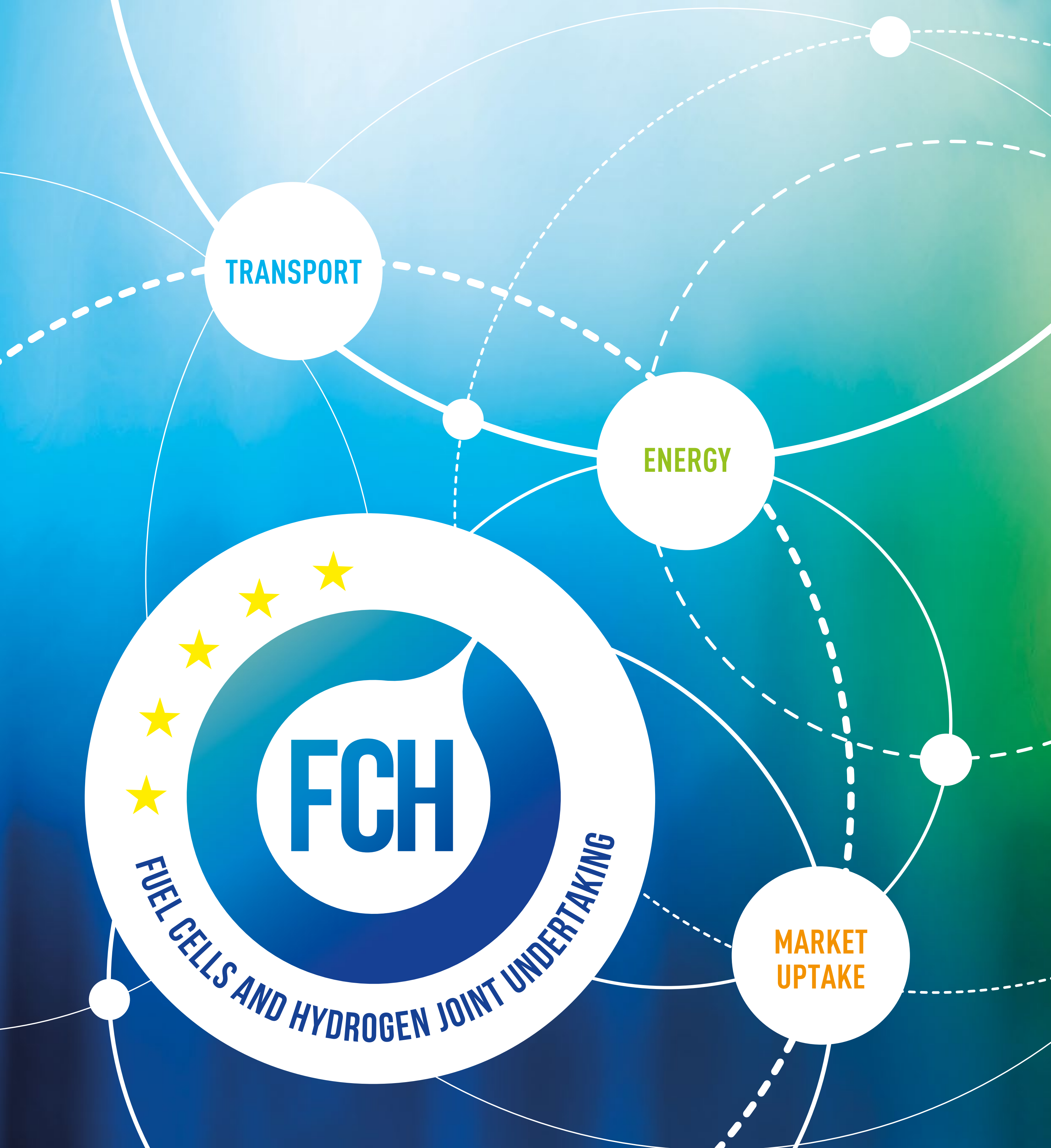
FCH JU Success Stories

# Making an impact on the clean energy transition




# A collection of success stories from FCH JU projects

Dear reader,

You hold in your hands an account of the Fuel Cells and Hydrogen Joint Undertaking's success stories. Preparing these success stories for publication gave us a chance to look back and see what we have achieved together over the past years. It is amazing to see the enormous progress that fuel cell and hydrogen technology has made. None of this is possible without the many dedicated men and women who work countless hours to make their projects a success. Each of these stories show how collaboration between research, industry and policy makers in a European partnership delivers the best innovations and accelerates the transition to a greener world. I hope you will enjoy reading these stories and helping us to spread the word about the latest developments in fuel cell and hydrogen technology. It is important that European citizens learn more about these successes and the many ensuing benefits for all. The hydrogen economy is just at the beginning of a long journey and I am sure that we will see many more success stories in future.

Thanks to all the people who contributed to make this brochure a reality.

**Bart Biebuyck**
Executive director of the FCH JU



Luxembourg: Publications Office of the European Union, 2019



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Making an impact on the clean energy transition

TRANSPORT

# COMPETITIVE, COMMERCIAL AUTOMOTIVE FUEL CELLS


© ZSW

**Fuel-cell-powered vehicles would reduce polluting emissions from transport while reducing Europe's reliance on imported fossil fuels. The FCH JU has been instrumental in the development of this transformative automotive technology, which is on the verge of being deployed commercially.**

## State-of-the-art stacks

Because hydrogen fuel cells produce little energy individually, many need to be layered or 'stacked' together to power vehicles. However, until recently, Europe had neither state-of-the-art fuel-cell stack products nor competitive stack suppliers for automotive applications. Performance, weight, size and cost issues also posed barriers to the commercial adoption of the technology. FCH JU co-funded projects have addressed these challenges. AUTO-STACK established a research cluster to drive the development of automotive fuel-cell stack technology in Europe. It was followed by STACKTEST, which created industry-wide harmonised test procedures for fuel-cell stacks. AUTO-STACK CORE then set up a platform to develop automotive stack hardware to address critical challenges to fuel cell commercialisation. The project's successive generations of stacks achieved increasingly high-performance results and power density at lower cost, while substantially improving economies of scale.

## On the road by 2020

These developments led car-equipment manufacturers to start a limited production of fuel-cell stacks and laid the foundations for an 'Autostack industry' project in Germany, bringing together automotive companies and suppliers to prepare for the commercial launch of fuel-cell vehicles in Europe by 2020. The project will enable the transition to the cost-effective automated assembly of high-quality, high-performance stacks, while further boosting fuel- cell performance, service life and reliability. Thanks to these initiatives, the competitive industrial-scale production of automotive fuel cell stacks in Europe is now close to becoming a reality.


© Powercell Sweden

# COMPETITIVE, COMMERCIAL AUTOMOTIVE FUEL CELLS

## KEY ACHIEVEMENTS

**10-150 kW**
power range of new fuel-cell stacks

**5 500 HOURS**
life-expectancy objective of new fuel-cell stacks in AUTO-STACK CORE

**EUR 30-40/kW**
cost projections in AUTO-STACK CORE for large-scale production of 95 kW fuel-cell stacks

**4 KW/LITRE**
volumetric power density

**≈ 55 %**
stack electrical efficiency

## BUILDING A EUROPEAN INDUSTRY

By overcoming the lack of state-of-the-art fuel-cell stack products and competitive stack suppliers for automotive applications in Europe, while addressing fuel-cell performance, weight, size and cost issues, the aim is to drive commercial take-up.

