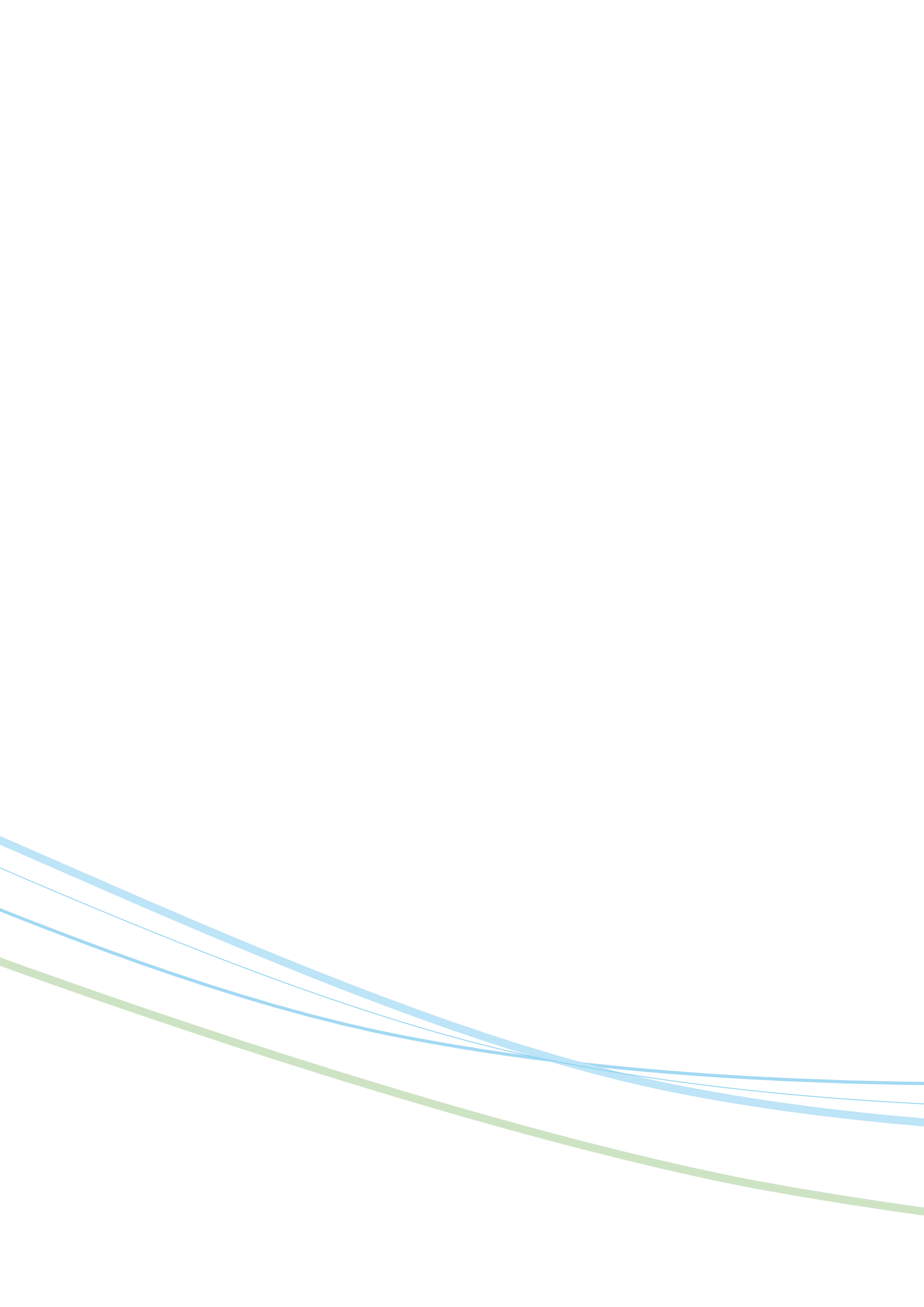
Fuel Cells and Hydrogen
Joint Undertaking

Trends in investments, jobs and turnover in the Fuel cells and Hydrogen sector

New Energy World JU
fuel cells & hydrogen for sustainability

Contents



Introduction

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) commissioned this report to a consultancy to get a better understanding of the past and future evolution of the European Fuel Cell and Hydrogen (FC&H) sector, and the role that public support has in that evolution.

The results of this report are based on three data sources:

- **Survey results:** A survey was sent out to 458 companies that are liaised to the FCH JU. 154 people responded. (see list in annex)

- **Desk research:** A wide range of industry reports was consulted to supplement and cross check the results of the survey. However, given the still nascent state of the industry, the information gathered with this exercise was limited.

- **Interviews:** Key stakeholders in the European FC&H sector were interviewed to get the qualitative story behind the results from the survey and the desk research. These stakeholders varied from fuel cell manufacturers to government officials, from energy companies to automotive OEMs.

For more information on this study, or the next steps, please contact the FCH JU: fch-ju@fch.europa.eu or www.fch-ju.eu

1. Substantial growth in recent years

Europe has set itself a goal to reduce CO2 emission levels by 2050 to 80% of what they were in 1990. To reach this target, Europe will have to change both its energy supply and demand side. Fuel cells and hydrogen have potential to contribute to overcoming the energy challenges that accompany this change.

