FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

FCH JU – KEY TO SUSTAINABLE ENERGY AND TRANSPORT . . .

. . . MAKING FUEL CELLS AND HYDROGEN AN EVERYDAY REALITY.

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CONTENTS

FOREWORD

Bart Biebuyck,
FCH JU Executive Director

In 2015, the Paris Agreement to tackle climate change set out the most ambitious climate deal in history. It sets a target to maintain the average global temperature increase well below 2°C, which makes a fundamental energy transition more crucial than ever.

The European Union also defines climate and energy policy as one of the most prominent priorities in its Energy Union strategy. In this context, affordable, clean and secure energy is something that Europe's citizens have come to expect.

Achieving these aims sustainably requires technologies that reduce energy dependency and emissions whilst enabling us to use more renewable energy.

In this context, fuel cells and hydrogen technologies constitute a significant opportunity to move away from fossil fuels in the energy and transport sectors. They allow to introduce more renewables in our energy system and develop sector coupling.

To secure the greatest benefits from fuel cells and hydrogen for society and economic growth, we need to make people more aware of the availability of these green technologies and the added value they offer for everyday life.

Already, citizens can step on to a fuel cell bus and enjoy a journey free of noise and carbon dioxide (CO_2) emissions. They can refuel their cars in less than five minutes and travel up to 700 km on a single tank without producing any greenhouse gases. Homes and businesses can produce heat and electricity more efficiently while reducing CO_2 emissions by at least 30 %, and in some cases by up to 80 %.

Fuel cell and hydrogen technologies are now entering the market. A concerted effort from public and private partners is necessary to boost innovation and trigger large-scale deployment. **The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is a catalyst for sustainable energy and transport by securing a productive partnership between the European Commission, industry and the research sector.**

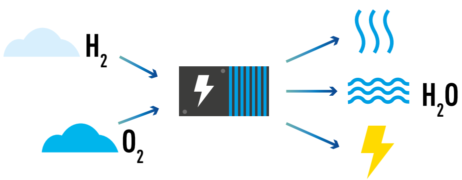
By implementing a strategic programme for research and deployment, the FCH JU creates a bridge to make hydrogen and fuel cells an everyday reality.

This brochure offers an overview of the main applications of fuel cell and hydrogen technologies and how they work, and provides insights into our programme and our accomplishments. I hope you will come away as convinced as I am of the importance of our work.

I. FUEL CELLS AND HYDROGEN

FUEL CELLS

A fuel cell is an efficient conversion technology that produces electricity and heat through a very simple chemical reaction between oxygen and a fuel. This electrochemical reaction, which differs from combustion, causes electrons to transfer between molecules through a defined circuit, which generates an electric current as well as heat. This provides electricity to power electrical engines and devices. If the heat is also exploited, this is known as combined heat and power generation (CHP).



This is a very clean reaction, producing no pollutants or carbon dioxide.

The technology is very flexible as fuel cells can be fed with different fuels. This allows it to be adapted easily to existing infrastructure.

However, the most promising fuel is hydrogen.

HYDROGEN

Hydrogen is the most abundant chemical element in the universe, present as an atom in more complex molecules such as water (H_2O) and hydrocarbons and in organic matter. As it does not occur in nature in its simplest form, hydrogen-containing molecules need to be broken down to extract the element.

For this reason, hydrogen is considered as an energy carrier rather than an energy source.

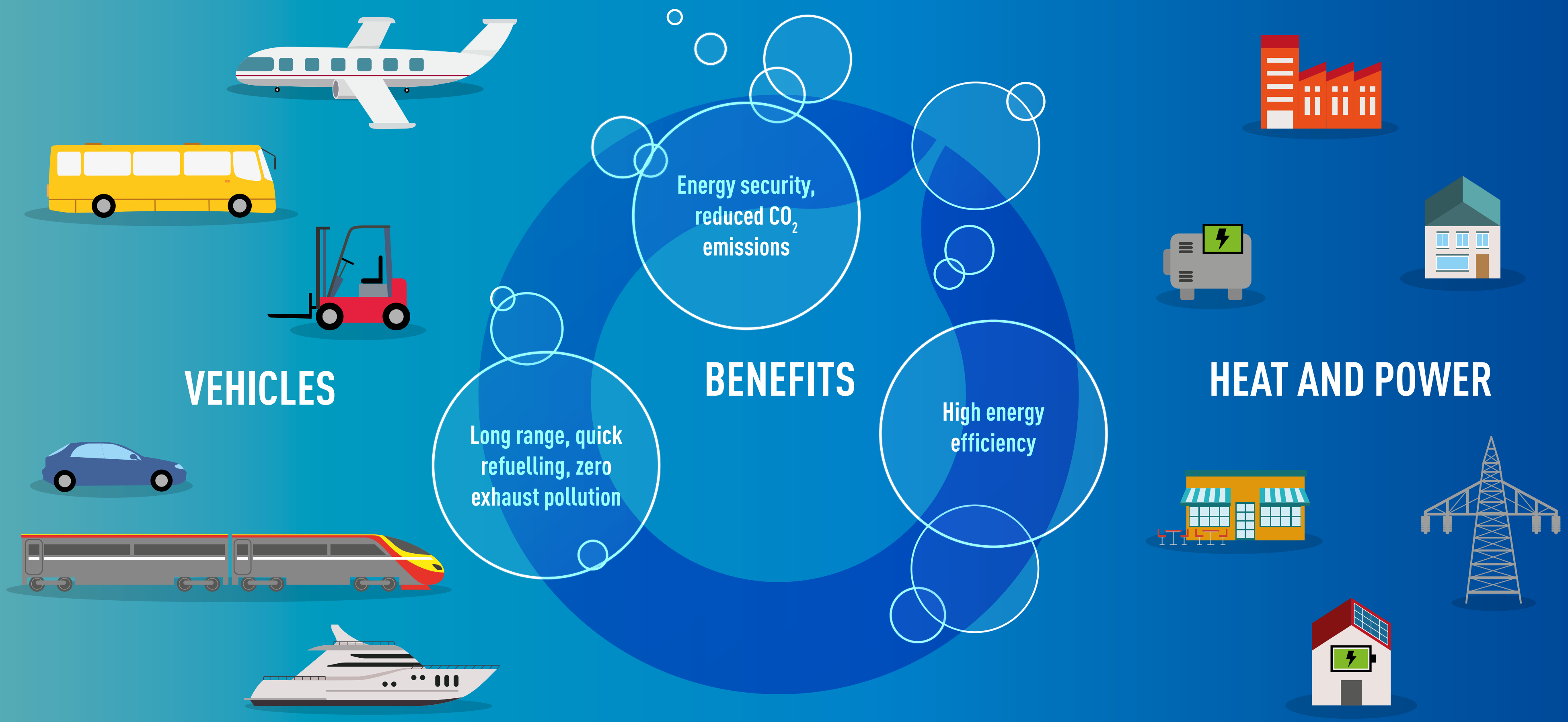
While several production modes exist, such as steam methane reforming (SMR), a carbon-free way to produce hydrogen is through the electrolysis of water using electricity from renewables such as wind or solar. **Greenhouse gas emissions are completely avoided when producing hydrogen from renewable sources.**

