

International Seminar on the Hydrogen Economy
for Sustainable Development – Reykjavik Sept. 2006

The Hydrogen Economy: An introduction

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Planet Earth – Habitat of Humans.


Main energy source: The Sun.

Secondary Energy source: geothermal and fission elements

Main energy carrier in 2006: fossil HydroCarbons

Energy and fuels

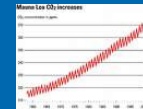
- Humankind has been burning biomass since antiquity. 

- The industrial revolution coincided with the harnessing of coal. 

- The first automobile century coincided with the utilization of oil and petrol. 

Humankind is faced with a number of energy related problems:

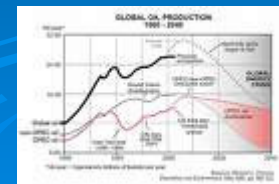
- Climate change due to the CO₂ content of the emission of burning fossil fuels



- Insecurity concerning the safe delivery of the hydrocarbons which sources are mostly owned by governments in a relatively small number of countries.



- Limited resources on planet Earth




Possible energy resources on Earth I

- Coal 6000 gigatons
- Oil 400 gigatons
- (Of which 6 gigatons oil used annually)
- Natural gas 350 gigatons
- Fission feedstock 0.004 gigatons



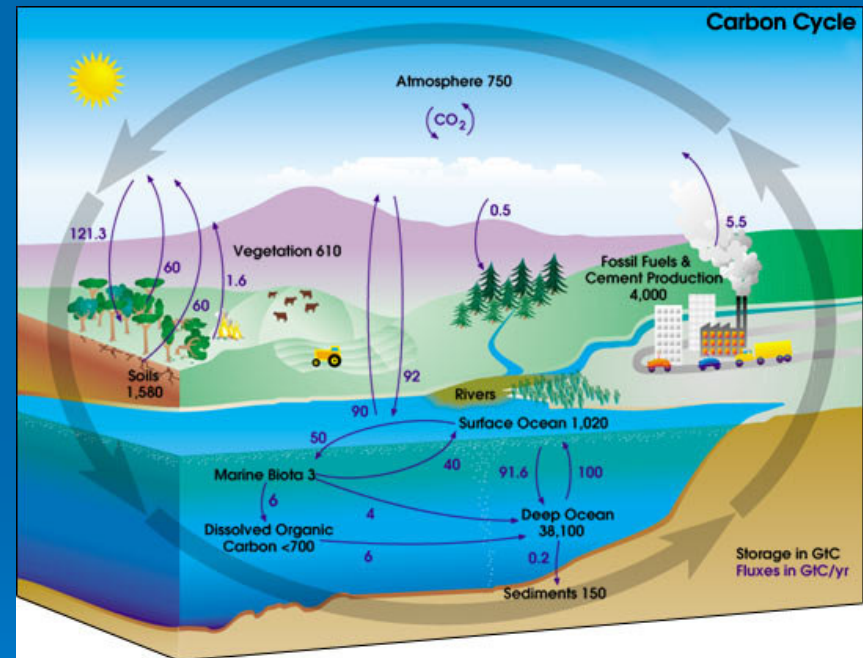
- A HydroCarbon economy on Earth is totally unsustainable.
- Are we the generation destined to change the vicious pattern?

Limits to our present utilization – limits to the growth of our civilization


- Hydrocarbons are limited by the CO₂ emissions. Carbon sequestration is a possible way to reduce the emissions but a biological cycle to renew the carbon source would be rather slow
 - Fission products are limited and lead to big environmental problems
 - The options left include renewables and water:
- 

Anthropogenic carbon cycle is suffocating the Earth

- Fossil fuel burning releases roughly 5.5 gigatons of carbon (GtC [giga=1 billion]) per year into the atmosphere and that land-use changes such as deforestation contribute roughly 1.6 GtC per year. Measurements of atmospheric carbon dioxide levels (going on since 1957) suggest that of the approximate total amount of 7.1 GtC released per year by human activities, approximately 3.2 GtC remain in the atmosphere, resulting in an increase in atmospheric carbon dioxide. In addition, approximately 2 GtC diffuses into the world's oceans, thus leaving 1.9 GtC unaccounted for.



Three interesting resources of choice

- Water 1400 million gigatons
 - Solar radiation and renewables that are solar derivatives – the irradiation of Earth is enormous
 - Biomass
- 
- The bottom right corner of the slide features a decorative graphic of several concentric, light blue circles that resemble ripples on water, set against the dark blue background.

Two hundred years of the development of hydrogen energy economy

- Water splitting by Nicholson in 1800
- H energy Prophesised by Jules Verne in 1874
- Fuel cell development from Grove to Bacon in a hundred years from 1840
- “Hydrogen Economy” Coined 1970
- H₂ a focus of IEA for decades
- International Partnership for the Hydrogen Economy founded in Washington 2003

Hydrogen by different pathways

Primary Method	Process	Primary feedstock	Other feedstock	Energy	Quantity of Resource <i>Gigaton level</i>	Carbon footprint or emissions
	Steam Reforming	Natural Gas	Water	Heat	10 * 2	Carbon sequestration
T		Oil		"	10 * 2	needed
H						
E	Gasification	Coal	Water, Oxygen	Steam at high T and P	10 * 3	Carbon sequestration
R						needed
M	Pyrolysis	Biomass		Moderately high temp.		Essentially
A				steam		renewable
L	Thermochemical	Water		Nuclear	10 * 7-10 * 9	Nuclear waste
						disposal problems
E C						
L H	Electrolysis	Water		Renewables incl. Solar	10 * 7-10 * 9	Emissions mostly
E E				wind, hydroelectric		related to Life Cycle
C M						
T I	Photoelectro-	Water		Direct sunlight	10 * 7-10 * 9	Minor emissions
R C	chemical					
O A						
L						
B	Photobiological	Water	Algaie strains	Direct sunlight	10 * 7-10 * 9	No emissions
I						
O						
L	Anaerobic	Biomass		High temperature steam		LCA related minor
O	digestion					
G						
I	Fermentative	Biomass		High temperature steam		LCA related minor
C	Microorganisms					
A						
L						

Hydrogen from Renewables and water

- Electricity produced from renewables
- Hydrogen produced by solar water splitting, electrolysis of water.....
- Transport system based on electric motors, regenerative braking and back-up energy from hydrogen and fuel cells

IPHE Partners



Russian Federation



USA



Canada



Iceland



IPHE Partners' Economy:



Japan



Republic of Korea



China



India

- Over \$35 Trillion in GDP, 85% of world GDP
- Nearly 3.5 billion people
- Over 75% of electricity used worldwide;
- > 2/3 of CO₂ emissions and energy consumption

United Kingdom



France



Germany



Italy



Australia



Brazil



Norway



European Commission



New Zealand



IPHE Goal



Efficiently organize and coordinate multinational research, development and deployment programs that advance the transition to a global **hydrogen economy**.