• **Mobility:** Worldwide, mobility applications have made up the largest share of fuel cell production in recent years. Hydrogen fuel cells in passenger cars and public transport reduce local emissions without compromising range. The cost trajectory of fuel cells vehicles (FCEVs) shows they will get closer to the cost-competitive range of incumbent and new technologies within the next decade. Niche applications, like forklifts, are already available on a commercial scale. Pilots and pre-commercialization projects are increasing in size and commitment. The most prominent example is H2 Mobility (H2M), the German hydrogen coalition of car manufacturers, energy companies and fuel providers who are jointly developing a business and implementation plan for a hydrogen refueling infrastructure, that allows for fuel cell vehicles to go to market. In other European markets, such as the UK, France, the Netherlands, Denmark and Norway, similar coalition efforts are being undertaken or launched.

• **Power and heat:** Stationary fuel cells offer highly efficient and reliable combined heat and power (CHP). The market can be roughly segmented into:

— Residential CHP (1 kW systems)
— Backup and off-grid solutions (3–20 kW)
— Commercial scale (50 kW and up)

Fuel cells are gaining market share especially in the middle segment, where they are competitive with the incumbent technologies (e.g., gas and diesel gensets) despite high technology costs.

• **Energy storage:** Hydrogen energy storage solutions have grown in importance given the intermittency issues that arise with increasing penetration of renewable energies (RES). This fact is further underlined by the many opportunities that have been created over the past years for hydrogen storage demonstrations: Vattenfall and Total have built a hydrogen storage project of EUR 21 million in Prenzlau, and the Eco Island of Wight (with IBM, ITM Power and others) has attracted over EUR 300 million of investment, part of which is used for hydrogen storage.

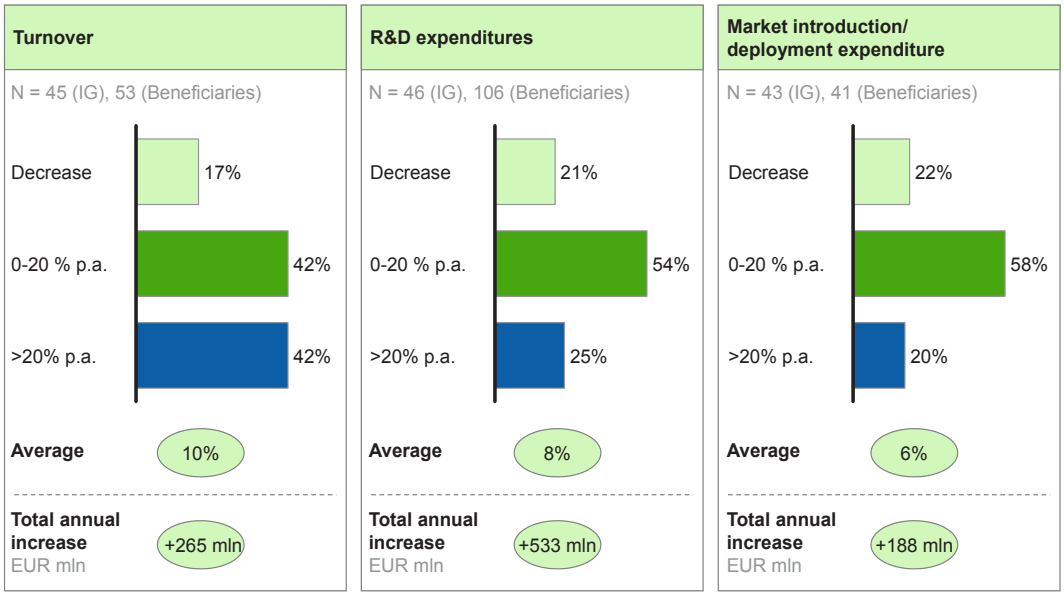
The FC&H sector in Europe has done well over the past five years: Survey respondents report that, on average, annual turnover has increased by 10% (on a 2012 total of EUR 0.5 billion), R&D expenditures by 8% (on a 2012 total of EUR 1.8 billion) and market deployment expenditures by 6% (on a 2012 total of EUR 0.6 billon).

This has led to increase in employment. Survey respondents estimate the total number of jobs has been increasing by about 6% per year since 2007, to around 4,000 FTE today. Even though this number excludes companies that have ceased to exist, the overall trend is significantly better than that of the average EU job market, which, over the same period, has actually contracted, registering a 0.3% annual reduction in employment.

Exhibit 1

Annual growth experienced by respondents in the FC&H sector

2007-11/12



In the number of patents granted, the FC&H sector also outpaced the rest of the industry: it saw a 16% annual increase in the number of patents granted in the EU to European companies, while the average annual growth for all EU industries was 1.5%. However, in the US and Asia the growth in FC&H patents outpaced that of Europe.

The rise in employment, turnover, expenditures and R&D activity is strengthened by combined public and private funding to improve hydrogen and fuel cells.