Electrolysis itself is a hundred years old; now electrolysers are being developed that better integrate with fluctuating renewable energy sources. Basic and applied research is also being carried out into other carbon-free production pathways, such as thermal dissociation of water (through concentrated solar energy), photoelectrolysis, biological methods or gasification of biomass.

APPLICATIONS

Fuel cells are versatile and have a wide range of potential uses. Typical applications being developed are for transport, including cars, buses, lorries, forklifts, boats, trams, trains and in aeroplanes; portable applications such as small charging stations for mobile phones; domestic heating and energy units (micro-CHP); and power stations and power generators, including for back-up power and power in remote off-grid locations.

FUEL CELLS CAN BE USED IN WIDE RANGE OF APPLICATIONS



II. ABOUT THE FCH JU

WHAT IS THE FCH JU?

Established in 2008, it is a European public-private partnership which aims to accelerate the development and deployment of fuel cell and hydrogen technologies. The FCH JU operated its first phase under the EU FP7 research programme (2008-2014) with a ring-fenced budget of €940 million.

After the successful first phase of the programme, it was agreed to continue the FCH JU under the EU Horizon 2020 framework programme.

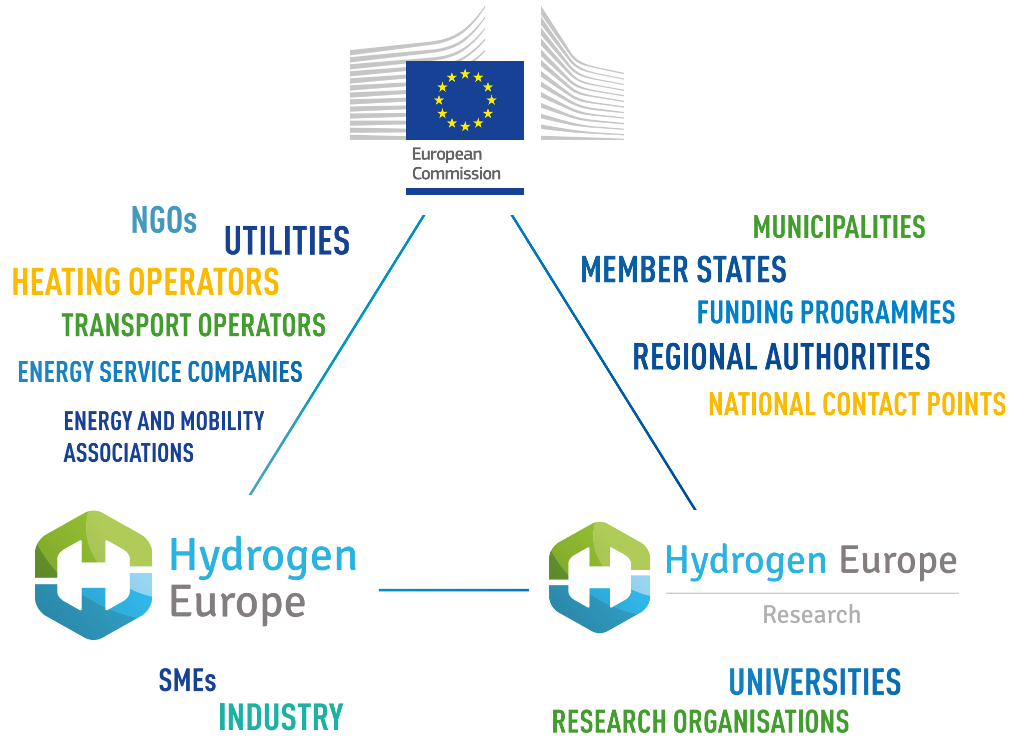
This new phase (2014-20), has a total budget of €1.33 billion, provided on a matched basis by the EU, represented by the European Commission, by industry and by research. The share from industry and research partners is provided through their contribution to the projects and additional activities related to fuel cell and hydrogen technologies.

The partnership contains three members: the European Union, represented by the European Commission, the industry grouping "Hydrogen Europe" and the research grouping "Hydrogen Europe Research".

Why a public-private partnership?

- The scale and scope of the research and market entry agendas for developing and deploying FCH technologies across the spectrum of applications goes beyond the capacity of single companies or public research institutions in terms of financial commitment, resources and capability.
- By pooling resources and creating a common platform where policymakers, industry and research come together, the FCH JU triggers the necessary backing for industry to be confident and to continue making the necessary investment.
- The FCH JU therefore creates a stable framework and facilitates the strategic cooperation needed between public authorities, industry and research to ensure fuel cell deployment on a large scale.

The platform initiated by the FCH JU stimulates interactions with actors beyond the initial FCH JU members' organisations. Many stakeholders and public players are involved in the path towards commercialisation of these innovative technologies.



WHAT ARE THE FCH JU'S GOALS?

H_2 STORAGE FOR GRID BALANCING

Demonstrate on a large-scale hydrogen's capacity to harness power from renewables and support its integration into the energy system

GREEN HYDROGEN PRODUCTION

Increase efficiency and reduce costs of hydrogen production, mainly from water electrolysis and renewables

HEAT & ELECTRICITY PRODUCTION

Increase fuel cell efficiency and lifetime

MINIMAL USE OF CRITICAL RAW MATERIALS

Reduce platinum loading

CLEAN TRANSPORT

Reduce fuel cell system costs for transport applications


eDrive
Hydrogen Fuel Cell
BMW Group Research and Technology

HOW DOES THE FCH JU WORK?

The programme

The FCH JU programme is structured around two research and innovation pillars, energy systems and transport, complemented with diverse cross-cutting activities as a third pillar, supporting the other two.

