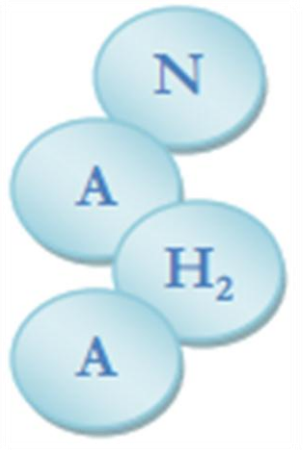
Role of hydrogen in an North Atlantic context

(and some Norwegian projects)

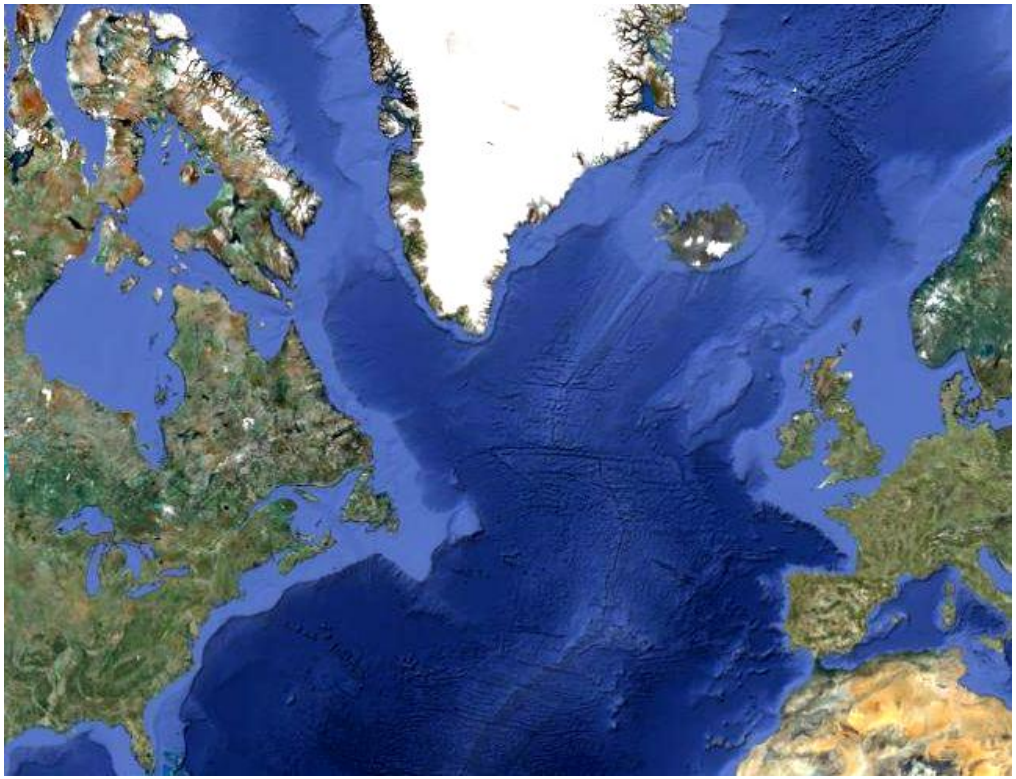


Christopher Kloed

Reykjavik October 2012

The North Atlantic Region

Some nationvide characteristics in the region that could help propell the application/use of hydrogen



- Abundant wind resources
- Abundant fresh water resources
- Large and active marine sector
- Well educated population
- Well functioning public sector
- Public transportation
- Good universities and high tech industries
- Favorabe R&D/demonstration grants