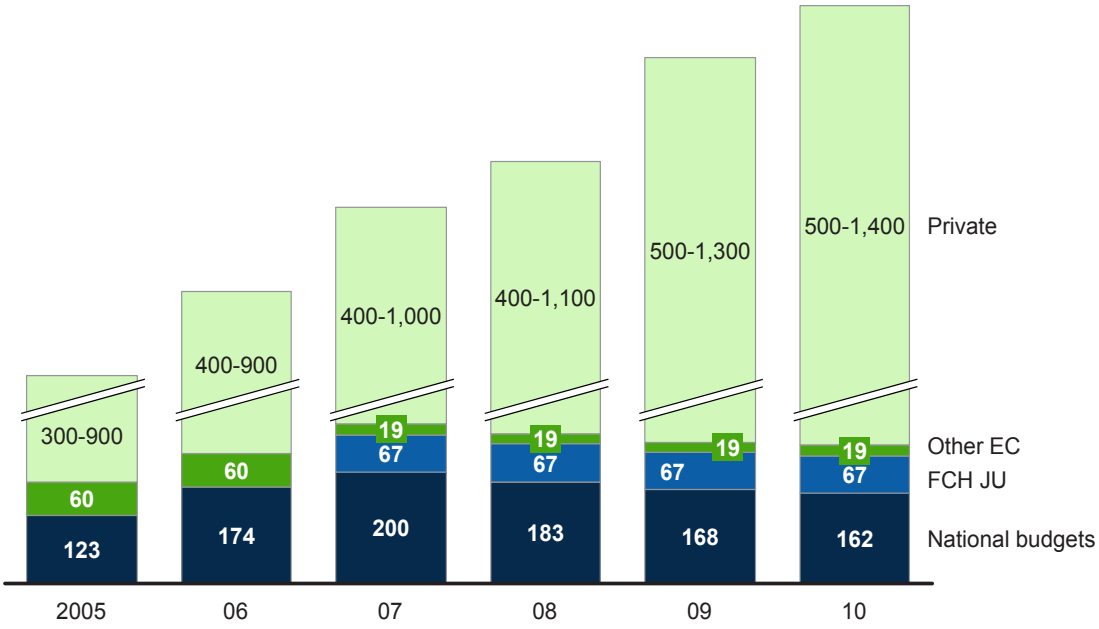
Exhibit 2 shows that private funding has been steadily rising in Europe, while public has remained constant (EU) or even declining (national budgets). Private funding is and has been the biggest contributor to R&D spend, totalling more than an estimated EUR 2.5 billion over the period 2005-2010. This figure roughly corresponds with the estimation that was made at the beginning of the period (corresponding to the launch of FP7 and preparation of the FCH JU)[1], the private sector has lived up to its original investment promise.

1. Calculation mechanism used to compile 2007 estimate and 2012 estimate varied, because of different sample group and sample size.

Exhibit 2

Expenditure for FC&H in the EU

EUR million



SOURCE: RD&D budget split from FCH JU survey; public support for FC&H from OECD/IEA statistics

Survey respondents claim that national programs (estimated at EUR 1 billion from 2005–2010) and EU programs (estimated at almost EUR 0.5 billion from 2005–2010) play a pivotal role in enabling private investment, though: larger companies depend on a stable investment, policy and "direction" climate to secure their funding levels. In addition it is mentioned that, small R&D companies – responsible for researching and realizing cost reductions in the sector –still depend on public funding from both national and European programs.

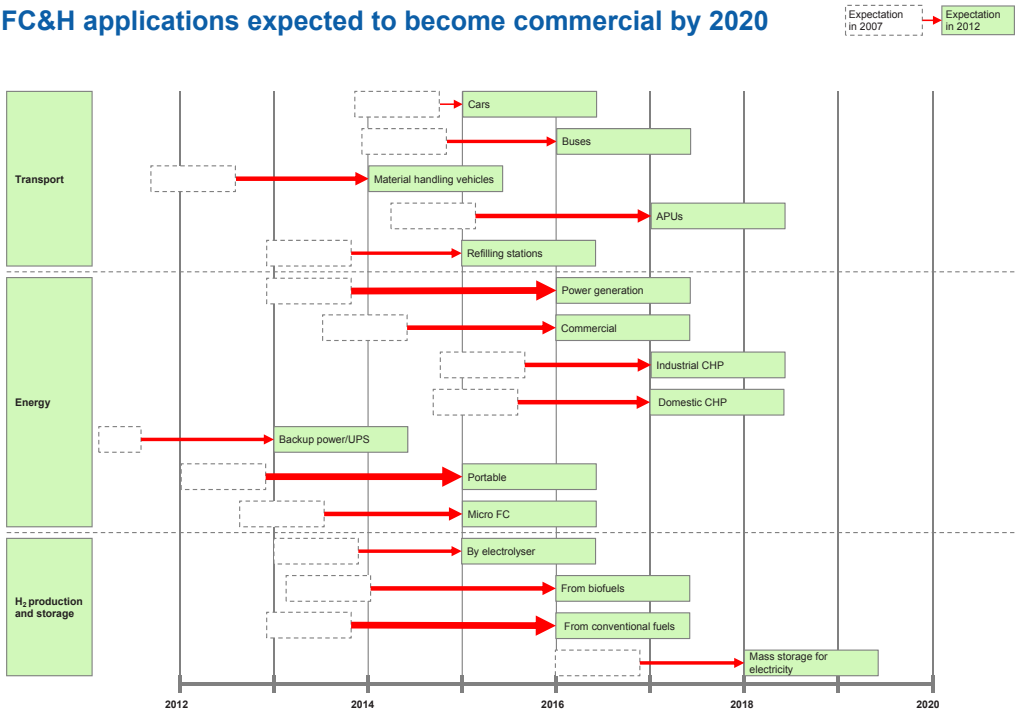
Many of the interviewees conclude that the combined effort of public and private funding has worked very well over the past years.