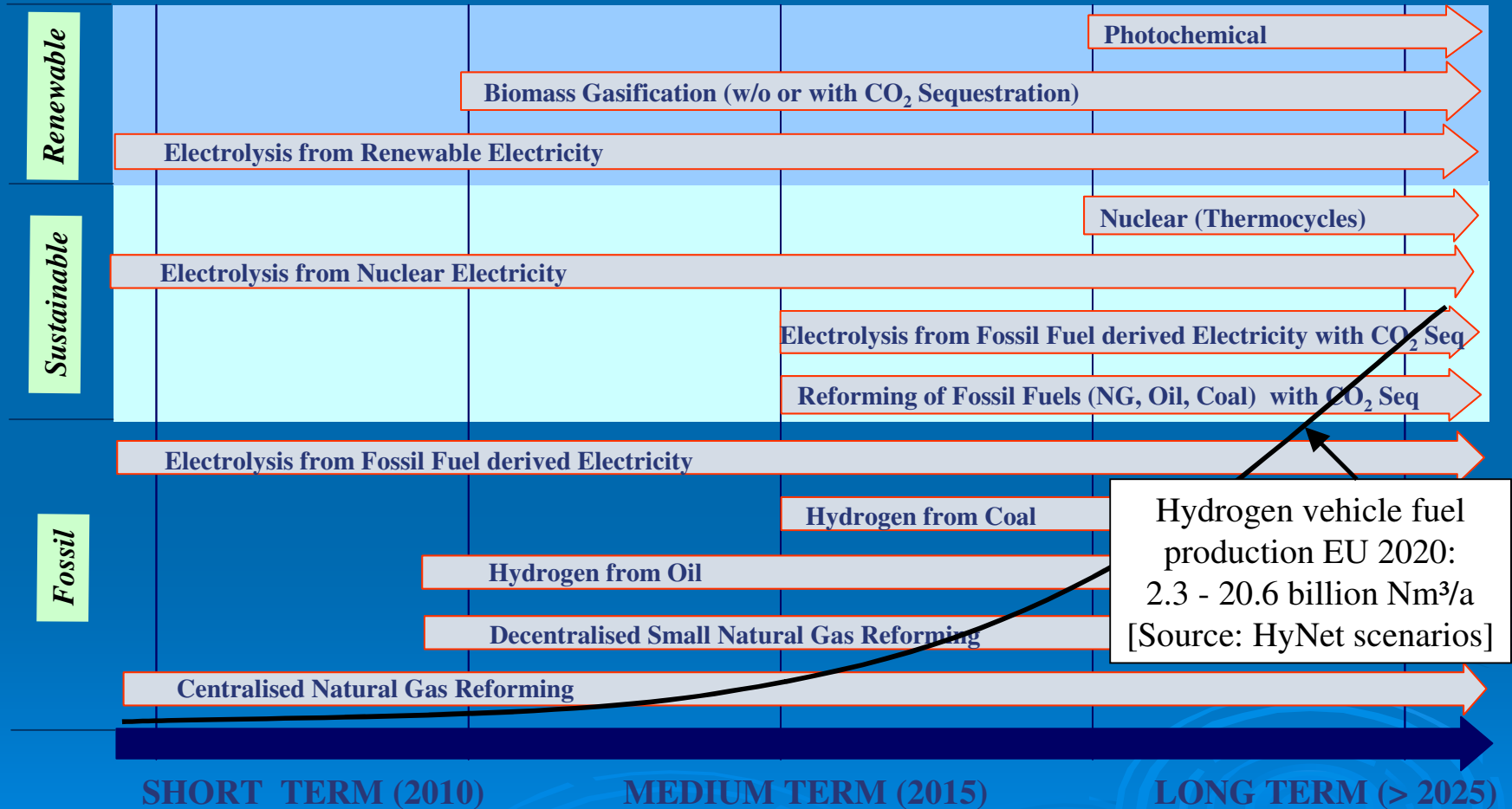
- So what is the modern hydrogen economy about?



The challenges of a hydrogen economy

- **Production**
- Price of renewable based hydrogen higher than hydrogen from hydrocarbons. IPHE wants to aim for a carbon neutral pathway.
- **Storage**
- The lightest and smallest of elements requires lot of space. Storage is a great challenge.
- **Distribution**
- The light element provides challenges to pipelines and infrastructure with related diffusivity etc.
- **Utilization**
- The most efficient utilization in fuel cells actually transforms our former Carnot efficiency limited energy economy with the advent of Gibbs Free Energy Economy