ENERGY

- Fuel cells for power and combined heat and power generation
- Hydrogen production and distribution
- Hydrogen for renewable energy generation (incl. blending in natural gas grid)

TRANSPORT

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

CROSS-CUTTING ISSUES

(e.g. standards, consumer awareness, manufacturing methods, studies)

A FUNDING AGENCY – WITH OPEN CALLS FOR PROPOSALS

In the framework of a multi-year plan, the FCH JU private partners set the annual priorities programmes to match market needs. The FCH JU launches annual competitive open calls for proposals.

PROCESS OF AN ANNUAL CALL FOR PROPOSALS

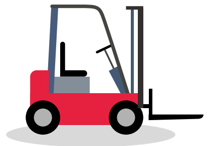
1. The FCH JU, together with its partners, defines research and demonstration topics to be financed.
2. European consortia are invited to submit proposals.
3. Following the receipt of proposals, the FCH JU assesses each proposal on a range of criteria with independent experts.
4. After evaluation, the highest scoring proposals are selected for FCH JU support.
5. The FCH JU provides financial support to projects in the form of grants.

WHAT ARE THE FCH JU PROJECTS ACHIEVING?

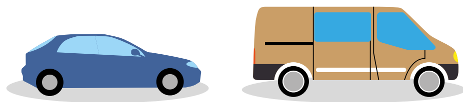
- Research projects advance technology and reduce costs.
- Demonstration projects test hydrogen and fuel cells in real life.
- Users have the opportunity to experience the technology in practice.
- Successful projects spur industry to invest in further development and production.

227 PROJECTS SINCE 2008, €844 MILLION FUNDING

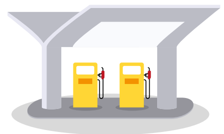
Planned numbers of applications (deployed numbers*)



Forklifts: **283 (116)**



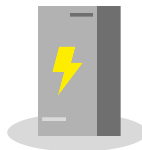
Cars and vans: **1850 (350)**



Refuelling stations: **99 (39)**

Bus: **360 (47)**

Trucks: **18**



Micro-CHP: **3761 (1112)**

Off-grid power supplies: **28 (20)**
Back-up power systems: **23**
Commercial CHP: **28 (3)**

Industrial CHP x CHP (500 kWe): **4 (2)**
H_2 production demonstration plants/ electrolysers: **31 (22)**

… CREATING THE BRIDGE BETWEEN TODAY'S ADVANCED TECHNOLOGY AND TOMORROW'S WIDESPREAD DEPLOYMENT.

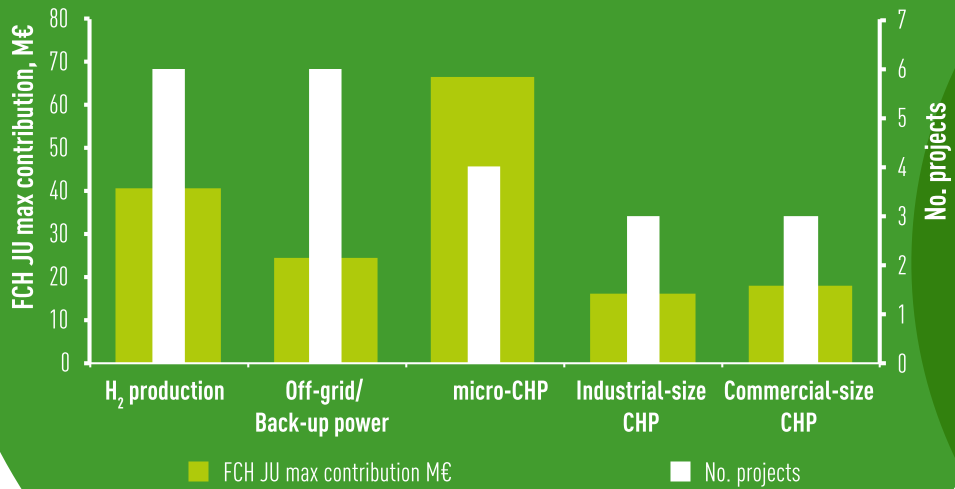
*As of 31 December 2017


海水 空气 电力 自然
CONNECTING VALUE WITH NATURE
THIS PEM FUEL CELL POWERPLANT TURNS WASTE HYDROGEN INTO CLEAN ENERGY
Ynnovate
FCH

HOW IS THE BUDGET DISTRIBUTED AMONG THE DIFFERENT PILLARS?

ENERGY

DEMONSTRATION ACTIVITIES



RESEARCH ACTIVITIES

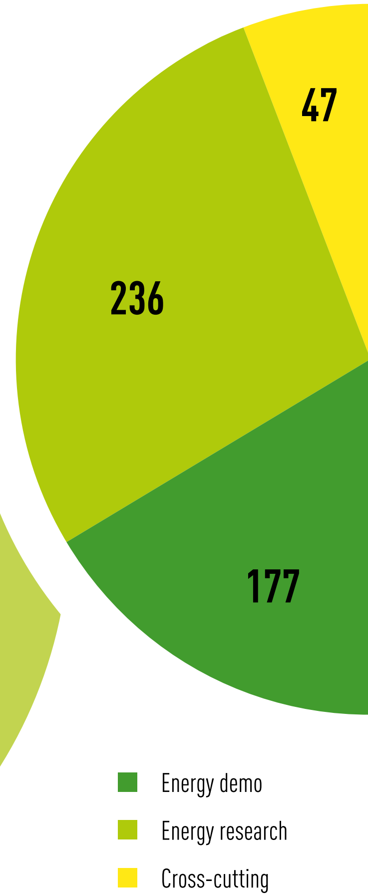
These focus on stationary fuel cells and hydrogen production.

The emphasis for fuel cells is on high-temperature fuel cells for diverse applications, to improve their performance and increase their durability.

Hydrogen production research targets better dynamic performance of electrolysers to improve their integration with variable renewable energy sources. It also aims to develop innovative routes for producing hydrogen, involving biogas via reforming, solar energy via concentrated solar power or photo-electrochemical means, or using wet or dry biomass via biological reactors or gasifiers.