The FC&H sector is building momentum in and outside the EU. In the US, forklift trucks are being commercialized, and Japan leads commercialization of micro CHP. Europe could soon follow the same trend. This is recognized by the survey participants, who expect all FC&H applications to become commercial by 2020 (see exhibit 3).

2. Industry is expected to continue to thrive

Exhibit 3

FC&H applications expected to become commercial by 2020



SOURCE: FCH JU survey; Interviews with industry experts

In most application areas, commercialization has been slower than industry experts had anticipated in 2007. Car manufacturers are the exception: they have been very consistent, estimating commercialization by 2015. These expectations of car manufacturers are further underlined by promising statements from Asian and European car manufacturers.

In other application areas, many interviewees mention the increased focus on energy storage through electrolysis: Although delayed in commercialization by about a year, recent developments in renewables roll-out have imposed new dynamics on transmission & distribution grids, but also on peak versus base power pricing – storage solutions like hydrogen are regarded by many as a potential mitigation and business opportunity in this space.

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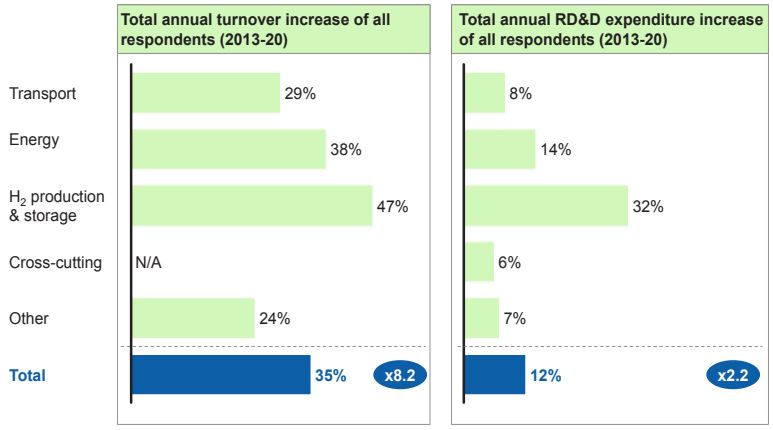
When asked for their expectation on turnover and Research, Development & Demonstration (RD&D), the respondents predict an exponential increase towards the end of the decade (see exhibit 4).

Exhibit 4

Rapid growth expected in turnover and RD&D

CAGR (Compound Annual Growth Rate), N = 33 (IG), 30 (Beneficiaries)



SOURCE: FCH JU survey

On average, they expect turnover to increase by 35% year on year towards 2020 (i.e., the turnover for the period 2013–2012 should be eight times higher than during the current period corresponding to the FP7 and the current FCH JU).

At the same time the RD&D is expected to increase by 12% year on year – or a doubling over the period 2013–2020.

The fact that turnover is outpacing RD&D expenditures is an indication that commercialization is within sight. This is supported by the perspectives of the interviewees (see exhibit 5).

Survey participants expect their future activity to be evenly spread across Transport, Energy, and H2 production & storage. The most progress is expected in hydrogen mobility and in energy storage.

Exhibit 5

The FC&H sector is building momentum

"German companies develop storage technologies for the energy transition at a high pace. Experts expect a billion dollar business."
– Focus, April 2011

"Vehicles powered by hydrogen fuel cells are more likely to be viable by 2020 than battery electric cars."
– Top executive at Toyota Motor Corp.

"Our ultimate goal is to build fuel-cell vehicles - and make them available from 2015."
– Steve Yang, CEO Hyundai

"What [the UK H2 mobility project] is about is creating a collaborative project that will deliver a genuine road map for what we think is an important technology."
– Mark Prisk, UK minister of state for business and enterprise

"It has been a time of investment – we are now expecting commercialization."
– EU CHP Manufacturer

"Hyundai will produce 1,000 cars in 2015, and 10,000 more thereafter."
– Hyundai, Sept 2012

"Nissan became the latest last week to say it is ready to mass-produce cars powered by hydrogen fuel cells. Honda, Toyota and Hyundai say they will have fuel-cell cars […] ready to go on sale by 2015."
– USA Today, Sept 2012

SOURCE: Press search; Interviews with industry experts

• **Mobility:** Car manufacturers expect to FCEVs in Germany by 2020, thanks to the H2M coalition effort. Similar projects are being undertaken in the UK and Denmark and expected to start in France and the Netherlands.

• **Energy storage:** Groups of utilities and electrolysis companies are partnering up to develop energy storage solutions for intermittent RES power generation. The scale of these programs is moving beyond "demo scale".

• **Industry:** Projects to deliver CO2 free hydrogen to industry are being examined . Recently, a group of companies studied a demonstration opportunity in Rotterdam to build a gas based hydrogen production facility (Steam Methane Reformer, SMR), combined with offshore storage of CO2. In doing so, it would create a CO2 abatement option for heavy industries.