## DRIVING DEVELOPMENT OF AUTOMOTIVE SOLUTIONS

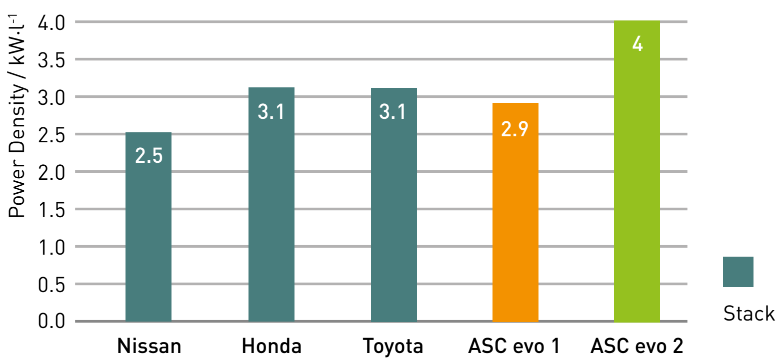
By combining the collective expertise of automotive original equipment manufacturers, component suppliers, system integrators and research institutes, FCH JU projects successfully addressed the lack of competitive automotive fuel-cell stack production in Europe. **The goal?** To create a competitive industrial supply chain enabling the standardisation of stack production, while improving the performance and lowering the cost of fuel cells. **Key results?** The commercial launch of fuel-cell vehicles in Europe by 2020.

## IMPACT

**30 000**
planned production volume of fuel-cell stacks per year from Germany's Autostack industry project

**EUR 23 MILLION**
overall budget (12 EUR million FCH JU budget) for three projects (AUTO-STACK, STACKTEST, AUTO-STACK CORE) supporting the commercialisation of fuel-cell stacks in Europe

## PEAK POWER DENSITY COMPARISON




FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
http://autostack.zsw-bw.de
http://stacktest.zsw-bw.de/

@fch_ju

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

A partnership dedicated to clean energy and transport in Europe

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TRANSPORT

# HYDROGEN BUSES MAKE INROADS IN CITIES

©FCH JU project CHIC

Hydrogen-fuelled buses are a clean and quiet urban transport solution, helping to protect the environment and public health. The FCH JU is playing a pivotal role in promoting commercialisation of such future-focused buses, boosting their presence on Europe's city streets and improving citizens' lives.

## Clean crowd-pleasers

Hydrogen fuel cell buses provide multiple benefits and are popular with both the public and transport operators. With zero emissions except water, they contribute to cleaner air in urban areas – positively impacting residents' well-being. Rides are quieter and smoother than conventional buses for passengers and drivers alike. Their ability to travel up to 400 kilometres without refuelling also makes them a strategic choice for sustainability-seeking city councils. The FCH JU co-financed flagship Clean Hydrogen in European Cities (CHIC) project, launched in 2010, deployed 56 fuel cell buses across Europe and Canada to demonstrate how cities can decarbonise public transport. Other FCH JU projects trialling bigger fleets followed – including High V.LO-City, HyTRANSIT and 3EMOTION. The latest projects – JIVE and JIVE2 – will see the number of hydrogen buses in Europe surge to almost 400.

## Driving commercialisation

With a market worth EUR 2.3 billion, Europe's fleet of hydrogen buses has the potential to expand to 1 000 by 2025. To achieve this, the FCH JU has been presenting a business case for fuel cell buses, supporting projects to prove their commercial viability, and providing proof to encourage investment in affiliated technology and refuelling infrastructure. It has also brought together supply-and-demand stakeholders to enhance their commitment, and has raised public awareness. The new generation of hydrogen buses being developed includes tram-like and double-decker models from up to 10 different bus manufacturers worldwide.

© Ben Tasimovicz

# HYDROGEN BUSES MAKE INROADS IN CITIES


## WHAT'S AT STAKE?

Hydrogen buses can help cities to improve air quality, cut noise pollution and transition to a low-carbon economy.

## EN ROUTE TO SUCCESS

To promote commercialisation of hydrogen buses, the FCH JU brought together manufacturers, operators and public authorities. **The goal?** To enable key stakeholders to share expertise, team up on projects and pledge their commitment, while assuring manufacturers and operators about future investments and the availability of reasonably priced buses. FCH JU-funded projects have focused on demonstration trials in commercial fleets. **Key results?** Proof that hydrogen buses are not only sustainable but also reliable and fully functional public transport alternatives.

## IMPACT

**29**
European cities with buses being deployed through FCH JU-funded projects

**360 +**
fuel cell buses being deployed

**10 000 000 km**
driven

**85 %**
fewer $CO_2$ emissions than diesel (with green $H_2$)

**MORE THAN 5 000 TONNES**
$CO_2$ emissions abated

**EUR 2.3 BILLION**
market potential for hydrogen buses in Europe

## KEY ACHIEVEMENTS

**300 – 400 km**
autonomy (range)

**88 %**
fuel cell bus availability

**3 FOLD**
increase in fuel efficiency

**OVER 50 %**
reduction in refuelling time

**58 %**
cut in fuel cell bus prices (from EUR 1.2 million to EUR 0.5 million)

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
www.fuelcellbuses.eu

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# HYDROGEN FUEL CELL ELECTRIC CARS: THE CLEAN TRANSPORT SOLUTION

© Daimler AG

## Long-range zero emission

FCEVs emit no pollutants and hydrogen fuel can be produced cleanly using renewable energy. Compared to battery-powered vehicles, FCEVs have an extended range, can cover comparable distances to conventional petrol or diesel cars, with similar refuelling times. Although the technology is well established and the cost has fallen sharply in recent years, FCEVs are still only built in small numbers and prices remain high. The lack of refuelling infrastructure is another impediment to adoption.

To address these challenges, the FCH JU has co-funded several projects, including HyFIVE which put 185 hydrogen vehicles and six refuelling stations into operation. The Hydrogen Mobility Europe (H2ME) projects helped to significantly expand the number of hydrogen vehicles and the refuelling network. H2ME deployed 29 hydrogen refuelling stations and 325 vehicles, while H2ME2 is adding 20 hydrogen refuelling stations and over 1100 vehicles. In addition, ZEFER is exploring the use of this vehicles in new business models with 180 vehicles which are currently being deployed.

**Hydrogen fuel cell electric vehicles reduce air pollution and fossil fuel use, while exceeding the performance and comfort of internal combustion engine cars. The FCH JU is laying the foundations for wider market uptake of FCEVs through projects addressing cost and infrastructure challenges.**

## Supporting commercial uptake

Looking to overcome challenges to the commercial uptake of FCEVs, FCH JU projects are encouraging car manufacturers and infrastructure providers to work hand in hand to demonstrate the potential of hydrogen-powered transport as a viable and competitive alternative to fossil fuels. As the technology continues to improve, prices come down and consumer confidence grows, FCEVs are well positioned to underpin sustainable zero-emission transport in Europe – providing cleaner air for all citizens.

© Daimler AG

## KEY ACHIEVEMENTS

**385-700 km**
average range of an FCEV

**3-5 MINUTES**
average refuelling time of an FCEV

**80 %**
the cost of fuel cells has fallen by over 80% in the last five years

**UP TO 60 %**
energy efficiency of a fuel cell is typically between 40 % and 60 %, compared to 25 % for a petrol engine

© Microcab

## IMPACT

**8 MILLION**
kilometres driven by FCEVs in the H2ME projects as of August 2019

**10**
countries with new FCEV refuelling stations built in HyFIVE and H2ME

**1 425**
FCEVs deployed in the H2ME projects

**49**
Refuelling stations built in the H2ME projects

**185**
FCEVs deployed in the HyFIVE project

**6**
refuelling stations built in the HyFIVE project

**1000 TONNES**
$CO_2$ emissions abated (based on FCEVs operating for 3 years 2016-2018)

**MORE THAN 2.6 MILLION CARS COULD BE PRODUCED IN EUROPE BY 2030**
equivalent to EUR 3 billion European production value

## ON THE ROAD TO MORE FCEVs

Lowering the price of vehicles and building adequate and widespread refuelling infrastructure will encourage the greater commercial adoption of FCEVs.