Some past/existing H2 projects in the North Atlanic Region

H2 storage system, Nuuk

H2 boat application, Reykjavík

H2 filling station, vehicles and buses, Reykjavík

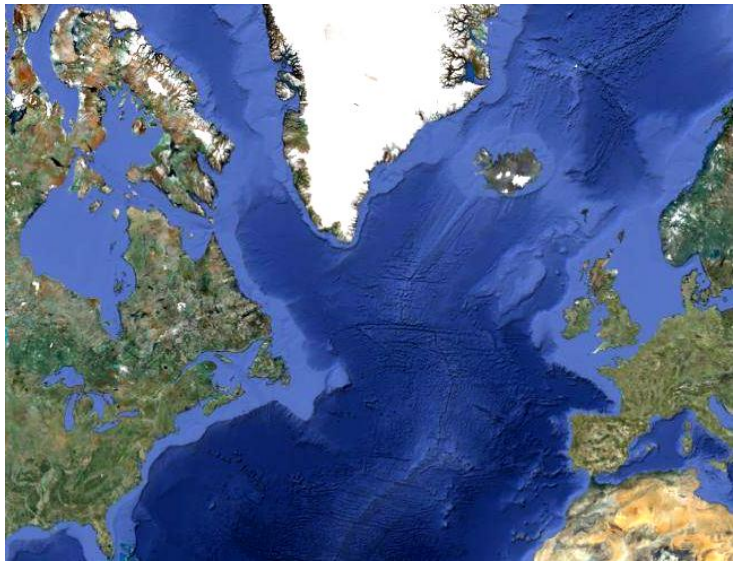
H2 and wind applications, Ramea Island

HyNor: H2 stations and vehicles

H2 and wind applications, Fife

H2 and wind applications, Utsira

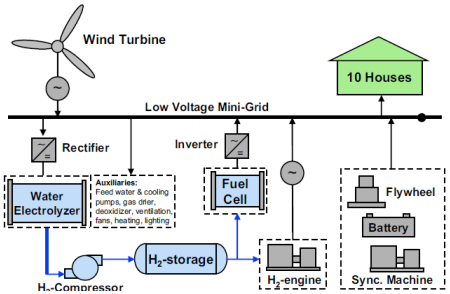
The years ahead – what H2 programs/projects should be prioritized/promoted?



