Past and Present Research in Europe on the Production of Nuclear Hydrogen by HTGR

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Energy Situation in the European Union

EU is a net energy importer

- Consumption
- Domestic production

Year

MTOE

The 1st COE-INES Int. Symposium, INES-1 Oct 31 - Nov 4, 2004, Tokyo, Japan
Principal Policy Objectives of the EU

- Maintaining security of energy supply
- Reducing the dependence of fossil energy imports
- Meeting Kyoto commitment of an 8% $CO_2$ reduction by 2008/2012, anticipating the need for much stronger reduction later
- Promoting industrial competitiveness
Nuclear Energy in the EU

- 15 of the 25 member states operate NPP, covering more than one third of the total electricity demand, but inhomogeneously distributed;

- Long-term intensive cooperation among nuclear vendors, utilities, research organizations;

- Meeting Kyoto commitments demands for clean fuel and CO$_2$-free energy sources (renewables, nuclear);

- Water and biomass are the two candidate raw materials for H$_2$ production on the long run.
Nuclear Process Heat Temperatures

- Production:
  - HTGR: up to 1000 °C
  - AGR: up to 650 °C
  - LMFR: up to 500 °C
  - LWR: up to 320 °C

- Use:
  - 1. District heating, Seawater desalination
  - 2. Petroleum refining
  - 3. Oil shale and oil sand processing
  - 4. Steam reforming of natural gas
  - 5. Gasification of hard coal and lignite, HT electrolysis of steam, IS thermochemical cycle

- Process heat temperature range:
  - 500 - 900 °C
  - 300 - 600 °C
  - 250 - 550 °C
  - 80 - 200 °C
  - 800 - 1000 °C
Nuclear Process Heat Applications

Nuclear process heat (PNP)

High-temperature heat
Process steam
Electricity

Gas factory

CH₄
H₂ and CO

SNG heat
SNG raw material
Direct iron ore reduction
Ammonium synthesis
Methanol synthesis
Indirect coal liquefaction
EVA / ADAM
PNP-500 Process Heat HTGR

Status of Project (~1990):

• 500 MW Prototype designed (950°C)
• Coal gasification processes demonstrated (1-10 MW)
• Main components tested in 10 MW scale
• Materials lifetime ~ 120000h
• Licensing assured (e.g. tritium / gas explosions)
• Economics under elevated oil prices
Coal Gasification Demonstration in Pilot Plants

Hydro

Steam
Component Test Loop (KVK)

Hot gas valve

Hot gas duct
He-He-IHX Manufacture by Steinmueller
Long-Distance Energy Transportation System

EVA / ADAM Energy Transmission System

EVA
(methane reforming)

ADAM
(methanation)

Helium 950 °C

Long-distance pipeline for H₂, CO, CO₂
Long-distance pipeline for CH₄
Long-Distance Energy Transportation System

EVA
steam reforming

ADAM
methanation
Energy Alcohol Production from Biomass
Hydrogen Supply Options and Demand

Sector sizes do not represent current or future markets.
Creation of Policy Groups

- **High Level Group on Hydrogen and Fuel Cells (HLG)**
  to develop European consensus on the introduction of hydrogen energy

  to develop coherent hydrogen research and deployment strategy for Europe
Timeline for H₂ Production Technologies

- **Renewable**
  - Electrolysis from Renewable Electricity
  - Biomass Gasification (w/o or with CO₂ Sequestration)
  - Photochemical

- **Sustainable**
  - Electrolysis from Nuclear Electricity
  - Electrolysis from Fossil Fuel derived Electricity with CO₂ Seq
  - Reformation of Fossil Fuels (NG, Oil, Coal) with CO₂ Seq

- **Fossil**
  - Electrolysis from Fossil Fuel derived Electricity
  - Hydrogen from Coal
  - Hydrogen from Oil
  - Decentralised Small Natural Gas Reforming
  - Centralised Natural Gas Reforming


Hydrogen vehicle fuel production EU 2020: 2.3 - 20.6 billion Nm³/a
[Source: HyNet scenarios]
Quick Start Initiative by EC

First call for proposals of FP6 (March 2004)

EC awarded 10 contracts in $H_2$ with 62 M E
EC awarded 6 contracts in FC with 30 M E
(to be matched by private funding)
## EU Contracts on Hydrogen in FP-6

