IEES

HYDROGEN ECONOMY

BASED ON RENEWABLE ENERGY SOURCES

HYDROGEN ECONOMY ?

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"Yes, my friends,

I believe that WATER will one day be employed as FUEL, that HYDROGEN and oxyden which constitue it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable...

WATER will be the coal of the FUTURE."

Jules Verne,

The Mysterious Island (1874)

HYDROGEN ECONOMY ?

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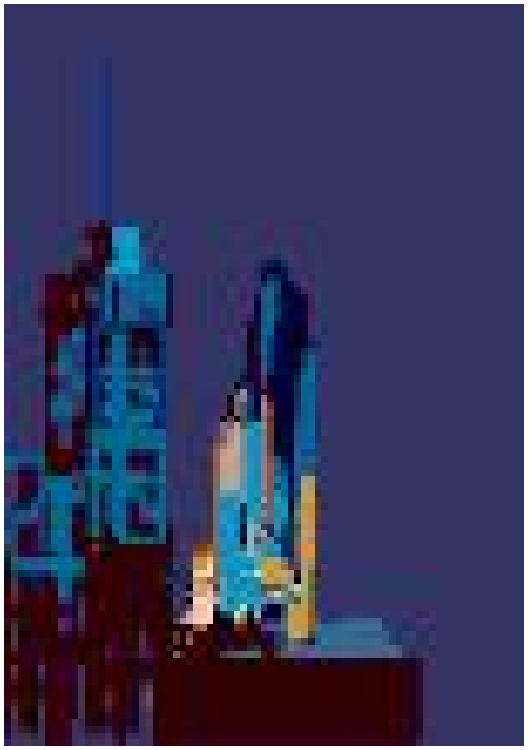
Yes,

100 years later the prediction of Jules Verne was realized.



- Man left the Earth using as a fuel the WATER components HYDROGEN and OXYGEN;
- The space crews rely on Hydrogen/Oxygen power devices, called FUEL CELLS, which operate the shuttle electrical systems and dring the by-product, which is PURE WATER.

HYDROGEN ECONOMY ?

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The challenging question is:

Can HYDROGEN take the leading position in the Earth's Energy System and replace the Fossil Energy System, which is now providing us with energy?

The answer is :

"YES"

THE FOSSIL ENERGY SYSTEM

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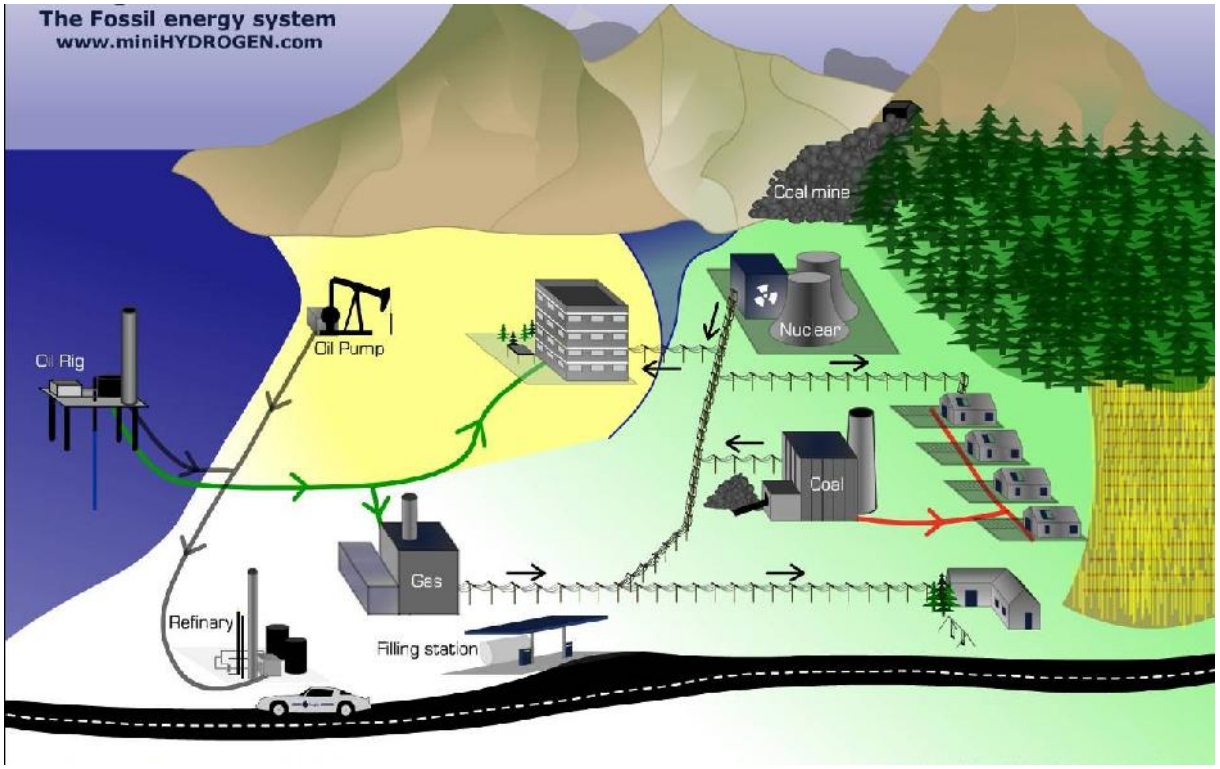
- reasons for change

- Today energy is used for:
  - electricity
  - heat
  - transportation
- Most of the world's energy comes from fossil fuels:
  - coal
  - oil
  - natural gas
- Additional sources are:
  - nuclear power
  - different renewable energy sources



THE FOSSIL ENERGY SYSTEM

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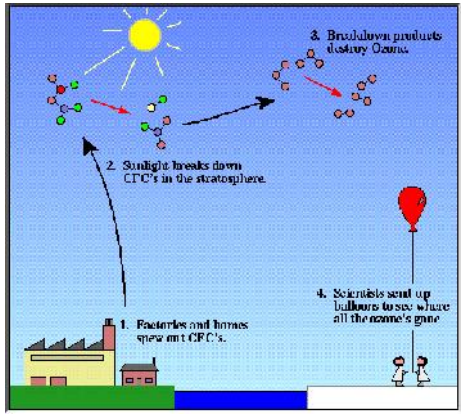
- reasons for change

