Hydrogen and transport

- ongoing activities & challenges for further development

Energy Transition Workshop,
NTNU, 7th – 8th November 2017

Dr. Steffen Møller-Holst
Vice President Marketing
SINTEF

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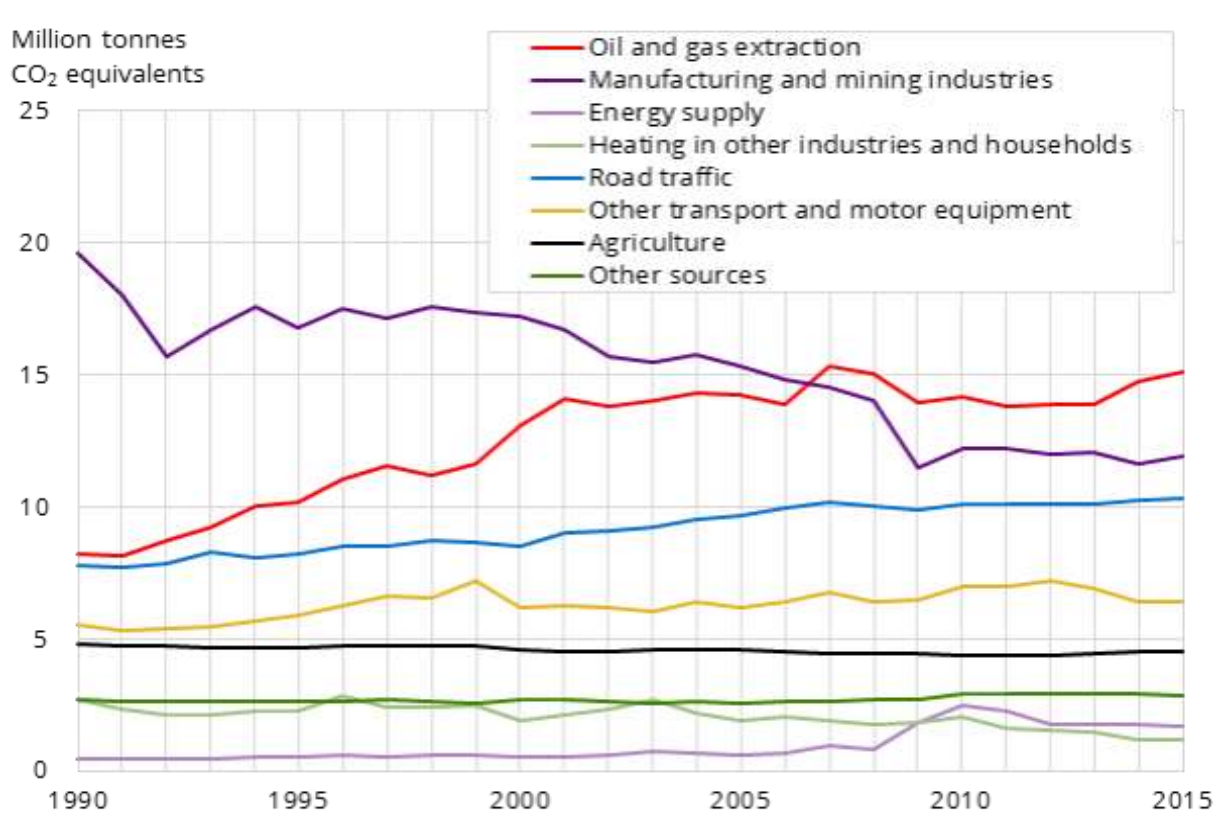
Hydrogen Europe Research
FCH

Norwegian hydrogen forum
Chairman
NORSK HYDROGENFORUM
hydrogen.no

Norway's domestic GHG emissions



Source: Statistics Norway 2015

Current GHG-emissions by sector:

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

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Areas where Norway can play a key role internationally within hydrogen technologies