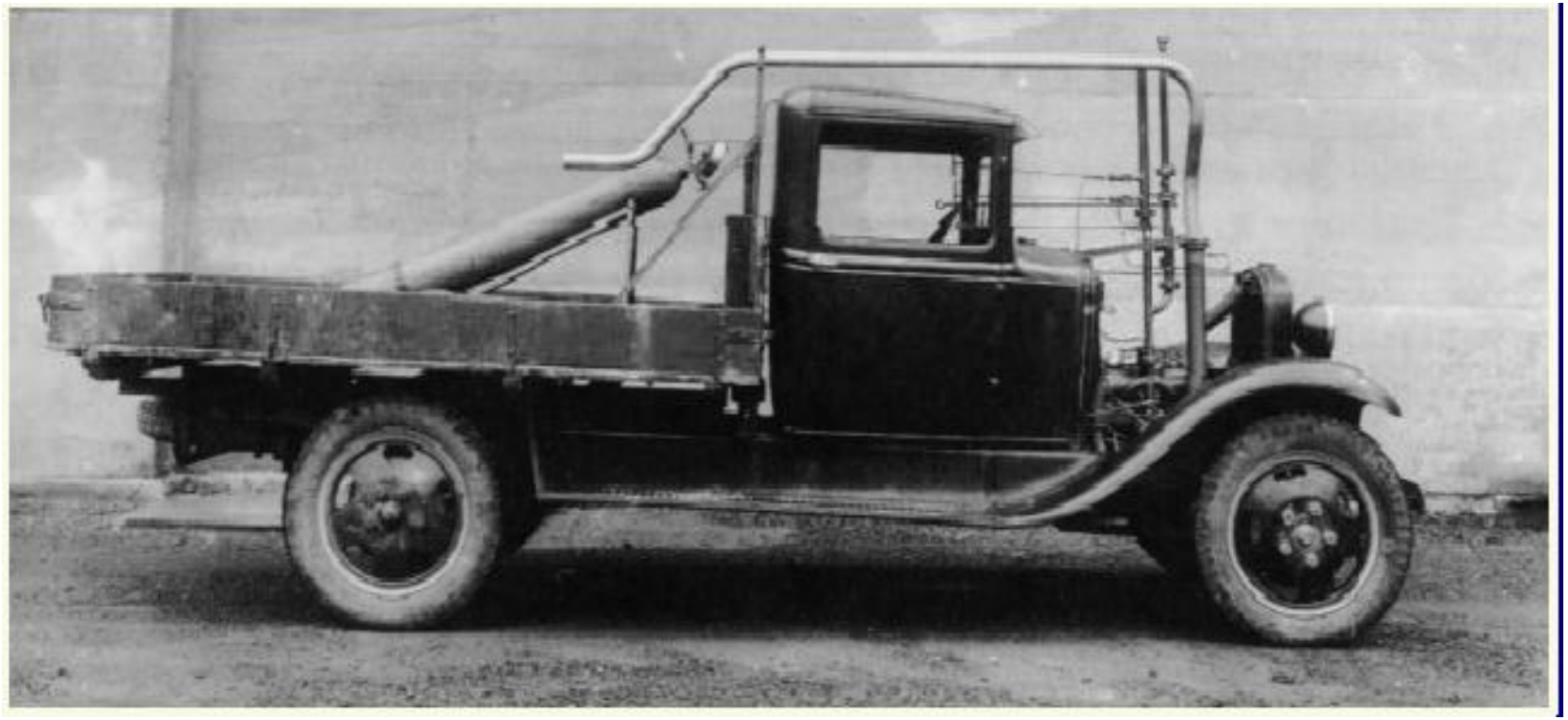
- Public and private transportation

- Marine propulsion/auxilliary systems

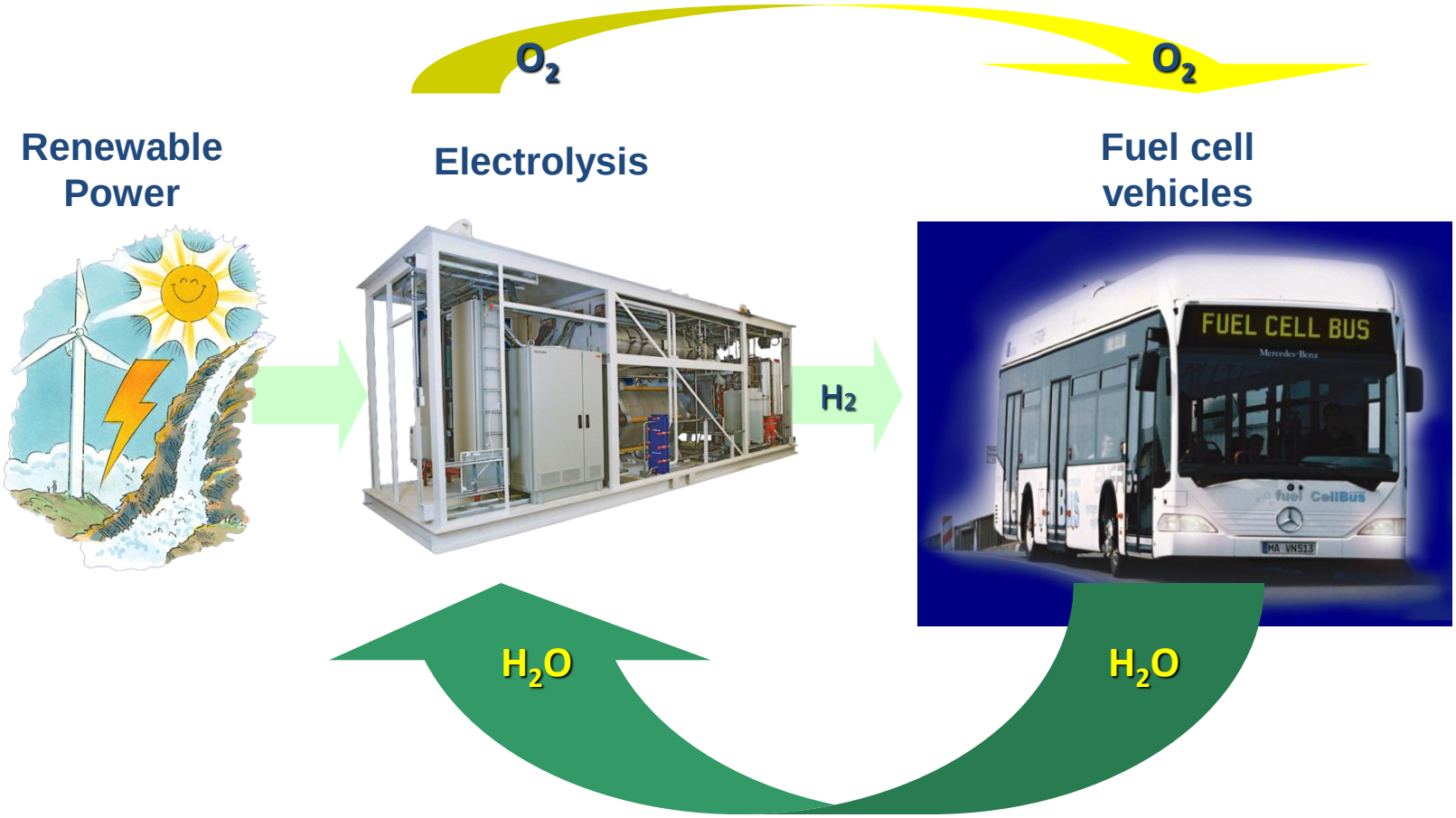