- The fossil energy system holds some threats with increasing negative impact:
  - Pollution – the burning of fossil fuel polutes
    - ✓ air pollution – smog and harmful particles
    - ✓ greenhouse gases emission – bringigng to climate changes
    - ✓ oil depletion
    - ✓ dependence of national energy on foreign oil from politically instable regions



THE FOSSIL ENERGY SYSTEM

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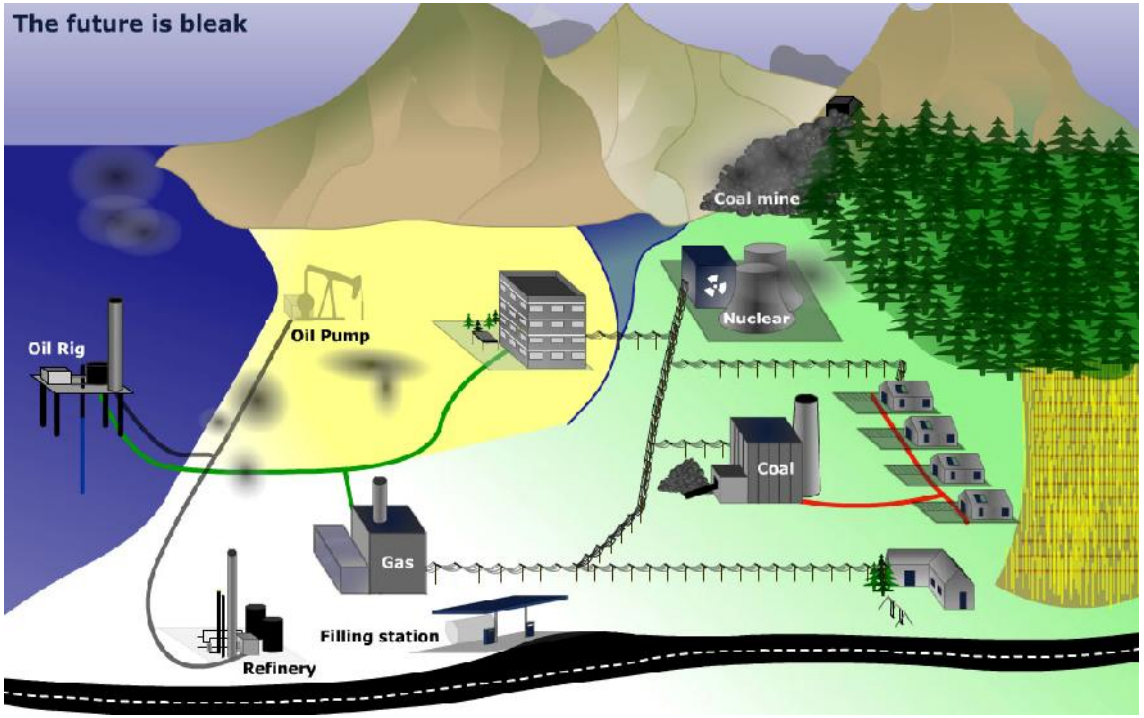
- reasons for change

- What is needed?
  - A more sustainable and clean Energy System
- What is the solution?
  - Replacement of the FOSSIL Energy System with HYDROGEN Energy System



THE HYDROGEN ECONOMY

- systainable & clean energy

- Although Hydrogen economy still belongs to the future, scientists expect that it will be realized in our century.

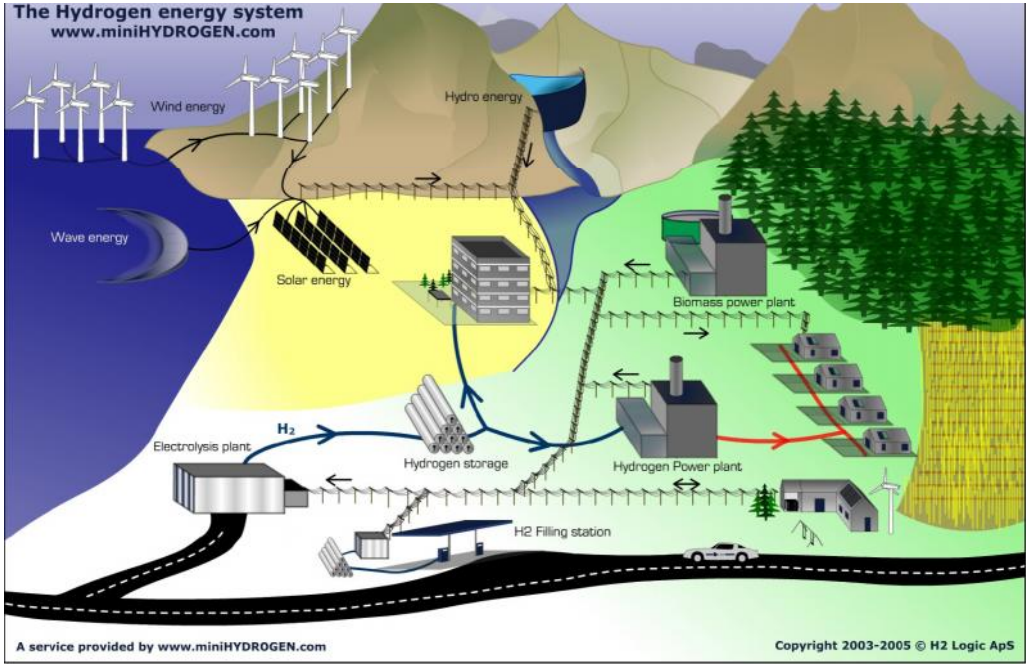
- In the Hydrogen energy system (known also as “Hydrogen & Fuel cells):

  - Hydrogen is universal energy carrier (and not an energy source)

  - Hydrogen will be produced mainly from water using renewable energy sources

  - Some stationary porduction of Hydrogen from fossil fuels would ensure proper disposition of the rerleased greenhouse gases