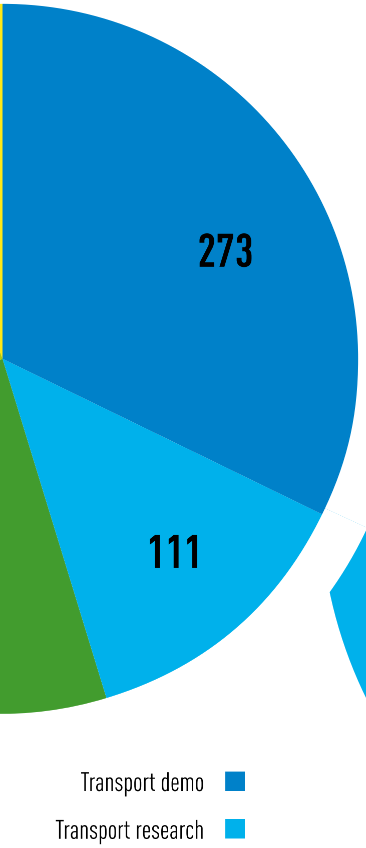
IN TOTAL, €844

FCH JU MAX CON



MILLION SO FAR

TRIBUTION IN €M



RESEARCH ACTIVITIES

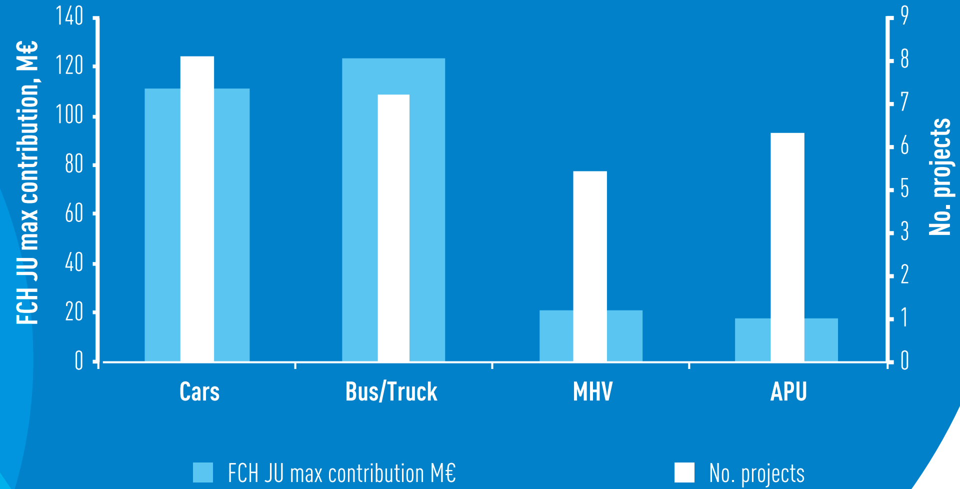
These aim to reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels competitive with conventional technologies.

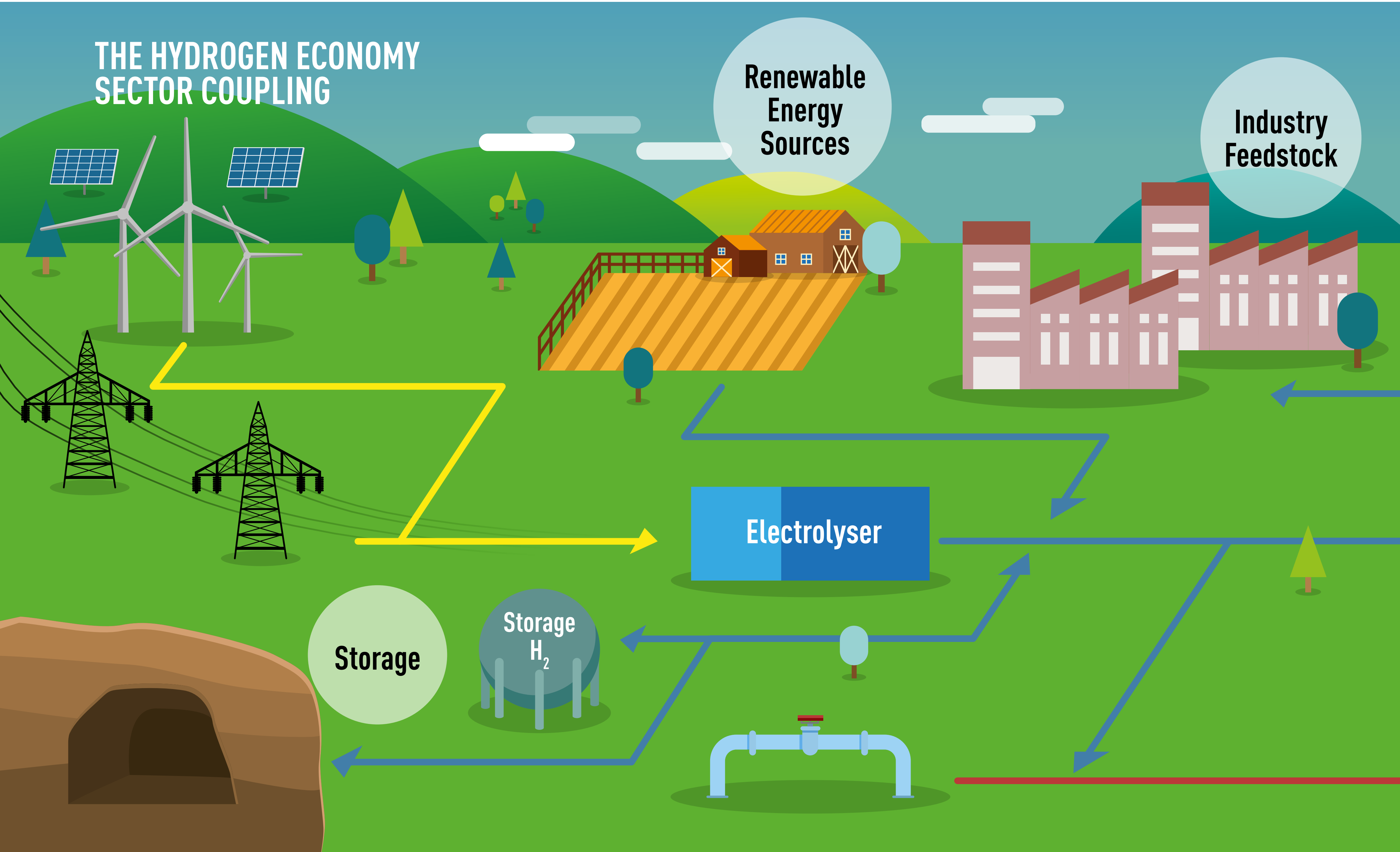
In particular, projects on membrane electrode assembly (MEA) aim to reduce the use of platinum and other critical raw materials; projects on bipolar plate (BPP) investigate advanced coatings; projects on stacks and on balance of plant (BoP) aim to improve manufacturing techniques.