- Stand alone wind/H2 systems



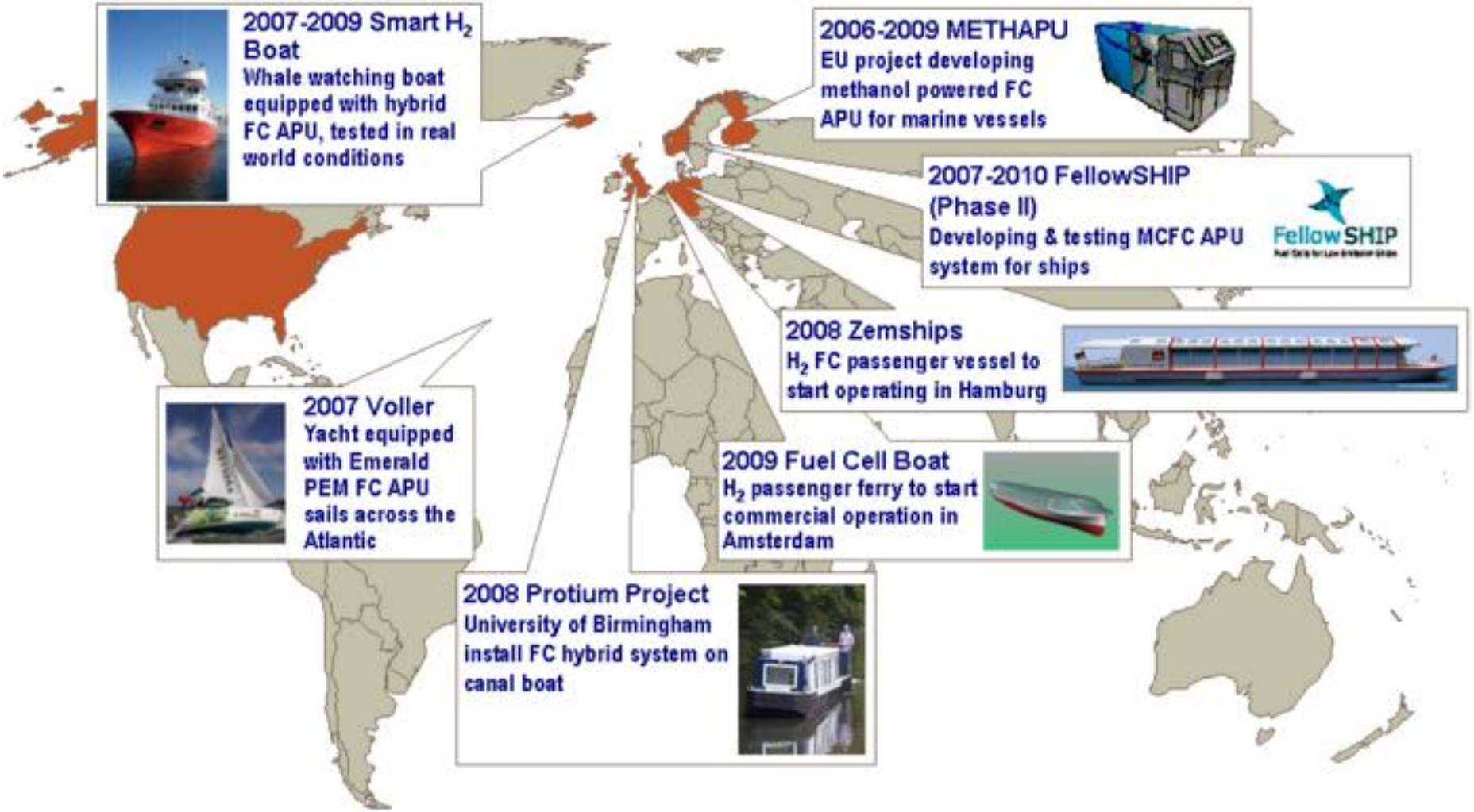
Norsk Hydro – an early promoter of alternative fuels in vehicles