  - Hydrogen can be converted again in energy in fuel cells



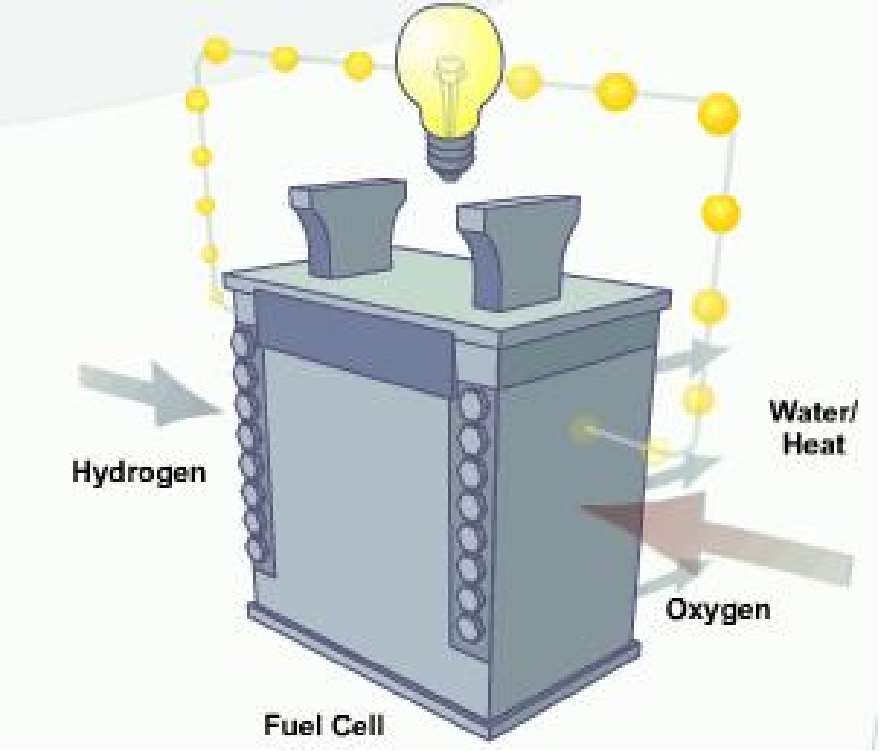
THE HYDROGEN ECONOMY

- sustainable & clean energy

- FUEL CELL is an electrochemical device in which hydrogen and oxygen (from air) react, creating ENERGY (electricity & heat).

- The only by-product is pure water
- As long as the fuel is supplied, the fuel cell will continue to generate power
- The process is clean, quiet and highly efficient

(2-3 times more efficient than fuel burning)



SOMETHING ABOUT HYDROGEN

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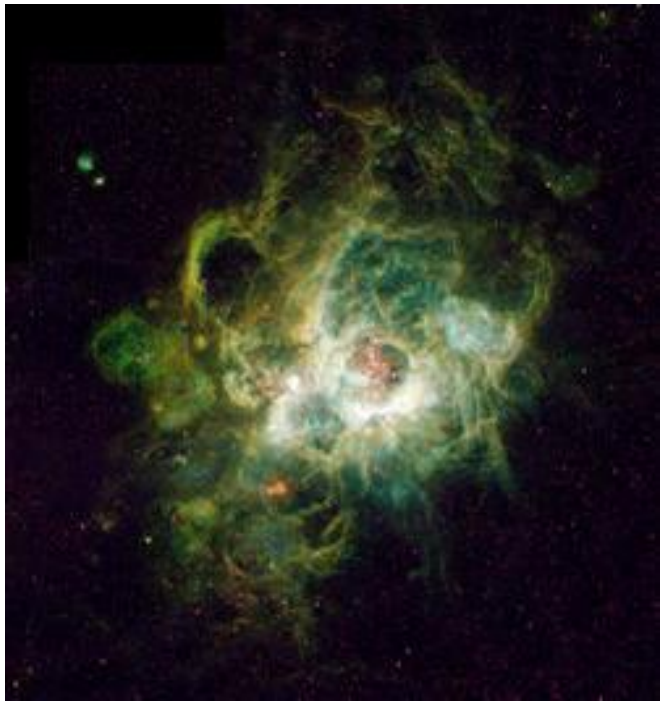
- Hydrogen is the most abundant of the chemical elements. It contributes 75% of the universe's elemental mass
  - Stars are mainly composed of hydrogen in plasma state
  - On Earth hydrogen is the third most abundant element. Most of it is in the form of chemical compounds as hydrocarbons and water
  - Advantages of hydrogen as fuel:
    - the highest energy content per unit of weight of any known fuel (3 times greater than gasoline)
    - highly flamable
    - its combustion does not produce Co_2, particulates or sulphur emissions



Region of ionized hydrogen in the Triangulum Galaxy

HYDROGEN PRODUCTION

- turning the universe into hydrogen

- From fossil fuels – today's cheapest technology
  - Steam Reformimg of natural gas – highest effisiency - about 80 %

$$CH_4 + H_2O \xrightarrow[20\,atm]{700\text{-}1100\,^oC} CO + 3H_2 \text{-}192\ kJ/mol$$

The heat required to drive the process is supplied by burning some portions of the methane

  - From carbon monoxide (produced from the steam reforming)

$$CO + H_2O \xrightarrow[catalyst]{130\,^oC} CO_2 + H_2 + 40\ kJ/mol$$

  - Partial oxidation of hydrocarbons

$$CH_4 + \frac{1}{2}O_2 \longrightarrow CO + 2H_2 + Q$$

Since the hydrogen production is concentrated in one facility (plant), the release of greenhouse gases can be avoided.

One promissing technology applied in Norway is the injection of CO_2 in an oil or gas reservoir.

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HYDROGEN PRODUCTION
- turning the universe into hydrogen

- From water – the way to produce hydrogen systainability is the ELECTOLYSIS of water, using:
  - Renewable energy that produces electricity:

- solar energy

- marine energy (waves and streams)

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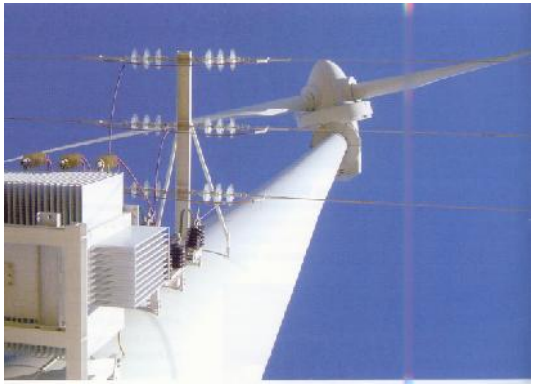
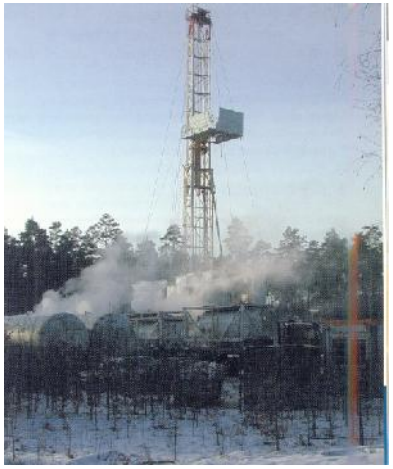
HYDROGEN PRODUCTION
- turning the universe into hydrogen