## ADDRESSING COST AND INFRASTRUCTURE CHALLENGES

To support the wider adoption of fuel cell electric vehicles, the FCH JU brought together vehicle manufacturers, infrastructure providers and public authorities. **The goal?** To lower the cost of FCEVs, demonstrate their commercial potential, increase consumer confidence and expand the refuelling network to provide for a viable alternative to fossil-fuel-powered cars. FCH JU-funded projects have focused on demonstration trials and expanding the refuelling infrastructure network. **Key results?** More than 50 refuelling stations across 10 countries, and trials involving over 1 500 FCEVs.

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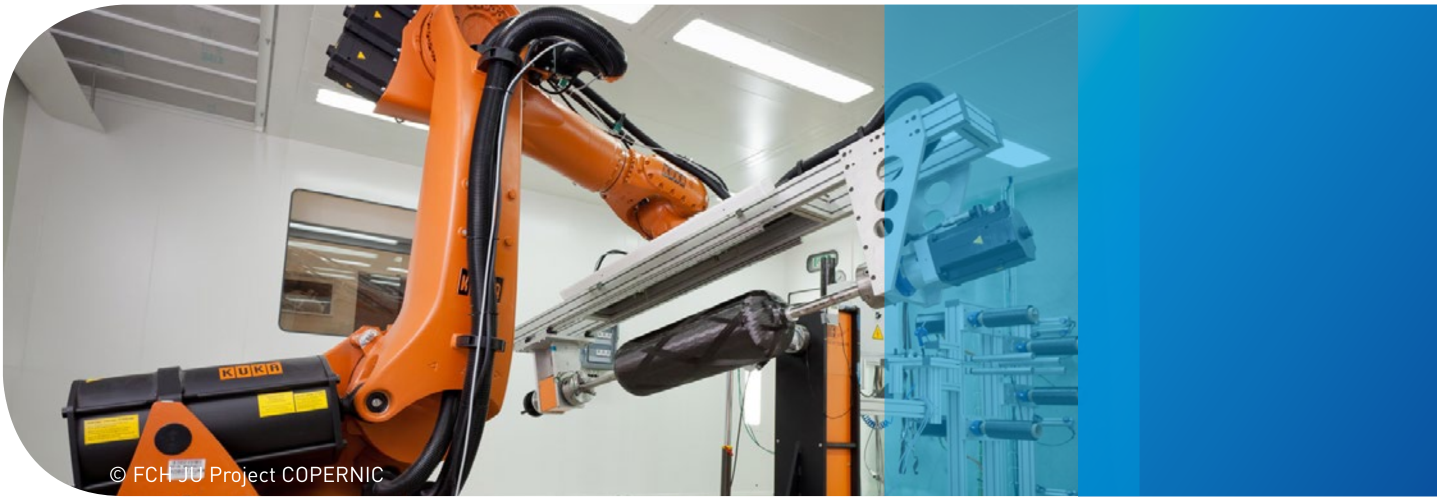
TRANSPORT

# SAFE, AFFORDABLE, HIGH-TECH HYDROGEN TANKS


© FCH JU Project COPERNIC

## Overcoming high cost barriers

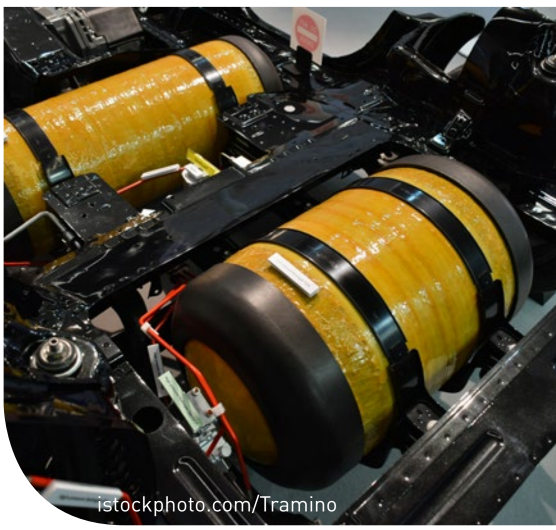
Hydrogen fuel cells are an ideal alternative to fossil-fuel-reliant combustion engines for transport. However, fuel-cell-hydrogen vehicles have faced a barrier to widespread commercial adoption due to the high cost of many components, not least hydrogen storage tanks. New manufacturing techniques and more efficient tank designs using novel, more affordable materials and fewer parts are making on-board hydrogen tanks commercially viable, while enhancing safety, weight and capacity.

The FCH JU-supported COPERNIC project made significant advances in improving the design and manufacturing of hydrogen tanks. By developing a novel carbon-fibre composite, optimising the structure of high-pressure tanks and implementing automated, scalable manufacturing processes, the project lowered the cost of a hydrogen tank by EUR 12 000. It also made tanks simpler and safer, incorporating a novel on-tank valve and real-time monitoring via optical fibres and sensors.

## Market-ready on-board storage

COPERNIC's success has enabled companies involved in the project, mostly SMEs, to propose prototypes to vehicle manufacturers and bring the technology closer to commercialisation. HIPHONE, an EU-funded project, is further developing and certifying the tank, while the HYCE joint venture has begun making a 64-litre, 700-bar vessel for on-board hydrogen storage, providing extended range for fuel-cell vehicles and further building interest in hydrogen's potential as a clean and commercially viable transport solution.

**The commercial success of fuel-cell-powered vehicles hinges on achieving ranges and refuelling times comparable to internal combustion engine cars at an affordable price. Research supported by the FCH JU has helped address these challenges through the development of high-performance, cost-effective hydrogen storage tanks.**


istockphoto.com/Tramino

# SAFE, AFFORDABLE, HIGH-TECH HYDROGEN TANKS

## KEY ACHIEVEMENTS

**150 > 80**
reduction in the number of parts in an on-board hydrogen tank

**6 kg > 3.5 kg**
weight reduction of hydrogen tanks valves achieved in COPERNIC

**20 %**
reduction in mass of composite material used for hydrogen tanks

**42 %**
reduction in composite winding time enabling mass production of hydrogen tanks

**EUR 600 PER kg OF HYDROGEN**
cost of hydrogen tanks developed in COPERNIC (assuming a yearly production of 8 000 units)

**5 kg OF HYDROGEN**
stored on-board in light-duty FCEVs

## IMPACT

**80 %**
reduction in the cost of hydrogen tanks achieved in the COPERNIC project

**18 % REDUCTION IN TANK COST**
of the total cost of a commercially available hydrogen car

**ENABLING NEXT GENERATION OF PRODUCTS**
trials show special shaped pressure vessels have 85-90 % structural efficiency

© FCH JU project TAHYA

## AFFORDABLE HYDROGEN TANKS

Range and refuelling times are important advantages of FCEVs over battery-powered vehicles but the cost of components must be addressed if FCH is to become a mainstream decarbonisation option in transport.

## INNOVATION OVERCOMES COMMERCIAL BARRIERS

By forging synergies among innovative SMEs, the FCH JU has supported the development of technological, material and manufacturing innovations. **The goal?** To address the high cost of fuel-cell-powered vehicles by improving manufacturing of on-board hydrogen storage tanks that offer better performance and safety, while contributing to EU leadership in the field. **Key results?** Rapid progress in addressing cost barriers means affordable hydrogen tanks are being manufactured and more hydrogen-powered cars will appear on the market sooner than expected.