<table>
<thead>
<tr>
<th>Project</th>
<th>Topic</th>
<th>Coordinator</th>
<th>EU Funding [M€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYTHEC-STREP</td>
<td>Thermochemical cycles</td>
<td>CEA (F)</td>
<td>1.9</td>
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<tr>
<td>CHRISGAS-IP</td>
<td>H₂ rich gas from biomass</td>
<td>Växjo Uni (S)</td>
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<tr>
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<td>HT electrolysis</td>
<td>EDF (F)</td>
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<td>European hydrogen roadmap</td>
<td>LBST (G)</td>
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<td>Infrastructure H₂-Nat. Gas mixes</td>
<td>Gasunie (NL)</td>
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<td>Storage for on-board applications</td>
<td>Magna Steyr (A)</td>
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<tr>
<td>HYSAFE-NE</td>
<td>Research in safety issues</td>
<td>FZK (G)</td>
<td>7.0</td>
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<tr>
<td>ZEROREGIO-IP</td>
<td>H₂ fuel cell fleet demonstration</td>
<td>Infraserv (G)</td>
<td>7.5</td>
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<td>PREMIA-SSA</td>
<td>Effectiveness of demo initiatives</td>
<td>VITO (B)</td>
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<tr>
<td>HYICE-IP</td>
<td>Internal combustion engines</td>
<td>BMW (G)</td>
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</tbody>
</table>
INNOHYP-IP (March 2003)

- 30 M Euro IP on innovative hydrogen production processes (incl. nuclear)
- Evaluate and compare different processes of $H_2$ production with focus on thermochemical cycles, but includes also steam reforming as well as “very innovative“ ways
- Not accepted (July 2003) Modified version to be relaunched as CA
HYSAFE-NE (March 2004)

- EU Network of Excellence
- Strengthening capacities to implement new technological solutions for \( H_2 \) as energy carrier
- Harmonize methodologies for safety assessment
- Focus on studies of fire and explosion safety, mitigation techniques, detection devices
- Promote use of \( H_2 \)
- Establish a European Hydrogen Safety Center
GenIV nuclear reactor: VHTR

- 400-600 MW(th) for electricity and process heat production;
- Helium-cooled, graphite-moderated, thermal neutron spectrum;
- Gas outlet temperature of 900-1000 °C;
- IHX for heat transfer to H₂ production plant or gas turbine.
Program Plan for VHTR by 2010

- Long-term technology improvement by making use of knowhow from HTGR development;
- HTTR and HTR-10 to demonstrate VHTR capabilities in pilot scale and in near term;
- INEEL co-generation project as full-scale demonstration of VHTR objectives with $H_2$ production system.
VHTR Hydrogen R&D program

- Developing and optimizing thermo-chemical water splitting processes of the sulfur family (reference: S/I, special focus on HT step);
- Evaluating alternatives;
- Advancing the high temperature electrolysis process.
V/HTR-Integrated Project in FP6

- 35 partners, coordinated by Framatome-ANP
- Facilitates and supports the EURATOM contribution to the GenIV International Forum (GIF) [at present technically represented by MICANET]
- Complements national efforts on HTR/VHTR
- Connected to hydrogen activities in FP6 by sub-projects „System Integration“ and „Safety“
- Currently under negotiation with EC
  [evaluation process: 26.5 out of 30 points]
V/HTR-IP Overall Objectives

- Study 1st generation of advanced gas reactor technologies with R&D support to existing demonstrator projects;

- Explore options for 2nd generation by developing systems for very high temperature (950 - 1000 °C) applications.
V/HTR-IP Breakdown Structure

2. Fuel Technology
4. Materials Development
5. Component Development
6. Safety
7. System Integration
8. Education & Training
Recommendations for an R&D Strategy on Hydrogen Production Processes

- Address present hydrogen market and transition phase
- Include HYDRICITY (exchangeability of H\(_2\) and electr.)
- Extend R&D to alternatives (e.g. thermochem. cycles)
- Take benefit from non-nuclear H\(_2\) process developments (e.g. solar steam reforming)
- Prepare „lighthouse“ demonstration projects (HTTR, NGNP)
- Establish international R&D programs (e.g. GIF)
Thank You for Your Attention

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