A Vision for a Sustainable Vehicle Fuel



Some recent marine projects



Viking Lady

World's first supply ship with auxiliary power from a LNG MCFC (330 kW)
Integrated in Norway (Eidesvik, DNV, Wärtsilä, and WPA)
2009 – present
2012 – positive position paper report from DNV
2012 –> Integration of hybrid system
Plans for full scale FC for propulsion

UTSIRA

UTSIRA – Main System Components

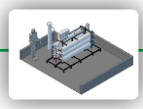
- *Trykk 0 – 210 bar*
- *Volume 12000 l.*
- *Vekt 24000 kg.*
- *Lengde 13 m*
- *Diam. 1,2 m*

Visit to utsira by Roman Abramovich

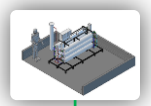
600 kW vindmølle

60 Nm3/h , 15 bar electrolyser

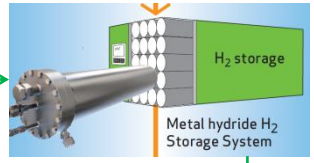
HSS MH compr.,
60 Nm3/h, 15 – 250 bar

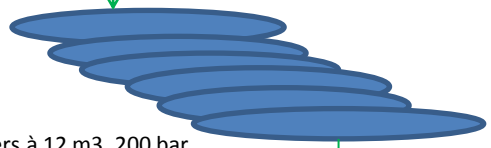


HSS MH compr.,
60 Nm3/h, 15 – 250 bar



200 bar underground storage,





6 cylinders à 12 m3, 200 bar
=14400 m3 hydrogen

The larger «Utsira»

Wind/hydrogen el. system
with 5 days back up. Time to fill
H2 storage = 10 X 24 hours

Local grid

Average total energyy consumption
1n 24 hours = 6240 KWh
(230 KWh throughout the day/night)