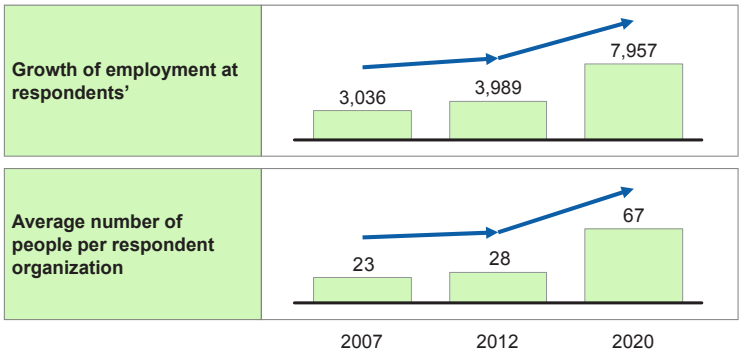
• **Power:** Although not as thriving as the micro CHP programs in Japan (ENE Farm), fuel cell manufacturers are starting to commercialize fuel cells in small – but still significant – market segments. German programs, for instance the Callux program, and the ENEFIELD project (deploying 900 domestic CHP units in the coming years) prove helpful in this. Commercialization options include backup- and off-grid solutions, but also industrial sites with excess hydrogen.

As a result of this progress, companies expect employment to increase even more sharply than in recent years: respondents expect 9% growth per annum, amounting to a doubling of the jobs over the period 2013–2020. In addition, the average number of people per respondent organization is growing faster (from 28 to 67), which might indicate a concentrating effect in a sector currently composed of small firms.

Growth in employment expected to accelerate

N = 46 (IG), 107 (Beneficiaries), Number of FTE

Exhibit 6



SOURCE: FCH JU survey

3. Critical challenges to overcome

The outlook set forward in the previous section is not guaranteed. Key stakeholders indicate in their interviews that there are five critical challenges that need to be overcome in order to be successful: the commercialization rate, infrastructure, the continuation and maturity of research, competition with other regions and technologies, and public acceptance.

• **Commercialization rate:** The expected date of commercialization has systematically fallen behind promises. Although the influence of the financial crisis and "usual setbacks" should not be neglected, many interviewees do worry that the time is "now or never". As one interviewee said: "Fuel cells and hydrogen have been said to commercialize within the next 10 years … .since 1954." Missing a credible and accurate time path is also a risk in attracting and retaining investors. Some interviewees indicate that large companies with a widespread portfolio of R&D activities might deprioritize or abandon FC&H if the industry does not mature in line with expectations.

• **Infrastructure:** In the mobility segment, fuel cell vehicles depend fully on a widespread fuelling infrastructure to attract customers. This poses the well-known "chicken and egg" problem: energy and fuel companies will invest only if there is a sizeable market of FCEV owners, and car manufacturers will produce FCEVs at scale only if the necessary infrastructure is present. Although these problems can be solved by cohesive, coalition-led activities, this is by no means an easy route. The German H2 Mobility is advanced in getting a joint suite of investments in place – but it is still too early to claim success for that effort, mention some interviewees.

• **Research:** Beneficiaries and respondents mention that Research and Development is vital for commercialization, and especially domestic and commercial CHP. The majority of this research along various parts of the supply chain is done by small companies. These companies depend on national and European funds and grants to finance their activities. The financial crisis might put this support for sustainable FC&H technology at risk. Respondents also mention that the research focus and quality of these companies do not always correspond with the priorities of companies further down in the value chain, and this limits the impact of the R&D done.

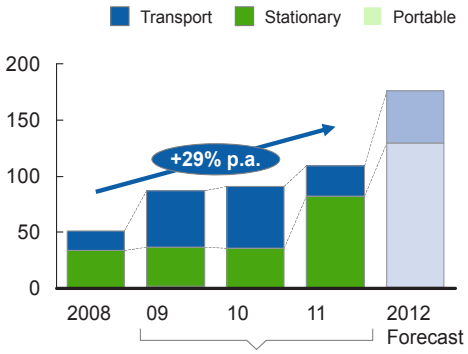
• **Competition from other regions and technologies:** Thus far, interviewees say that the US and Asia have been more successful in bringing FC&H products to market. Forklifts applications are introduced in the US, while Japan has a successful ENE Farm project. The challenge of competition is also illustrated by the shipment of technology in sectors where Europe is lagging (see exhibit 7) and by comparing national investment levels and patent applications (see exhibit 8). Although the majority of mobility related hydrogen activities occurs in Europe, many say the European industry sector should be careful that the nucleus of knowledge development does not permanently shift out of Europe. "This could put the current and expected employment opportunities at risk and jeopardize Europe's competitive advantage in sustainable technologies".

Exhibit 7

Shipment of fuel cells

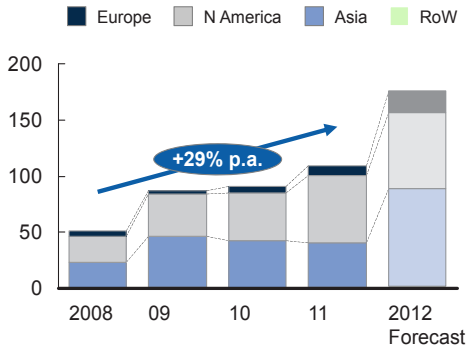
MW shipped

Sector breakup – stationary sector is the main contributor to growth



A number of factors combine to create a (likely continuing) surge in stationary. Transport saw big demos in 2009 and 10

Regional break – Asia is the main contributor to (projected) growth



Steep rise in megawatt production is predominantly caused by

- **A surge in large stationary fuel cell shipments**
- **Continued growth in the residential stationary micro-CHP sector**
- **Launch of 3 portable fuel cell consumer electronics chargers**