Scenarios for hydrogen

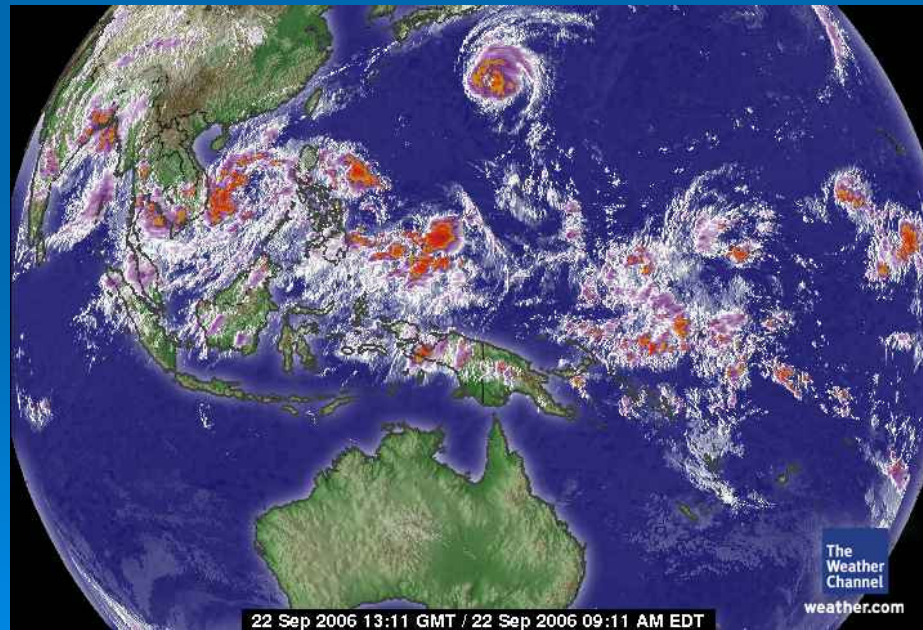


Let us take a look at a number of scenarios where a hydrogen economy components are being tested in projects around the world with very high carbon neutrality:

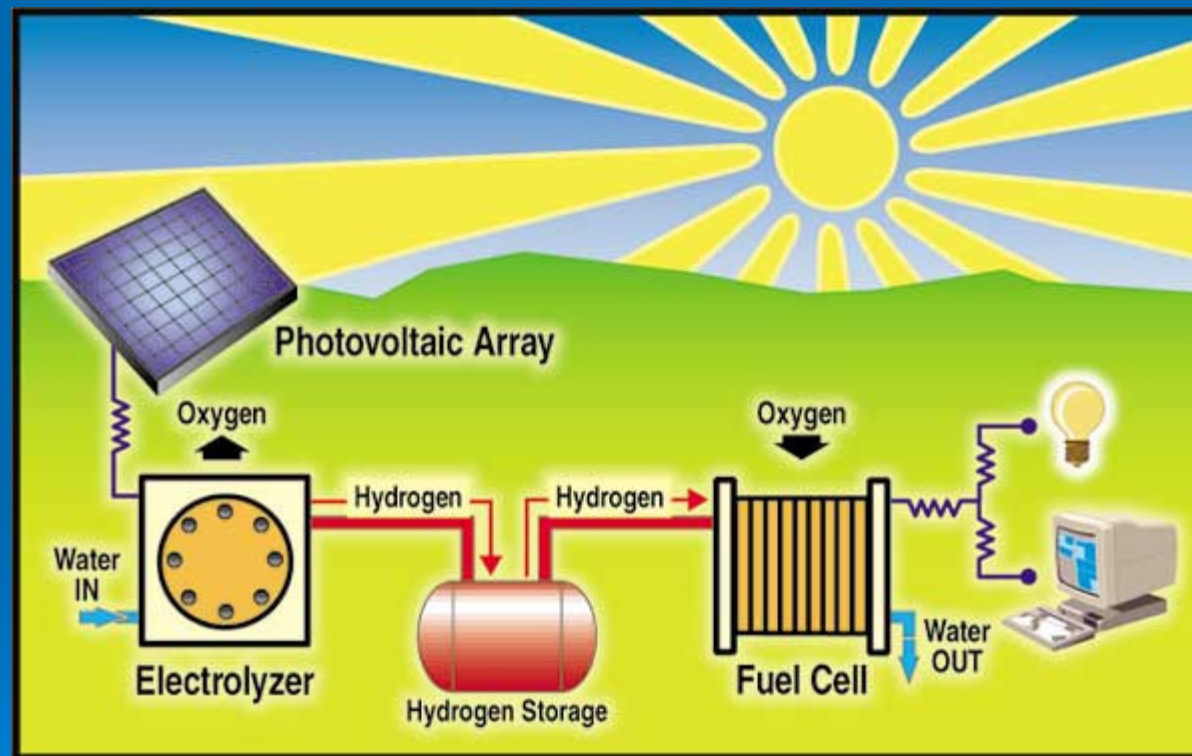


Hydrogen scenario: Hydrogen for an island or isolated territory

- Assuming access to renewables: solar, wind, geothermal and possibly later ocean currents or waves.

