"Recent development in Norway:

-H_2 ships, national programme, & international cooperation"

H_2@ports Workshop, Marines' Memorial Club & Hotel

San Francisco, September 10-12, 2019

Dr.Steffen Møller-Holst

Vice President Marketing

SINTEF

Chairman

NORSK HYDROGENFORUM

hydrogen.no

Chair for Transport

Hydrogen Europe

Areas where Norway can play a key role internationally within hydrogen and fuel cells

SINTEF *Technology for a better society*

Outline

- Why Norway is heavily involved in new technologies within maritime transport
- Recent and ongoing activities and projects to reduce emissions from shipping
- Political engagement & National programs to foster market development
- Examples from recent public procurement processes
- Regional activities in central Norway
- International collaboration
- Summary/Conclusions

SINTEF - Scandinavia's largest independent research organization

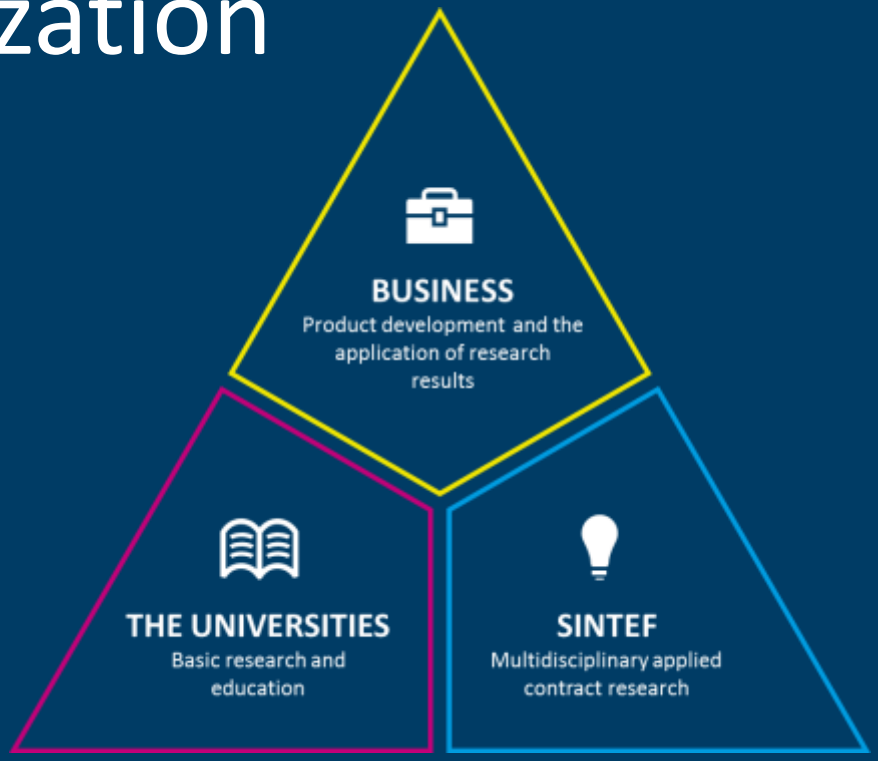
2000
Employees

75
Nationalities

4000
Customers

NOK 3,1 billion
Revenues

NOK 450 MILL
International sales



SINTEF, a key player in low & 0-emission technologies (R&D → Implementation):

- *development of Combustion-, Battery- as well as H_2 & Fuel Cell technologies*
- *> 30 years in H_2-technologies, 28 EU-projects (2010→), budget 60 MNOK/a (2016)*
- *interdisciplinary approach: Technology ↔ Economy ↔ Societal aspects*