Modelling of cells, improvements in compression technologies at hydrogen refuelling stations (HRS) and the manufacture of low-cost H2 on-board tanks complete the span of the FCH JU research portfolio.

TRANSPORT

DEMONSTRATION ACTIVITIES




THE HYDROGEN ECONOMY
SECTOR COUPLING
Renewable Energy Sources
Industry Feedstock
Electrolyser
Storage
Storage H_2

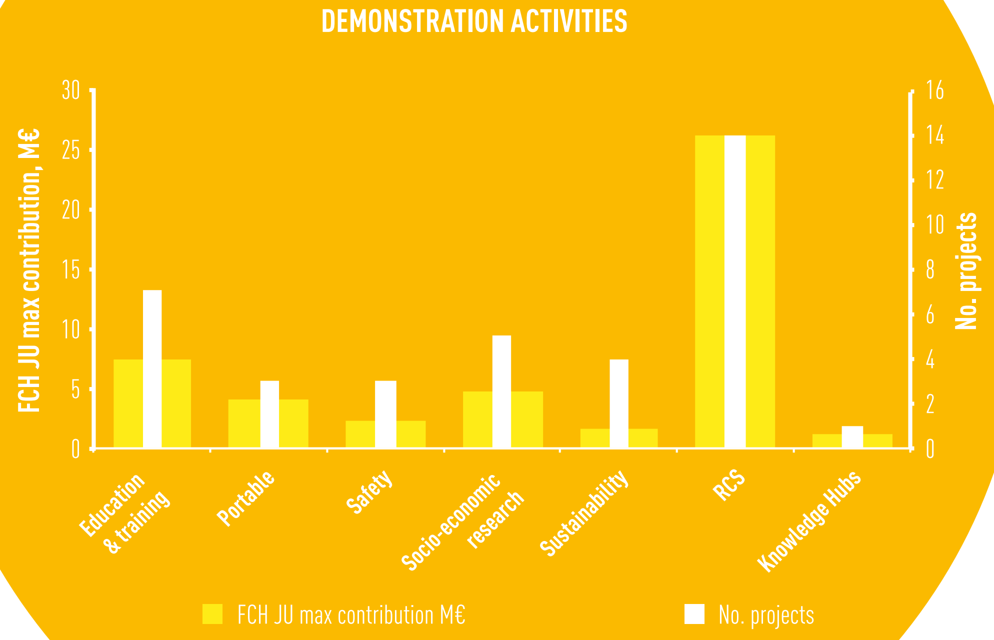

Transport
Heating & Cooling
NG
H_2

CROSS-CUTTING PROJECTS

The FCH JU programme also covers a wide range of cross-cutting activities that support both energy and transport developments.

Backing deployment activities and technical developments alone is not enough to ensure smooth entry into the market. It is crucial to remove regulatory barriers and encourage the public to be aware of and have trust in emerging technologies.

Therefore an important part of the FCH JU portfolio supports projects dealing with topics that help technical developments become part of everyday life. These include safety innovations and tests, education and public awareness, and pre-normative research – research whose results are used to develop regulations and standards.

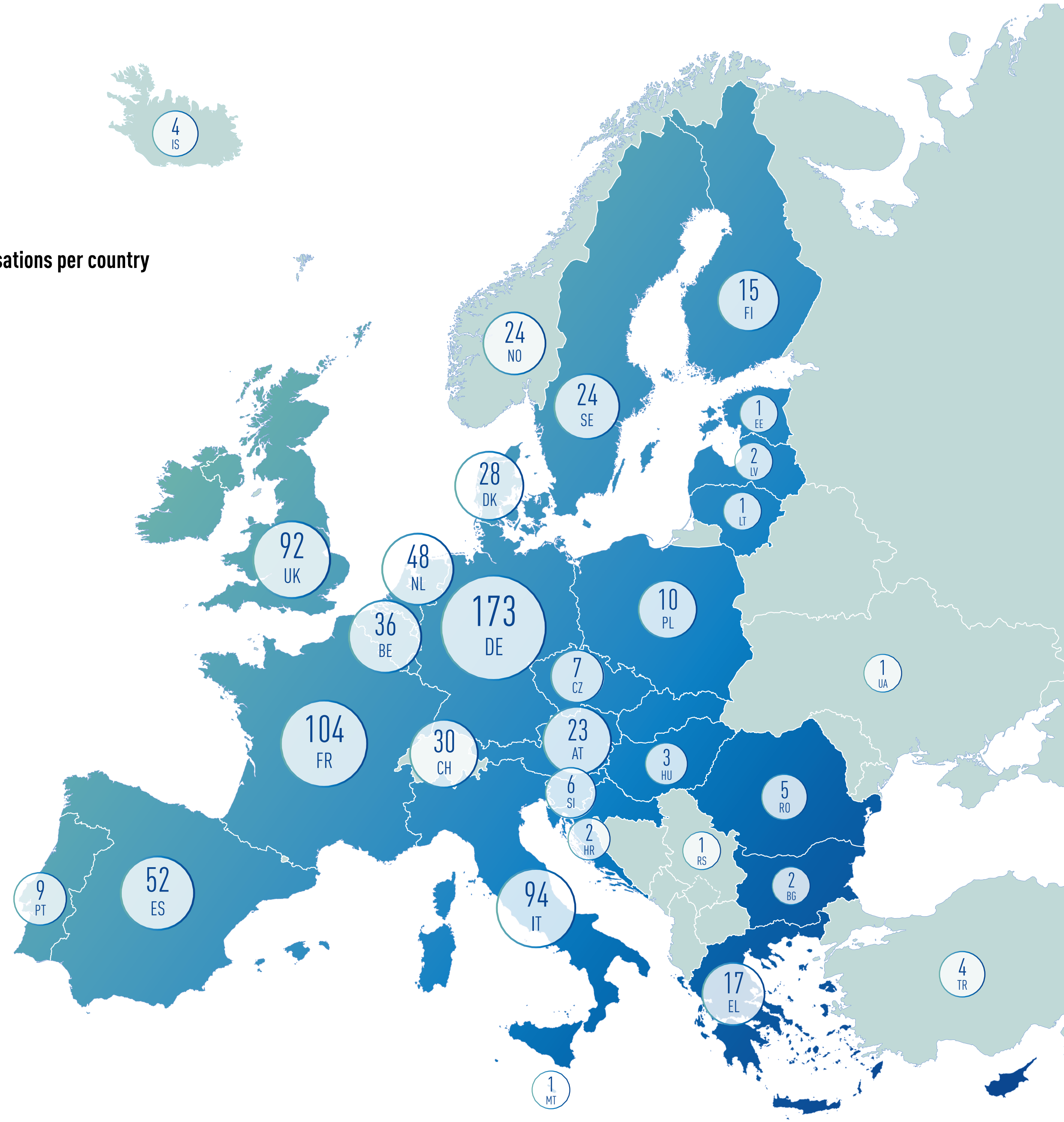



BOMBEROS
SAN JOSE
FIRE
ENGINE

COUNTRY DISTRIBUTION

The figures indicate the number of FCH JU participating organisations per country

