FCH 2 JU State of Play
Transport and Energy applications
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http://www.fch.europa.eu/
Fuel Cells & Hydrogen technologies in the context of the European Energy policy

**Sustainability**
- H₂ is a clean energy carrier
- Transport and Energy applications, generate electricity and heat with very high efficiency
- Possibility for storage of renewable energy sources
- Reduction of CO₂ emissions

**Energy Security**
- Increase independence from unstable outside regions

**Competitiveness**
- research excellence leading to industry innovation and growth
The SET plan includes several initiatives:

- **The European Industrial Bioenergy Initiative**
- **The European CO2 Capture, Transport and Storage Initiative**
- **The European Electricity Grid Initiative**
- **The Fuel Cells and Hydrogen (FCH) Joint Technology Initiative**
- **The Sustainable Nuclear Initiative**
- **The Solar Europe Initiative**
- **Energy Efficiency – The Smart Cities Initiative**
- **The European Wind Initiative**

The SET plan = Strategic Energy Technology Plan, the technology pillar of the Energy Union!

**EU 2030 targets**: 
- 27% increase in renewables
- 27% increase in efficiency
- 40% decrease in emissions

From 80% dependency on fossil fuels to 80% reduction in GHG emissions in 40 years! → A reinvention of our energy system...

*European Council, October 2014
**continuation of previous exercise for 2008-2013 with a budget of approx. 1 bill.€
Continuous Support in the EU Framework Programmes

* 470 mill EUR implemented by FCH JU + about 10 mill EUR already spent from EU 2007 budget, before FCH JU in place
** 665 mill EUR only to be implemented by the FCH2 JU + additional budget from EU programmes for low TRL (basic research) and structural funds/smart specialisation
Strong Public-Private Partnership with a focused objective

Fuel Cells & Hydrogen Joint Undertaking (FCH JU)

Hydrogen Europe
Industry Grouping
Close to 100 members
~ 50% SME

European Commission
Research Grouping
Over 60 members

The Joint Undertaking is managed by a Governing Board composed of representatives of all three partners and lead by Industry.

To accelerate the development of technology base towards market deployment of FCH technologies from 2015 onwards

Legal basis:
Council Regulations:
521/2008 of 30 May 2008 (FP7)
& amendment 1183/2011 of 14 Nov 2011
559/2014 of 6 May 2014 (H2020)
+10% average increase of annual turnover (on a 2012 total of €0.5 billion)

+8% average increase of R&D expenditures (2012 total €1.8 billion)

+6% average increase of market deployment expenditures (2012 total €0.6 billion)

+6% growth in jobs per year (~4,000 FTE in 2012) while average EU job market has contracted

+16% annual increase in patents granted in the EU to European companies (average 1.5% for all European industries)

Industrial applications
- Residential CHP
  - Natural gas, biogas, coal, biomass
  - Renewable generation, storage and ‘buffering’
  - Methanisation feed to natural gas grid

Transport
- Feed to electricity grid
- Reduction of production costs of long lifetime FC systems to be used in transport applications

FCH 2 JU objectives
- Increase of the electrical efficiency and durability of low cost FCs used for power production
- Increase the energy efficiency of low cost production of hydrogen from water electrolysis and renewable sources
- Increase the energy efficiency of low cost production of hydrogen from water electrolysis and renewable sources
- Large scale use hydrogen to support integration of renewable energy sources into the energy systems
- Reduce the use of critical raw materials
- By-product from Chemical Industry
- Existing natural gas, electricity and transport infrastructures
Multi-Annual Work Plan, MAWP (2014-2020)

• Hydrogen production and distribution
• Hydrogen storage for renewable energy integration
• Fuel cells for power and combined heat & power generation

• Road vehicles
• Non-road vehicles and machinery
• Refuelling infrastructure
• Maritime, rail and aviation applications

Cross-cutting Issues
(e.g. standards, consumer awareness, manufacturing methods, ...)