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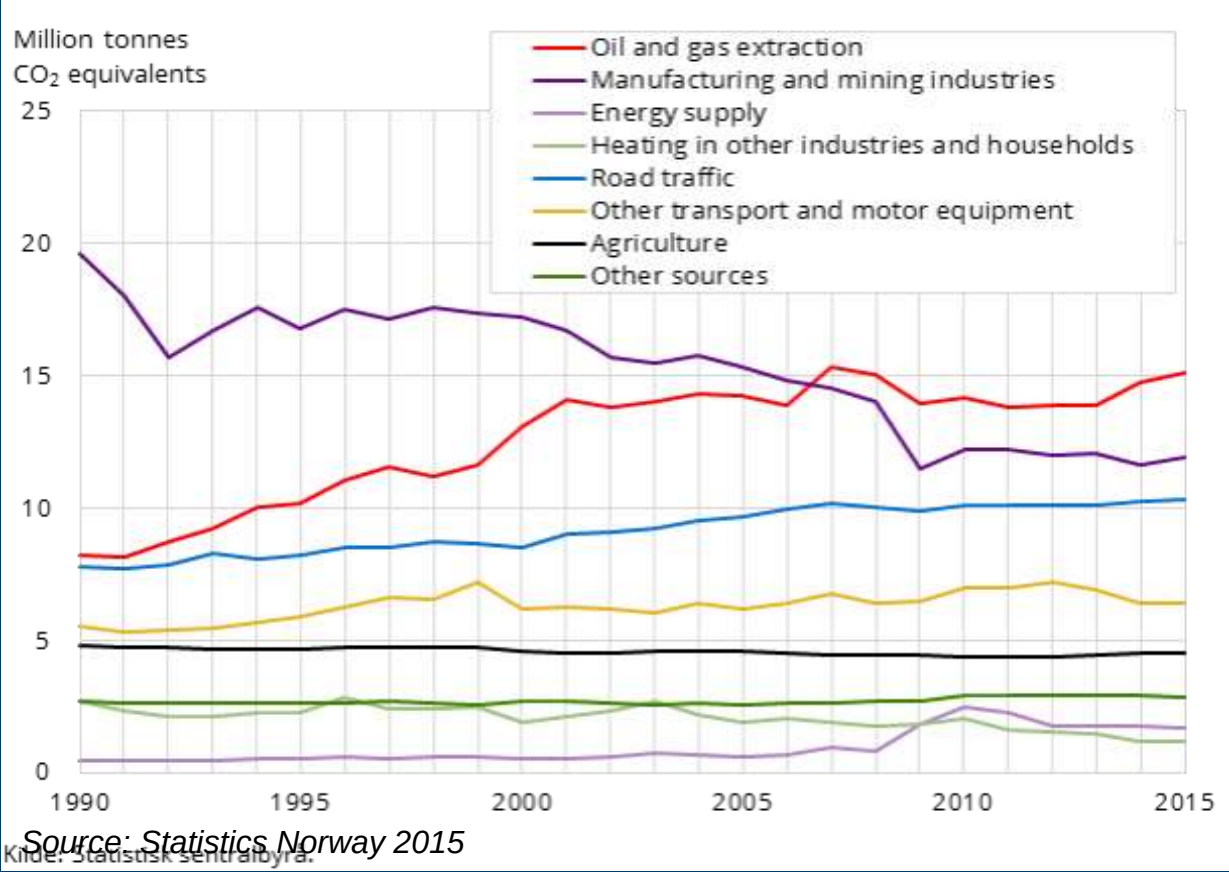
Rationale for why Norway is engaged

- Norway has the second longest coast-line of all nations (>20 000 km)
- Norwegians is a people of the sea, fishing / ship building / coastal transport
- Maritime industry is the 2nd largest, total value creation of NOK 130 billion
- Maritime activities contribute significantly to Norway's GHG emissions
- Cruise ships frequently visit our World Heritage Fjords → NO_x, SO_x, PM
- Norway has world leading H_2-technology suppliers (e.g. NEL, Hexagon)
- Ambitions to 5 times increase the fish farming industry → emissions

GHG emissions by sector in Norway



Source: Statistics Norway 2015

Electricity production from RES,

No natural gas grid !

- Oil & gas extraction ~ 28 %
- Transport contributes by > 30 %
- Electricity production: 1,7 %

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GHG emissions & H_2 initiatives in Norway

Passenger vehicles, 5,3 mill tonnes

CO_2

Vans and heavy duty vehicles 4,5 mill tonnes

CO_2

H_2-delivery trucks in 2018 →

Domestic maritime and fishing, 2.9 mill tonnes

Other mobile sources 2.3 mill tonnes

Domestic air traffic 1,3 million tonnes

Motor bikes and scooters 0,1 million tonnes

Railroads, 0,1 million tonnes

Passenger trains, Germany 2018 →

0 emission passenger trains in Norway?

5,6 MW H_2/FC freight train in Norway by 2025?