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TRANSPORT

# MARITIME HYDROGEN: THE NEXT BIG WAVE

© FCH JU project MARANDA

## New fuel for an expanding market

Cargo vessels, cruise ships and ferries are all important parts of the global economy. For example, about 90 % of all freight goods are transported at sea. But most ships burn fossil fuels for power, emitting $CO_2$ and other pollutants. Ocean freight shipping alone releases about 3 % of global greenhouse gases, a figure which is predicted to grow as the maritime sector continues to expand. In April 2018, the shipping industry committed to a GHG target of reducing emissions by 'at least' 50 % by 2050. Achieving this target will require new ships, new engines and – above all – a new fuel.

## Clean fuel in cool conditions

Two FCH JU-funded projects are researching the use of hydrogen fuel cells to replace fossil fuels to power ships. The MARANDA project, which started in 2017, aims to develop a 165-kW fuel-cell powertrain able to provide power to a research vessel's electrical equipment and its dynamic positioning while in research mode, in the extreme cold of the Arctic. The FLAGSHIPS project is demonstrating that two commercial vessels, a push boat for river navigation and a passenger and car ferry, could operate on hydrogen fuel cells.

**The maritime sector includes activities as varied as cruise-boat tourism, freight shipping, and ferry transport. It is also a big contributor to $CO_2$ emissions. The FCH JU is promoting research to develop and integrate efficient, hydrogen-powered fuel cells on ships and boats. The results could help to slash $CO_2$ emissions by a minimum of 50 % by 2050 (which is the target defined by the International Maritime Organization).**

## Charting a new industry course

MARANDA's researchers have designed hydrogen-storage containers and a fuel-cell system that are currently being tested and improved before their integration on-board the ship. Meanwhile, representatives of the recently launched FLAGSHIPS project have met with vessel operators to discuss safety aspects of hydrogen applications on push boats for inland waterways. Once completed, both projects will disseminate their results widely to boost the market potential of fuel cells in the maritime sector. Hydrogen and hydrogen-based fuels have great potential to meet the same operational requirements (range, refuelling time) as conventional fuels for ships. This is the task for the FCH2 JU in the future.

# MARITIME HYDROGEN: THE NEXT BIG WAVE


## KEY ACHIEVEMENTS

**1**
megawatt of PEM fuel-cell power to be installed in both vessels in the FLAGSHIPS project

**3**
FC types suitable for maritime transport (low- and high-temperature PEM and SOFC)
(Study on the use of fuel cells in shipping, EMSA, 2017)

**21**
hydrogen boats/ferries put into operation or under construction worldwide

**70 %**
proportion of $H_2$ needed in the maritime fuel mix to reach an ambitious 80 % carbon reduction in 2035
(beyond 50% by 2050)
(Decarbonising Maritime Transport, OECD, 2018)

**2026**
creation of the world's first zero-emission zone at sea in the UNESCO heritage Norwegian fjords

**1.7 MtH2**
annual volume of $H_2$ consumed in nine industrial hubs around the North Sea

**250 MW**
announced size of the electrolyser in Rotterdam's harbour
(https://safety4sea.com/eus-biggest-hydrogen-plant-to-be-constructed-in-rotterdam/)

## THE UPSHOT

Hydrogen fuel cells can provide power for ferries, cruise ships and boats, lowering $CO_2$ emissions in the rapidly expanding maritime sector.

## WIDENING THE HORIZONS FOR HYDROGEN FUEL CELLS

To increase the market potential of hydrogen fuel cells in the maritime sector, JCH JU brought together vessel manufacturers and operators. **The goal?** To demonstrate that hydrogen-fuel-cell technology can power ships and boats whilst also withstanding the shocks, vibrations and saline environments of maritime use. Two FCH JU-funded projects will demonstrate hydrogen-fuel-cell power. **Key results?** Outcomes will show that hydrogen fuel cells can compete with their fossil-fuel equivalents, enabling the broader market adoption of this technology and cutting greenhouse gas emissions.

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
https://www.vtt.fi/sites/maranda/
https://flagships.eu

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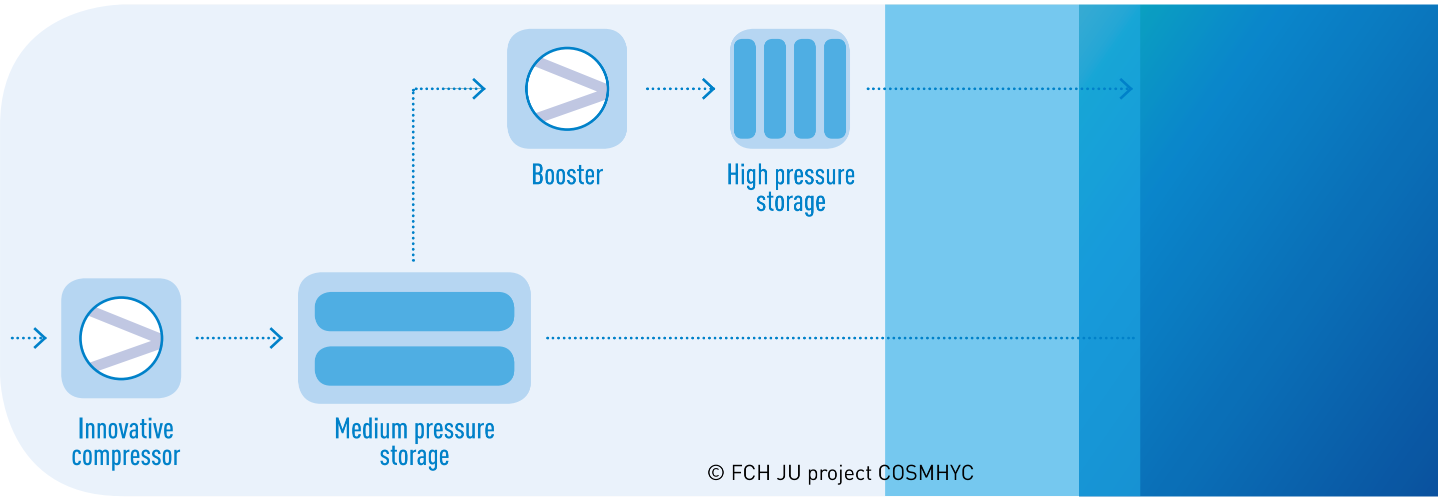
# BRINGING HYDROGEN COMPRESSION TO THE NEXT LEVEL



© FCH JU project COSMHYC

**Hydrogen-fuelled vehicles could help the drive to a greener European future. But to be used as vehicle fuel, gaseous hydrogen must be compressed at refuelling stations. Funding from the FCH JU has led to new technologies that will significantly facilitate hydrogen compression, providing better refuelling stations offering transport an attractive renewable fuel.**

## Greater efficiency and reliability

Hydrogen is usually produced at low pressure and must be compressed before it can be used at a hydrogen refuelling station. Current compressor technologies are expensive and energy consuming, thereby reducing the efficiency of hydrogen mobility. Therefore, breakthrough solutions to increase the efficiency of hydrogen compressors are needed. Two FCH JU-financed projects are aiming to make hydrogen compression more flexible and reliable, reducing costs for customers at the fuel pump.

The COmbined hybrid Solution of Multiple HYdrogen Compressors (COSMHYC) project, launched in 2017, is developing and testing a hybrid compression system which combines a mechanical compressor with a compressor based on metal hydrides. This innovative solution contains no rare earth material, reduces maintenance and operating costs while achieving top performance levels.