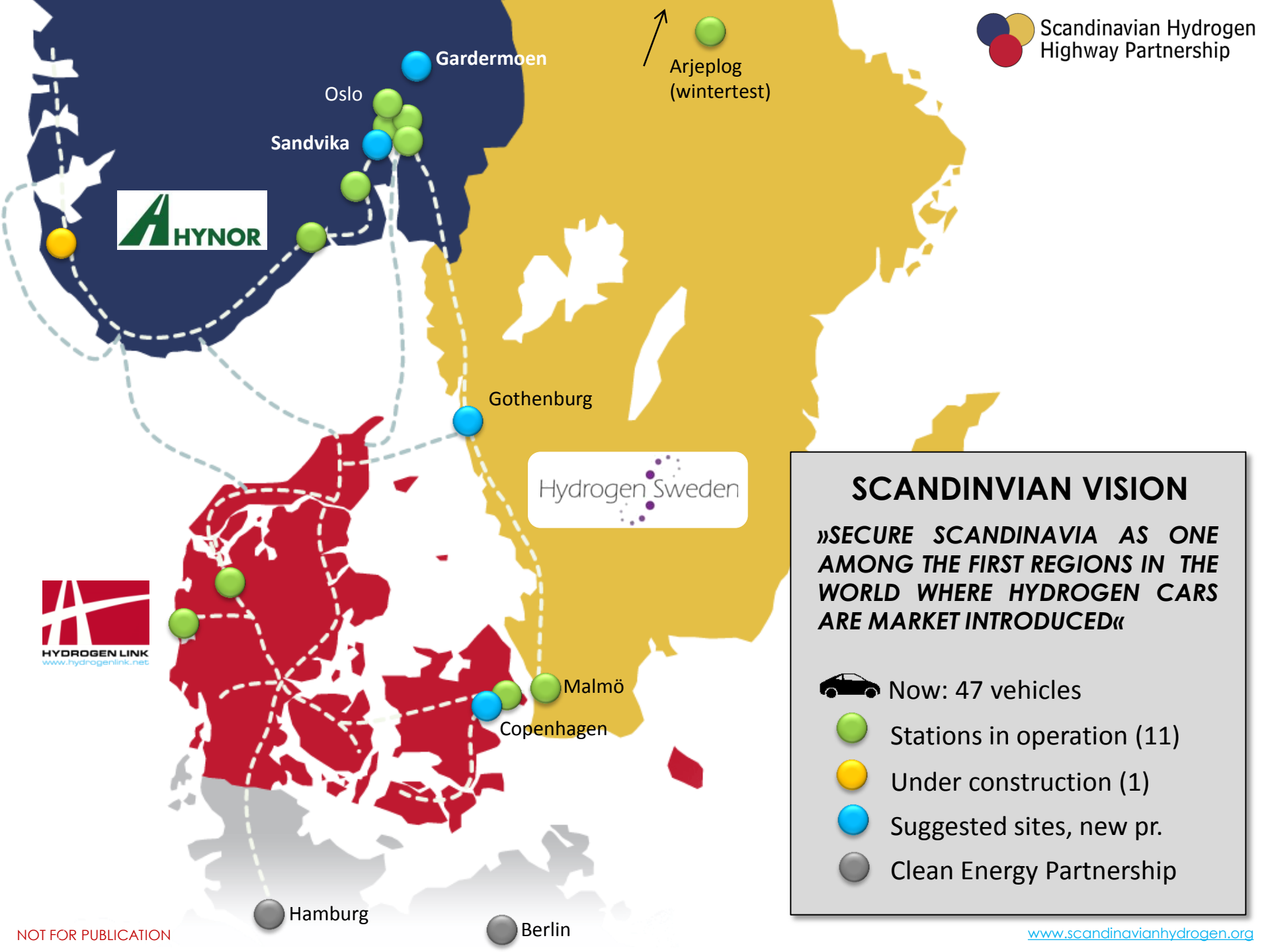
250 kW solid oxide
Fuel cell (Siemens/Westh.)

The larger «Utsira» - Assumptions and calculations

- 250 inhabitants, 100 houses + school, local administration, harbour installations etc.
- H2 land average consumption, day and night = 2 kWh X 130 «houses» X 24 hours = 6240 kWh
- Assume H2 back up system shall operate for 5 days
- 5 days operation consumes = 31200 kWh
- Reelectrifying unit – the fuel cell - is a solide oxide fuel cell with a 60% efficiency, which means that with an el. output of 31200 kWh some 52000 kWh has to be fed to the fuel cell.

52000 kWh = 14857 Nm3 with hydrogen. 14857 Nm3 H2 = 1322 kg. H2

H2 storage = 1322 kg



The Oslo Hydrogen Refuelling station

– 200 kg/day & 20 kg within one hour
– Corresponding to 50/5 vehicles
– Combined onsite production/trucked-in hydrogen supply
– Refuelling pressure: 700 bar