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Towards 0-emission ships

- Regulatory framework for LNG as maritime fuel established during 1990s
- World's first LNG-powered ferry in operation 2000 →
- Conceptual design of H_2-ferry (1999-2001), Grove Symposium 2001
- FCSHIP, 1st EU-project (FP5) 2002-2004 (SINTEF), recommendations to EC
- FellowShip-project, Viking Lady, 320kW MCFC, 2003→2011
- World's 1st LNG-bunker vessel M/S Seagas, Fiskerstrand (2014), refuelling Viking Grace
- World's 1st battery powered (120) car ferry (1MW) Ampere in operation 2015→
- Design of 1 MW FC powered H_2-ferry (Fiskerstrand Yard) 2017-19, construction 2020-21
- Parliament decision: 0-emission regulations in Norwegian fjords 2026→

Low and zero emission initiatives/**projects**

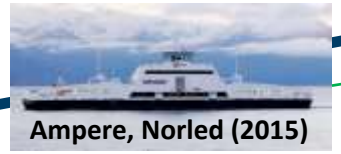
Trondheim Sept 3rd, 0-emission High speed passenger boat concepts

BLUE MARITIME CLUSTER

Norwegian Centres of Expertise
NCE Maritime CleanTech

Statens vegvesen
Norwegian Public Roads Administration

H_2-ferries, public procurement



Hjelmeland: LH_2/battery > 2021

Statens vegvesen
Norwegian Public Roads Administration

Caroline, Tromsø

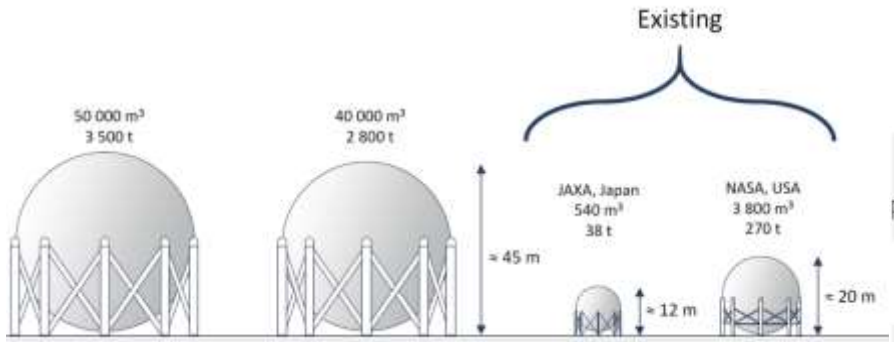
Berlevåg, fishing boats

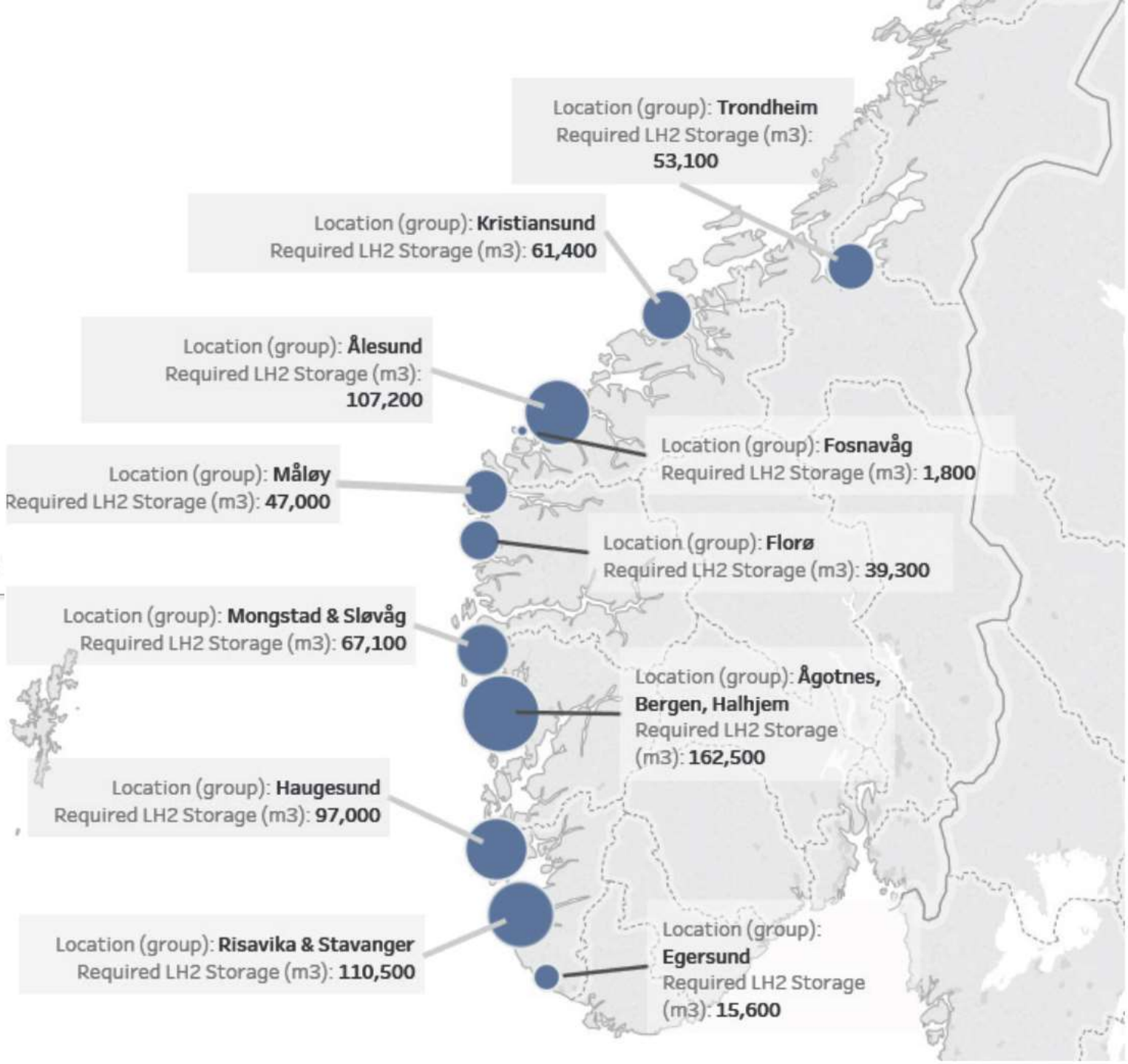
Glutra ferry (2000)
Now 21 LNG ferries

- Hybrid
- Hydrogen
- Battery
- LNG

Grenland, Yara Birkeland (autonomous)

Liquid hydrogen?