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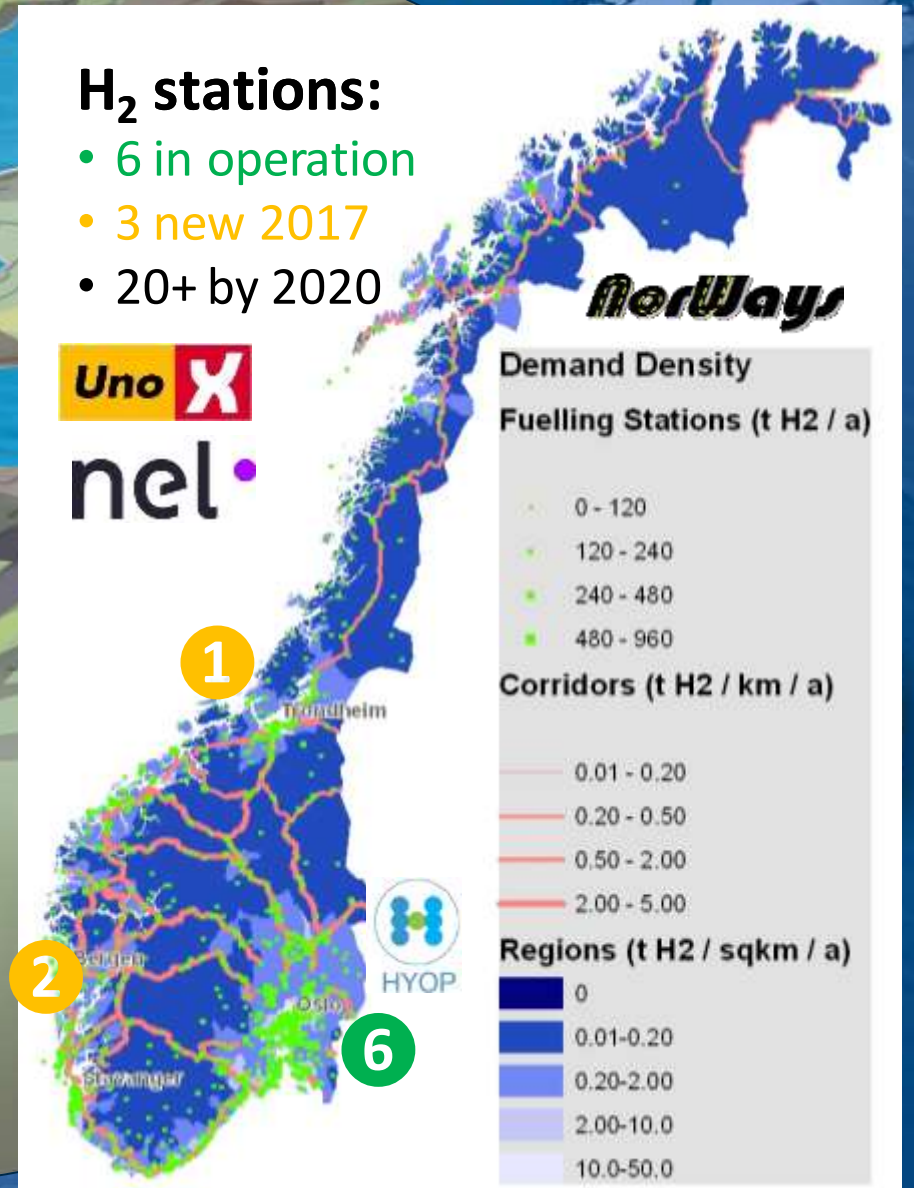
H_2 stations:

- 6 in operation
- 3 new 2017
- 20+ by 2020

Uno X

nel



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H-stations

1940 RJUKAN

1953 GLOMFJORD

World's largest 135 MW

3 TONs Hydrogen/ hour

enough to power > 200 000 Mirais

HEXAGON COMPOSITES

nel

PROTON ON SITE

H2 Logic

World´s largest factory for hydrogen refuelling stations

Alkaline elektrolyser
2 MW, 13.5m x 4 m,
Mature technology

HEXAGON xperion

supplier to e.g.,

DAIMLER SCANIA TOYOTA

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GHG emissions from transport & H_2 demos in Norway