INTERNATIONAL COOPERATION	
CANADA	3
CHINA	3
ISRAEL	2
REPUBLIC OF KOREA	1
RUSSIA	1
UNITED STATES OF AMERICA	2




ITM POWER
Energy Storage | Clean Fuel
HYDROGEN FUEL STATION
ITM POWER
HYDROGEN PRODUCED
hyFIVE
ITM POWER

III. ADDRESSING ENERGY UNION PRIORITIES

THE VISION OF THE ENERGY UNION

- A sustainable, low-carbon and climate-friendly economy that is designed to last;
- Strong, innovative and competitive European companies that develop the industrial products and technology needed to deliver energy efficiency and low-carbon technologies inside and outside Europe;
- Citizens at its core, where citizens take ownership of the energy transition, benefit from new technologies to reduce their bills and participate actively in the market, and where vulnerable consumers are protected.

The FCH JU makes a key contribution to the three priority targets of EU policy on the Energy Union and climate action:

- Reduction of greenhouse gas emissions by 40 % compared to 1990: the FCH JU stimulates a mass market for zero-emission hydrogen energy in power generation and transport to make a major contribution to meeting this target.
- Increase in renewable energy to 27 % of total production: the FCH JU supports the introduction of commercial technologies for producing and storing hydrogen from sun and wind, enabling a greater uptake of renewable energy.
- Making 27 % energy savings compared to 1990: fuel cells are more efficient than diesel, petrol or gas technology. Their mass market uptake will substantially reduce total energy use.

> “I want to reform and reorganise Europe’s energy policy in a new European Energy Union.”
>
> Jean-Claude Juncker
> (President of the European Commission)

We need to sustain and accelerate progress to meet these EU targets.

The Energy Union strategy has five mutually reinforcing and closely interrelated dimensions:

- **Energy security, solidarity and trust**
- **A fully integrated European energy market**
- **Energy efficiency contributing to moderation of demand**
- **Decarbonising the economy**
- **Research, innovation and competitiveness**

Fuel cell and hydrogen technologies support all five dimensions:

Storing hydrogen allows the intermittent character of renewables to be addressed and, as such, opens the door to uninterrupted availability of energy sources. This also allows higher penetration of renewables into sectors such as industry and transport. Similarly, fuel cells – as high-efficiency conversion devices – can help reduce the consumption of imported fossil fuels

Hydrogen is an energy vector. As such, it can be stored and transported across borders.

Furthermore, hydrogen contributes to the integration of the electricity and gas sectors.

The electrochemical conversion of fossil fuels in fuel cells is more efficient than conventional combustion-based technologies and avoids completely the emission of NO_x and SO_x.

This allows energy and transport applications to make better use of energy sources, reducing the amount of energy consumed.

Hydrogen is CO_2-free when produced from renewable energy sources. When used with a fuel cell in industry, in transport or for heating in the residential sector, this technology contributes in decarbonising the economy

Transport and stationary fuel cells using hydrogen from renewable energies emit zero greenhouse gases.

In Europe, research and innovation efforts in the field of fuel cells and hydrogen are provided through the FCH JU.

By funding further research and innovation projects in this field, Europe has the potential to become the world leader in this sector, helping to create jobs and wealth in Europe

IV. SUCCESS STORIES

HOW DOES THE FCH JU ADVANCE HYDROGEN AND FUEL CELL TECHNOLOGY AND DEPLOYMENT?

The FCH JU is a focus for European experts on fuel cells and hydrogen to reach targets together. This has helped the technologies to progress significantly, especially in terms of reduced life-cycle costs and increased overall performance, durability and efficiency.

An early commercialisation process has already started, beginning within specific market segments across Europe: buses, passenger cars, forklift trucks, CHP units, and portable and back-up applications.

In some locations, thanks to the FCH JU support, fuel cells and hydrogen solutions already allow renewable energies to be exploited much more efficiently – producing electricity at high conversion rates for residential and industrial applications – and offer vehicles with no noise, vibrations or CO_2 emissions.

1. HARNESSING THE FULL POWER OF RENEWABLE ENERGY WITH HYDROGEN

As Europe deploys more renewable capacity, from vast wind farms to roof-top solar arrays, hydrogen is set to be an essential integrator, harnessing excess generated power and releasing it when needed.

The production of electricity from wind and solar energy accounts for less than 20 % of all renewable production and around 5 % of total energy supply in Europe, but is increasing. Under the high-RES scenario in the European Commission's Energy Roadmap 2050, 85 % of energy would come from renewable sources, with 65 % from intermittent sources such as wind and solar. Meeting that target will result in a 10-fold increase in demand for energy storage to balance supply and demand.

Electrolysis is a key technology for storing energy from renewables. It uses excess electricity not supplied directly to the grid to split water molecules into oxygen and hydrogen. The hydrogen is then available to a number of applications or sectors: to be fed to fuel cells to generate electricity for the grid, for injection into the natural gas grid, as fuel for transport applications or as feedstock to refineries, ammonia or steel plants.

Of the 53 FCH JU projects related to hydrogen production, 30 support development of electrolysers for energy applications. Two such projects are **HPEM2GAS** and **ELY4OFF**, which are researching technologies for converting energy into hydrogen gas for grid-connected and off-grid energy storage respectively. More recently, projects **PRETZEL** and **NEPTUNE** are aiming to push the performance of electrolysers much further beyond state of the art.

Hydrogen's stable chemistry allows it to hold energy longer than any other medium, either as gas under high pressure or as liquid at very low temperatures. Large-scale, long-term storage will be pivotal for the sectorial integration through hydrogen. The **HyUnder** project has assessed the potential of salt caverns, which could provide thousands of cubic metres of high-pressure, low-temperature space across Europe, to store renewably sourced hydrogen and possibly interact with the transport sector and other markets.