## COSMHYC goes heavy-duty

A follow-up project, COSMHYC XL, is extending this new technology to extra-large refuelling stations. It will develop a hybrid compression concept suitable for heavy mobility operations such as trucks, buses, regional trains and taxi fleets. Industry partners for both projects are targeting a short time-to-market period after a variety of long-term tests on the prototypes. In addition, a technical economic assessment and exploitation plan will help industry to adopt the new compressor technology.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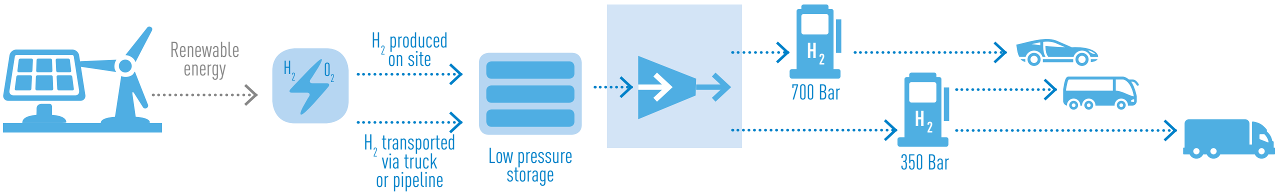
## COMPRESSION FOR CLEAN AND EFFICIENT HYDROGEN MOBILITY




## KEY ACHIEVEMENTS

**THE MANUFACTURE OF RARE-EARTH-FREE METAL HYDRIDES**
providing the right properties and performances for hydrogen compression

**OPTIMISED SYSTEM INTEGRATION**
specifically adapted to maximise metal hydride compression performance while matching end-user requirements

## IMPACT

**BELOW 60 DB**
compressor noise level at 5 metres

**20 %**
overall reduction in hydrogen costs

**20 %**
increased energy efficiency of the compression process

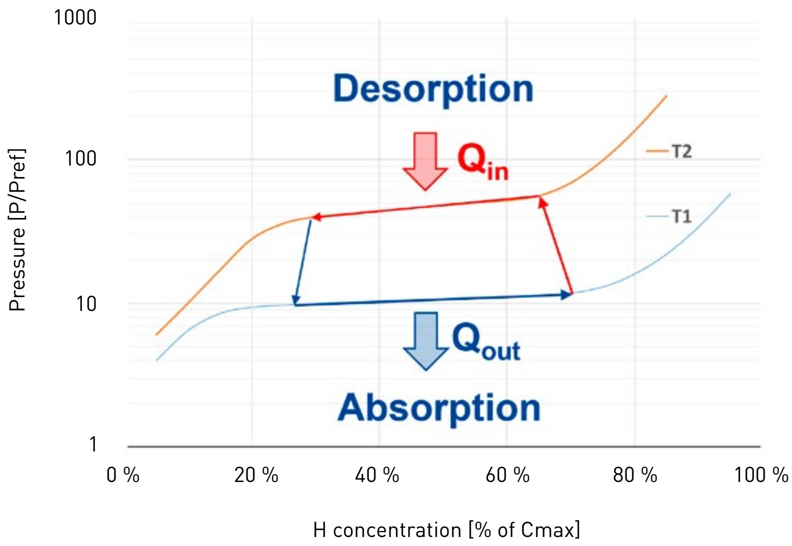
**UP TO 50 %**
reduction in maintenance costs for hydrogen refuelling

## WHAT'S AT STAKE?

Advanced hydrogen compression technologies increase the energy efficiency of compression and enable reductions in hydrogen costs at the refuelling station.

## ACTION STATIONS!

To find better ways to compress hydrogen at refuelling stations, the FCH JU brought together manufacturers, innovators and operators. **The goal?** To develop cutting-edge hydrogen compression technologies to enable reliable and cheaper hydrogen refuelling. **Key results?** Outcomes include an innovative compression solution based on metal hydrides which offer the best performance for compression, without using rare earths. The new metal hydride compressor is combined with a new mechanical compressor to provide various compression levels.

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# DRIVING FORWARD FUEL-CELL TECHNOLOGY


© FCH JU project INSPIRE

## The price dividend

Fuel-celled cars remain expensive, partly because the technology behind them is still relatively costly. Driving down those costs while enhancing performance are among the main goals of the FCH JU, which is helping to stimulate market growth and get greener vehicles on to Europe's roads. FCH has paired top expertise from academia and the industry to drive its goals forward.

The FCH JU has funded projects such as VOLUMETRIQ, PEGASUS, CRESCENDO and GAIA to design and develop solutions to make proton-exchange membrane fuel cells a lot more affordable.

## Cost-efficient

One way to make fuel cells more affordable will be to reduce the use of expensive materials (e.g. platinum for the catalysers). Several projects have been investigating how to reduce or completely displace such material while ensuring that the cells' key performance indicators (power density and durability) continue to improve.

Innovative manufacturing techniques with reliable embedded quality controls are another approach being pursued by the FCH JU to increase EU capacity for the production of polymer electrolyte membranes (PEM). Overall, the goals are to lower manufacturing costs, ensure sufficient capacity to meet projected future market demands, and respecting the automotive industry's demanding quality standards.

**Fuel-cell technology is still a relatively expensive exercise for the automotive industry.**
**The FCH JU has brought together industry and university experts to drive down costs and increase performance.**
**The aim is to pry open market potential, ensuring a greener future for the EU's transport sector.**


© Johnson Matthey PLC

## KEY ACHIEVEMENTS

**REDUCTION OF -80 % IN PT LOADING (FROM 1.5 G/kW IN 2008 TO AVG. 0.3 G/kW IN 2017)**
ensuring lower costs for membrane electrode assembly

**DURABILITY**
over 5 000 hours

**1.55 W/cm²**
Single cell power density target in 2020

**POWER DENSITY: 1W/cm² WAS THE 2016; 1.3 W/cm² WAS ACHIEVED IN 2017**
resulting in shorter, lighter and cheaper stacks for the same power output.