Passenger vehicles, 5,6 mill tonnes

CO_2

Vans and heavy duty vehicles 4,4 mill tonnes

CO_2

H_2-delivery trucks in 2018 →

nel HEXAGON SCANIA ENOVA SINTEF

Battery ferry 2015 → 1MW

Domestic maritime and fishing, 3.7 mill tonnes

Other mobile sources 2.3 mill tonnes

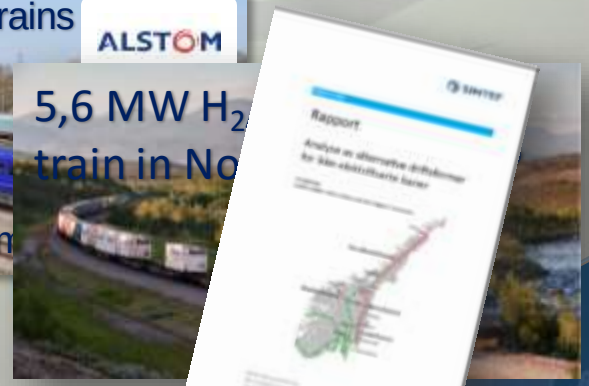
Motor bikes and scooters 0,1 million tonnes

Railroads 0,05 million tonnes

Domestic air traffic 1,3 million tonnes

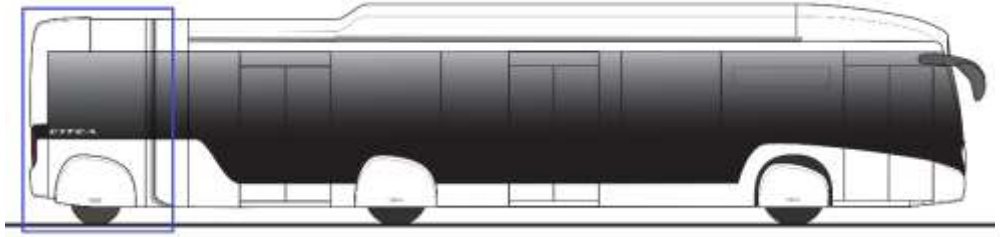
100 passenger trains 2017-2021

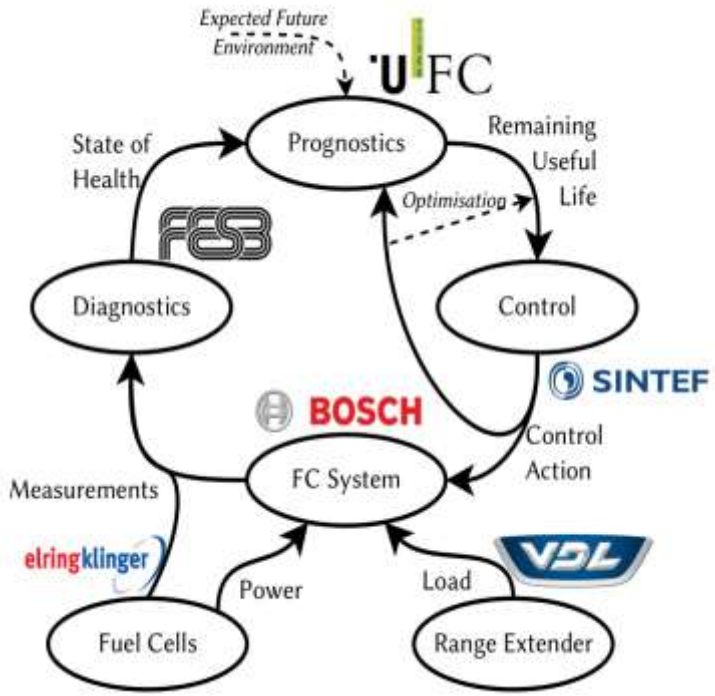
ALSTOM



EXAMPLE: One of SINTEF's 25 EU-projects in FCH JU, Giantleap:
Control & Prognostics for increased lifetime of PEMFCs