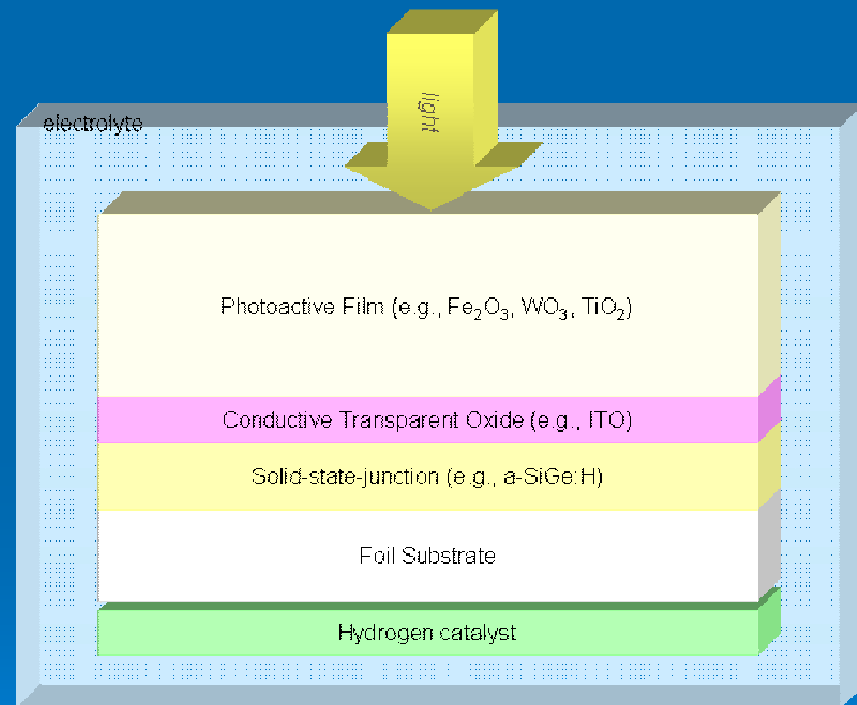


Photovoltaic solar hydrogen



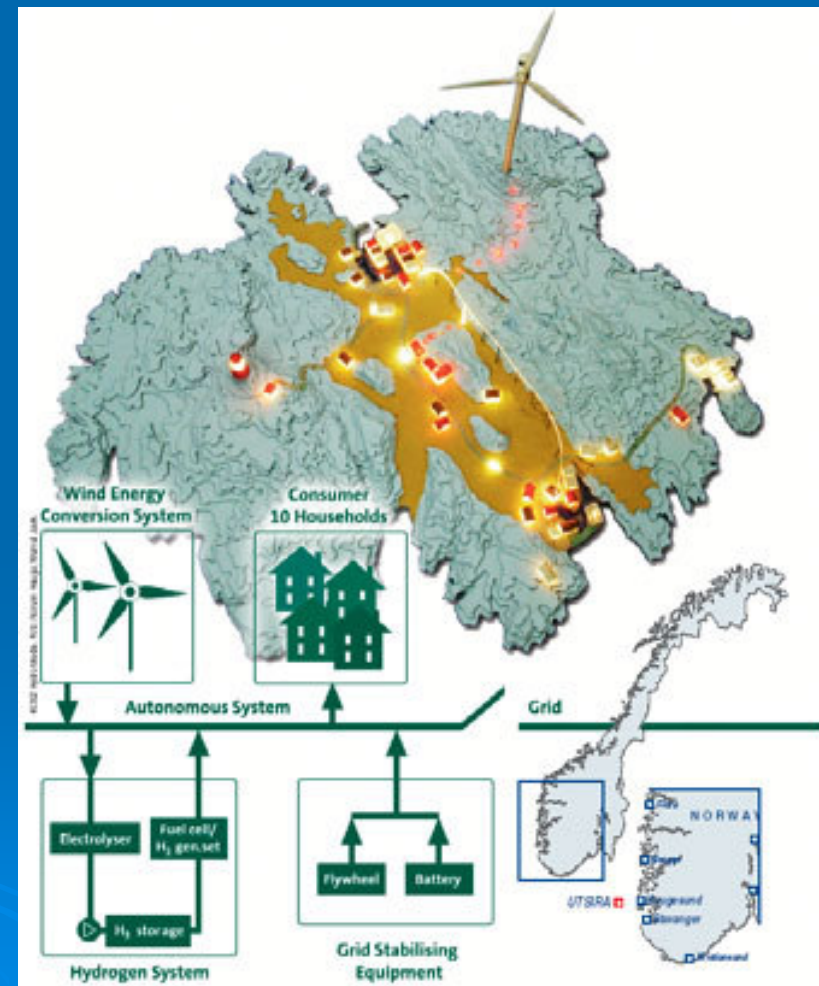
Hydrogen from light

- An exciting relatively new development is taking place in the area of photochemical hydrogen production which was first introduced by Fujishima and Honda in 1972. In a *photoelectrochemical* system (PEC) a semiconductor material which is photoactive is arranged to form a junction in contact with a liquid (or sometimes solid) electrolyte. When such a junction is lit by sunlight, electron-hole pairs are formed at the junction. These light-induced electron-hole pairs in turn drive a chemical reduction and an oxidation in the electrolyte of the PEC system.