## IMPACT

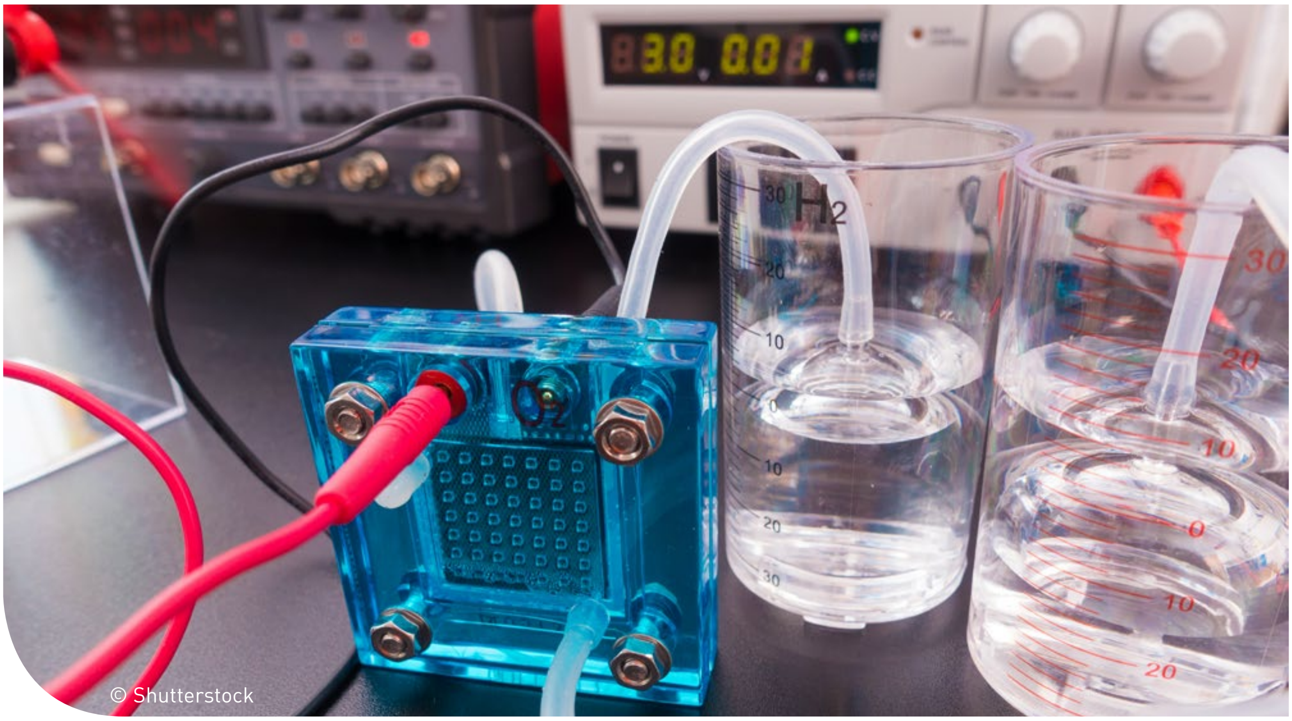
**140 EUR MILLION FUNDING TO DRIVE DOWN COSTS AND INCREASE PERFORMANCE**

## TOO EXPENSIVE

Fuel cells stacks are expensive, creating obstacles to marketing and commercial entry for a globally competitive automotive industry in Europe.

## MORE FOR LESS

FCH JU is trying to stimulate market growth in an area of high potential by supporting research that tackles key commercial problems. **The goal?** The goal is to develop the projects by bringing together key industry and academic experts to drive down the costs behind the technology. **Key results?** FCH JU funded projects have so far demonstrated that it is possible to reduce costs of fuel cell production while improving performance durability for large-scale automotive fuel cell commercialisation.



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www.fch.europa.eu/page/fch-ju-projects
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# HYDROGEN DRIVING SHIFTS INTO GEAR


© Microcab

## In the real world

Hydrogen-powered vehicles produce only water vapour as waste and will complement battery electric vehicles with lower $CO_2$ emissions across Europe. But real-world demonstrations and upfront investment were required to test this emerging technology in practical driving conditions.

A project co-financed by the FCH JU – Demonstration of Small 4-Wheeled fuel cell passenger vehicles Applications in Regional and Municipal transport (SWARM) – showed that hydrogen-powered vehicles are both practical and powerful. Launched in 2012 and completed in 2017, SWARM helped UK SMEs to develop and deploy a fleet of small hydrogen-powered passenger vehicles. One of these SMEs has developed a new business model to offer their clients in rural Wales, UK, clean transport services using their vehicle. The other one is looking for investors or partners to take their vehicle to the next stage of development or manufacturing.

## Powering through

The project brought together research centres, new SMEs and other larger industrial stakeholders which allowed, through intense collaboration, the development, manufacturing and testing of three concept car models, two of which have already been their second-generation products and have been deployed in a small fleet of 11 vehicles. The vehicles have been tested in various European regions, from Wales to North-western Germany. A fleet of one of the vehicles will soon manufactured and used in an innovative clean transport services business model in rural Wales. The other one is seeking investors or partner to move to the next stage of development or manufacturing. With the capacity to be built in two configurations, four sitter for taxi purposes or two sitter with cargo capacity for small logistic purposes, we might soon see it in our roads.

**Not long ago, the idea that hydrogen-powered vehicles would some day cruise along European roads was mainly 'hot air'. However, the FCH JU has co-funded a project which helped two UK SMEs develop and demonstrate their concept hydrogen-powered vehicles to bring them closer to commercialisation.**
**One of these SMEs will use their fleet of vehicles in a new business model offering transport services to their clients in rural Wales. The other one is looking for investors or partners to take their vehicle to the next stage.**

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## KEY ACHIEVEMENTS

**3**
new refuelling stations added to existing networks

**1**
SME in negotiation to mass manufacture their vehicle

**3**
new small hydrogen-powered passenger vehicle models

**13**
vehicles built or demonstrated in the project

**1**
new business model offering transport services in rural communities;

**0.54**
kg H2/100km for the Microcab

**750**
kg weight of the Microcab

## WHAT'S AT STAKE?

SMEs demonstrate the feasibility of small hydrogen-powered vehicles on European roads to help accelerate transition to a zero-emissions transport sector.

## THE ROAD TO SUCCESS

The FCH JU worked with universities and SMEs to lay the foundations for the development and manufacturing of small hydrogen-powered vehicles. **The goal?** To enable these stakeholders to make the key technical innovations necessary for such vehicles to be available for new zero-emission transport services for European customers. **Key results?** The FCH JU-funded project included a demonstration phase that uncovered many of the requisite innovations that helped to improve later generations of vehicles. The project also financed the necessary hydrogen refuelling stations to test the vehicles and the business model.

## IMPACT

**UP TO 100 %**
savings on CO2 emissions compared to conventional vehicles

**EUROPEAN SMES DEVELOPED THE FIRST PILOT FCEVS IN EUROPE**

Making an impact on the clean energy transition

TRANSPORT

# HYDROGEN-POWERED TAXICABS CRUISE INTO EUROPE'S CITIES

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**Fuel cell electric vehicles (FCEVs) show great promise in reducing $CO_2$ emissions, particularly within European cities. Powered by hydrogen, FCEVs have short refuelling times, and the only waste they produce is water. But their novelty and a lack of refuelling stations have discouraged captive fleet operators such as taxi companies from adopting them. Now the FCH JU is working with industry leaders and municipal authorities to bring vehicles such as taxicabs and police vehicles on to our streets.**

## $H_2O$ instead of $CO_2$

FCEVs have a vital role to play in European cities striving to reduce urban pollution. The FCH JU is helping Paris, Brussels and London to adopt a new business model that incorporates FCEVs into taxicab fleets. The fast refuelling times of FCEVs allows for a high intensity of usage which is not feasible with electric battery vehicles.

Three FCH JU-financed projects have helped promote the adoption of FCEVs in European cities: Zero Emission Fleet vehicles for European Roll-out (ZEFER), Hydrogen Mobility Europe (H2ME), and Hydrogen Mobility Europe 2 (H2ME 2). In Paris, STEP taxi fleets will deploy 60 FVECs. In Brussels, BREATH taxi fleets will use 60 hydrogen vehicles. In London, Green Tomato Cars will adopt 60 vehicles and the Metropolitan Police will use 10. To date, these projects have resulted in 1.7 million kilometres driven and 200,000 kilograms of $CO_2$ not emitted.

## Tomorrow's fuel, today

In cooperation with the FCH JU, these projects provide a 'complete package' for hydrogen taxi services: the vehicles themselves, the hydrogen refuelling station network they require, the ride-booking system, and even taxi licensing. Held in demanding conditions, these project demonstrations are raising awareness that hydrogen-powered vehicles are ready for widespread use. FCEVs are matching both city expectations for improved air quality and commercial expectations from taxicab operators.

## KEY ACHIEVEMENTS

**250+**
taxis to be deployed in fleet operation including London, Paris and Brussels

**4 000 TO 6 000 km**
travelled by each taxi every month in Paris

**130 000**
expected FCEV mileage in km/year in London, Paris and Brussels

**385 TO 700**
new FCEV driving range in kilometres from one full tank of hydrogen

## IMPACT

**STRONG POTENTIAL FOR DECARBONISATION**
Taxis represent 5% of the European local public transport

**12,000**
customers per day is the potential capacity to be served through 250 deployed taxis

**3 TO 5**
minutes required to fill a new FCEV's tank

**200,000**
kilograms of $CO_2$ not emitted from 2017 until 2018

**1.1 MILLION**
kilograms of $CO_2$ per year can be saved when full deployment of 250 taxis

**2025**
when a mature, self-sustaining market for FCEVs is expected to be created

## CLEARING THE AIR

Hydrogen-fuelled taxicabs will lower $CO_2$ emissions in European cities, reduce other forms of pollution and help to create and promote a circular economy.