Infrastructure for scalable renewables

One of the biggest benefits of hydrogen energy storage is its scalability: a one-megawatt hydrogen electrolyser is roughly the size of a shipping container and can be easily installed next to a field of wind turbines or a distribution substation, producing almost half a ton of hydrogen per day. The **Don Quichote** project tested the commercial viability of an integrated hydrogen storage system and refuelling facility in Belgium, using electricity from solar panels and a wind turbine to generate hydrogen through proton exchange membrane (PEM) electrolysis technology to fuel back-up power supply and fuel cell vehicles.

Project **Hybalance** is demonstrating an advanced PEM electrolyser in Denmark with over one-megawatt capacity, producing hydrogen from renewables to be supplied to a light industry and fuel for 60 fuel cell vehicles, providing electricity grid services at the same time. Project **H2Future** is demonstrating a 6MW PEM electrolyser in Austria in view of greening the steel industry by using green Hydrogen for direct iron ore reduction.

Other methods of converting renewable energy to hydrogen are also being investigated. The **Hydrosol** family of projects focuses on producing hydrogen through the thermolysis of water, in which solar heat is used to break the chemical bonds between oxygen and hydrogen. Other projects, such as **ARTIPHYCTION** and **PECDEMO**, are working to achieve the same results using light in a process known as photoelectrolysis, whereby light falling on a special solar panel breaks water molecules using a catalyst.

Each of these initiatives addresses a single problem. Together, they contribute to hydrogen reaching its potential as a commercially viable energy carrier.


BlueGEN

2. DOMESTIC FUEL CELLS: THE POWER WITHIN

Residential fuel cell units could allow millions of homes in the EU to produce their own electricity for light, appliances and heating. This would reduce both their environmental footprint and residents' living costs. The FCH JU has supported the first EU wide large-scale field trial. Thanks to this, a track record of installations exists today. Further support to large-scale demonstrations is ongoing to allow EU industry to produce such units on a commercial scale and to develop the next generation of products.

The technology is based on fuel cell micro CHP (mCHP) units, designed to supply individual flats or houses. They replace the more traditional boiler, generating electricity as well as producing heat and hot water.

While the first thousands of units are already on the market in Europe, the technology has yet to be rolled out on a larger scale. Trials have enabled manufacturers to refine their products, and a follow-on project is paving the way for mass production.

The fuel cells in mCHP units produce electricity and heat from hydrogen, typically by internally transforming natural gas from the grid. Compared to a state-of-the-art condensing boiler and grid power supply, fuel cell mCHP units can reduce CO_2 emissions by at least 30% and in some cases by up to 80 %. The extent of the reduction depends on the energy mix of the grid.

The units produce no nitrogen or sulphur dioxide and are completely silent. Impact on local air quality is therefore minimal. Homes fitted with this technology are also expected to require less primary energy than for boilers (on the basis of the superior efficiency of fuel cells), and can feed any surplus energy they produce back into the grid. Any house that is connected to natural gas can be equipped with this technology, which has the potential to reduce customers' energy bills by up to €1000 per year.

Development and domestic trials

Trials across 10 EU countries were launched in 2012 by the **ene.field** project, which has deployed over thousand residential installations. Ended in October 2017, the project – which builds on the outcomes of a predecessor project implemented in Germany – has reported encouraging results. Households participating in the trials received a unit for three years and many users have asked to keep the appliance. While user conclusions from the trials are generally positive, the tests have also enabled the participating manufacturers to gain experience and to refine their products' technology and business models. Thanks to this project, a track record of installations has been created and customer confidence has been gained.

A number of manufacturers, along with several other partners, have now joined forces in PACE, a five-year FCH JU project launched in June 2016 to take the technology closer to mass commercialisation. Key aims in PACE include installing 2650 units with commercial customers, enabling manufacturers to scale up production and boosting the durability of the fuel cells at the core of the units. These should also enable the partners to reduce the cost of their units by at least 30 %, which they aim to achieve by moving from current manual production towards mass manufacturing.

Fuel cell mCHP technology is still developing towards full commercialisation. Financial incentives are also important to bring it within the reach of an average household. These were central to the technology's success in Japan, where it is already well established. In Germany, an incentive was launched at the end of 2016, which intends to realise fuel cell micro-CHP sales in the region of tens of thousands per year. Other countries such as the UK have in place a feed-in-tariff scheme that included FC mCHP. These support schemes are already helping to make an economical case for FC mCHP today. Widespread adoption in Europe could significantly increase energy independence, while reducing households' impact on the environment and their energy bills.

3. CLEANER URBAN TRANSPORT WITH HYDROGEN BUSES

Trials in cities around the world have demonstrated that fuel cell passenger buses can cut emissions and noise pollution while providing good-quality public transport. New FCH JU projects are doubling Europe's fleet of hydrogen buses with almost 400 buses in operation or committed – reducing vehicle and infrastructure costs per bus to boost take-up of the technology.

Fuel cell buses are an attractive solution for public transport – they can travel long, cost-effective shifts before being refuelled quickly at bus depots, yet are quiet and produce no carbon or particulate emissions, which minimises their environmental and health impacts.

The buses are powered by fuel cells that combine hydrogen stored in high-pressure tanks with oxygen from the air to generate electricity, heat and water. Performance compares well to the more established diesel, trolley (tram) and battery bus technologies. According to trials, there is no perceptible difference: hydrogen buses are clean, smooth and easy to drive. A fuel cell bus can drive for 300-450 kilometres before it needs to be refuelled, says an FCH JU report. This gives the technology an edge over most established battery buses, which have more limited ranges. And as they carry enough fuel on board for a full shift, the buses need very little route infrastructure, unlike trolley buses and some battery buses.

Hydrogen fuel cell buses continue to improve. In the last 15 years, their fuel efficiency has increased threefold to around 8-9 kg H_2/100 km, while refuelling times have more than halved to under 10 minutes. Small-scale demonstration trials of fuel cell buses have been taking place in commercial fleets around the world. These provide data on costs and good operational practice, improve economies of scale and supply chains, give operators a say on how to develop bus models, and raise public awareness of the technology. They also encourage bus fleet operators to invest in the new vehicles and drive economies of scale in manufacturing and post-sales support.

Capacity-building

Across Europe, 125 fuel cell buses are estimated to be in operation. FCH JU funded projects **CHIC**, **High V.LO-City**, **HyTRANSIT** and **3Emotion** are trialling bigger and bigger fleets, reaching up to 20 buses in some cities. In total, 42 buses are now on the road thanks to the FCH JU support.

