

## "Norway's prospects in an international context

- the role of hydrogen in decarbonising various sectors"





*Copenhagen, 19<sup>th</sup> September 2019* 

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Chairman Transport

# Outline

- H<sub>2</sub> in the European Climate and Energy Policy Framework
- Initiatives and activities towards a H<sub>2</sub>-oriented economy in Europe
- Norway's prospects for retaining the position as an energy exporting country
- Hydrogen technology for reduced emissions in transport & industry
- Potential for value creation from export of H<sub>2</sub> and H<sub>2</sub> technology
- Summary and Conclusions





## Increasing political engagement











SINTEF

## Industry engagement\_Hydrogen Council



## Hydrogen Council, "Hydrogen - Scaling Up"

#### Exhibit 3: Hydrogen can play 7 roles in the energy transition



## **Climate Neutral Europe 2050**

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	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers	Electrification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resource and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050		-80 ["w	-80 % GHG (excluding sinks) ["w ell below 2°C" ambition]			-90% GHG (incl. sinks)	-100% GHG (incl. sinks) ["1.5°C" ambition]	
Major Common Assumptions	<ul> <li>Higher ener</li> <li>Deployment</li> <li>Moderate c</li> <li>Digitilisatio</li> </ul>	y efficiency post 20 of sustainable, adva rcular economy mea	IO       • Market coordination for infrastructure deployment         nced biofuels       • BECCS present only post-2050 in 2°C scenarios         sures       • Significant learning by doing for low carbon technologies         • Significant improvements in the efficiency of the transport system.					
Power sector	(demand-side r	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization sponse, storage, in erconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS deployment faces limitations.						
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	Higher recycling rates, material substitution, circular measures	Combination of most Cost- efficient options from "well below 2°C" scenarios with targeted application (excluding CIRC)	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	Increased modal shift	Mobility as a service			<ul> <li>CIRC+COMBO but stronger</li> <li>Alternatives to air travel</li> </ul>
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid				Limited enhancement natural sink	<ul> <li>Dietary changes</li> <li>Enhancement natural sink</li> </ul>

#### Detailed assessment supported by scenario analysis

Brussels, November 2018



CLIMATE NEUTRAL

#EU2050

EUROPE

2050

## **Increasing focus on Hydrogen in Europe**

### Hydrogen Roadmap Europe:

- Sector Coupling • Hydrogen is required to achieve the energy transition in Europe
- Hydrogen may close up to ~ 50 % of the gap towards a 2°C target
- Points at import of H<sub>2</sub> from regions with abundant wind energy
- Concludes that the most cost optimal decarboniztion solution include both water electrolysis and reforming of natural gas
- Asks for immediate and concerted action to establish a masterplan for decarbonization for the European Union



A SUSTAINABLE PATHWAY FOR THE EUROPEAN ENERGY TRANSITION

## Hydrogen provides increased flexibility









# Trends and Activities in Europe - mobility

Press release 27<sup>th</sup> September 2018:

#### "H2busEurope"

- 600 hydrogen buses
- Connecting Europe Facility (CEF) program
- 40 M€

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First H<sub>2</sub>-powered passenger train commercial operation (Alstom/Hydrogenics) III IN SARE SER ..... .....





- 49 new stations
- > 1400 cars & vans
- M€ 170 total cost
- M€ 67 funding
- > 40 organisations

Viable business case for 1600 H<sub>2</sub>-fuelled (FC) Heavy Duty Trucks in Switzerland