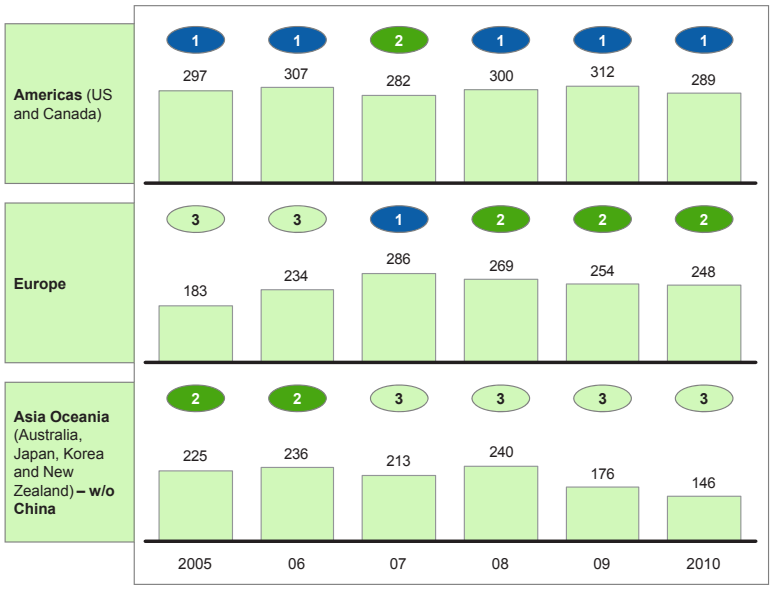
SOURCE: Fuel cell today industry review 2012; World Electric Power Plants Database (UDI)

Exhibit 8

Governmental RD&D budgets for FC&H

EUR millions

XX First, second or third largest spend



SOURCE: OECD/IEA statistics; Fuel cell today industry review 2012; Interviews with FC&H industry players

Public acceptance: The press coverage for FC&H technologies is limited to the perspective provided by industry players – and to this date, have not received wide-spread public attention. Although the arguments put forward progressively indicate a preference of fuel cells, as for instance stated recently by Toyota officials, the opinion makers are not yet pronounced in their stance towards hydrogen. Once commercialization is nigh, public awareness and acceptance will need to be very carefully managed. Recent activities like the EU Hydrogen Roadshow are good examples of how to manage this awareness and acceptance.

4. Public support required in the coming years

The need for public funding

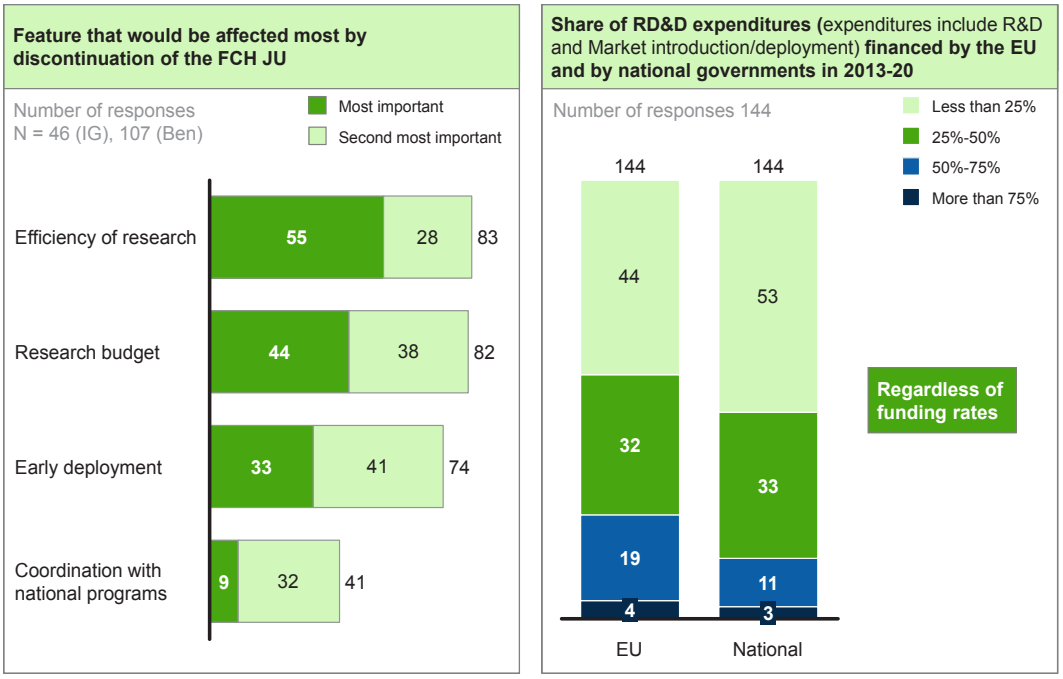


Exhibit 9

SOURCE: FCH JU survey; Interviews with FC&H industry players

Interview and survey participants say the EU should keep investing in fuel cells and hydrogen production development in 2013 -20 to overcome the challenges of deployment. They also mention it should continue to co-fund R&D to drive down costs and enhance performance of products (see exhibit 9).

Out of 153 survey participants, 55 indicated that efficiency of research would be most affected in case the FCH JU would be discontinued, and 44 indicated that the research budget itself would be most impacted.

