Application of waste hydrogen in energy production. Case study on base of the implementation of the method in selected chemical plant in Poland

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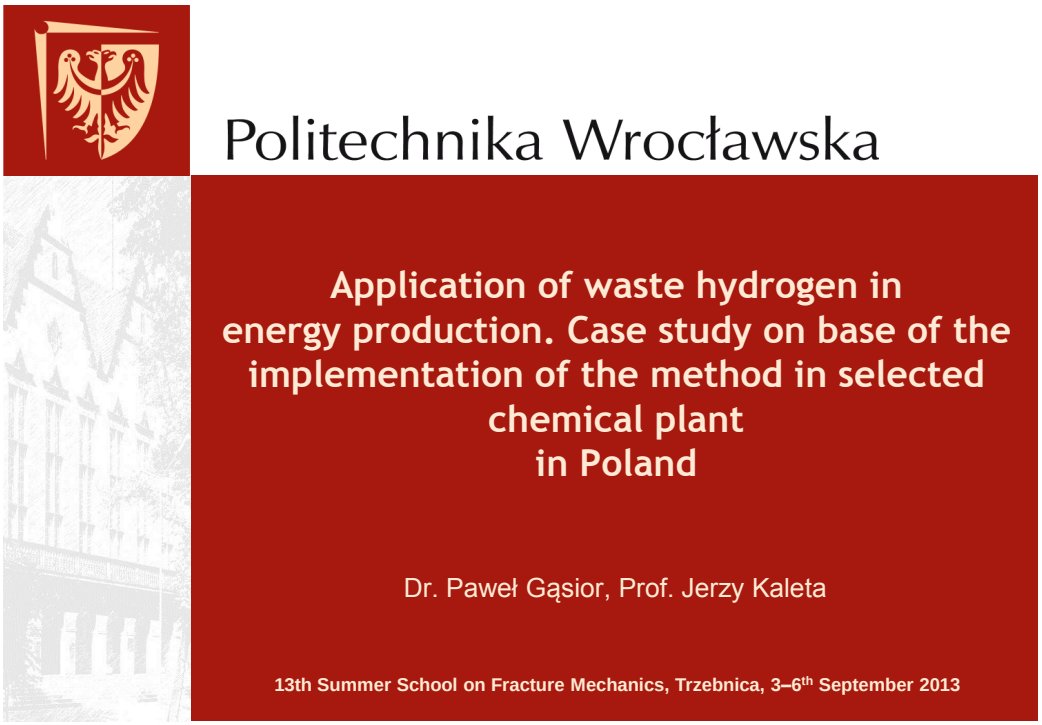
Trzebnica, 3–6 th September 2013



*Wrocław University of Technology, Institute of Materials Science and Applied Mechanics

Outline

- Hydrogen production und utilization levels in EU (including the surplus for energy production use)
- EU demonstrative projects in the use of H_2 for stationary applications (energy production)
- Preliminary estimation for Poland
- The use of by-hydrogen („waste hydrogen”) in the energy sector in chemical plants, selected examples

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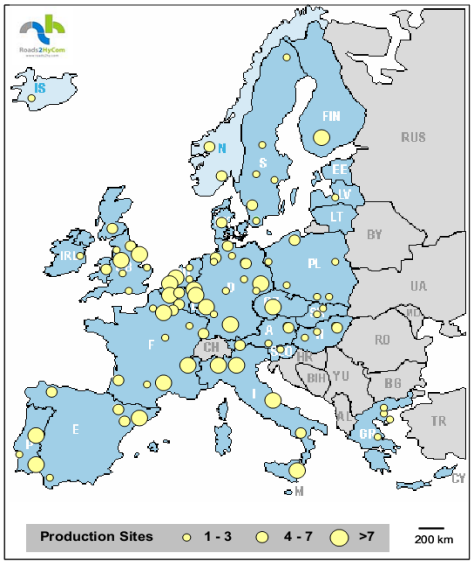
Hydrogen production sites

- Geographic distribution of identified industrial hydrogen production facilities.
- Main clusters: Benelux, Rhein-Main, Midlands and North Italy



Source:

- Roads2HyCom

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Hydrogen production sites

- Total European production is estimated at about 90bn m^3 (2003): 80bn m^3 for European Union members (including 22bn m^3 for Germany, 10bn m^3 for the Netherlands, and approximately 5-7bn m^3 for both the United Kingdom, France, Italy, Spain and Belgium), 2bn m^3 for EFTA countries, and 10bn m^3 for Candidate Countries (CC). Poland – 4.2 bn m^3.
- Total hydrogen consumption in Western Europe is estimated to be about 61bn m^3 (2003), 80% of which was consumed by mainly two industrial sectors: the refinery (50%) and the ammonia industry (32%), which are both captive users. If one adds hydrogen consumption by methanol and metal industries, those four sectors cover 90% of the total consumption.
- "Surplus hydrogen" in Europe: 2-10bn m^3 hydrogen. It is possible to supply about 1-6 million vehicles (1.5-3% of all vehicles in the EU; estimated at 190m)

Source:

- Roads2HyCom

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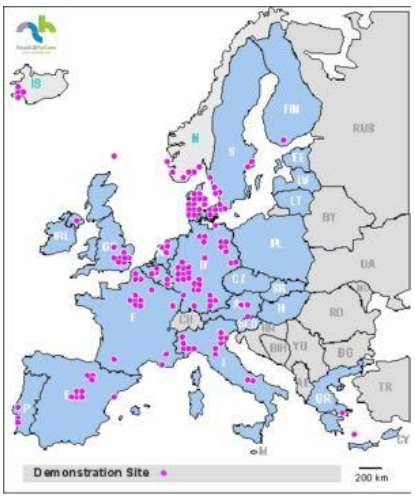
Demonstration hydrogen projects in EU

- Geographic distribution of identified hydrogen demonstration projects.
- Centres of aggregated activity are the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden Clusters

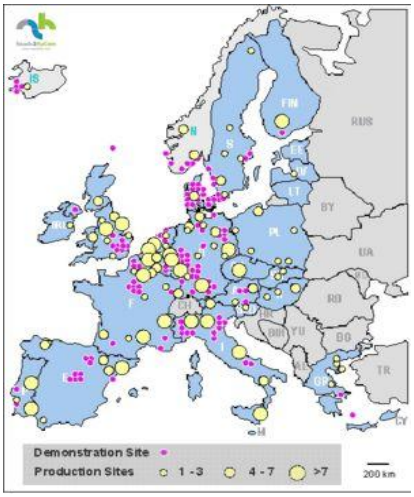


Source:

- Roads2HyCom

Hydrogen production sites and demonstration project

- Often, but not necessarily always, the location of a production site coincides with the location of a demonstration project.
- Centres of aggregated activity are the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden Clusters.



Geographic distribution of identified hydrogen demonstration projects and industrial hydrogen production sites.

Source:

- Roads2HyCom

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By-product hydrogen by chlor-alkali industry

- World production of chlor-alkali hydrogen: 16 billion m3/year
- Hydrogen vented by chlor-alkali industry: 2.4 billion m3/year
- Vented H2 converted with fuel cell power: 420 MWe (assuming 50 % conversion efficiency)
- Advantages: Reduction of electricity consumption of chlor-alkali plant by 20% when all byproduct hydrogen is converted to power (conversion efficiency = 50%; PEM fuel cells)

Source:

- NedStack Fuel Cell Technology, Arnhem, Netherlands
- Akzo Nobel Base Chemicals, Amersfoort, Netherlands
- 2008 Fuel Cell Seminar & Exposition, Phoenix, Arizona / October 27-31, 2008

By-product hydrogen in Europe

- "Surplus hydrogen" in Europe: 2-10bn m^3 hydrogen. It is possible to supply about 1-6 million vehicles (1.5-3% of all vehicles in the EU; estimated at 190m - Roads2HyCom)
- Fifty* milion Nm^3 is the amount of hydrogen by-product coming from European industries every day and not sold out to the gas or chemical industry (about: 15bn m^3/y).
- This number represents an equivalent net production of 150 GWh/day (hydrogen energy content).

Source:

- *Hinicio report, 2011 (Supports the Valorisation of Hydrogen Industrial By-product)

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Hydrogen production by regions, Poland

Poland	Centralny	Mazowieckie	0.04
	Polnocno - Zachodni	Zachodniopomorskie	0.80
	Polnocny	Kujawsko-Pomorskie	0.86
		Pomorskie	0.00
	Total Polnocny		*0.86*
	Poludniowo-Zachodni	Dolnoslaskie	0.03
		Opolskie	0.59
	Total Poludniowo-Zachodni		*0.62*
	Poludniowy	Malopolskie	0.27
		Slaskie	0.00
	Total Poludniowy		*0.27*
	Wschodni	Lubelskie	1.59
		Podkarpackie	0.01
	Total Wschodni		*1.57*
Total Poland			**4.18**

Source:

- HyWays

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Hydrogen Fuel Cells and Electromobility in European Regions - HyER

Source:

- HyER

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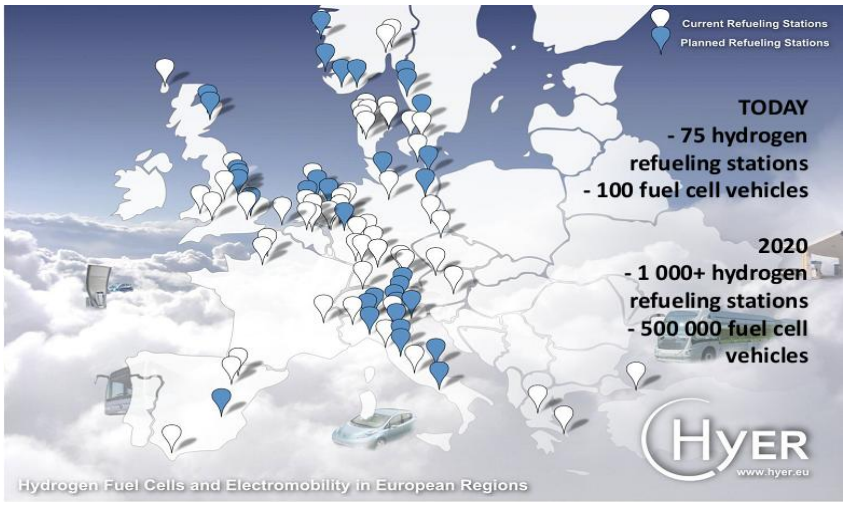
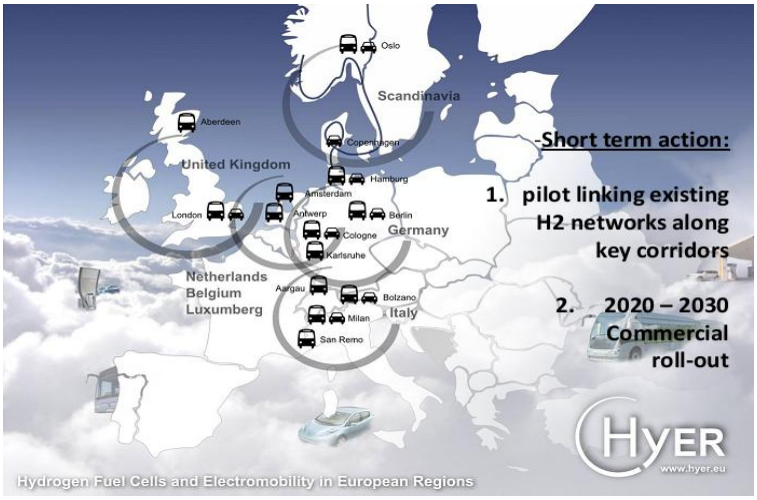
HyER - current Hot Spots



Source:

- HyER

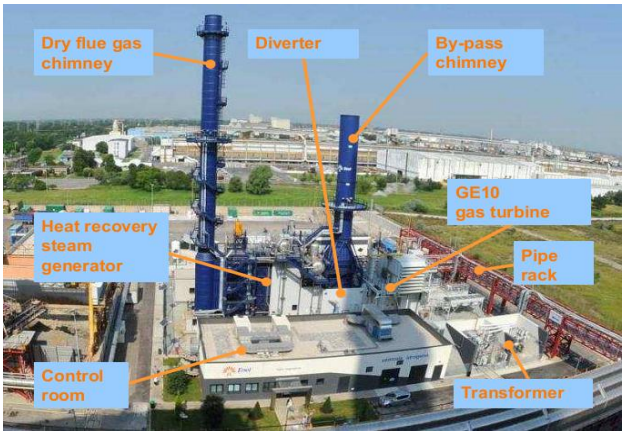
HyER - Connecting the dots….. along TEN-T corridors



Source:

- HyER

The hydrogen power plant Fusina, Italy



Innovations:

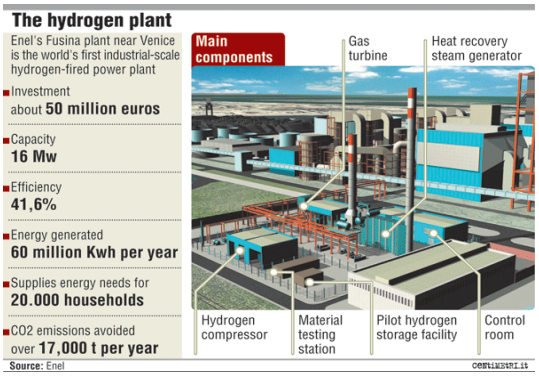
- First combined cycle worldwide designed to operate with pure hydrogen.
- First low-NOx combustor for hydrogen (400 mg/Nm3 in experimental phase, 100 mg/Nm3 in commercial operations).
- Condensing HRSG (*heat recovery steam generator*) for the maximum energy recovery.