- From water – the way to produce hydrogen systainability is the ELECTOLYSIS of water, using:
  - Renewable energy that produces electricity:

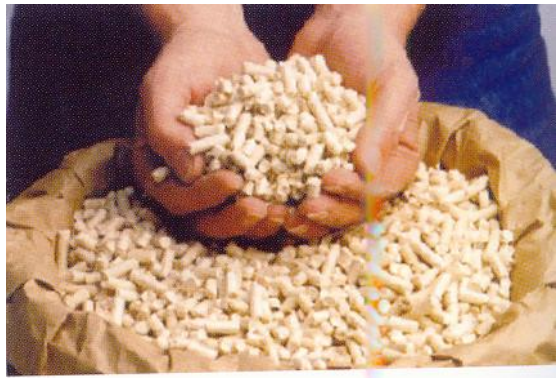
- wind energy



- geothermal energy



- bio-energy



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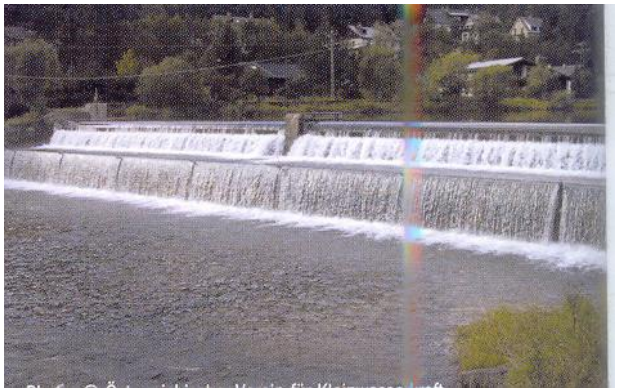
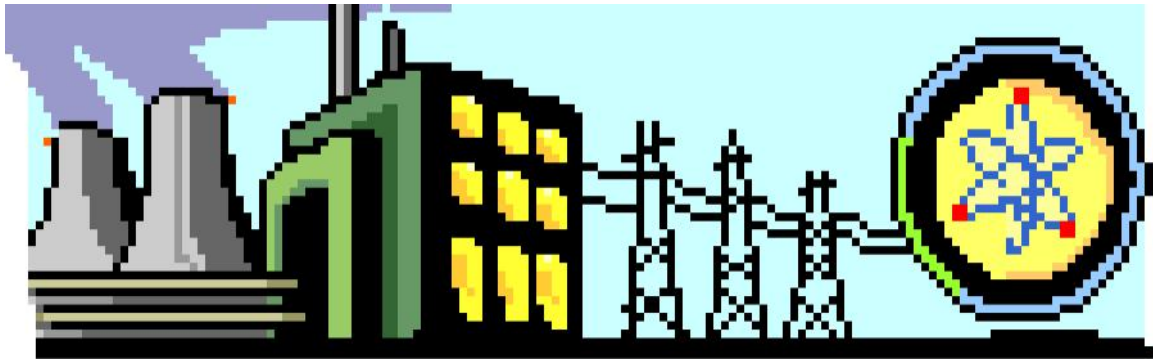
HYDROGEN PRODUCTION
- turning the universe into hydrogen

- From water – the way to produce hydrogen systainability is the ELECTOLYSIS of water, using:

➢ Nuclear reactors and hydroelectrical stations electricity during the night, when the consumption demands are lower.





HYDROGEN PRODUCTION

IEES - turning the universe into hydrogen

- WHAT IS ELECTOLYSIS – the process electrolysis consists in splitting water with the help of electricity into its constituent elements HYDROGEN + OXYGEN:

$$H_2O \xrightarrow{electricity} H_2 + \frac{1}{2}O_2$$

- The electrolyzer technology is well developed, but still more expensive than the steam reforming

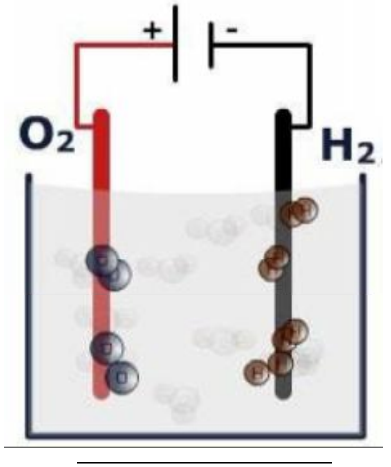
Electrolysers working with electricity from wind energy

HYDROGEN PRODUCTION

IEES - turning the universe into hydrogen

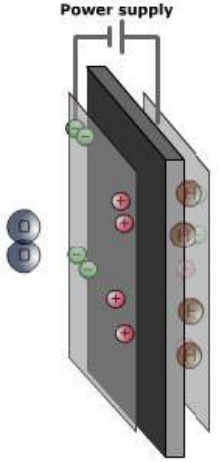
- ELECTOLYSIS
  - Liquid Alkaline Electrolyzers –for large scaled production

✓ The electrical current is applied to conductive liquid (water) electrolyte, which brings to the formation of H^+ cations and OH^- (hydroxile) anions. The H^+ are attracted to the cathode, where H_2 is formed. The OH^- are attracted to the anode, where O_2 is formed.



- Proton Exchange Membrane Electrolyzers – for small and medium scale applications

✓ The electrolyte is a solid polimer membrane, which is permeable only to the H^+ (protons) and thus ensures the separation of the hydrogen from the oxygen.

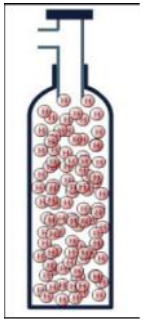


HYDROGEN STORAGE

IEES

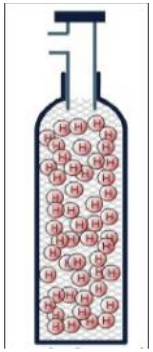
- turning the universe into hydrogen

- Hydrogen contains most energy compared to its weight, but the least compared to its volume. The challenge is to store it, increasing its energy density.



