Making Way for Scotland’s Hydrogen Economy

Fuel Cells – a Reality in Europe
FuelCellEurope is the association representing the interests of fuel cells in Europe.

An independent, privately funded European association based in Brussels.

FuelCellEurope counts 40+ member organizations from 10 European countries, USA, Japan, Canada and China.

Membership includes fuel cell equipment manufacturers, energy companies, automotive OEMs, service companies, academia, research institutions and potential users.

Our Mission: "Accelerate the development and market uptake of fuel cell technologies in Europe for applications in transport, stationary and portable power."

www.fuelcelleurope.org
Because fuel cells are a solution the world believes in

FuelCellEurope stands for:

✓ Promoting fuel cells as a key solution for EU energy policies.
✓ Promoting of fuel cells as a very significant potential for EU economic activity.
✓ Pursuing the creation of better conditions to successfully integrate fuel cells technology in the European market and society, now and in the long term.
✓ Accelerating the development and market uptake of fuel cells and its industry in Europe today.
1. Transport applications:
   - Special purpose vehicles / scooters
   - Inner-city buses
   - Vehicle fleets
   - Passenger cars
   - Handling materials / forklifts

2. Stationary applications:
   - CHP (combined heat and power large and small)
   - UPS - Backup power (telecom, data centers, critical applications)
   - Auxiliary Power Units
   - Onsite power generation

3. Portable and micro power
   - Electric tools
   - Laptops
   - Battery chargers
   - Marine
   - Defence
Because fuel cells are a solution the world believes in

Communication tools:

• News alerts for members
• E-zine
• E-flash

Our mailing list includes everyone you want or need to reach
Members have joined us because of...

1. Advocacy and Monitoring Benefits
   - Support and contribution to shaping the future of fuel cells in Europe
   - Access to often urgent updates on EU policy, regulatory and financial developments
   - Participate in lobbying activities
   - Preview and shape position papers on EU policies
   - Contribute and influence the strategic direction of FuelCellEurope
   - Participate in all key decisions of the Association
Members have joined us because of...

2. Market and Industry Development Benefits

- Stimulate the demand side, by participating in Customer and User Application groups, set up for early market areas
- Access to often urgent updates on business news and leads
- Access to important information on EU funding and subsidies opportunities
- Visibility as member company on FuelCellEurope’s website, in the e-zine and the newsletter
- Exchange about opportunities, demands, offers, partnerships, employment...
Members have joined us because of...

3. Networking Benefits

– Create business opportunities at low cost
– Knowledge sharing and best practice with like-minded people
– Access to the Members-only area of FuelCellEurope website, providing all the information of the association, news, reports, presentations and working documents.
– Active participation in application focused events and members’ only events.
– Free access to, or discounts for selected major events and conferences.
"Energy = Thermodynamics + Economics + Politics"

<table>
<thead>
<tr>
<th>In the past 15 years:</th>
<th>In the next 5 years:</th>
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<tbody>
<tr>
<td><strong>70-80% Thermodynamics:</strong></td>
<td><strong>20-30% Thermodynamics:</strong></td>
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<tr>
<td>- R&amp;D</td>
<td>- Design optimisation</td>
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<tr>
<td>- Technology development</td>
<td>- Performance optimisation</td>
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<td>- Overall design</td>
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<td>- IPR</td>
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<tr>
<td><strong>15-20% Economics:</strong></td>
<td><strong>40-50% Economics:</strong></td>
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<tr>
<td>- Market understanding &amp; preparation</td>
<td>- Cost reduction and industrialisation</td>
</tr>
<tr>
<td>- Educating supply chain partners</td>
<td>- Market deployment</td>
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<tr>
<td>- Pilot projects</td>
<td>- Supply chain agreements</td>
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<tr>
<td>- Heavily subsidized projects</td>
<td>- Go to market strategies</td>
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<td><strong>0-5% Politics:</strong></td>
<td><strong>20-40% Politics:</strong></td>
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<tr>
<td>- Generate the necessary government subsidies to co-finance the R&amp;D effort</td>
<td>- Large scale demonstration projects</td>
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<td>- Impact on energy and environment debate</td>
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<td>- Government purchase</td>
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<td></td>
<td>- Energy Efficiency</td>
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<td>- Subsidies for end users</td>
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<td>- Regulatory frameworks</td>
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We've reduced the cost of fuel cells by 75% since 2002*

- 2008 cost projection validated by independent panel**

As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs (BOP costs shown here include system assembly & testing).