- Applied on city battery buses with **fuel-cell range extender**
- Increasing **lifetime** and **reliability** of FC system (*not just the stack*)
- Battery-FC **hybridisation** gives more freedom to life-maximising control
- Targets:
  - System availability > 98%
  - Lifetime 2×12 000 h
  - Cost: bus 650 000 €, FC system 500 €/kW
- SINTEF is coordinator; total budget 3.26 M€





Coordinated by SINTEF:
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H_2 as fuel for delivery trucks and forklifts

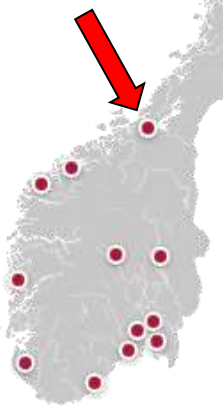
ASKO

SCANIA

- Concept conceived jointly with SINTEF
- Support secured from Enova April 2016
- Solar Cells (PV) on distribution centre roof
- 3-4 delivery trucks for regional use
- Ten H_2-forklifts in operation 2017→
- Local hydrogen production, electrolysis
- Refuelling at 350 and 700 bars

Emission reductions (4 delivery trucks):

- CO_2 ÷216 tonnes/year
- NO_x ÷1130 kg/year,



Financially supported by ENOVA

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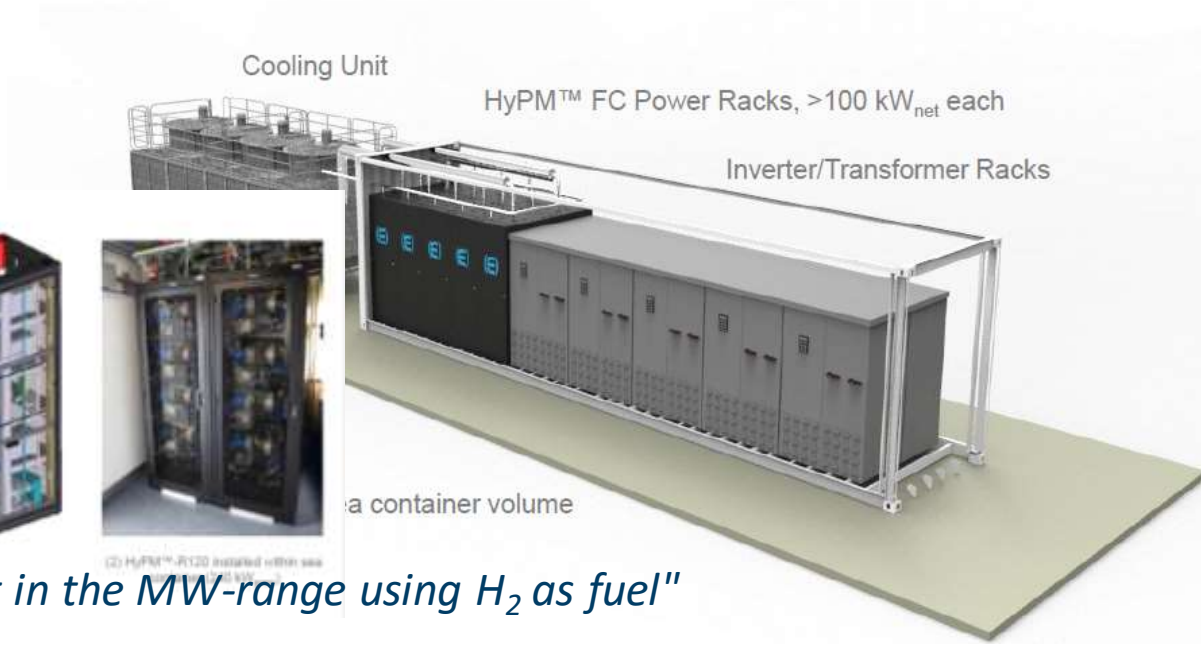
Fuel Cells in ships, ferry