Source:

- http://de.amiando.com/eventResources/r/v/kfKncJZVrUe3Xh/Electricity_from_hydrogen_with_combined_cycles_-_The_Fusina_Project.pdf

The hydrogen power plant Fusina, Italy

- **The Fusina power plant, featuring a gas turbine that can use hydrogen as its main fuel along with a condensing-type heat recovery steam generator**

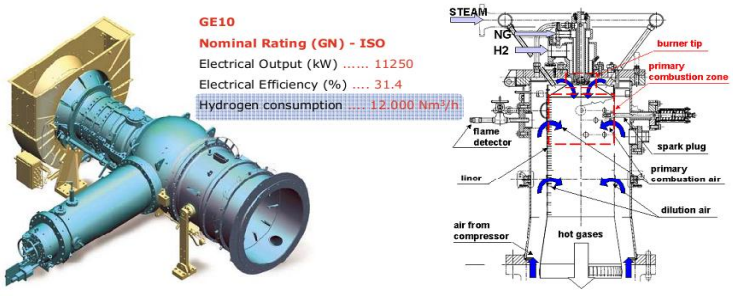


Source:

- http://www.powerengineeringint.com

The hydrogen power plant Fusina. Gas turbine

- The gas turbine was supplied by General Electric – Nuovo Pignone.
- The hydrogen fuelled combustor has been specifically developed for the Fusina plant with support of Enel.
- Combustor configuration is suitable for research activities (silos-type single-can combustion chamber, diffusive flame, steam injection for NOx abatement).



Source:

- http://de.amiando.com/eventResources/r/v/kfKncJZVrUe3Xh/Electricity_from_hydrogen_with_combined_cycles_-_The_Fusina_Project.pdf

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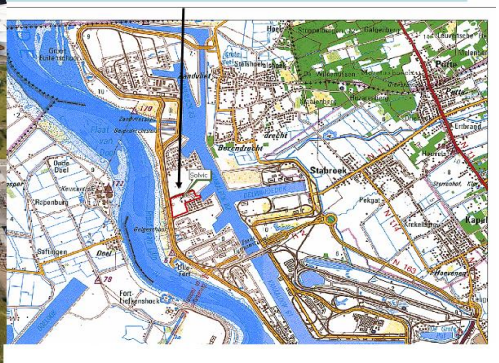
Implementation at Solvay Antwerp chlor-alkali plant

350,000 Tons / yr Chlorine
10,000 Tons / yr Hydrogen



Source:

- http://www.fch-ju.eu/sites/default/files/documents/ga2010/patrick_francoisse.

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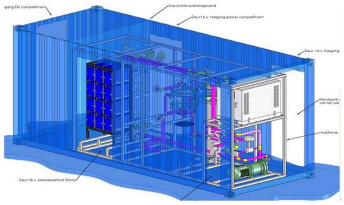
Pilot PEM Power Plant at Delfzijl (50kW)

- complete system fits inside 20 ft sea container
- start of construction: June 2006
- first power to Delfzijl grid: 11 April 2007
- soda contamination: July-Aug 2007
- 6000 hrs, 300 MWh to grid: 10 July 2008

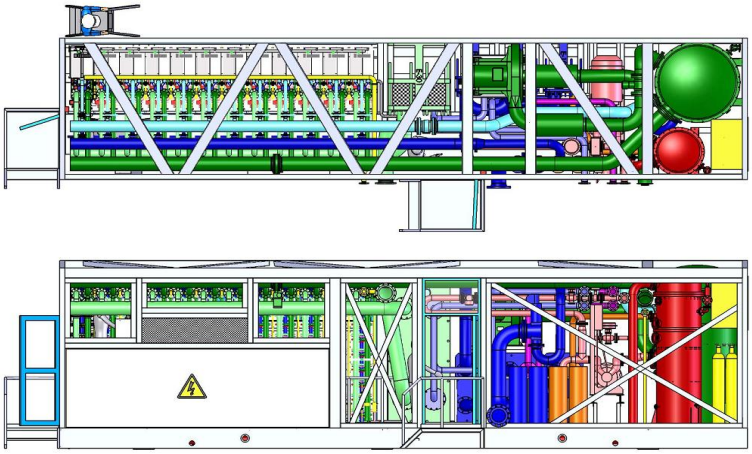


PEM - Proton exchange membrane fuel cells

Source:

- NedStack Fuel Cell Technology, Arnhem, Netherlands
- Akzo Nobel Base Chemicals, Amersfoort, Netherlands
- 2008 Fuel Cell Seminar & Exposition, Phoenix, Arizona / October 27-31, 2008

Implementation at Solvay Antwerp chlor-alkali plant. Schematic drawings (1 MW, 2011)



1 MW installation fits inside 40 ft. sea container

Source:

- http://www.fch-ju.eu/sites/default/files/documents/ga2010/patrick_francoisse.