- Storage as a gas – hydrogen is stored in bottles under pressure (200 bars), which increases the energy density. Putting H_2 under pressure takes a lot of energy.

- Storage as a liquid – cooled to -253º C, hydrogen becomes liquid and thus its energy density is increased. The cooling also needs too much energy.



- Solid State Storage – hydrogen can be stored in solid form as metal hydride. Some metals as Mg, Ni, Fe and some metal alloys can expand their lattice and fill it with hydrogen, forming metal hydrides ($NiH_{0.5}$, $NaAlH_4$ etc.). Hydrogen can be easily released with an increase of the temperature (up to 100 – 150ºC).

HYDROGEN APPLICATION

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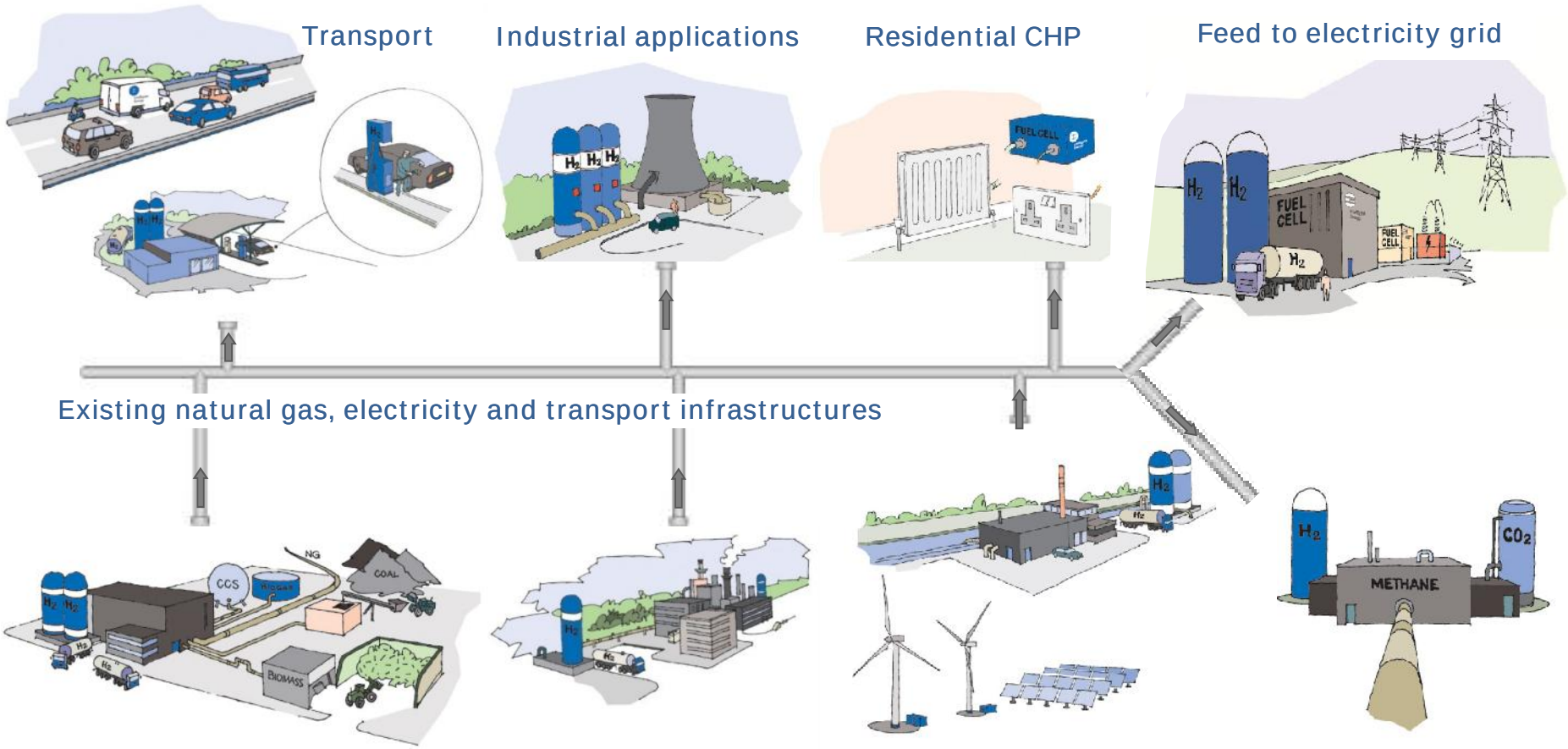

Natural gas, biogas, coal, biomass

By-product from Chemical Industry

Renewable generation, storage and 'buffering'

Methanisation feed to natural gas grid

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HYDROGEN FOR HEAT AND ELECTRICITY - produce your own energy