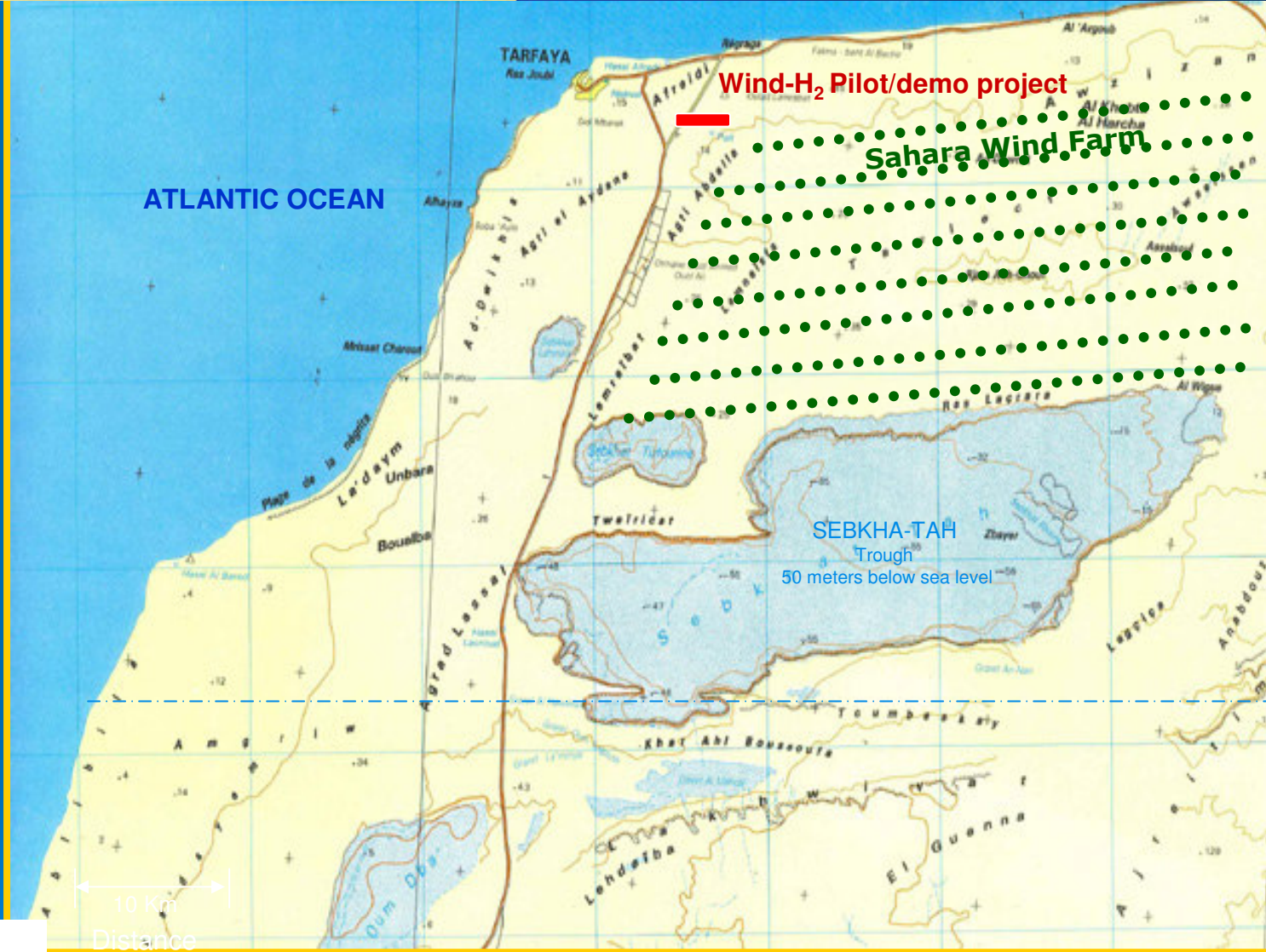
Utsira – Hydrogen island in Norway

- On the island of Utsira in the Atlantic Ocean just outside the fjords of Norway Norsk Hydro and its partners have been running a wind generator based hydrogen system since 2004. Two wind generators of 600 kW each deliver electric energy to a small electrolyser which stores its hydrogen under pressure. The hydrogen is used for powering a number of houses on this small island. There is a 12kW fuel cell from a Danish producer, IRD, delivering the power in addition to some 50kW of electric energy stemming from an internal combustion-based generation unit. The combustion generator has an appreciably longer start up time than the fuel cell and the interplay of the two has proven a development challenge. The system also uses a flywheel for stabilisation





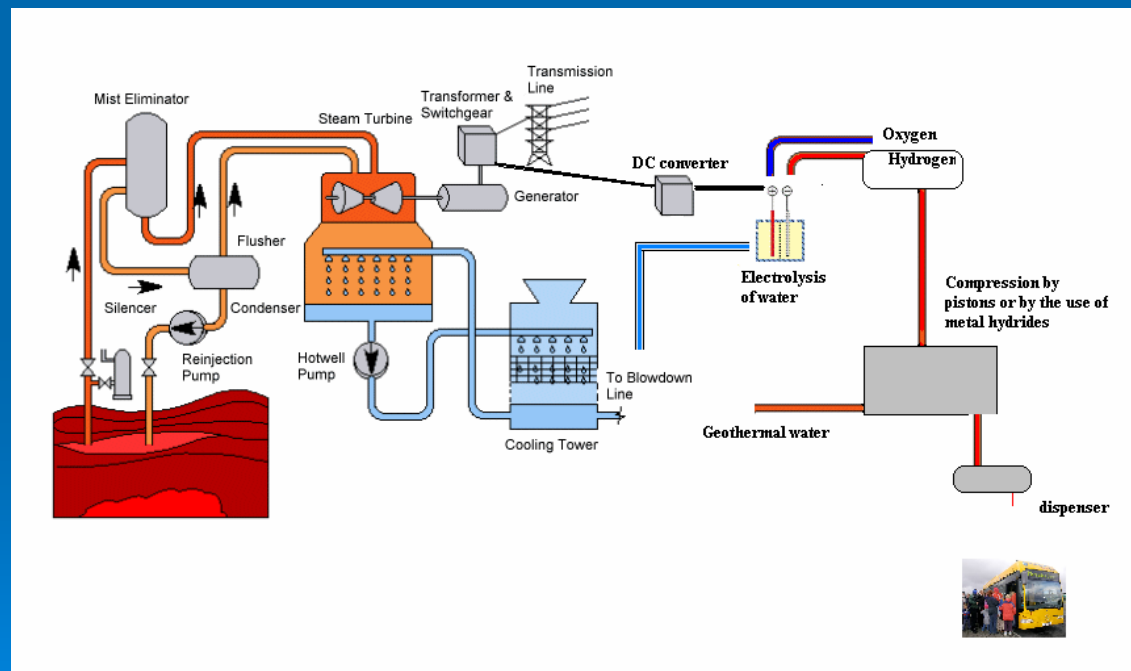
UN
DP



UNIDO/ICHET - Sahara Wind-H₂ Demo Project
UNDP/GEF - Sahara Wind Phase 1: 400-500 MW