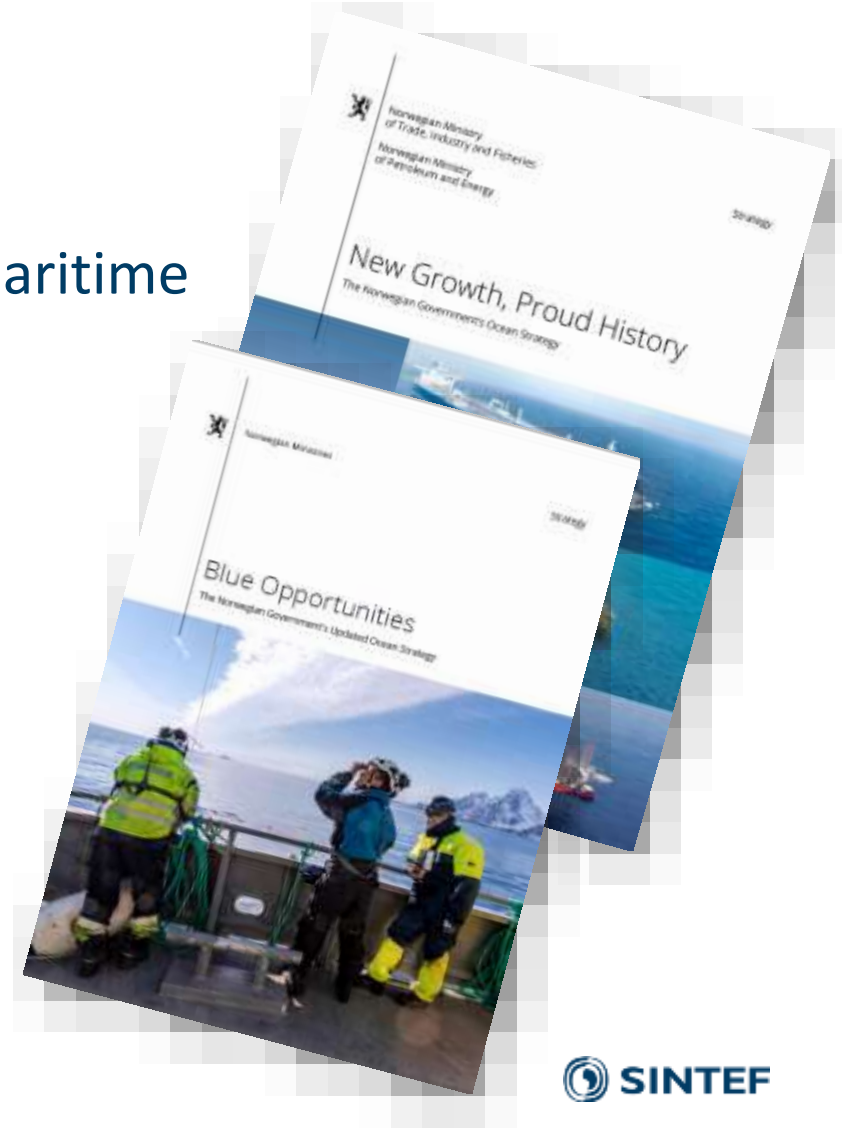




Government's Ocean Strategy

- Ambition to cut by half the emissions from domestic maritime traffic and fisheries by 2030
- Support R&D development across the ocean industries
- Strategy recently updated

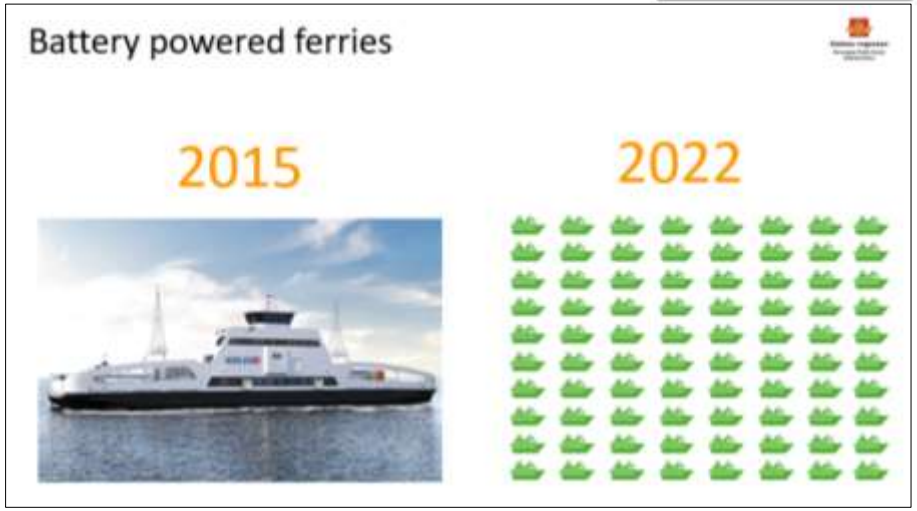
- *Few direct implications for hydrogen as maritime fuel*
- *National hydrogen strategy to be launched early 2020*



Ferry market development

Statens vegvesen
Norwegian Public Roads Administration

- 130 routes, 200 ferries, 20 mill vehicles & 40 million passengers/a
- Involvement and commitment* from Norwegian authorities and NPRA
- Funding that reflects the level of ambition
- A competent, efficient and professional procurement organization