*Based on projection to high-volume manufacturing (500,000 units/year).
**Panel found $60 - $90/kW to be a "valid estimate": http://hydrogenadoe.gov/peer_reviews.html
Fuel cells are needed

Challenges for Europe:

1. Climate change
   A. Reducing GHG emissions
   B. Energy efficiency
   C. Renewable energy storage

2. Local air pollution
   A. Road transport has a deep impact
   B. Health care costs

3. Economic sustainability
   A. Employement
   B. Energy security

FC&H have very good answers:

1. Combined with renewable hydrogen fuel cells can have zero emissions
2. Fuel cells are the most efficient energy conversion technology
3. Help optimize integration and storage of renewable energies
4. Fuel cells allow considerable reduction in noise and air pollution
5. Fuel cells have a great long-term economic potential in terms of green jobs potential along the value chain
6. Hydrogen can be produced from a very wide variety of resources thus reducing security risk to a minimum
Fossil Resources – Renewable Energy Future

Fuel based energy system
Fuel to electricity (low efficiency)

Electricity based energy system
Electricity to fuel (low efficiency)

Transition phase

Legend
- Renewable electricity
- Renewable heat / fuel
- Fossil / nuclear fuel

Total primary energy supply in [Mtoe]


Coal
Natural Gas
Oil
Solar thermal power plants (STP)
Photovoltaics
Wind power
Biomass
Heat / fuel
Electricity
Renewable energies

Ludwig-Bölkow-Systemtechnik GmbH, 2008
The 2050 target

*Keep global warming under 2°C by end of century*

www.eutransportghg2050.eu
Possible timing of policy instruments for transition to sustainable vehicles & fuels

- Market stimulation for efficient vehicles
- Regulation of (conventional) vehicles
- Regulation of energy carriers
- R&D stimulation for sustainable alternatives
- Stimulation of early markets for sustainable alternatives

Create level playing field for sustainable options

- Generic regulatory framework
- Improved tax framework
- Economic instruments
  - CO₂ tax
  - Cap & trade
The need for power regulation is already present in DK. Possible solutions are PEMEC + PEMFC, electric cars or central regulation of power supply/demand.
• Hydrogen is ideal for storing large quantities of energy over longer periods of time
• Producing H2 with electrolysers using surplus intermittent renewable energy and base load
• Allows to stabilize electricity demand (peak shaving)
• Reduce overall electricity production capacity needed and prices
• Gas to grid is much less efficient than gas to CHP or transport applications
• Decentralised H2 production avoids high transport costs
Vestenskov

Field test in Danish micro chp project.
Fuel Cell reality check

**Our proposal:**

- As of today, >19,000 fuel cell systems shipped
- >7 million operating hours in end user environments

<table>
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<tr>
<th>Products</th>
<th>Stacks</th>
<th>Stationary / UPS</th>
<th>Mobile / Maritime</th>
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<tbody>
<tr>
<td><strong>PM 200</strong></td>
<td>PM Module S5</td>
<td>PM Basic A09</td>
<td><strong>PM Module S17</strong></td>
</tr>
<tr>
<td>- 2 to 9 kW</td>
<td>- 1.5 to 5.5 kW</td>
<td>- 6 to 50 kW</td>
<td>- 5 to 18.5 kW</td>
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<tr>
<td>- 20 to 150 A</td>
<td>- 50 to 100 VDC</td>
<td>- 20 to 180 A</td>
<td>- 53 to 100 VDC</td>
</tr>
<tr>
<td>- 5000 h lifetime</td>
<td>- 300 to 600 VDC</td>
<td>- 20 to 150 A</td>
<td>- 20 to 450 A</td>
</tr>
<tr>
<td><strong>PM 400</strong></td>
<td>PM Module S50</td>
<td>PM Basic M50</td>
<td><strong>Fuel Cell Range Extender System</strong></td>
</tr>
<tr>
<td>- 6 to 20 kW</td>
<td>- 6 to 50 kW</td>
<td>- 6 to 50 kW</td>
<td>- 80 VDC</td>
</tr>
<tr>
<td>- 53 to 100 VDC</td>
<td>- 300 to 600 VDC</td>
<td>- 300 to 600 VDC</td>
<td></td>
</tr>
<tr>
<td>- Up to 450 A</td>
<td>- 20 to 150 A</td>
<td>- 20 to 150 A</td>
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“Developing New Energy for the future: Europe launches a 1 billion Euro project to get into pole position for the Fuel cells and Hydrogen race”

- Budget being made available by the European Commission to be matched by industry
Four major Applications Areas (AA):

- **AA 1: Hydrogen vehicles and infrastructure technologies**
  - Main goal: improve & validate hydrogen vehicle and infrastructure technologies to the level required for commercialisation decisions by 2015 and a mass market rollout by 2020