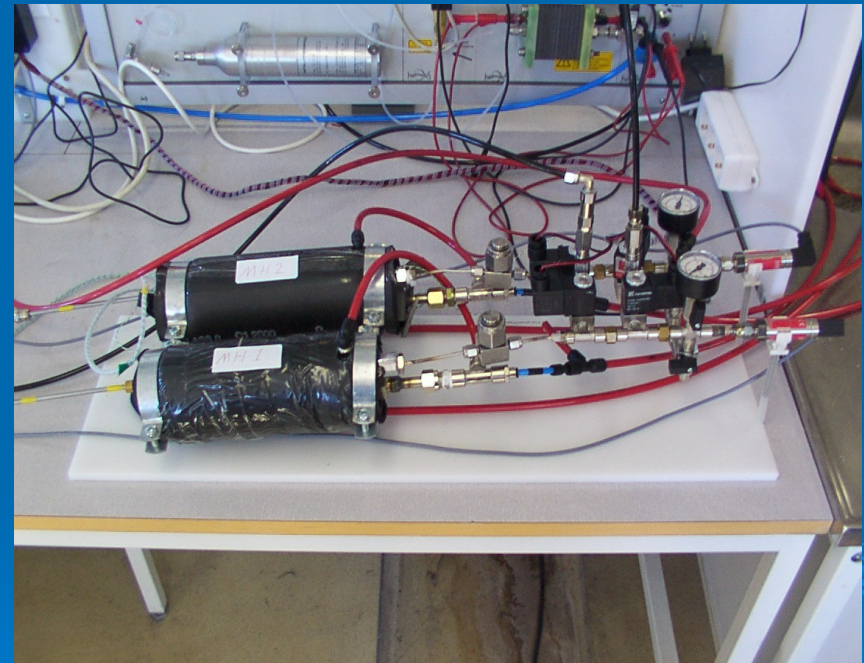


Utilization of geothermal heat for hydrogen production, storage and distribution



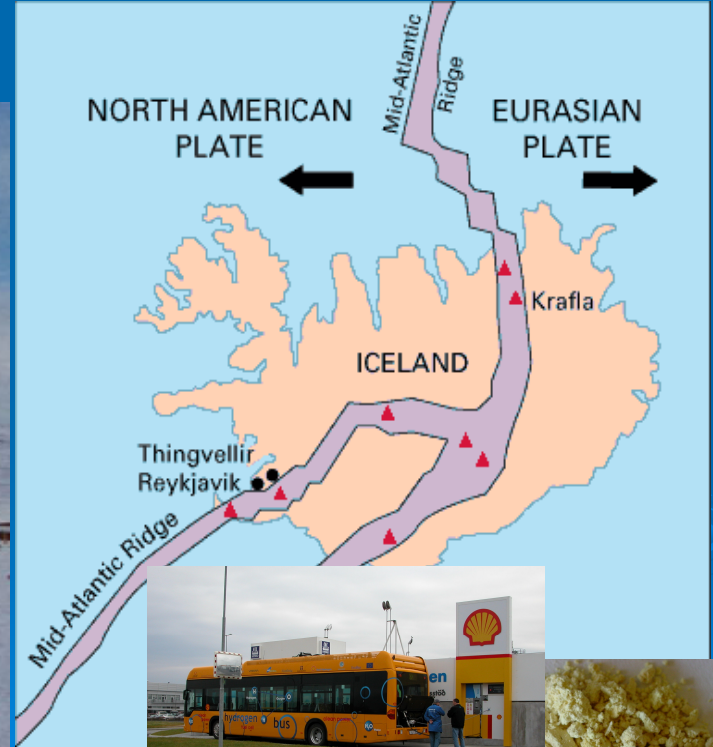
Geothermally Operated Hydrogen Compressor

- This metal hydride-based compressor was designed and constructed as a joint effort between the University of Iceland and Varmaraf ehf. A tandem arrangement of these devices is capable of pressurizing hydrogen gas up to hundreds of bars and is intended to represent a component of a proposed hydrogen fueling station. Hallmar Halldorsson and Thorsteinn I Sigfusson

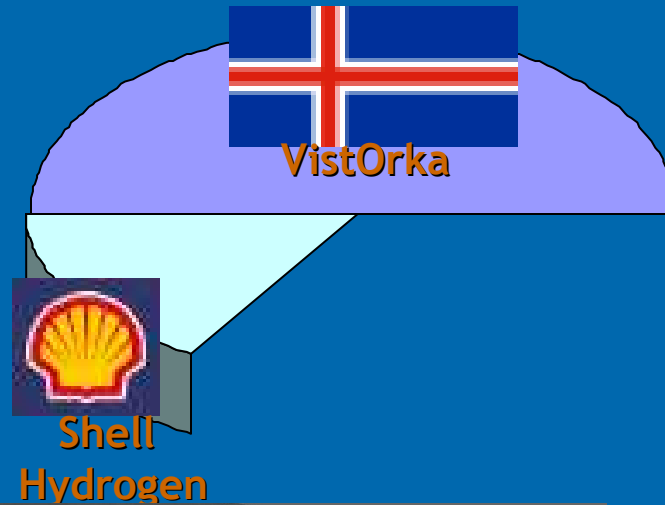


The Mid-Atlantic Ridge divides Iceland; the country drifts apart by an inch a year. Magma fills the void. There are boreholes in Iceland bleeding up to 50 tonnes of molecular hydrogen annually.

Geothermal Vents Along the Terrestrial Section of the Mid-Atlantic Ridge at the Bjarnarflag Geothermal Field, Near the Krafla Volcano, Northern Iceland...