Transportable refueller →

CHIC / HyNor Oslo Bus

the fuelling station by night and day

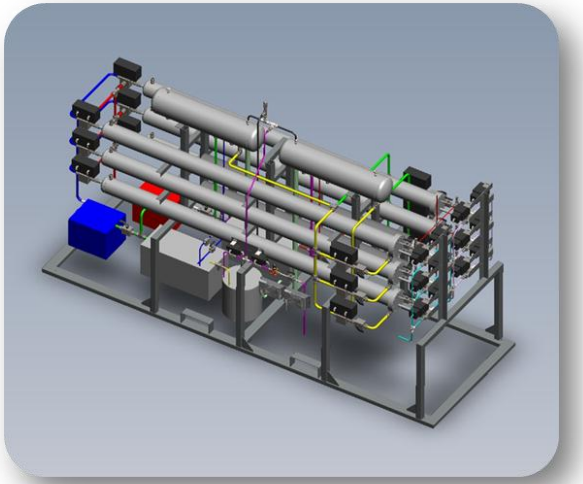
2 each 60 Nm3/h electrolysers
Daily capacity=260 kg H2

5 VanHool busses

HYNOR

HyNor Lillestrøm

2 new concepts



Metal Hydride Compressor
From Hystorsys

Small prototype

Potential
+ 100 MW

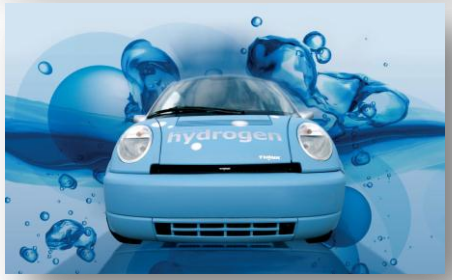
Conversion of fossil fuels to hydrogen
and electricity with an efficiency of about 80-90% and with integrated CO2 capture

HYNOR

Hydrogen-vehicles in Norway

4

2



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National Hydrogen Action Plan

The Hydrogen Council

May 2012

HYNOR

The Hydrogen Council recommends the overreaching national vision:

«Norway – Pioneering Sustainable Hydrogen»

Main reccommendations:(I/II)

- for the period 2012-2015

- Establish incentives that ensure the operation of hydrogen stations
- Maintain and strengthen the means for effective phasing in of zero emission vehicles
- Strengthen Transnova
- Increase the support to transport research

Main reccommendations (II/II)

- for the period 2012-2015

- Involve Norwegian SMBs in the growing hydrogen technology market
- Finance national light house projects within hydrogen technology
- Evaluate the potential for large scale export of sustainable hydrogen from Norway
- Set demands for share of ZEVs in public tenders for vehicles and vehicle services.

The Outlook

In 2002 the Norwegian oil and – gas sector
employed approx 80000 persons. It all started in 1965.
Could hydrogen/hydrogen systems have a similar effect in the North Atlantic region -----

YES!!!

Extra

How much electricity and natural gas is used to explore for petroleum, extract it, transport it, refine to gasoline (or diesel, etc.), transport it again, and then pump it into your tank?

Just to refine the oil to make gasoline, it may take 3kWh or 7.5kWh (plus many therms of natural gas?), so for the refining alone, it could be used to move an EV 30-50 miles -- without using the gasoline!

Table 1. Summary of fuel cell EV attributes compared to those of the advanced battery EV for 200-mile and 300-mile range

	300 miles Range			200 miles Range		
	Fuel Cell EV	Battery EV	Ratio BEV/FCEV	Fuel Cell EV	Battery EV	Ratio BEV/FCEV
Vehicle Weight (kg)	1280	2270	1.77	1256	1750	1.39
Storage Volume (Liters)	100	560	5.60	75	300	4.00
	310	560	1.81	215	300	1.40
Greenhouse Gases (g/mile)	234	535	2.29	232	445	1.92
Incremental Cost ($)	3,600	19,500	5.42	2,830	10,200	3.60
Natural Gas Req'd (MBTU)	0.81	1.18	1.46	0.53	0.66	1.25
	0.81	1.77	2.19	0.53	0.99	1.87

Story Simultaneous.XLS; Tab 'AFV Cost'; N 63 3/25/2009

Present situation - Transport

- Total Global CO2-emissions: 49 Gt CO_2e
- 17% of global GHG emissions in 2005 = 8.3 Gt CO_2e