Estimated budget of €1.33 billion
Strong industry commitment to contribute inside the programme + through additional investment outside, supporting joint objectives.
Strong FCH community in Europe

Projects involving 22 EU Member States (under FP7)

1266 Participations
545 Beneficiaries:
  - 192 Industries (35%)
  - 154 SMEs (28%)
  - 149 Research Organizations (27%)
  - 20 High Education Institutions (4%)
  - 30 Others (6%)

Incl international cooperation outside EU
(Additional non-EU countries: CH, NO, IL, TR, IS, RS, CN, RU & US)

Funding of beneficiaries categories

- Higher Education: 2%
- Research: 32%
- Industry: 32%
- SME: 27%
- Others: 7%
FCH JU portfolio of projects

169 projects supported for about 520 mill €
(of which FP7: 155 projects for 446 mill €)

Similar leverage of private funding: 532 mill €

50/50 distribution between Energy and Transport pillars

Continous/constant annual support (through annual calls for proposals)
Total FCH JU support:
- 242M€ for 42 projects
- 183.1M€ for demos

TRANSPORT portfolio

- Total of 544 passenger cars in 5 projects
  - Of which 125 with FCs as range extender
- Total of 67 buses from 4 projects in 12 locations
- Total of 40 refuelling stations
- 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
Advanced FCEV and HRS programs

- **France** – a large private consortium has agreed a strategy based on a transition from captive fleets to nationwide infrastructure for FCEVs.

- **Germany** –
  - the H2Mobility project has already signed a “term sheet” linking six industrial players to deploy 100 stations by 2017 and 400 by 2023 for 350 M€.

- **Scandinavia** – An initial network provides coverage for FCEVs, which can be purchased at equivalent ownership cost.

- **UK** – a consortium with significant Government presence has agreed a strategy based on seeding a national network of 65 stations by 2020. 7.5M£ have been committed by the Government for 15 HRS by 2015.

Similar initiatives are starting or running in other countries: **Austria, Belgium, Finland, Netherlands** (plan to be published before the end of 2014), **Switzerland**.
Likely implementation of the network by 2020 onward (>80 kg/day stations)

### France
- The French network will keep on expanding with **30-40 HRS** by 2020 and **100 HRS** by 2023

### Germany
- The German network will keep on expanding with **400 HRS** in 2023

### Netherlands
- The Dutch network will keep on expanding with **20 HRS** by 2020 and **40-50 HRS** by 2023

### Scandinavia
- The Scandinavian network will keep on expanding with **35-40 HRS** by 2020 and **50 HRS** by 2023

### UK
- The UK network will keep on expanding with **60-70 HRS** by 2020 and **100 HRS** by 2023
Concept description:

- Joint initiative from the **most ambitious** European hydrogen mobility initiatives
- The project will see the deployment of **29 new HRS** and **325 FCEVs** (200 FCEVs and 125 FC RE-EVs)
- One ‘working framework’ linking the hydrogen mobility initiatives of 10 countries, which will provide the opportunity to:
  1) **identify optimal commercialisation strategies and synergies between countries**
  2) **develop a pan-European strategy for commercialisation**
  3) **Refine sales and support strategies for the early FCEV customer across Europe**

Endorsers:
Buses - Study

Current study
- Local high-level cost analyses
- Mobilisation of interested locations
- Preparation joint procurement

- Detailed cost analyses
- Grant application for demo project
- Engineering of H$_2$ refueling infrastructure

2014-2015

2016

VISION – FC electric buses commercially viable and rolled-out in Europe
- Execution of demo projects
- Local, national and EU funding schemes for demos
- Regulations framework to support roll-out

Scale effects Incentives Regulation

2020 onwards
A broad stakeholder coalition of 82 organisations has been established - Operators and local governments from 35/45 locations

**Participating locations**

- Operators and local governments from 35/45 locations
- Secure commitments for roll-out and large scale demos

**Industry coalition members**

- **Bus manufacturers**
  - EvoBus
  - MAN
  - Solaris
  - SKODA

- **Infrastructure/ H₂ providers**
  - Linde
  - Hydrogenics
  - Ballard

- **Technology providers**
  - Siemens
  - Advanced Hydrogen Solutions

- **Other organisations**
  - Government of the Netherlands
  - Die Verkehrsunternehmen
Current FCH JU-funded fuel cell bus projects