Pilot-E-project, 2017-2019

1st phase, IPN funded by RCN

- Objective (HYBRIDSKIP):

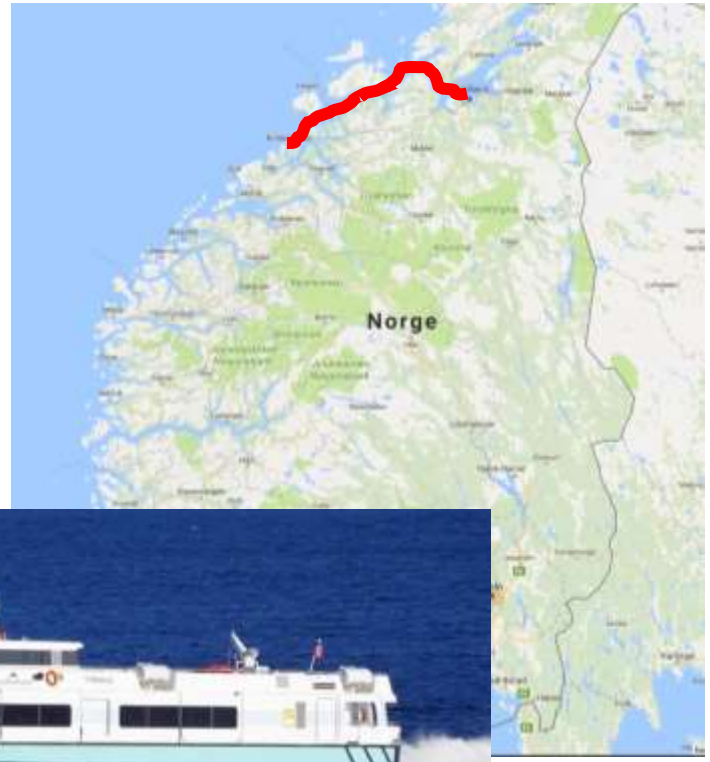
  "Outline the design of a Fuel Cell powered ferry boat in the MW-range using H_2 as fuel"

- Ambition of realisation 2020-2021
- Road Administration: H_2-ferry in 2021
- SINTEF's role:
  - Technical advise on H_2/FC technologies
  - Component scaling and system simulations
  - Testing of down-scaled hybrid system in laboratory

Fuel Cells in high-speed passenger boats

Sør-Trøndelag County, feasibility study:

- Trondheim - Kristiansund, ~3.5 hours, 2.5 tons H_2/day
- Mapping possibilities and challenges for H_2-vessel
- **H_2-infrastructure, delivery and bunkering (SINTEF)**
- Cost analyses for technical solutions
- Planning a call for technical development contract (excl. operation) ultimo 2018



SØR-TRØNDELAG FYLKESKOMMUNE

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Fuel Cells in high-speed passenger boats

Sør-Trøndelag County, feasibility study:

- **H_2-infrastructure, delivery and bunkering (SINTEF)**

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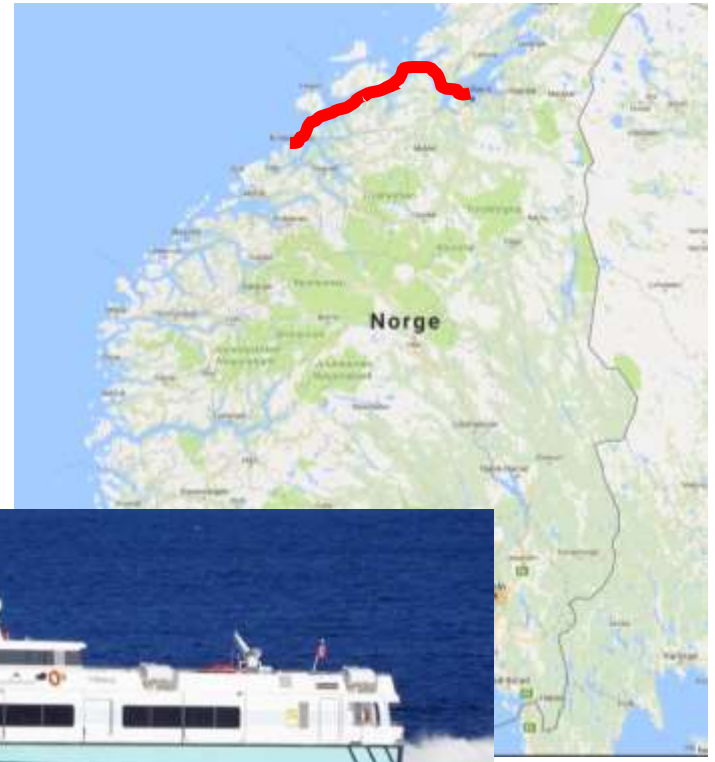