#### Trends and Activities in Europe - energy . . . . . Hydrogen is an energy vector facilitating an increased share of RES **Operating strategy** ENERGY SECURITY **EEX price** day-ahead **BOOST EU** load / price COMPETITIVENESS regional max. load electrolyser wind Polan production limits electrolyser DECARBONISATION OF EU ECONOMY .... 00:00 03:00 06:00 09:00 12:00 15:00 18:00 21:00 00:00 time Czech Republic Electrolysis — Power price — Threshold price -Wind - $Grid \rightarrow Hydrogen$ b ludwig bölkow systemtechnik **10 MW PEM-electrolyser** Water electrolysis (PtG) Rheinland Refinery, Switzerland Hydrogen storage High power (MW-GW) - Underground storage Wesseling, Germany SINTE .... .... - Coupling w/intermittent - Solid state storage \_ \_ \_ \_ \_ \_ ..... energy sources - $LH_2$ SINTEF . . tm powi ....

elementenergy





## Admixture of H<sub>2</sub>

- Business cases
- Injection system
- End user equipment
- **Regulating authorities**



# Trends and Activities in Europe - energy



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

> Exporter of H<sub>2</sub> & H<sub>2</sub>-technologies

SINTEF

Early user of H<sub>2</sub> in transport & industry





Technology for a better society



#### . . . . . . . --- - ----.... . . ..... ... ... ........ Norwegian energy export ----. ...... .... -----------.... ..... \_ \_ \_ \_\_\_\_\_ \_\_\_\_\_ .... . . . . . NORWAY EUROPE ......... -----\*\*\*\*\* ----------10.10.00.00.00.00.0 ..... Hydropower .... 10.10.00 .... 利用用用用 \*\*\*\*\*\*\*\* \*\*\*\*\*\* \*\*\*\*\* ..... \*\*\*\*\* Wind .... \*\*\*\*\* \*\*\*\*\*\* **WARREN** ..... No. of all other \*\*\* ..... **FA** .... .... \*\*\*\*\*\* ....... 11111 M 10 10 10 10 ..... ......... NES DEED ........ H G .... \*\*\*\*\*\*\*\* ..... ................... ..... \*\*\*\*\*\*\*\*\*\* \*\*\*\*\* \*\*\*\*\*\*\* -----....... Hydrogen 10.00.00.00.00.00.00.00.00.00.00 ...... ........... \*\*\*\*\*\*\*\* BERNSON BE ---新年月月 1 -Gas ...... 12 年 1 STREET, STREET ........... \*\*\* .......... -----10.10 \*\*\*\*\*\*\*\*\* \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* \* 1.00 101 100 \*\*\*\* \*\*\*\*\* CO. 00000 10 10 10 \*\*\*\*\*\*\*\*\*\*\*\* ....... \*\*\*\*\*\* IN COLUMN 2 IN COLUMN \*\*\*\*\*\* 14.3 .... \*\*\*\* ..... ......... ..... -------SINTEF .... .....



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# Norwegian energy balance





One of SINTEF's 28 EU-projects under the FCH JU-program

# Wind $\rightarrow$ 1000 kgH<sub>2</sub>/day

- Electrolyser (2,5 MW) installed in Berlevåg in 2020
- Directly connected to Raggovidda wind park (avoiding grid tariff)
- Electrolyser exhibit fast response
  - Stabilize grid voltage and frequency
- EU (FCHJU) -project:
  - Total budget 7 M€ (70 % public support),
  - Start January 2018, duration 4 years

HYI Shift Po

Berlevåg





## 💋 VARANGER KRAFT





Kawleige Environment Security Se



## Replace coal-based energy in Svalbard?



# Stranded wind power

- Pilot-project: 2,5 MW  $\rightarrow$  1 ton H<sub>2</sub>/day
- Concessions 225MW  $\rightarrow$  100 ton H<sub>2</sub>/day
- Wind potential 2 GW  $\rightarrow$  1000 ton H<sub>2</sub>/day
- Enough fuel for 1 mill. passenger cars (40%)
- Applications in Finnmark region:
  - Passenger cars, light & heavy duty trucks, Snow mobiles
  - Fishing vessels, Trawlers, Coastal 'steamers' (Hurtigruten)
  - Fish farming/Agriculture (O<sub>2</sub> & heat), Industry (NH<sub>3</sub>?)