- **CHIC**
  - Bolzano – 5 FC buses
  - Aargau – 5 FC buses
  - London – 8 FC buses
  - Milan – 3 FC buses
  - Oslo – 5 FC buses
  - Cologne* – 4 FC buses
  - Hamburg* – 6 FC buses

- **High V.LO-City** (operation start planned for 2015)
  - Liguria – 5 FC buses
  - Antwerp – 5 FC buses
  - Aberdeen – 4 FC buses

- **HyTransit**
  - Aberdeen – 6 FC buses

Current national/regional-funded fuel cell bus projects:

- **3Emotion** (operation start planned for 2016/2017)
  - Cherbourg – 5 FC buses
  - Rotterdam – 4 FC buses
  - South Holland – 2 FC buses
  - London – 2 FC buses
  - Flanders – 3 FC buses
  - Rome – 5 FC buses

Legend:

- CHIC countries
- In operation
- Planned for operation
- * Co-financed by regional/national funding sources

84 buses in operation or about to start
96 projects under Energy pillar, for more than 240 mill €

Technology neutral approach, however most support to Solide Oxide and PEM for both fuel cells and electrolyser applications

28 projects at TRL ≥ 3 for about 100 mill € (‘Stationary Demo’ type), mainly focusing on system integration and field demonstration (e.g. components development, including control systems; proof-of-concept; field demonstration of CHP and back-up power units)
Solid Oxide Fuel Cell micro-CHP Field Trials

39 BlueGen Pathfinder Systems + 26 Integrated Fuel Cell Appliances (SIFC)
Total: **65 Fuel Cell Systems**

**FC system Electrical efficiency (HHV) >40%** (from 56% to 42% (HHV) and from 61.5% to 46.0% (LHV) over lifetime)
The mean overall system efficiency of the SIFC units was 79.0% for UK and 78.3% for German sites (an integrated Fuel Cell system is more efficient than modular!)

**Achieved: 25% BlueGen Cost Reduction** via Reengineering components & supply chain enhancements

**FC system life time >10,000 h**
(at end of project: 12,792 hours & given its degrade rate expected to reach 27,118 hours)
Field demonstration of small stationary fuel cell systems for residential and commercial applications

up to 1,000 residential fuel cell micro-CHP installations, across 11 key Member States

- 400 units have been installed across the 8 active field trials as of February 2016 in 8 countries: DE, UK, FR, DK, AU, CH, LUX and IT (the others 90% contracted)

- 30–150 identical units from each manufacturer! (first stage demonstration)
Field demonstration of large-scale stationary power and CHP fuel cell systems

240 kW system (built in UK, installed in Germany)

Commissioning of KORE System and production of power at Stade, Germany

Conversion efficiency (electr.): 61% per tier

Expected lifetime: 13,500hrs by the end of the project

3 major components:

Electrodes: produce the power
Cartridges: house stacks
Balance of plant: fluid management, superstructure, safety systems, C&E, integration into customers site
FC based CHP / Decentralised production of energy - Study

**Roland Berger Study: Advancing Europe's energy systems: Stationary fuel cells in distributed generation**

- Industry coalition composed of more than 30 stakeholders – Results reflect common understanding
- The most comprehensive assessment of the commercialisation potential of stationary fuel cells in Europe (4 focus markets, 6 generic fuel cells, 35 years time horizon, 45 different use cases, >30 benchmark technologies, >3 energy scenarios, >34,000 resulting data points)

Today FC can reduce CO₂ emissions by more than 30%, while NOₓ emissions can be eliminated entirely; however, to become economically competitive, capital costs must be reduced substantially by increasing production volumes

**Use-case specific environmental benchmarking**

**Use-case specific economic benchmarking**

**Industry sees ambitious potential** (larger volumes allow for automation and bundled sourcing strategies, standardisation must increase within and across technology lines)

**Industry is fully committed to decreasing cost with sufficient installation volumes!**
Fuel cells are the highly efficient and complementary choice to future energy systems based on more and more renewables.