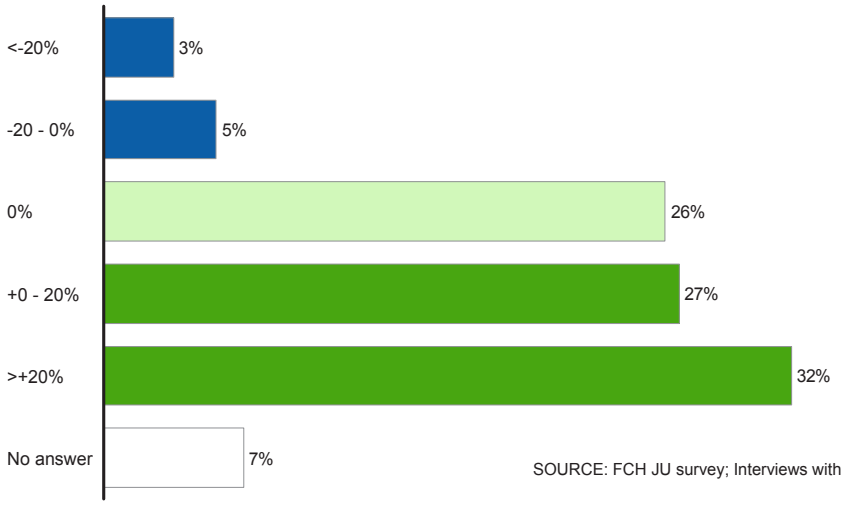
The latter is further illustrated by the fact that 56% of the respondents depend on EU financing of their RD&D expenditures for at least 25% or more. It proves to show that EU needs to continue to co-fund R&D to drive down costs and enhance performance of products.

Interviewees add that maintaining a consistent investment policy is crucial to ensure the survival of the nascent FC&H industry: demand of fuel cell technology will only pick up when the supply side has matured sufficiently and vice versa. They mention it is too early for the industry to reach sufficient maturity on private sector investments alone. Furthermore, Europe should keep up with the rest of the world in investments in R&D. These investments could sustain the leading position Europe currently has in mobility. Public opinion is required to change from fear for safety to vocal support for carbon-neutral FC&H technology. The industry needs a consistent and facilitating policy to make the FC&H industry into a success.

5. Way forward for European support

Exhibit 10
FCH JU survey; Interviews with FC&H industry players

Effect on R&D expenditure over 2007-2012 because of FCH JU establishment
Percentage of responses, N = 153



SOURCE: FCH JU survey; Interviews with FC&H industry players

Survey participants indicate that the FCH JU has sparked investments across the FC&H industry, resulting in significant leverage: almost 60% out of 150 organisations asked have increased their R&D expenditures/budgets because of the FCH JU's existence (see exhibit 10). In addition, interviewees and survey respondents acknowledged the achievements of the FCH JU in the past years:

• **Providing stability and long-term commitment to the industry:** The FCH JU has united the various stakeholders in the European FC&H community. Due to the support it receives from a collective of public and private stakeholders, the individuals inside and outside the FCH JU find stability in this collective. The existence and longer term outlook provide a stable environment and, as one interviewee said, "Without the FCH JU being there, our company would have exited hydrogen in dire economic times."

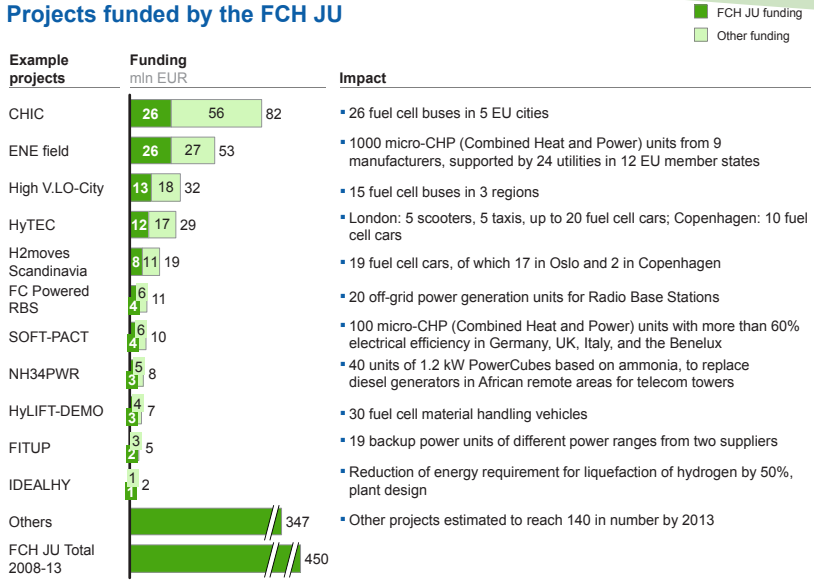
• **Leading as one voice to address policy makers:** The collective of stakeholders has a single voice towards regulators in the EU via the FCH JU. Many interviewees applaud the connections that the FCH JU has fostered, and the inroads that have been made – especially when compared to similar other industry bodies they are involved in.

• **Building coalitions as a central focal point that brings parties together:** Interviewees mention as a clear example of this the recent Bus study – the FCH JU took the initiative and led the effort of comparing the various bus drivetrains. In situations where individual companies cannot or will not be the frontrunner in taking initiative, the FCH JU can.