- **AA 2: Sustainable hydrogen supply**
  - Main goal: 10-20% of the hydrogen supplied for energy applications should be CO2 lean by 2015

- **AA 3: Fuel cells for CHP and power generation**
  - Main goal: Commercially competitive fuel cells for CHP and Power generation. >1GW capacity in operation by 2015

- **AA 4: Fuel cells for early markets**
  - Main goal: Thousands of early market fuel cell products sold by 2010
• Germany:
  – National Innovation Program (NIP): 10 years program adding 700M€ to current R&D programs for H&FCs.
  – Program aligned with JTI.
• France:
  – New HyPAC platform since 2009
  – **Budget: +/- 100M€ over the next 5 years.**
  – Early market priorities: micro cogeneration, emergency power, portable, decentralized power
  – *involvement of automotive OEMs and energy players very weak*
• United Kingdom:
  – The UK government committed 200M£ in 2008 for low carbon technologies including renewable energies, CCS and hydrogen & FCs.
  – The UK Carbon Trust committed 90M£ for low carbon technologies.
  – SUPERGEN (Sustainable Power Generation and Supply) program coordinating research in new energy technologies financed by several government councils (EPSRC, BBSRC, ESRC).
  – Estimated annual public funds for hydrogen & fuel cells programs in UK: 20M€
• **Spain:**
  – National Hydrogen and Fuel Cell Technology Platform (PTE-HPC) created in 2005
  – Spain currently **building a major National Center** on Hydrogen and Fuel Cell Technology Experimentation in Castilla la Mancha (operational towards 2010)
  – Substantial allocation of resources and program essentially at **regional level**. Focus at **synergizing** developments with RE

• **Norway:**
  – **May ban (non hybrid) petrol cars to be sold after 2015**
  – Opened on 11 May 2009 its **hydrogen highway** between Stavanger and Oslo (580km).
  – 7 hydrogen refueling stations to be built
  – **HyNor** project counts 50 players from the industry, transport, regional governments and organizations
Examples of important regional and local initiatives:

- NRW (D): +/- 20M€ budget in 2008
- Hamburg (D): +/- 2M€ budget in 2008
- Aragon (E): +/- 3M€ budget in 2008
- British-Midlands (UK): +/- 4M€ budget in 2008
- Piemonte (IT): +/- 3M€ budget in 2008
- Rhône-Alpes (FR): +/- 500K€ budget in 2008 (new strategy in development for the future)
- DutchHy (NL): +/- 10M € in 2009/2010
Fuel Cells and Hydrogen are in the SET plan

- No European Industry Initiative because existing JTI

- “additional public and private funding needed for fuel cells and hydrogen technologies is currently estimated as € 5 bn (5.000.000.000) for the period 2013-2020.”

- +/- 10% of the total SET

⇒ 12% UK = £ 73.432.714 p/a*
⇒ 12% Scotland = £ 8.811.926 p/a*

*Based on the % of population
<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
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<tbody>
<tr>
<td>Wide diversity of players (SMEs, large players and research centers)</td>
<td>Fragmentation / duplication of efforts</td>
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<td>Excellent material science/research</td>
<td>Lack of European fuel cell stack champion</td>
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<td>A few national and regional champions</td>
<td>Relative lack of system integrators and early market &quot;gurus&quot;</td>
</tr>
<tr>
<td>Strong government support at National Level (Germany) and Regional/Local Level (NRW, Hamburg, Aragon, Piemonte,..)</td>
<td>Lack of private equity investment</td>
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<tr>
<td>Multiannual financial frameworks</td>
<td>Hydrogen and fuel cells not regarded as short term solutions to energy and climate change policies</td>
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<tr>
<td>OPPORTUNITIES</td>
<td>THREATS</td>
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<td>European JTI may help gain the required level of <strong>coordination and critical mass</strong></td>
<td>Fuel cell developments (too) much driven by transport in Europe</td>
</tr>
<tr>
<td>Basic EU regulatory framework in place for hydrogen vehicle type approval</td>
<td>No European <strong>common taxation and subsidy scheme</strong></td>
</tr>
<tr>
<td>Synergies between renewable electricity production and hydrogen / fuel cells as a storage mean</td>
<td><strong>Where is the business case to build up a hydrogen infrastructure?</strong></td>
</tr>
<tr>
<td>European/ national/regional and local funding available</td>
<td>Economic recession impact corporate R&amp;D budget expenditures and investors' risk profiles</td>
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<td><strong>Electric battery</strong> vehicles are getting a lot of attention currently</td>
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</table>
Conclusion

• Fuel cell are a reality in Europe
• Europe has a structural challenge
• Much more will need to be done to ensure a future for the fuel cell industry in Europe
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