European vision for stationary fuel cells

**Fuel cell vision**

- Highly efficient conversion of natural gas (and eventually green gas or pure hydrogen)
- In distributed generation, i.e. at the site of consumption
- Lowering the carbon footprint of energy supply
- Playing a complementary role to renewables

A coalition composed of more than 30 stakeholders – Results reflect common understanding of this group

Stylised overview of main benefits of stationary fuel cells

- Highly efficient distributed solution (electrical & CHP)
- Reduced primary energy consumption
- Enabler for more renewables in the power mix
- Substantial CO₂ emission savings
- Near elimination of pollutants, particulates and noise
- Driver of distributed generation reducing transmission losses

Fuel cell initially as bridge technology with significant potential to reduce primary energy demand and emissions

Afterwards, transformation to a renewable technology through decarbonisation of the gas grid

Potential development stages and pathways of the fuel cell technology

1. Fuel cell systems reach competitive cost level to high-end heating solutions
   - Policy support to trigger market pick-up and thus cost reduction
   - Starting point in the residential segment

2. Fuel cell systems reach competitive cost level to mass-market solutions
   - Continuous support if cost targets are reached
   - Commercial segment to be supported

3. Fuel cell systems become a renewable technology through decarbonisation of gas supply
   - Further growth and mass-market solution possible if gas supply becomes greener and more domestic
Hydrogen enables us to get the most out of our Wind and Solar energy

**Achievements**

On-site installation of **hydrogen equipment after receiving exploitation permit**, certification and CE conformity:

- Coupling to solar panels (800 kWp) and wind turbines (1500 kWp)
- 2 Electrolysers (one alkaline and one PEM): 130 kg H$_2$/day
- 2 Compressors: one mechanical and one electrochemical **(planned)**
- Hydrogen storage capacity 100 kg at 45 MPa
- Hydrogen dispenser for a fleet of 9 fuel cell forklifts and FC cars
- 100 kW Fuel Cell connected to the grid

**Context**

To demonstrate the technological readiness, performance, reliability and total costs of ownership of installations for production and short-term storage of hydrogen via water electrolysis from renewable electricity sources, with subsequent supply as a high value fuel and as controllable load for grid services.

In 2015, the European Parliamentary Research Service published an in-depth analysis presenting energy storage via hydrogen production as one of the ten technologies which could change our lives.

**Challenges**

- Installation and continuous operation of a standalone forecourt water electrolyser (between 100 and 500 kg H$_2$/day)
- Hydrogen production from renewable energy sources
- High level of availability (95%)
- Electricity consumption below 60 KWh/kg H$_2$
- Hydrogen purity
- Hydrogen production facility turn-key CAPEX: 3.5 M€/(ton/day)

**Next set of Actions**

- Increased capacity of **the electrochemical compressor** (from 2 to 60 kg H$_2$/day)
- **Field testing of the PEM unit** (60 kg H$_2$/day)
- Overview of pricing of renewable electricity green certificates
- **Running of test phase 2** (8000 hours in operation monitoring)
Energy Storage Study:

**CONTEXT:** There are 4 main options for integrating renewables, but all the options have significant limitations.

<table>
<thead>
<tr>
<th>RES integration solution</th>
<th>Deficit solved?</th>
<th>Surplus solved?</th>
<th>Residual load¹</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case situation</td>
<td></td>
<td></td>
<td>Deficit +</td>
<td>Hydro and biomass quantity is limited</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surplus -</td>
<td>Fossil fuels generate CO₂ emissions</td>
</tr>
<tr>
<td>Dispatchable generation (hydro, bio-mass, fossil)</td>
<td>✔️</td>
<td>✗</td>
<td></td>
<td>No utilization of excess energy</td>
</tr>
<tr>
<td>Transmission and distribution expansion</td>
<td>✔️</td>
<td>✔️</td>
<td>Deficit +</td>
<td>Ineffective if RES production correlated over large area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surplus -</td>
<td>Hampered by permitting issues and long construction times</td>
</tr>
<tr>
<td>Demand side management</td>
<td>✔️</td>
<td>✔️</td>
<td>Deficit +</td>
<td>Limited by amount of demand that can be shifted and time for which it can be delayed</td>
</tr>
<tr>
<td>Power-to-power</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td>Focus of this study</td>
</tr>
<tr>
<td>Conversion to heat and heat storage</td>
<td>✔️</td>
<td>✔️</td>
<td>Deficit +</td>
<td>Technologies considered in the study included:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surplus -</td>
<td>- Batteries (Li-ion, NaS, Lead-acid, Flow-V)</td>
</tr>
<tr>
<td>Conversion to Hydrogen for use outside power sector</td>
<td>✗</td>
<td>✔️</td>
<td></td>
<td>- Mechanical storage (pumped hydro, compressed air, liquid air)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Hydrogen power-to-power storage</td>
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<td>- Heat storage</td>
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<td></td>
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<td></td>
<td></td>
<td>- Hydrogen for use outside of power sector</td>
</tr>
</tbody>
</table>