• **Supporting nascent technologies beyond local or private possibilities:** The FCH JU has funded a broad range of research projects in the FC&H space (see exhibit 11). Without these funds, it is said by interviewees, many technology breakthroughs would not have occurred, nor would some of the smaller companies involved in this research have been able to thrive.

Exhibit 11
FCH JU

Projects funded by the FCH JU



SOURCE: FCH JU

Interviewees and survey respondents also suggested some improvements for the FCH JU to maintain its momentum:

• **Focusing on an overarching strategy to increase effectiveness.** Most interviewees see an ever larger role for the FCH JU in actively shaping the R&D agenda for FC&H. Some suggest that investments are at times too piecemeal, not assessed on "bang for the buck", and following a logic of spreading the funding evenly across FCH JU participants, instead of awarding more funding to a smaller number of players. Interviewees suggest that the FCH JU shapes an agenda of topics that are deemed most critical, within and across sectors/applications, and assigns funding accordingly based on "return on investment". This also requires the FCH JU to take a stance on what they believe to be true priority areas in technology development.

• **Ensuring a first "big success", which can be celebrated and promoted.** The long and often slipping timeline of commercialization has led stakeholders of various sizes to a point where they will need to convince their internal and external stakeholders that FC&H truly is near commercialization. Many interviewees therefore ask the FCH JU to ensure a large success, which can be celebrated across the sectors and used to demonstrate the viability of a number of applications. The German H2M project is often mentioned in this context: successfully bringing this to a close is regarded as pivotal for the survival of the entire sector: "If even large companies cannot find a way to make this work, this clearly is not a sector with a bright future".

• **Improving execution speed and lowering complexity for the grant award process.** Some of the respondents mentioned that, although the process of securing project funding through the FCH JU has significantly improved over the past years, it is still too slow. If research priorities are more clear and broadly shared (as proposed in the first improvement point listed above), it would reduce the complexity and assessment time of proposals.

Annex

List of participating industrial groupings, which completed the survey and agreed to sharing their name

- Abengoa Hidrógeno
- Adelan
- Advanced Energy Technologies
- AFC Energy
- Air Liquide
- Air Products
- Alstom
- CETH2
- Daimler
- EFCF
- Electro power systems
- Green Vision / HyGear
- H2 Logic
- Honda R&D Europe (Deutschland)
- Hydrogenics
- HyET
- Hyundai Motor Company
- Iberdrola
- INEA
- Institut Pierre vernier
- Intelligent Energy
- IRD
- ITM Power
- Johnson Matthey
- LBST
- MES
- Nedstack
- NuCellSys
- Powercell Sweden
- Riversimple
- Shell
- SolviCore
- Sunfire
- Topsoe Fuel cell
- Umicore AG&Co KG
- Vattenfall
- Wärtsilä

List of participating beneficiaries, which completed the survey and agreed to sharing their name

COMPANIES

- 1515
- Ballard Power Systems
- Bitron
- British Gas
- DBI - Gastechnologisches Institut gGmbH Freiberg
- Domel
- DONG Energy A/S
- ElringKlinger AG
- GETT Fuel Cells International AB
- Hexagon Composites ASA
- hySOLUTIONS GmbH
- IHT
- INOVA+
- Ion Power
- Madden
- MARION TECHNOLOGIES
- MBN nanomaterialia
- PAXITECH
- PLANET GbR
- Riesaer Brennstoffzellentechnik GmbH
- Riviera Trasporti spa
- Serenergy
- Synergesis consult. ing
- TecnimontKT Spa
- TÜV SÜD Industrie Service GmbH
- VAN HOOL N. V.
- Vattenfall Europe Innovation GmbH
- Vestel Savunma Sanayi A.S.

RESEARCH ORGANISATIONS

- Aalborg University
- Aalto university
- AIJU
- CEA
- Centre for Researcha and Technology Hellas
- CENTRO SVILUPPO MATERIALI CSM
- CIRPS- Sapienza
- CNRS Montpellier
- CPERI/CERTH
- DTU
- EIFER
- ENEA
- Fondazione Bruno Kessler
- FORTH/ICE-HT
- Fraunhofer ISE
- Fundacion Hidrogeno Aragon
- Gas- und Wärme-Institut Essen e.V.
- German Aerospace Center
- Helmholtz-Zentrum Geesthacht
- Institut für Mikrotechnik Mainz GmbH
- Institute for Energetics and Interphases (IENI-CNR)
- Institute for Energy Technology
- Institute of High Temperature Electrochemistry
- Instytut Chemii Przemyslowej im. prof. Ignacego Moscickiego
- INTA
- Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano" of Consiglio Nazionale delle Ricerche
- Karlsruher Institut für Technologie, Institut für Werkstoffe der Elektrotechnik
- Lucerne University of Applied Sciences and Arts
- Matres scrl
- NEXT ENERGY - EWE-Forschungszentrum für Energietechnologie e. V.
- Paul Scherrer Institut
- Politecnico di Torino
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- Swerea IVF
- TECNALIA
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- University of La Laguna
- University of Perugia
- University of Salerno
- University of Stuttgart, LBP
- University of Ulster
- Vienna University of Technology
- VTT
- West Pomeranian University of Technology, Szczecin

OTHERS

- Aberdeen City Council
- ARMINES
- Birmingham city council
- FAST
- Hydrogen Sweden
- International Center for Hydrogen Energy Technologies (ICHET)
- Transport for London
- WaterstofNet

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Joint Undertaking

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