- Joint effort from the public procurers (critical mass)
- Consistent and predictable requirements
- Individual tenders – assessment of economic risk on the ferry companies and predictable conditions



"The Government is requested by the Parliament, to ensure that requirements for zero-emission technology (and low-emission technology) are included in all future tenders for public ferries, when the technology allows for it."

Areas where Nor
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SINTEF *Technology for a*

The City of Trondheim

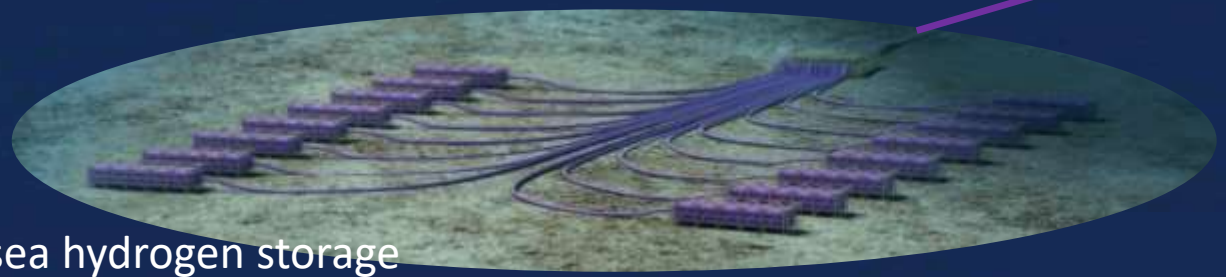
Large scale subsea hydrogen storage in ports

H_2-refueling station for:

- *High Speed passenger boats*
- *HD Trucks and Buses*
- *Car ferries*
- *Train?*