## THE FUTURE IS CLEAN

The FCH JU has collaborated with industry operators and public authorities to ease the adoption of hydrogen-powered taxicabs in European cities. **The goal?** To create a 'complete package' business model that encourages FCEV use in captive fleets such as taxicabs. **Key results?** Some 180 FCEVs will be deployed in Paris, Brussels, and London in taxicab and municipal police fleets. Potential customers – both captive fleet operators and individual vehicle owners – are starting to realise that FCEVs are safe, reliable and practical.

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FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
**ZEFER** https://zefer.eu
**H2ME AND H2ME 2** https://h2me.eu

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@ZEFER_EU
@H2ME_eu

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING
A partnership dedicated to clean energy and transport in Europe

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TRANSPORT

# TAKING $CO_2$ OUT WITH THE RUBBISH

© E-trucks

## Clean power for big rigs

In Europe, around 16.5 million lorries transport freight on our roads and carry out public services like refuse collection in our cities. Such trucks are also responsible for 27 % of $CO_2$ road transport emissions, although they represent only 4 % of all road vehicles. With road freight traffic expected to grow 56 % by 2050, effective measures are needed to move the EU towards decarbonising its lorry sector.

The FCH JU is co-financing two projects testing hydrogen-powered lorries focusing on zero $CO_2$ emissions. The H2Haul project will demonstrate that large fuel cell trucks can carry freight in long-haul traffic with driving ranges, refuelling times and load capacities comparable to diesel lorries. The Refuse Vehicle Innovation and Validation in Europe (REVIVE) project will operate 15 fuel-cell trucks as dustbin lorries in 7 European cities, aiming to reduce the environmental impact of transport from pollutants, noise, etc.

**Heavy-duty transport vehicles are disproportionately large contributors of $CO_2$ emissions. Now two FCH JU-funded projects are set-up to demonstrate that such vehicles can run on hydrogen, generating water vapour rather than $CO_2$ and supporting EU moves towards decarbonising the truck sector.**

## Fit for purpose

Conventional heavy-duty vehicles transporting freight in Europe average between 70 000 to 140 000 kilometres a year. For every kilometre they travel, these lorries can emit 690 to 1080 grams of $CO_2$. Conversely, fuel cell trucks release no $CO_2$ emissions and create fewer vibrations and almost no noise. Since they produce no particulate emissions, such as sulphur oxides, FC trucks will improve air quality in our cities. The H2Haul and REVIVE projects will help to overcome the technical and administrative obstacles preventing heavy-duty vehicle manufacturers and transport operators from entering the FC market, paving the way for widespread deployment in Europe.


© FCH JU project DESTA

## LIGHT GAS FOR HEAVY-DUTY USE

Hydrogen-powered heavy-duty vehicles can cut $CO_2$ road transport emissions while performing as well as conventional vehicles.

## MAKING HYDROGEN THE NEW TRANSPORT NORMAL

To demonstrate the practical uses of hydrogen-powered heavy-duty vehicles, the FCH JU formed an alliance between manufacturers, municipal authorities, and operators. **The goal?** To remove technical and administrative barriers to the intensive use of these vehicles for tasks such as long-haul freight transport between cities and refuse pick-up within them. **Key results?** The projects will show that hydrogen-powered heavy-duty vehicles are safe, practical and cost-effective. Spill-over effects from anticipated technological advances will boost the broader fuel-cell transport sector.

## KEY ACHIEVEMENTS

**15**
Hydrogen-powered dustbin lorries supported by the REVIVE project

**16**
Hydrogen-powered lorries designed, built and tested by the H2Haul project

**11**
Number of sites across Europe where REVIVE and H2Haul lorries will operate

**0 g**
of $CO_2$ emitted per km by hydrogen-powered lorries (assuming hydrogen deriving from renewable energy sources) vs **690 - 1 080** g by conventional lorries

**15**
project partners, including municipalities, operators and manufacturers

## IMPACT

**4 %**
of all vehicles on the road are heavy-duty trucks

**56 %**
increase in road freight traffic predicted between 2010 and 2050

**STRONG POTENTIAL FOR DECARBONISATION**
(27% of total road transport emissions are emitted by heavy-duty vehicles)

**STRONG POTENTIAL FOR EU LEADERSHIP**
600 000 European SMEs in the heavy-duty vehicle sector and 6.5 million Europeans employed

**17 000 UNITS COULD BE PRODUCED IN EUROPE BY 2030**
equivalent to EUR 220 million European production value

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

**Making an impact on the clean energy transition**

ENERGY

# HYDROGEN AND RENEWABLES: A MODEL FOR DECARBONISATION

© FCH JU project BIG HIT

## Zero-waste energy

With more than 1 000 wind, wave and tidal energy installations serving 10 000 households, the Orkney Islands have one of Europe's highest levels of renewable energy use. In fact, so much renewable energy is generated that it can exceed the capacity of the electricity grid: over 30 % of the potential annual output of wind turbines on the islands of Shapinsay and Eday is being lost.
The FCH JU-funded BIG HIT project is implementing an innovative solution. Renewable energy is powering electrolysers to generate hydrogen. This green hydrogen fuels vehicles, powers ferries while docked and heats buildings, including a school and community centre.

## Sharing and inspiring

The project's ultimate goal is to create the world's first replicable 'hydrogen territory' whereby low-carbon energy solutions are enabled by renewable power sources resulting in a fully integrated model of hydrogen production, storage, transportation and utilisation for heat, power and mobility. The model's replication potential for isolated territories will be key. Dissemination and knowledge sharing will be achieved through a 'remote territories platform' to showcase and support upscaling this solution for larger territories. Thus, the project's impacts will go far beyond the Orkney Islands, inspiring other regions to transition to a low-carbon future powered by renewables and supported by hydrogen.

**Scotland's Orkney Islands are a test case for a low-carbon future. An FCH JU project is converting excess electricity from renewables in the remote archipelago into clean hydrogen to power vehicles, buildings and ships, demonstrating a realistic alternative to fossil fuels and inspiring other European regions.**

## KEY ACHIEVEMENTS

**50 TONNES**
of hydrogen will be produced each year using excess energy from renewables

**1 MW**
electrolyser installed on Shapinsay Island to convert excess electricity into hydrogen

**0.5 MW**
electrolyser installed on Eday Island to convert excess electricity into hydrogen

**75 kW**
hydrogen fuel cell in Kirkwall to supply heat and power for several harbour buildings, a marina and three ferries, when docked