These demonstration projects have been successful with operators and passengers alike. For example, as part of CHIC, a small fleet of eight fuel cell buses in London (UK) operated along a busy route popular with tourists. It performed so well that the participating transport company intends to expand its hydrogen fleet.

The recently signed projects **JIVE** and **JIVE2** will bring the number of buses in operation close to 400 with fleets as large as 40 buses in several cities. Interest expressed so far by bus operators could expand Europe's fleet to over 1000 buses, with the potential European market worth €2.3 billion. Fuel cell buses could catch up to battery bus production and technical levels in five to ten years.

The FCH JU played a pivotal role in bringing the demand and supply sides together, helping Europe become a world leader in the technology. These efforts could be the first step in developing a fully competitive market using hydrogen-based zero-emission urban transport. The implications are enormous in terms of the environment, job creation and economic development.


Tower Gateway
RV1
WSH62991
Powered by hydrogen fuel cell – zero emission bus
Another red bus
going green for LONDON
WSH62991
hydrogen
bus
LK60 HPE

4. HYDROGEN DRIVES EUROPE TOWARDS EMISSION-FREE TRANSPORT

A clean revolution is quietly taking place on Europe's roads. Hydrogen fuel cells are powering fleets of public buses and refuelling stations are being deployed. Building on the results of several pilot projects, uptake of the technology is accelerating rapidly, putting hydrogen fuel cells in a position to underpin zero-emission transport Europe-wide.

There has been an enormous leap forward recently in terms of the technology, cost and infrastructure, and the trend will undoubtedly accelerate over the coming years.

Next to the expansion of fuel cell buses, the number of refuelling stations is set to rise, and is expected to increase from about 140 today to more than a thousand in the next decade. Meanwhile, several car manufacturers have progressed from testing hydrogen fuel cell electric vehicles (FCEVs) to producing them commercially. The trend is driven by growing demand among citizens and decision-makers for efficient clean transport solutions that reduce urban air pollution, lower dependence on fossil fuels and minimise carbon dioxide emissions. It is being powered by a technology that can provide improved performance and equivalent convenience, range and refuelling time to petrol and diesel-powered vehicles at a fraction of the environmental cost.

In addition to the environmental advantages of hydrogen fuel cell technology over conventional fossil fuel engines, the energy efficiency of a fuel cell is typically between 40 % and 60 %, compared with an average of 25 % for a petrol engine. With respect to battery-powered electric vehicles, hydrogen fuel cell technology has two key practical advantages: an extended range and no lengthy recharging time. FCEVs on the market today can travel up to 700 km on a single tank, and can refuel in minutes as opposed to being recharged for hours.

There are still some pre-commercial barriers to the widespread use of FCEVs, but these can be overcome by supporting vehicle deployment and building the required infrastructure that should take FCEVs from a demonstration to a market initiation phase. That is where the FCH JU support becomes crucial.

Transport projects

FCH JU projects include **H2Moves**, **HyFIVE**, **Swarm**, **HyTec**, **H2ME**, **H2ME2** and **ZEFER**.

In HyFIVE, for example, five leading car manufacturers, infrastructure providers and other partners deployed 130 hydrogen fuel cell vehicles across Europe as well as refuelling stations. Likewise, the H2ME and H2ME2 projects are setting up 49 refuelling stations and will place a total of more than 1400 vehicles on the road. The project has built a network of stations that is producing hydrogen from water electrolysis using electricity generated from renewable and carbon-neutral sources to create the first 100 % sustainable and zero-emission hydrogen supply – the highest share in the world for an entire station network.

Once complete, projects such as HyFIVE and H2ME/H2ME2 should allow an FCEV driver to travel from Sweden to Italy or from the UK to Austria without worrying about where to refuel.

By deploying FCEVs and refuelling stations in key regions, the FCH JU is planting the seeds that will gradually spread the use of hydrogen for transport across Europe. It will also address the so-called "chicken-and-egg" situation, where there is no first-mover advantage to building refuelling stations if there are not enough cars on the road to support them.

In addition to more accessible infrastructure, lower prices for FCEVs should also contribute to demand. FCEVs now cost less than €70 000 and are increasingly price-competitive with high-end combustion engine vehicles. The cost of fuel cells has declined by more than 80% over the last five years, and as research continues and economies of scale improve the price of FCEVs should continue to fall.

Inside cities, the deployment of hydrogen-powered buses for urban public transport is also becoming widespread. Cities such as Aberdeen, Antwerp, Cologne, London, Oslo and Riga are all gaining fleets of fuel cell buses thanks to the FCH JU bus projects (refer to previous article). These and earlier projects are proving the practicality, reliability and safety of hydrogen-powered vehicles: data recorded in 2016 from buses and cars in operation show that they have already travelled more than 7 million kilometres in total and in 2016 alone, around 2.5 million kilometres and refuelled more than 170 tonnes of hydrogen. The upshot of these projects alone is that around 14 200 tonnes of CO_2 emissions have been avoided, assuming half the hydrogen fuel was generated using renewable energy.

In urban areas in particular, increasing restrictions on the use of polluting combustion-engine vehicles are set to increase demand for FCEVs and fuel cell buses. At a broader level, lowering carbon dioxide emissions limits to less than 95 grams of CO_2/km for all cars in the EU from 2020 could encourage many manufacturers to turn to hydrogen technology.

Regulatory factors will be a clear driver of uptake, and could bring about dramatic changes in the European transport sector over the next decade.

During the same period, efforts will intensify to switch from mostly producing hydrogen from natural gas to producing it through water-based electrolysis powered by renewable energy, resulting in a transport system that is truly CO_2-emissions free.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AIR

V. WHAT NEXT FOR THE FCH JU?

TO DEVELOP BY 2020:

- Very efficient fuel cell systems;
- Successful demonstration of fuel cell applications for homes and businesses across many countries;
- Cleaner transport solutions.

BY 2030, THROUGH THE JU'S SUPPORT:

- Fuel cell cars, buses and generators will be an affordable and convenient option for users' needs;
- Fuel cells and hydrogen will make a big contribution to EU targets to reduce greenhouse gas emissions by 40 %, increase renewables to 27 % of Europe's energy needs, and reduce energy use by 27 %.

BY 2050, THROUGH THE JU-INITIATED MARKET EXPANSION:

- Zero-emission transport will be achieved, with fuel cells playing a major part;
- Zero-carbon energy, with renewable energy, fuel cell generators and hydrogen will become an everyday reality.

2020

2030

2050

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