Fuel cells

Electrolyzer



Subsea hydrogen storage

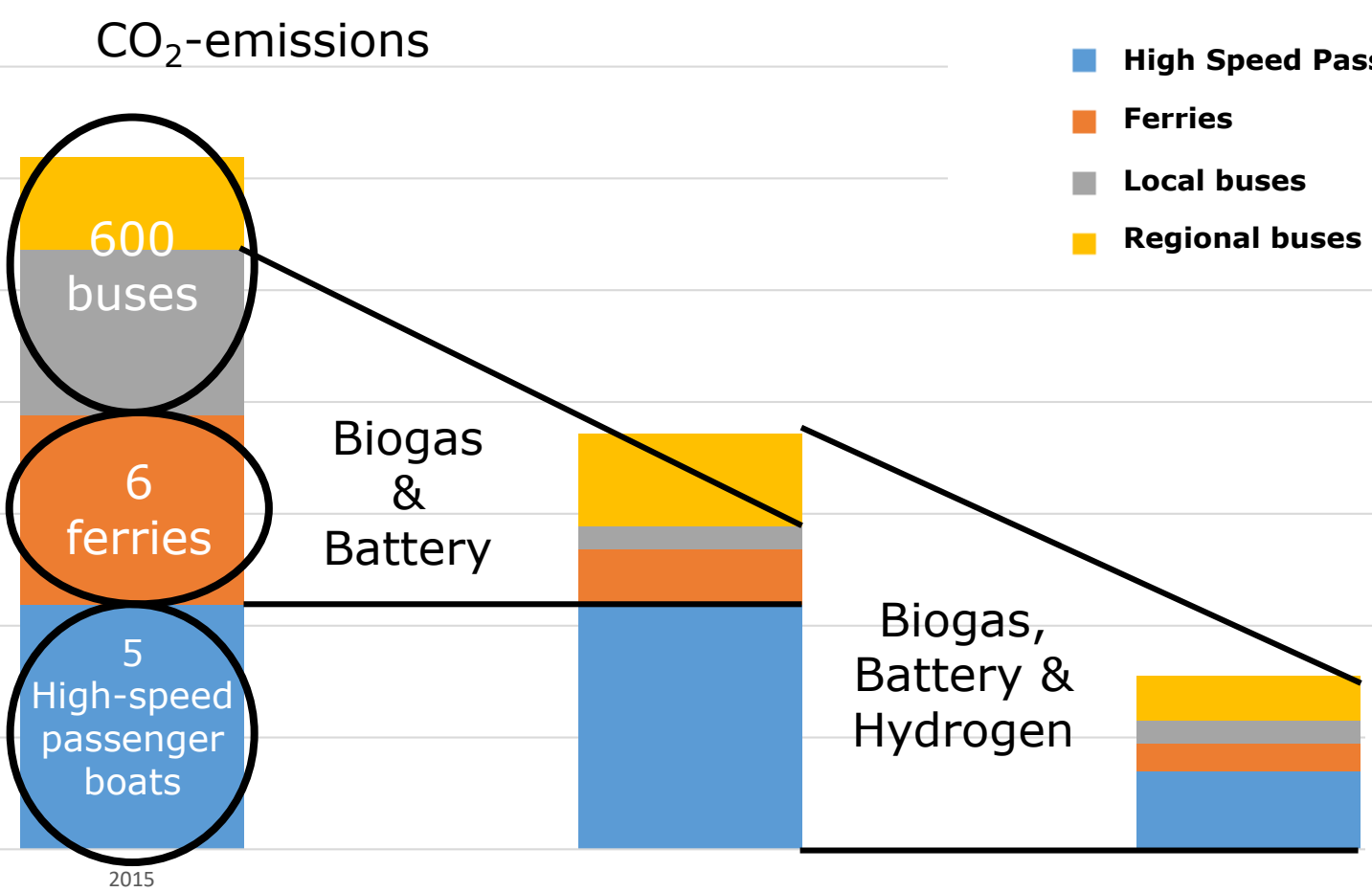
TechnipFMC

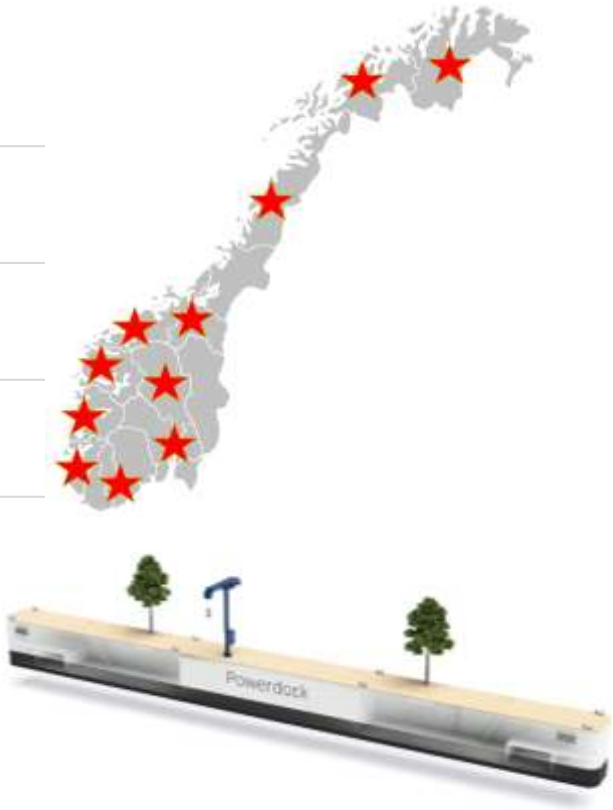
Deep Purple

The Region around Trondheim

REGIONAL PUBLIC TRANSPORT

Trøndelag fylkeskommune



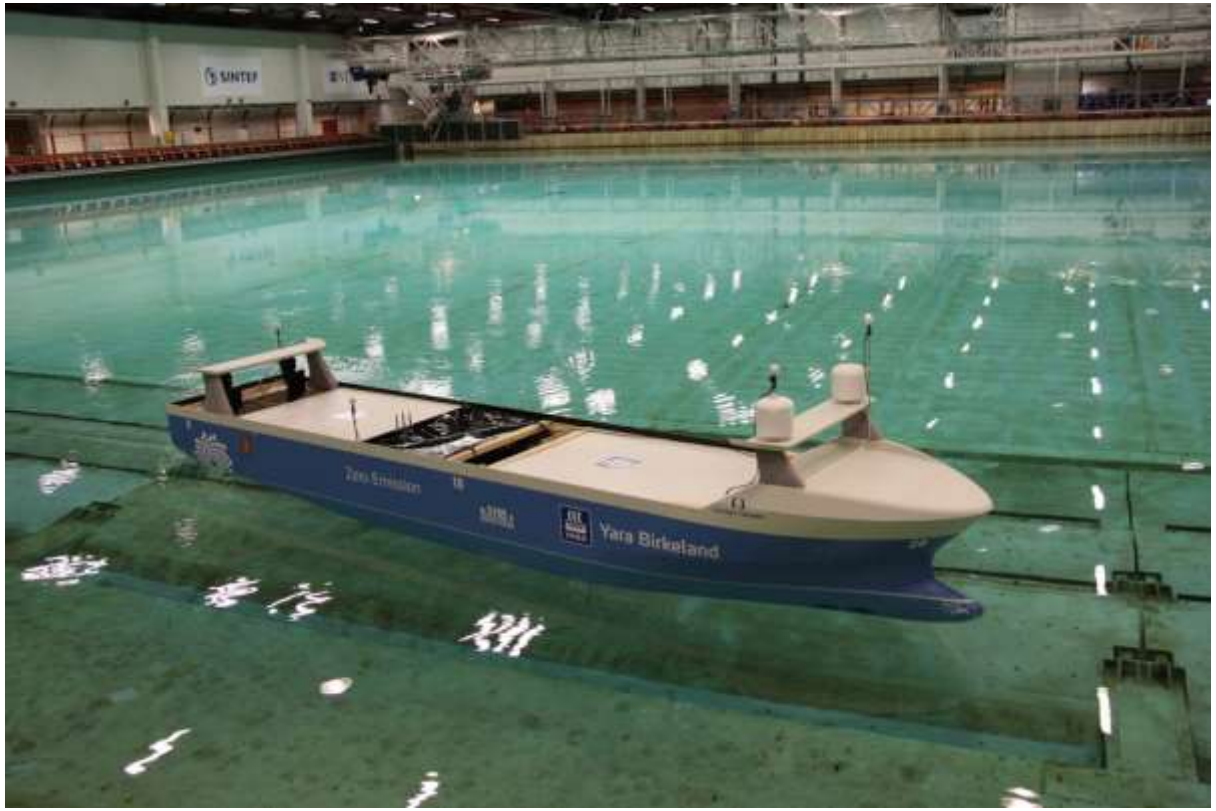


High speed passenger boats

Trøndelag fylkeskommune

- Trondheim to Kristiansund, ~3.5 hours, 2,5 tons H_2/day
- Pre-study to investigate feasibility of H_2 as fuel (SINTEF):
  - *H_2-infrastructure, bunkering and supply*
  - *Techno-Economic assessments (vessel)*
- Dialogue w/technology suppliers 2018→
- Concept developments/testing 2019→
- Public Procurement of vessels 2020 →
- Vessels in operation (target) 2023 →