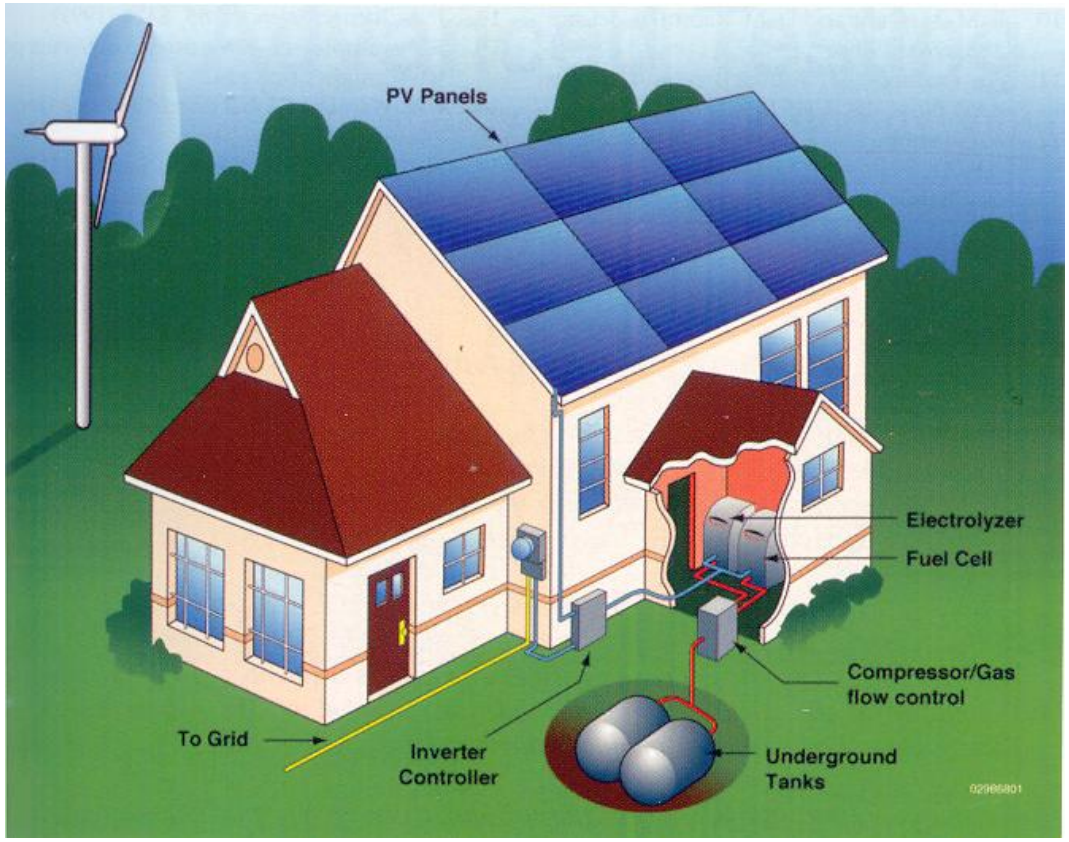
- The Hydrogen energy holds the potential for everybody to produce their own energy. The concept is known as POWER POOL.

  - Every house will have:

    ✓renewable energy production technologies (wind and solar on the example)

    ✓fuel cells for production of electricity from hydrogen

    ✓electrolyzer for H_2 production



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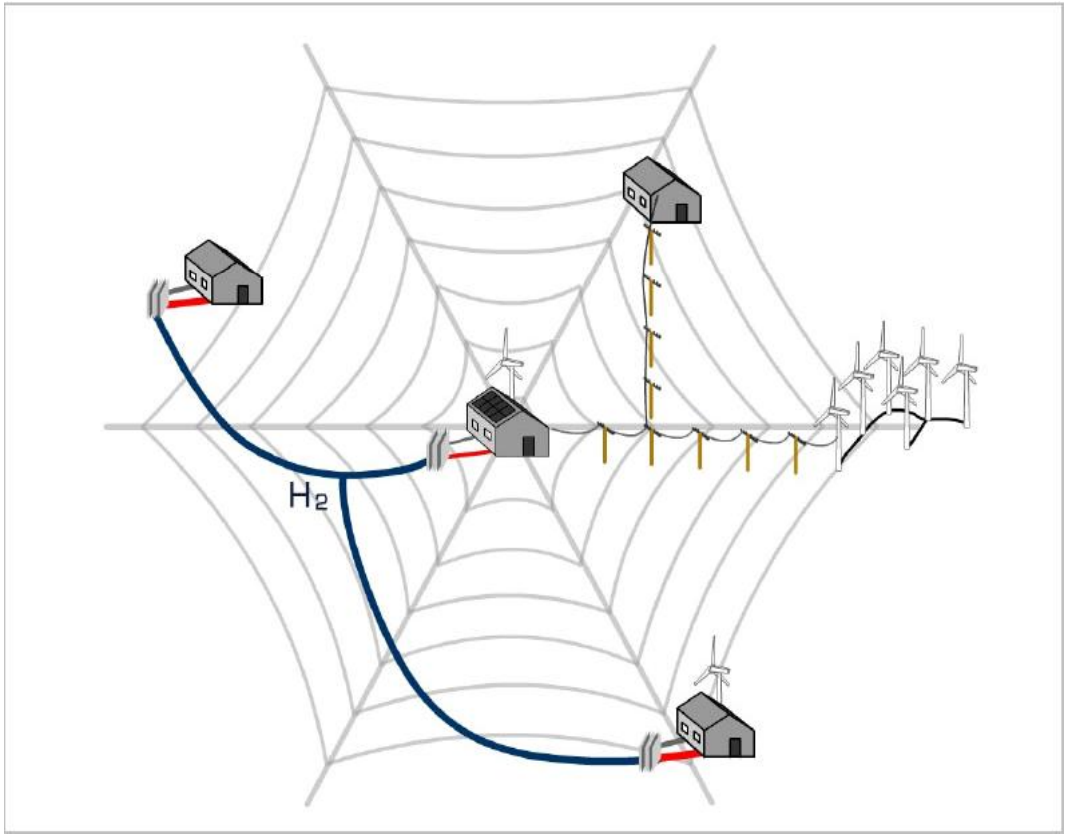
HYDROGEN FOR HEAT AND ELECTRICITY - produce your own energy

- The Hydrogen energy holds the potential for everybody to produce their own energy. The concept is known as POWER POOL.

- All the houses form a POWER GRID in which every house can cell or buy power.

- The idea is to conduct the Power Grid as the INTERNET, consisting of small units, connected to one BIG POWER POOL.



HYDROGEN FOR TRANSPORTATION
- clean, scilent, futuristic

- Hydrogen for transportation is expected to be a major market

- General Motors Hy-Wire (Hydrogen/fuel cell) car paves the road to futuristic cars

Hy-Wire

HYDROGEN AND FUEL CELLS in Europe

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Fuel cells and hydrogen Joint Undertaking - FCH JU

Public-private partnership

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING = + Hydrogen Europe + ONERGHY

- Aim: to accelerate the market introduction of the technologies

- Support:

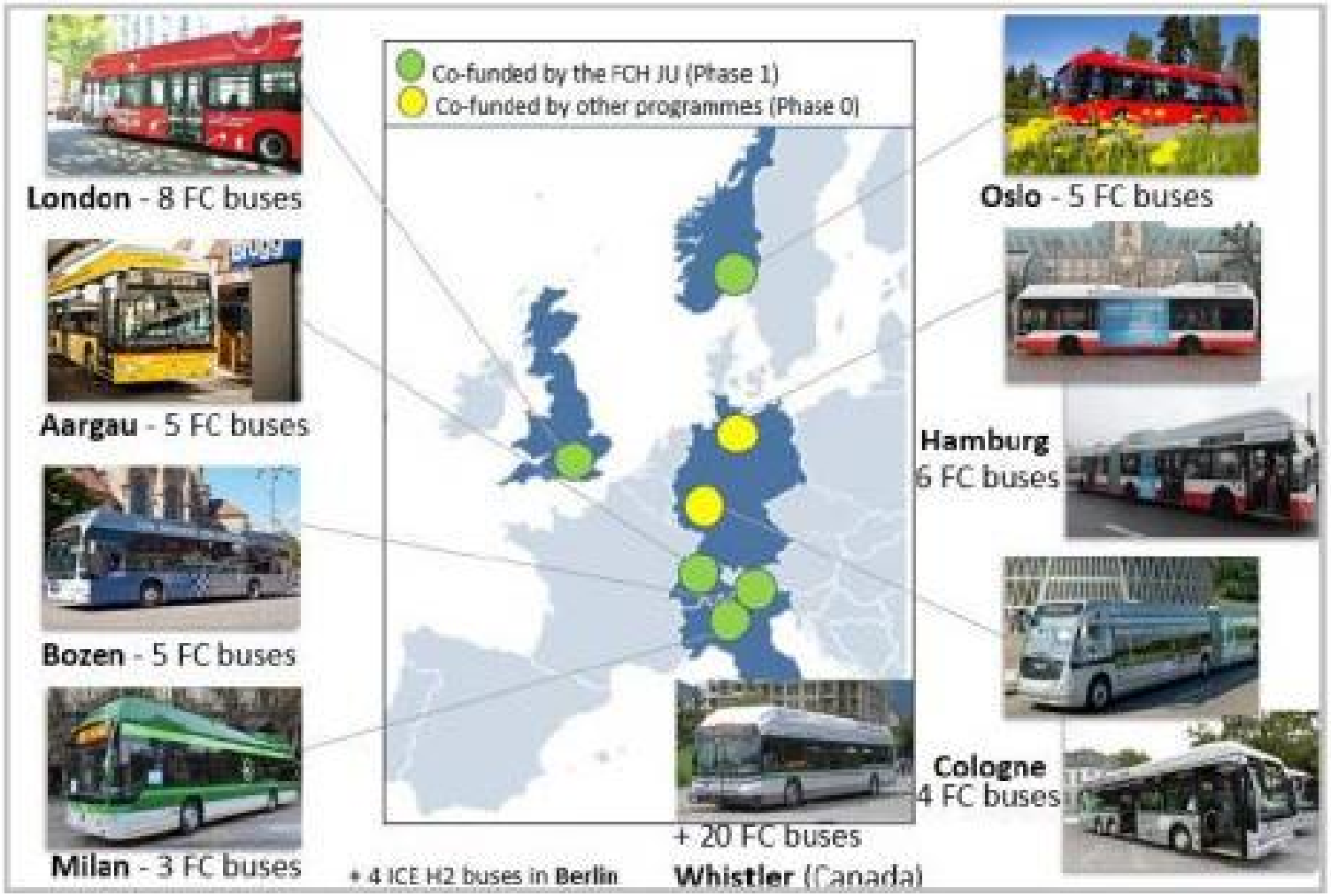
  - 2008-2013 – 960 Million €
  - 2014-2020 - 1.33 Billion €
  - About 150 projects

HYDROGEN AND FUEL CELLS in Europe

IEES

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Fuel cell electric buses: already cleaning transport



HYDROGEN AND FUEL CELLS in Europe

IEES | FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

COMMERCIALISATION

- Total of 585 passenger cars in 5 projects of which 125 with FCs as range extender
- Total of 40 refuelling stations

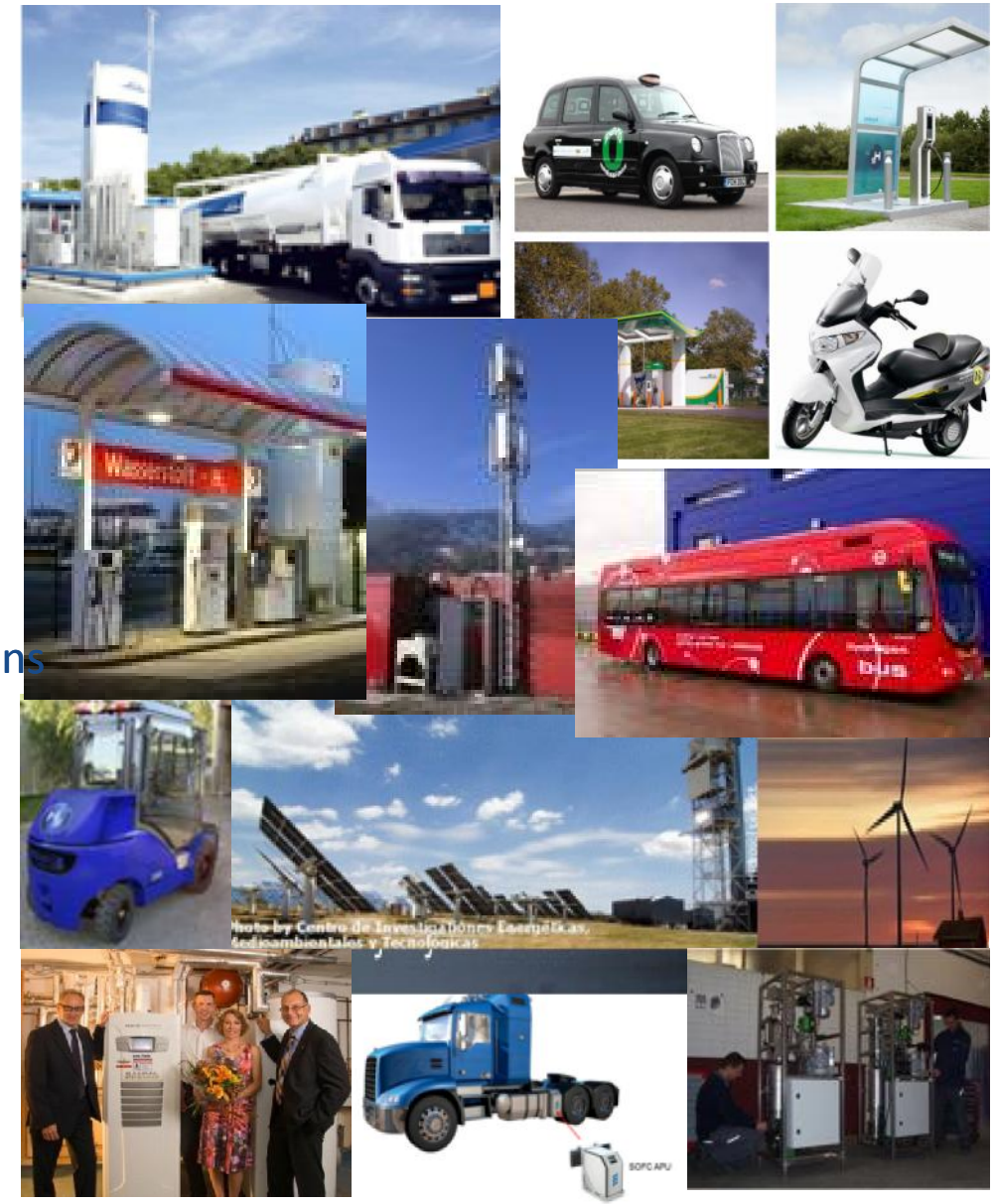
H2moves.eu SCANDINAVIA | HyTEC | hyFIVE | SWARM