¹ Difference between demand and intermittent RES production

All of these options come at a cost to society.
At realistic values of hydrogen, large installed electrolyzer capacity would be viable and able to utilize nearly all excess RES energy in the 2050 horizon.

Non-hydrogen P2P and heat storage will only be able to absorb a small part of the excess energy generated, resulting in the necessity of curtailment – from societal point of view, such electricity could be used at close to zero cost.

The excess energy can be used to produce hydrogen via water electrolysis for re-electrification or use outside of the power sector.

If the value of hydrogen at the point of production can reach a price in the range of 2-4 €/kg very large installed electrolyzer capacity would be economically viable and able to utilize nearly all of the excess electricity.

Such use of the excess electricity would create value for the society and the surplus could be divided between the electricity and hydrogen producer.

Economic demand for electrolyzers assuming a best case of 2 EUR/kg of H2

<table>
<thead>
<tr>
<th>Year</th>
<th>High Connectivity</th>
<th>Low Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030 High-RES</td>
<td>4</td>
<td>46</td>
</tr>
<tr>
<td>2050 High-RES</td>
<td>115</td>
<td>170</td>
</tr>
</tbody>
</table>

Reduction in excess energy

Percent

-25

-97

-99

-100

1 Installed electrolyzer capacity achieving 60 EUR/installed kW per year of benefits at given hydrogen plant gate cost – this corresponds to 370 EUR/kW capex, 8% WACC, annual opex at 1.2% of total capex and 10 years lifetime (FCH JU 2014)
Water electrolysis (WE) can be a commercially viable element of the future energy system
  - Hydrogen for transport
  - Industrial hydrogen uses

Gigawatt scale cumulative deployment is plausible by 2030
  - In line with stakeholder expectations
  - Coherent with emerging hydrogen infrastructure plans

But this is hard to achieve and requires:
  - Continued technology development and cost reduction
  - Supportive regulatory and policy framework conditions
  - Clear requirements for emerging WE energy applications
- Aim: to identify most promising green H$_2$ production pathways based on a number of key parameters
- 11 pathways assessed, 6 selected
Fuel Cells and Hydrogen Joint Undertaking Achievements

The scope of applications is widening with time

- Hydrogen Packard car (1927) - Woikoski
- Backup power
- Energy storage
- Large scale stationary applications
- Marine & aerospace
- Forklifts
- Hybrid FC Buses
- FCEV
- FC in commercial planes
- FCEV RE
- Hybrid FC
- Buses
- 1995
- 2000
- 2005
- 2010
- 2015
- 2020
- CHP Systems
- Portable applications
Annual calls to be published in January each year

Call 2016 plan

Publication date: 19 January 2016
Deadline: 03 May 2016
Estimated budget: EUR 117.5 million

Studies to support the multi-annual strategy and industry road-maps for the different technologies and applications:
- Business models for FC-CHP applications
- Hydrogen storage business cases/models (e.g. to integrate excess RES)

Continuous work with Members States Representatives (SRG) and National Programmes to coordinate/complement sources of funding for market penetration/early-commercialisation (H2 mobility initiatives, FC-CHP subsidies etc)
Thank you for your attention!

Further info:
- HYDROGEN EUROPE: www.hydrogeneurope.eu
- N.ERGHY: http://www.nerghy.eu