Towing Tank @SINTEF/NTNU, 1939 ➔



NTNU

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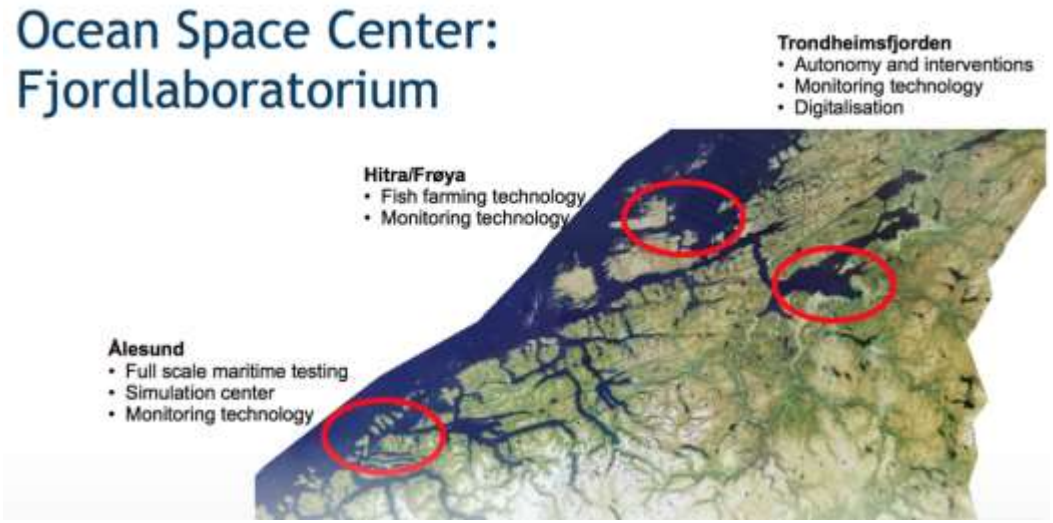
Ocean Space Center

- 2000 **Ocean Space Center** initiative by SINTEF & NTNU
- A wide range of concepts/designs/approaches
- **Governmental grant for realization secured last week**
- 2020 – 2021 Pre-study
- 2022 – Construction to start
- 2025 – Completion of Ocean Space Centre



NTNU

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World's 1st H_2/FC car ferry?

Pilot-E funded project 2017-2021:

- ✓ *Optimal FC/battery/H_2-storage capacity for various operation profiles (kW/time)*
- ✓ *Design, safety and risk assessment*
- ✓ *Testing of a down-scaled hybrid system (FC/battery) in SINTEF's laboratories*

- Ferry service (location), Approval
  ➔ Rebuild vessel, Pilot operation 2021?

International cooperation

- Safety, Regulation, Codes & Standards (SH2iFT-project (SINTEF), DNV GL, ABB, Siemens etc.)
- Inter-governmental Oceanographic Commission (food production, health, transport)
- The Arctic Council (8), circumpolar political collaboration body at government level
- The International Council for the Exploration of the Sea (North Atlantic)
- Washington Maritime Blue (US) / NCE Maritime CleanTech (N) (MoU June 2019→)
- Europe/Norway: FCHJU-funded RD&D-projects, Maritime WG (Hydrogen Europe)
- Japan/Norway, H_2-technologies, Bilateral Workshops (2003 – 2019)

Summary/Conclusions

- Norway is a shipping nation with long traditions
- Maritime activities contribute significantly to value creation and emissions
- Norwegian stakeholders have engaged in low emission maritime transport since 1990
- Hydrogen is becoming an integral part of the portfolio of maritime fuels
- Government, public administrations, industry & R&D institutions are joining forces
- Administrative and regulatory frameworks are being developed, *Public Purchasing*
- *International collaboration is key to accelerate implementation of FCH technologies!*

Thank you for your attention!

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Technology for a better society