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Fuel Cells and Hydrogen in cruise ships

Viking Cruises' H_2-ship initiative (2015➔)

- 23 MW FC, liquid H_2,
- SINTEF engaged (2016➔)
  - Scientific support in meetings with NMA (Sjøfartsdirektoratet), class (DNVGL), funding agencies, yards, component suppliers
  - Mapping:
    - Potential H_2-suppliers in Norway
    - Public support schemes
    - Relevant Norwegian stakeholders/H_2-technology suppliers

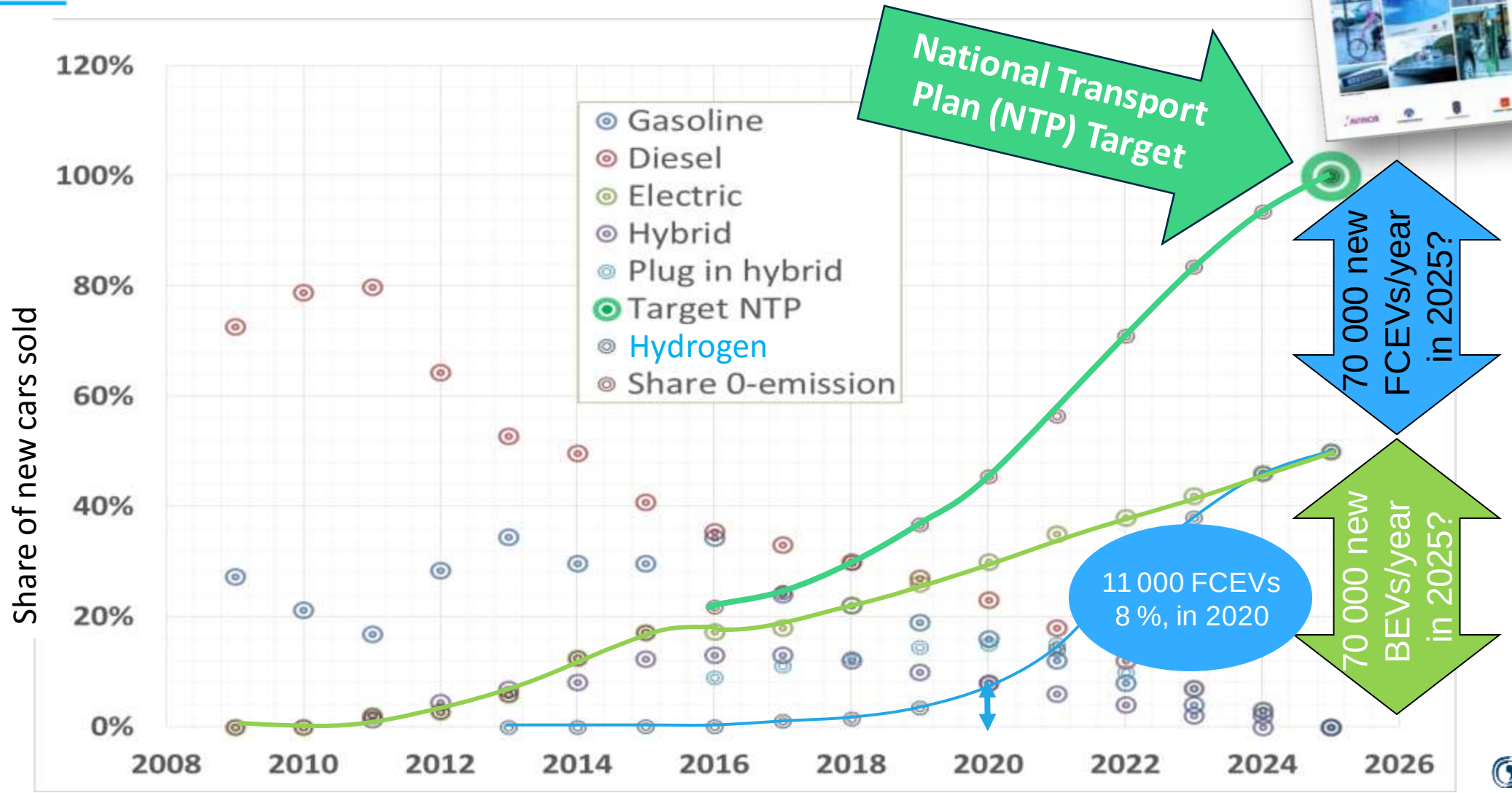
Norway – an early market for FCEVs?