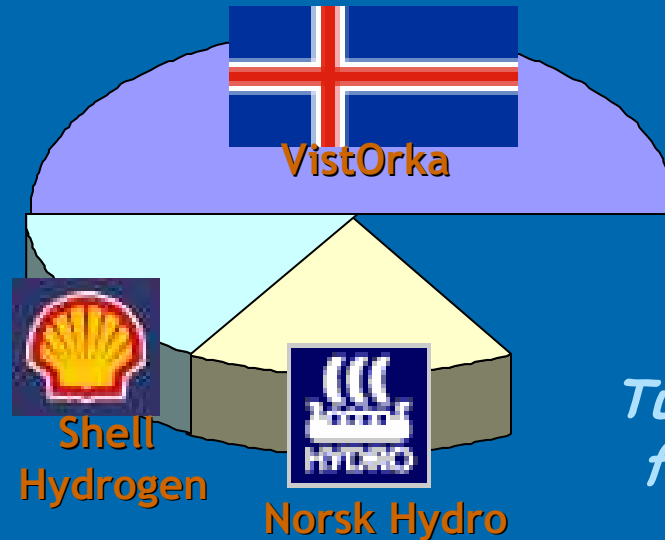


Unique INE in Iceland structure / objective



Design for the
future H₂
infrastructure

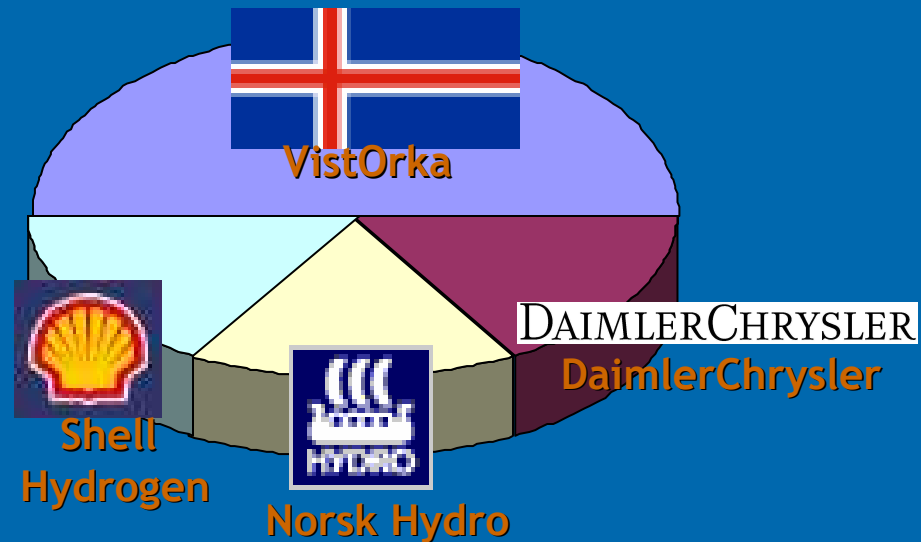
Unique INE structure / objective



Turn key solutions for the future H2 infrastructure

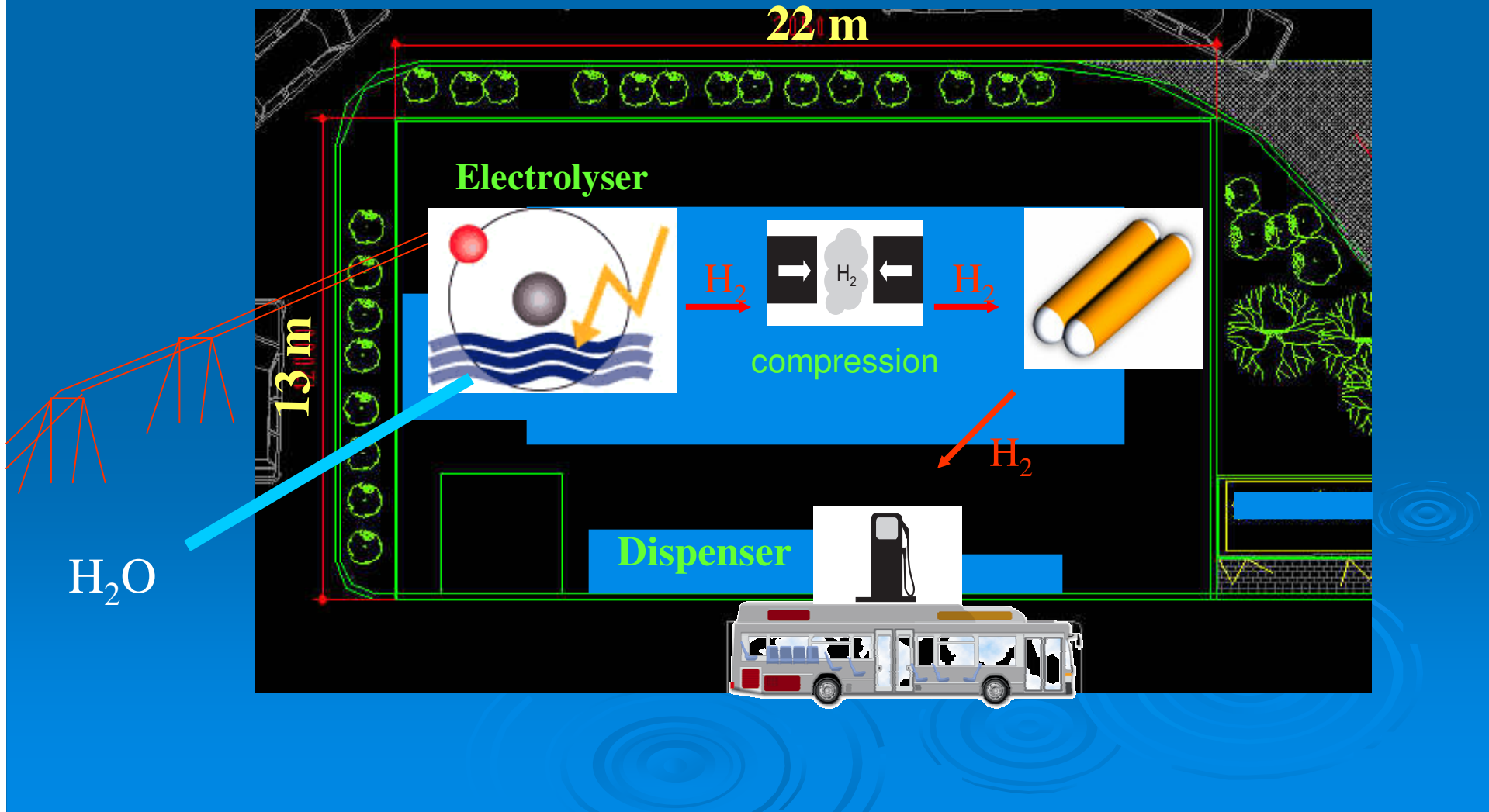


Unique INE structure / objective



H₂ and fuel cell
vehicle development

The ECTOS-project on transport Infrastructure in Iceland



Hydrogen Station

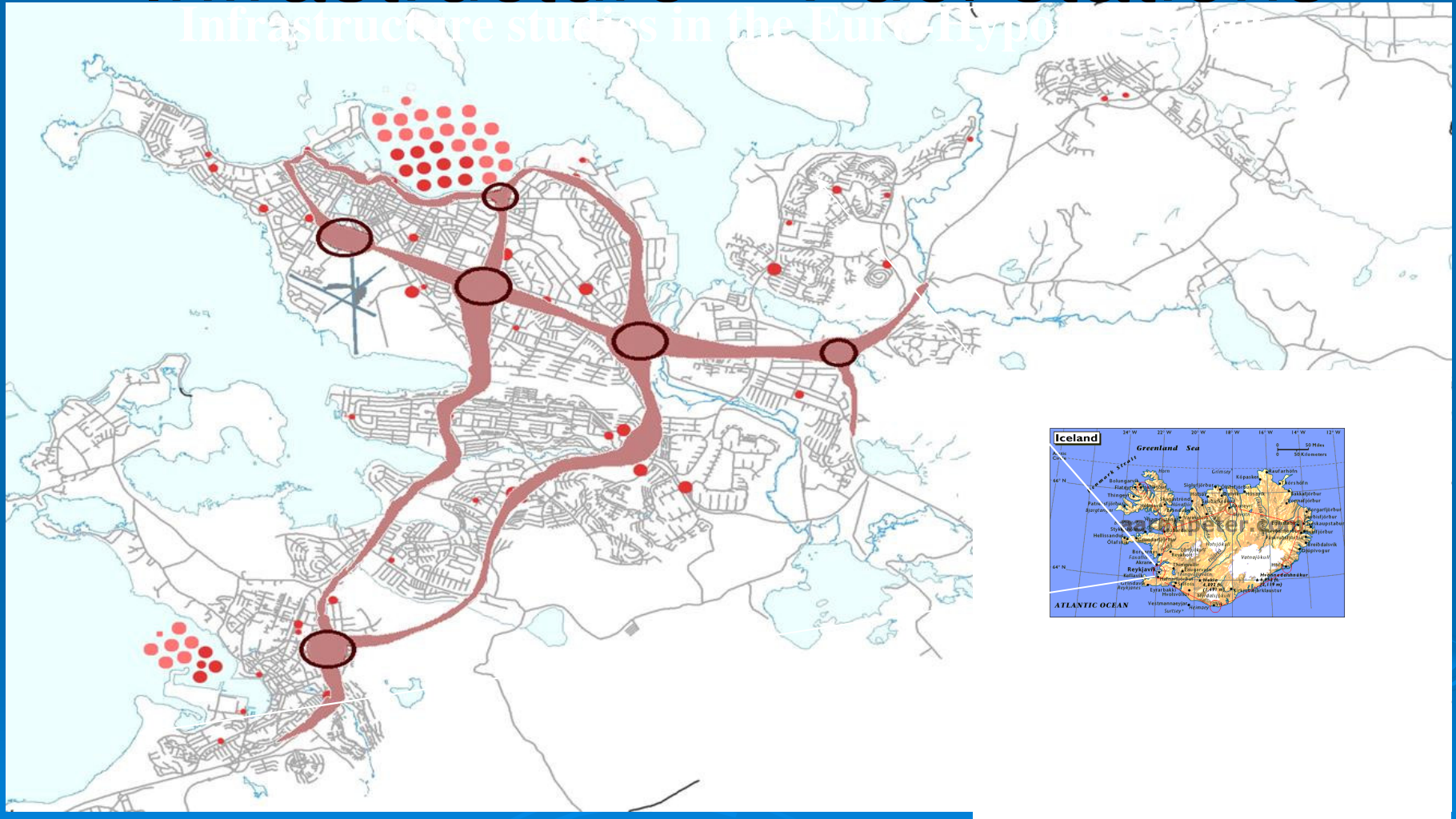
