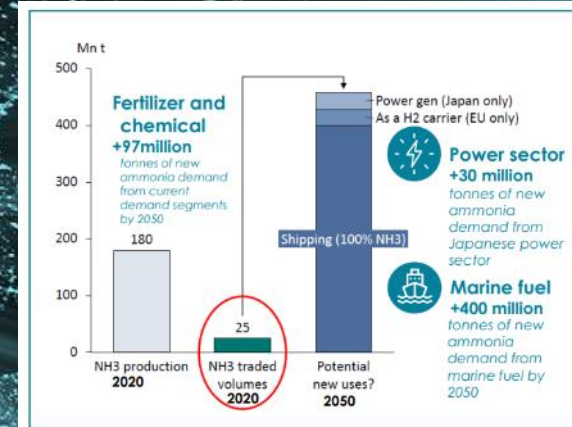
CHEMICAL INDUSTRY

FERTILIZER

POWER

Project partners:

Equinor
Vår Energi



Stella Maris – Think Big

To get CCS costs down, large scale solutions are required!

10 Mt CO₂ / year

Infrastructure will include:

- Carbon Collection Storage Offloading units (2-3) to be located at key location(s) as export hubs
- A fleet of large CO₂ shuttle carriers (up to 50 000m³)
- Offloading and continuous injection of CO₂ offshore into saline reservoir
- Zero emission Project
- Scalable Worldwide
- Solution deployed for large scale emitters, clusters and/or nation states in 2025
- One stop-shop from collection to storage
- Cooperate close with industry and policy makers nationally and internationally

Partners

Infrastructure/ownership:

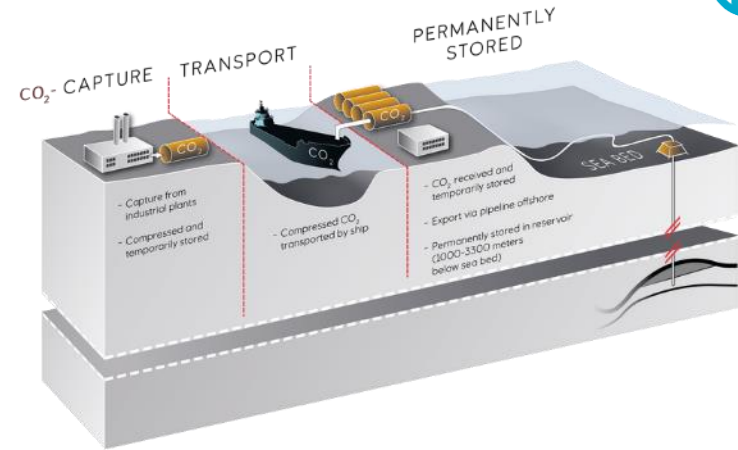


Industrial partners:



CO₂ ship transport – Northern Lights project

- Moss LNG experience → Moss LCO₂ design
- 2019: Moss engaged by Equinor, Total & Shell for design of cargo system for the Northern Light CO₂ ships
- Ship transport by 7500 m³ ships for CO₂ captured & liquefied from various sources – storage in Norwegian continental shelf
- Moss work scope: Basic design of the ship CO₂ handling systems
 - Process definitions of cargo system including operational procedures
 - Layout & piping basic design
 - Equipment definitions & budgetary pricing



TCM testing campaigns



- World's largest and most advanced test center for developing CO₂ capture technologies
- Leading competence center for carbon capture



Testing campaigns under the direction of technology providers

- Aker Solutions (Norway)
- Alstom/BHGE (USA)
- Cansolv Technologies (Canada)
- Carbon Clean Solution (UK/India)
- ION Engineering (USA)
- Fluor (USA)



Testing campaigns under the direction of owners

- Mono Ethanol Amine (MEA)
- Aerosolve
- Align
- DOCPCC
- CCSi2



Global centre of expertise

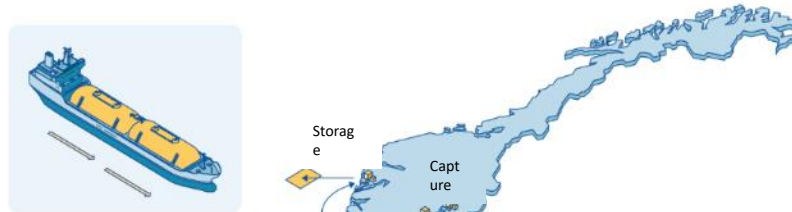
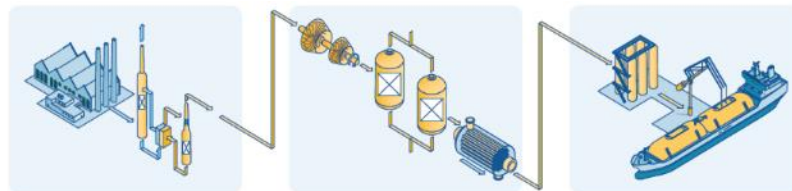
- Fortum Oslo Varme
- HeidelbergCement Norcem
- Guandong, China
- OGCI-CI
- DNV GL

Gassnova-expertise at every stage of the CCS value chain



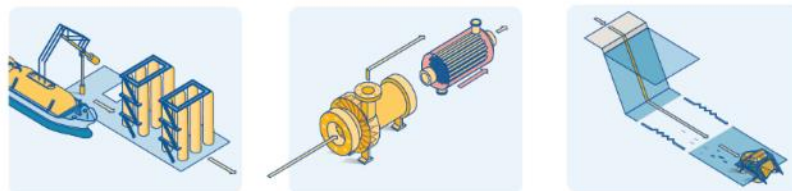
Capture

- Technology types
- Integration with sources
- Project maturation
- Cost estimates
- Industrial application
- Building and operating of facilities



Transport

- Logistics
- Transportation of ships and piping
- Material requirements/corrosion
- Design tools
- Flow modelling
- CO₂ specification requirements



CCS

- Project maturation
- Cost estimates
- Technological risk
- HSE related to CCS
- Government processes
- Regulatory matters
- Overview of operators: R&D, suppliers and end users
- National and global CCS networks

Storage

- Storage options
- Monitoring technologies
- Leak risk
- Injection wells
- Reservoir modelling for CO₂ movement

**Gassnova's expertise represent
Norwegian supplier capabilities**

Gassnova - established by the Norwegian authorities to development of technologies and knowledge related to carbon capture and storage (CCS)



Norway - Status today and summary

- High focus on environmental solutions over the latest decades
- In the lead of the green shift – especially in the maritime and offshore segment
- Strong reference list for environmentally friendly technologies
- Supplier of green and blue hydrogen and related technologies
- Research, development and demonstration of low emission technologies
- Several incentives from the government and clear targets for the green shift:
 - High pricing of emissions (e.g. CO₂).
 - Reduce taxes and fees for environmental solutions/vessels.
- Public procurement specifies environmental friendly requirements
- Government, industries and customers work together – creating win-win solutions
- Norway has a well-developed supply chain within the hydrogen and hybrid value chain and CCUS value chain

For further information about
Norwegian suppliers contact:



Eirik Melaaen, Ph.D.

Director Midstream & LNG, East Africa and Singapore

Mobile: +47 95 96 73 77

E-mail: eirik.melaaen@norwep.com



Norwegian
Energy Partners

Oslo

Hoffsveien 23, P.O. Box 631, Skøyen,
N-0214 Oslo

Stavanger

Innovasjonspark, Prof. Olav Hanssens vei 7A,
N-4021 Stavanger

Bergen

Godvikveien 58,
N-5179 Godvik