Climate strategy

Introduction of low- and zero-emission technology

- After 2025, new private cars, city buses and light vans are to be zero-emission vehicles
- By 2030, new heavy vans, 75 % of new long-distance buses, and 50 % of new lorries are to be zero-emission vehicles
- By 2030, goods distribution in major uban centres are to be almost emission free

Norway – an early market for FCEVs?



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Infrastructure cost

- Cost for chargeable vehicles (BEV, PHEV) is estimated at 16.4 Bill. NOK (NTP/Enova)

Hva koster det?

Dersom hele utslippsreduksjonspotensialet skal tas med elbiler vil personbilene trenge om lag 156 000 normalladepunkter (inntil 5,5 mrd. kr) og opp mot 7 800 hurtigladepunkter (inntil 5,9 mrd. kr), totalt inntil 11,4 mrd. kroner. Til 250 000 el-varebiler trengs om lag like mange ladepunkter (med dagens batterikapasitet) til totalt 5 mrd. kr. Deler av kostnaden vil måtte dekkes av det offentlige. ENOVA er i den gjeldende ladestrategien i ferd med å utvikle muligheten for lading i de viktigste vegkorridorene.

enova

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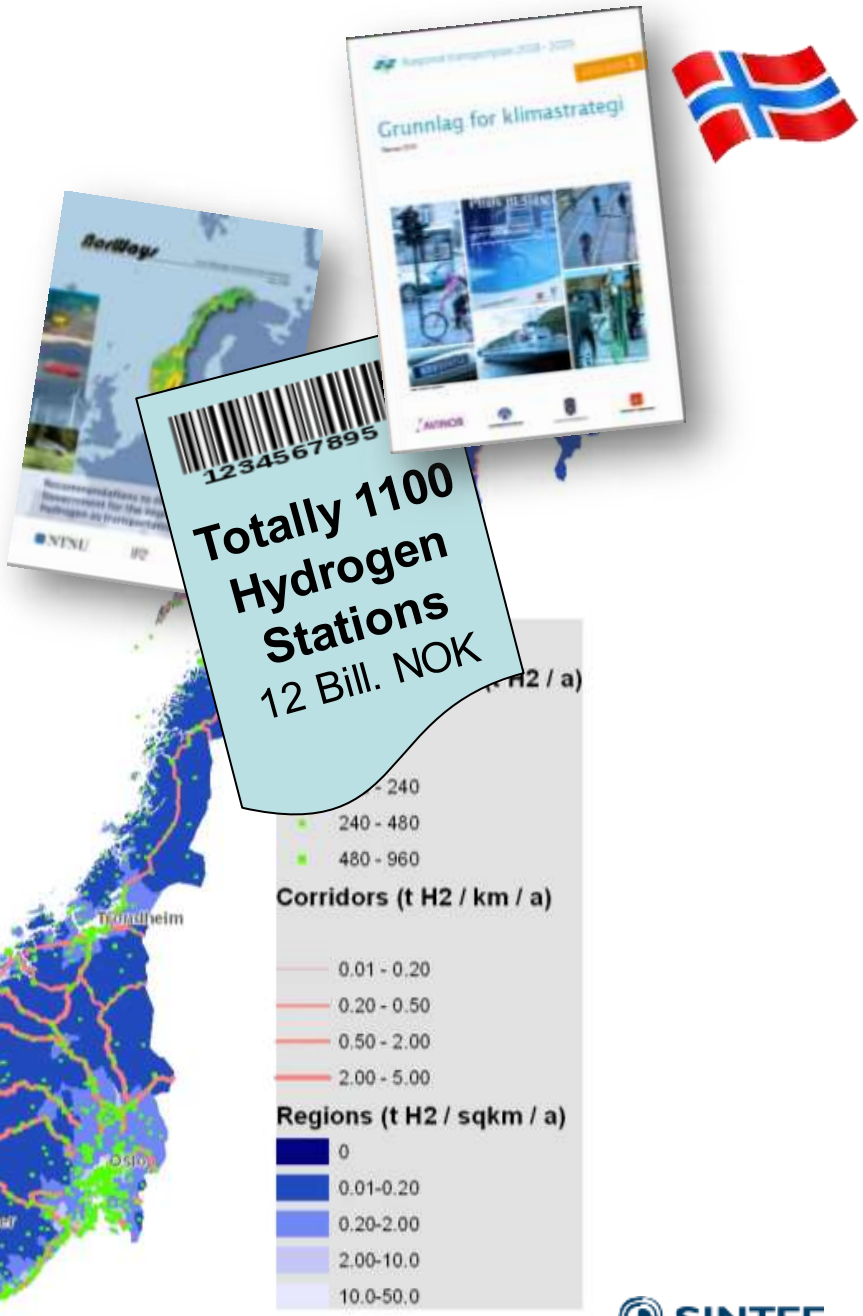
Infrastructure cost

- Cost for chargeable vehicles (BEV, PHEV) is estimated at 16.4 Bill. NOK (NTP/Enova)
- Complete H_2-refuelling station network cost: 12 Bill. NOK (RCN/SINTEF)
  - 68 NOK/capita year (2015-2050)
- In agreement with studies in EU and US*:
  - Hydrogen € 1000-2000/vehicle (5 % of total cost)
  - Electricity € 1500-2500/vehicle



* *Natl. Research Council US (2008)*

Hydrogen demand, recent SINTEF-study

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Various fuels in segments of transport