Opened April 24, 2003

Only station in the world operating at a conventional gasoline station (has full commercial license)

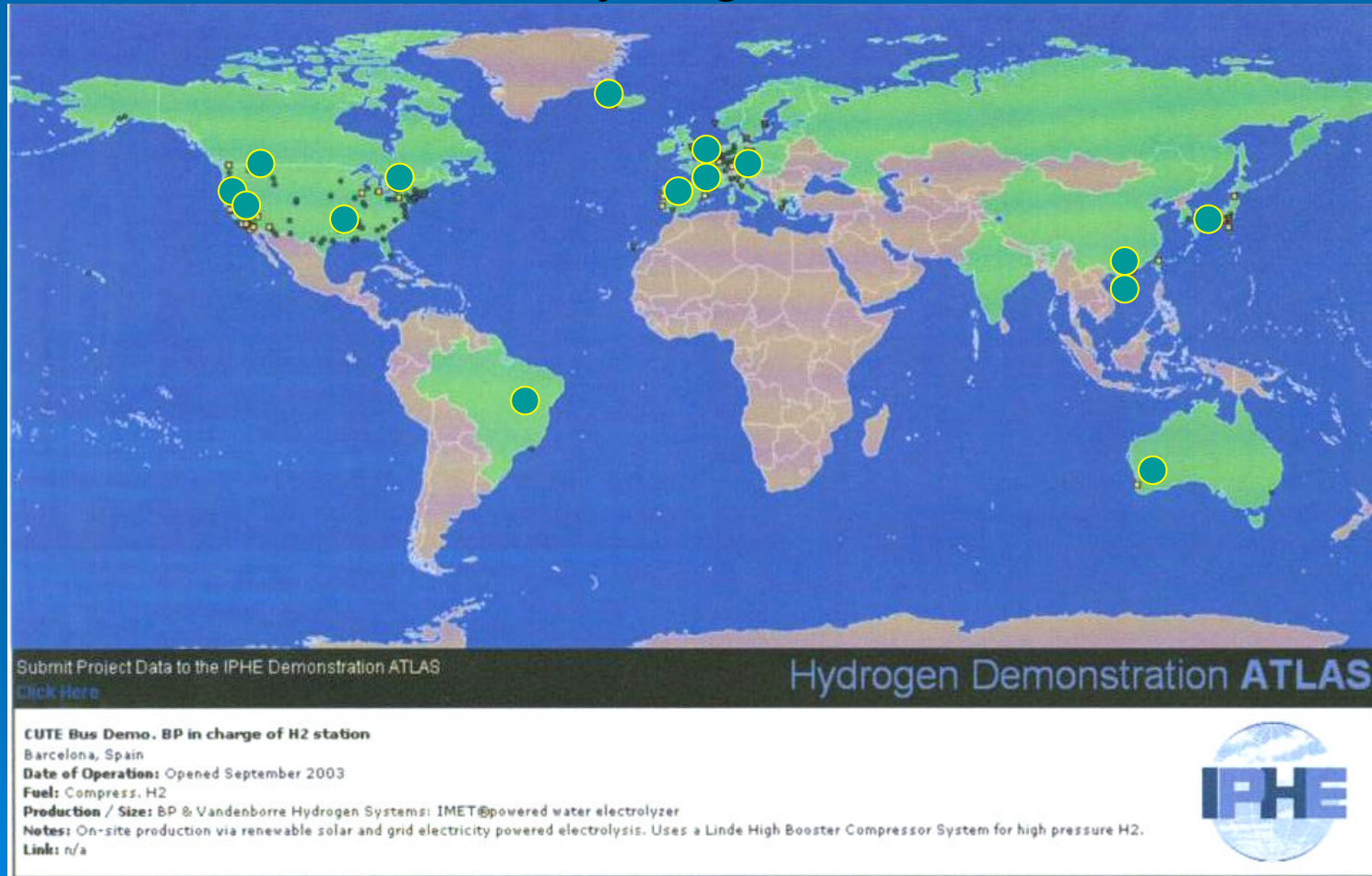


Infrastructure – Fuel stations

Infrastructure studies in the Euro-Hippo



I would like to see as one of the results of this Reykjavik meeting – that demonstration projects be started in areas of the developing world outside the present main hubs of hydrogen!



➤ With best wishes of success for our conference/workshop

➤ Thank you!