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Ballard Power Plant (by-product hydrogen; 1MW)

- Canadian companies Ballard Power Systems and K2 Pure Solutions have finalized a sales agreement to deploy a PEM fuel cell power generator to be sited at a K2 Pure Solutions' bleach plant in Pittsburg, California
- Power to 1 megawatt
- It's the size of a tractor trailer, it's on wheels and completely transportable
- Start of full exploitation: mid 2012

Source:

- http://smr.newswire.ca/en/ballard-power-systems/worlds-largest-hydrogen-fuel-cell-generator-set-to

Wastewater-Hydrogen Fuel Plant

- Air Products opened its latest hydrogen fueling station in Orange County California (August, 2011). The hydrogen is produced from methane gas emitted from wastewater in holding tanks in Fountain Valley.
- The plant is equipped with a fuel cell that reforms the methane into hydrogen, which is used to generate 250 kilowatts of electricity.
- The technology used in plant can be applied to other biogas including agricultural, food and brewery waste streams, as well as landfill gas. Converting all these into hydrogen could supply enough fuel for 200 million fuel cell vehicles in the US.

Source:

- http://cleantechnica.com/2011/08/17/hydrogen-for-200-million-vehicles-air-productsorange-county-open-wastewater-hydrogen-fuel-plant/

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By-product hydrogen

- In Shanghai there are two central hydrogen plants (Air Liquid, Linde), but many industries produce yearly about 550,000 tons of hydrogen from:

Hydrogen resources distribution in Shanghai

- coal gasification
  - methanol
  - ammonia
  - acetic acid
- coking oven gas (COG)
- chlor-alkali
- electrolysis
- etc.

Source:

- Ma Jianxin, Clean Energy Automotive Engineering Center Tongji University, Hyforum 2008 August 5, 2008, Changsha, China

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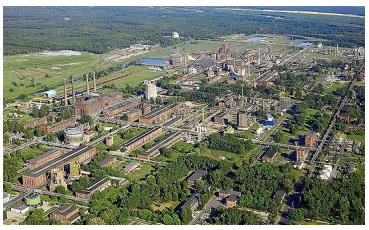
Waste-Hydrogen power plant in Poland - pilot project

- Main features of new H_2 power plant:
  - Total electrical power: 1 MW (max 5 MW)
  - Power generators: 2 x 400 kW + 1 x 200 kW
  - Gas source: 4 different lines (octan and butyl alcohols, propylen purge gas, coke-oven gas)
  - Fuel cells unit: 20 kW (pure H_2)
  - SHM system for on-line pipeline monitoring (leakage detection)
  - Pilot instalation for power generation and methodology testing



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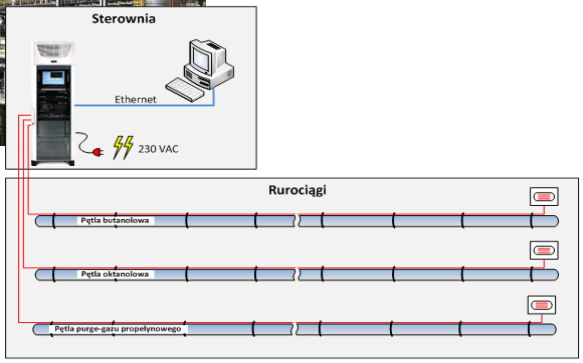
Leakage detection on hydrogen pipelines



Leakage detection by optical fiber based Structural Health Monitoring system (so called distributed sensors with temperature measurements by Raman effect)

Conclusions

- Any unused hydrogen, which is the result of technological processes in the chemical industry (or from from biomethane gas) , can be used to generate electricity and heat.
- There are known and controlled technologies (know-how) for energy production (electricity and heat) from hydrogen. Generators are powered by internal combustion engines, gas turbines, and/or fuel cells.
- Recently, the leading chemical companies in Europe and Canada / USA, launched stationary systems for energy production (uses "waste" hydrogen) with a capacity measured in MWs.
- First pilot project in Poland is currently implemented.