- Total of 67 buses from 4 projects in 12 locations

CHIC | HyTransit | HIGHVLOCITY

- Over 400 MHVs in 4 projects
- MHVs operated for 12,413hrs = 2200 shifts with overall availability of 95%
- 4,000 refuellings with 99.5% HRS
- availability

HyLIFT Clean Efficient Power For Materials Handling www.hylift.eu | HAWL | H2 Moby Post mobility with hydrogen for postal delivery



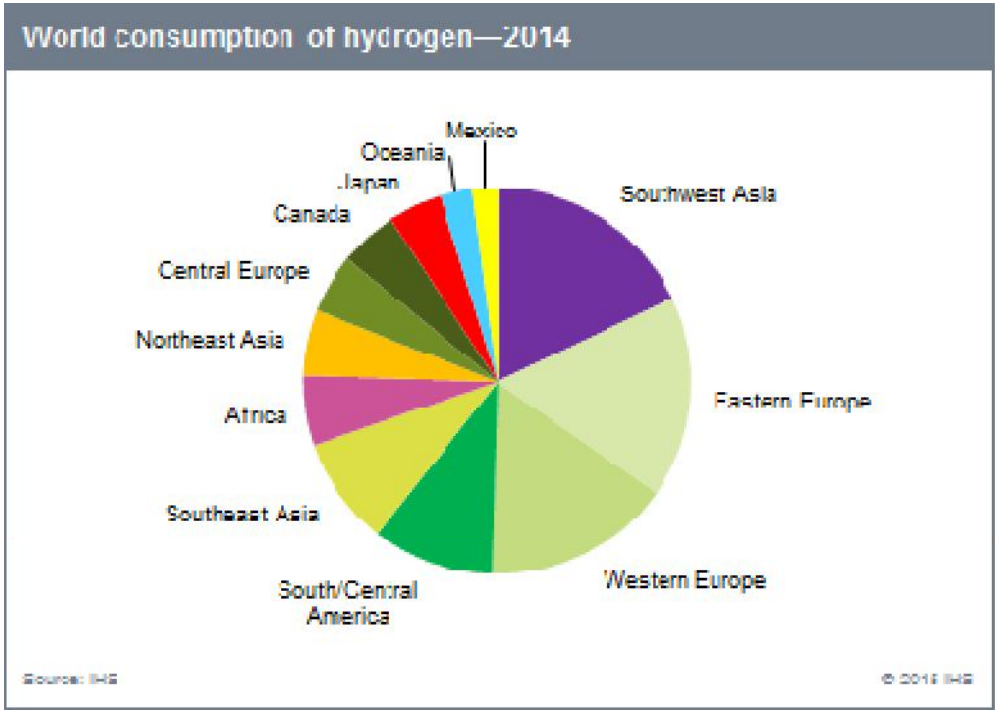
HYDROGEN AND FUEL CELLS in Europe

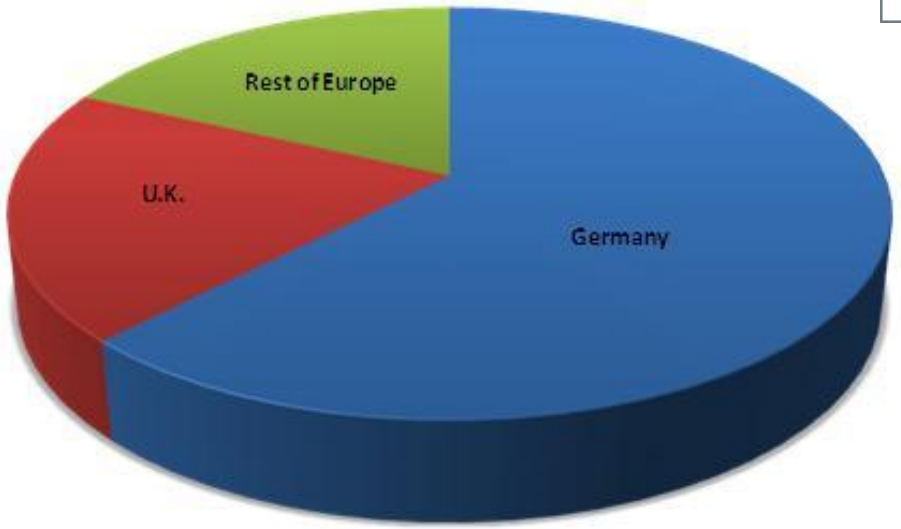
IEES | FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

COMMERCIALISATION

- Europe vs. WORLD:

- Europe Fuel Cell Technology Market:





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WATER will be the coal of the FUTURE."

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The Mysterious Island (1874)

CONCLUSION

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IF YOU WANT TO BECOME AN INVENTOR, just read carefully JULES VERNE

This material is prepared and disseminated in the frames of the projects: ENDURANCE (funded under Grant Agreement No 621207 of the European Union's Seventh Framework Programme (FP7/2007-2013) Fuel Cells and Hydrogen Joint Undertaking (FCH-JU-2013-1) and IMOOD (funded under Grant Agreement No E02/3/2014 of the National Science Foundation – Bulgaria).