	Road transport						Aviation	Rail	Sea Transport		
	Persontransport			Vare- og godstransport							
											
Range →	Short/City	Medium	Long>500km	Short	Medium	Long			Short	Coastal	Ocean
Natural gas	LNG							LNG		(LNG)	LNG
Electricity											
Biofuels											
Hydrogen											LH_2

The fuel is well suited in this transport segment / biofuel is a limited resource

The fuel is less suitable, but may be used in this transport segment

The fuel is not expected to be suitable in this transport segment within 2025

* Technologies are under continuous development and the above picture will shift significantly between 2030 & towards 2050

Based on EU's expert panel for Alternative Fuels (https://www.slideshare.net/EBAconference/12-antonio-tricas-aizpun)

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Summary

Thank you for your attention!

- Transport contributes by close to 30 % of Norway's domestic GHG emissions
- Norway is paving the road for 0-emission transport; incentives and funding schemes
- Fuel Cells & H_2 is gaining increased attention as fuel for heavy duty/maritime transport
- SINTEF is a key player in Europe (primarily in R&D), also H_2 technology implementation
- Regulations, codes and standards need to be adopted/verified through risk analyses
- H_2 as fuel in transport: "chicken and egg", other markets larger (industrial/households)
- Regional clusters are established; foster value creation (public/industry/academia)
- H_2 technology implementation is hampered by the lack of a national hydrogen strategy

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Technology for a better society