Greenhouse



Ammonia plant Hydrogen plant

Fishfarming with Data storage in oxygen from wind turbine hydrogen plant





## Hydrogen as energy carrier

### **Energy sources for hydrogen production in Norway**





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## Hydrogen as energy carrier

**Energy sources for hydrogen production in Norway** 





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# Norway's domestic GHG emissions





## GHG emissions & H<sub>2</sub> activities in Norway

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# **Next Wave**

## Next Nordic Green Transport Wave – Large Vehicles

Duration:2019 – 2021Budget:3,8 mill. NOK (50% funding from Nordic Innovation)Program:Nordic Smart Nobility and Connectivity

- Accelerate decarbonisation of the heavy-duty transport sector with fuel cell vehicles. The project will analyze large-scale transport of hydrogen, action plans for business potential for roll-out of hydrogen buses and trucks in the Nordic region, stimulate demand side and analyze potential for other heavy-duty equipment.
- contribute to National and Nordic hydrogen strategy processes
   providing input to a possible Nordic Hydrogen Strategy.

The short-term goal of the project is fourfold:

- 1. To perform thorough analysis on large-scale transport of hydrogen
- 2. To develop and design an integrated hydrogen infrastructure roll-out plan for HD vehicles
- 3. To encourage Nordic industry to join forces in delivering such hydrogen equipment
- 4. To stimulate Nordic companies to demand and use hydrogen for heavy-duty transport

Co-financed by:



Partners:



Scandinavian Hydrogen Highway Partnership







VATGAS

SVFR

Brintbranchen Hydrogen Denmark

Supporting partner:



## GHG emission initiatives, maritime transport

Trondheim Sept 3<sup>rd</sup>, 0-emission High speed passenger boat concepts



Location (group): Trondheim Required LH2 Storage (m3): 53,100

Location (group): Kristiansund Required LH2 Storage (m3): 61,400

Location (group): **Ålesund** Required LH2 Storage (m3): **107,200** 

Location (group): Måløy 20 m Required LH2 Storage (m3): 47,000

> Location (group): Mongstad & Sløvåg Required LH2 Storage (m3): 67,100

Location (group): Haugesund Required LH2 Storage (m3): 97,000

Location (group): Risavika & Stavanger Required LH2 Storage (m3): 110,500 Location (group): Fosnavåg Required LH2 Storage (m3): 1,800

Location (group): Florø Required LH2 Storage (m3): **39,300** 

> Location (group): **Ågotnes,** Bergen, Halhjem Required LH2 Storage (m3): **162,500**

Location (group): Egersund Required LH2 Storage (m3): 15,600

# Liquid hydrogen?



Wilhelmsen / Equinor LH<sub>2</sub> pilot tanker

Norwegian future value chains for liquid hydrogen



# Hydrogen use in industry



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## The City of Trondheim

## Large scale subsea hydrogen storage in ports

## Hydrogen Hydrogen

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

Subsea hydrogen storage

Electrolyzer

Fuel cells

Hydrogen





# Value creation, H<sub>2</sub>-technology export





# Summary and Conclusions

- The contour of a H<sub>2</sub>-oriented economy is eventually emerging in Europe
  - Stronger alignment in Europe's energy & climate policies, H<sub>2</sub> for <u>Sector Coupling</u>
  - Hydrogen as feedstock for industry and a key solution to decarbonize the heat sector
  - Multiple H<sub>2</sub>-mobility initiatives, increasing focus on heavy duty trucks, trains & maritime applications
- Norway is actively preserving its role as energy nation and front runner
  - Stranded renewable and abundant fossil resources suitable for H<sub>2</sub>-production
  - Increased focus on CCS in industry and attention at governmental level (value creation)
  - Continued strong incentives for low and zero emission transport, new deployments @ road & sea
- High potential for closer & increased volume of Nordic cooperation



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

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Technology for a better society