**5**
hydrogen fuel-cell vehicles operated by the Orkney Islands Council

**30 kW**
hydrogen catalytic boiler installed at a primary school on Shapinsay Island

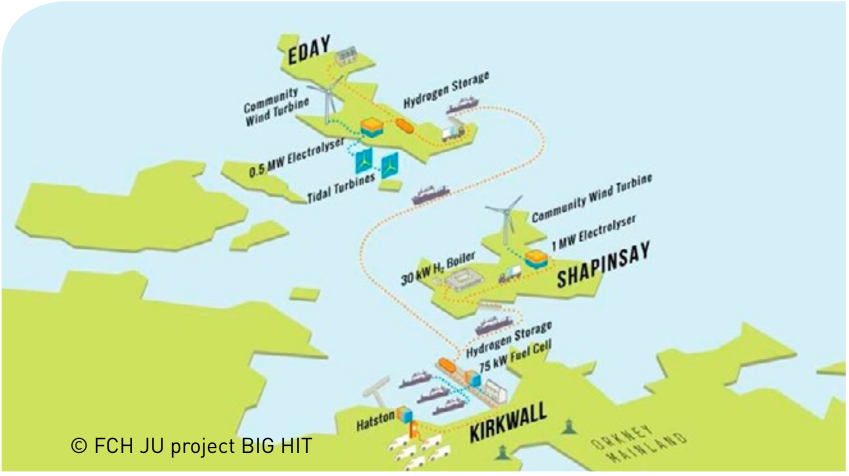
## IMPACT

**2.7 GWh / YEAR**
conversion of curtailed wind and tidal energy into hydrogen

**330 TONNES/YEAR**
rduction of $CO_2$-equivalent emissions

**EUR 2.5-3 / kg**
forecast cost of green hydrogen under optimised conditions

**12**
partners from across Europe participating in BIG HIT



© FCH JU project BIG HIT

## OVERCOMING GRID-CAPACITY CONSTRAINTS

By harnessing excess renewable energy that would otherwise be wasted due to grid constraints to generate green hydrogen for heating buildings and fuelling vehicles, a hydrogen territory is being created in the Orkney Islands which can be replicated elsewhere.

## A REPLICABLE ENERGY MODEL

The FCH JU collaborative project BIG HIT brings together 12 European partners aiming to learn from the results and apply a similar energy model locally. **The goal?** To create the world's first replicable hydrogen territory that demonstrates the feasibility of using excess renewable energy to generate hydrogen for other applications. **Key results?** A novel low-carbon energy solution enabled by renewable power sources and a fully integrated model of hydrogen production, storage, transportation and utilisation applicable to other regions worldwide. Locally produced hydrogen can contribute to a region's energy independence, and boost local skills, jobs and economic growth, while reducing pollution and improving quality of life.

Making an impact on the clean energy transition

ENERGY

# EXPANDING FUEL-CELL APPLICATIONS FOR GREENER INDUSTRIES

© FCH JU project DEMOSOFC

## Clean, circular energy

The concept of a circular economy has gained significant prominence, becoming more widespread and pervasive over the last 10 years. Taking into account the whole product life cycle, the circular economy offers an alternative model that promotes reuse, repair, refurbishment and recycling, recuperating rare raw materials and transforming waste into a resource. The FCH JU is also supporting projects in line with the circular economy as fuel cell technologies enable the production of clean energy from fuels resulting from waste treatment.

## Fuel cells at the core of energy transition

The DEMOSOFC project is bringing into operation the largest biogas-fed fuel cell plant in Europe. The waste-water treatment process generates sludge, normally treated as a waste. Thanks to the biological anaerobic digestion, sludge is turned into biogas comprising methane and carbon dioxide. In Italy, a 174 kWe system[1] consisting of three modular solid oxide fuel cells recovers the biogas produced by Turin's waste-water treatment and uses it to generate zero-emission energy.

Most waste water in Europe and beyond is treated in facilities with a technical biogas potential below 500kWe. Fuel cells offer much higher power conversion efficiencies and are also cleaner than conventional technologies as they do not rely on combustion. This project also exemplifies the increasing range of fuel-cell applications, and their attractiveness within the service and small industry sectors.

[1] 2 of the 3 modules adding to a total of circa 100 kWe already installed and running.

**Fuel cell hydrogen technology can play an important role in greening the service and industry sectors in support of a circular economy. FCH JU projects are developing innovative solutions for waste-to-energy conversion and to help the transition to a carbon neutral future.**

**The focus now is on scaling up the technology, improving performance and reducing costs, along with applying these solutions to meet circular economy goals through system-wide innovation.**

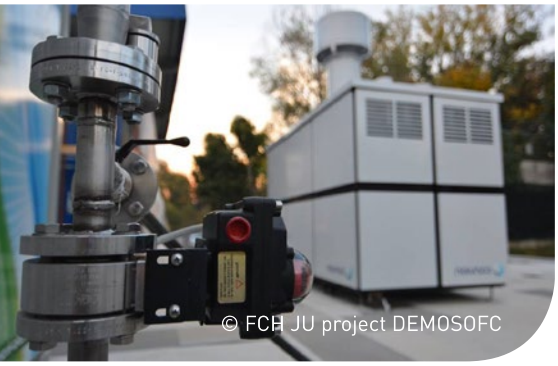
© FCH JU project DEMOSOFC


## FCH TECHNOLOGY, THE NEXT LEVEL

By scaling up fuel-cell technology, the aim is to improve performance and reduce costs to meet the needs of different applications. The FCH JU is also supporting research activities for cutting the costs associated with conditioning the biogas product.

## MANY APPLICATIONS, MUCH POTENTIAL

Supporting a first-of-its kind installation, the FCH JU is showcasing the benefits of fuel cells in reducing pollution and carbon emissions. **The goal?** To increase interest and scale up the technology while cutting costs. **Key results?** The fuel-cell plant generates zero-emission energy as it is $CO_2$ neutral and emits no contaminants into the air. The replication potential for this type of installations is significant: it is estimated that 90 % of the waste-water treatment plants in Europe could use the same technology. In addition, this and other FCH projects have led to the development of the next generation of the technology, which will be demonstrated in the later stages of DEMOSOFC.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## KEY ACHIEVEMENTS

**FIRST-OF-ITS KIND INSTALLATION**
largest biogas-fed fuel-cell plant in Europe

**ZERO CARBON EMISSIONS AND CONTAMINANTS**
released from electrical and thermal power generated by DEMOSOFC's SOFC plant

**>50 % NET ELECTRICAL EFFICIENCY**

**85 % COMBINED HEAT AND POWER EFFICIENCY**
exceeding power efficiencies achievable with conventional CHP technologies of the same size

**>7 000 HOURS OF OPERATION**
reaching availabilities of up to 91 %

**EUR 4.5 MILLION OF EU FUNDING FOR THE FUEL CELL**
with additional regional funds providing the biogas clean-up unit

## IMPACT

**MORE THAN 26 800**
Waste-water treatment sites in Europe (90 % of the total) could use the waste-to-energy technology being developed in the DEMOSOFC project

**20 GWe MARKET POTENTIAL BY 2030 OF FUEL CELLS OF 5 TO 100 KWe**
equivalent to EUR 1 200 million European production value

**NEXT GENERATION OF THE FUEL-CELL TECHNOLOGY AVAILABLE**
achieving better performances and lower costs

# A GAME CHANGER IN EUROPE'S RENEWABLE LEAD


## An electrifying future

Electrolyser technologies are key to the production of green hydrogen, paving the way for the greening of industry, transport and heating sectors through the increased penetration of renewable energy. Electrolysers are commercially available today, however the development of more efficient, more dynamic and cheaper electrolysers like proton exchange membrane (PEM) electrolysers or Solid Oxide (SO) electrolysers remains a challenge.

The FCH JU is taking a two-pronged approach to promoting break-through solutions in PEM and SO electrolysis technology. It is supporting the development and demonstration of the largest innovative electrolysers worldwide while focusing on reducing costs and boosting performance. FCH JU-funded research projects – like NEPTUNE, PRETZEL, GAMER and REFLEX – are now driving Europe's global leadership in the field.

## Innovating hydrogen

Europe is already a world leader in low temperature PEM and high temperature SO electrolysis, aiming to develop green hydrogen as a key energy carrier for the implementation of renewables in the EU's energy transition. Europe has published twice as many publications and patents on PEM electrolysis as the United States. Likewise, EU patent and publication leads are also significant in the field of solid oxide electrolysis development, a process in which an electrochemical device generates hydrogen utilising waste heat, thus achieving even higher efficiencies. Alongside research into innovative renewable energy storage solutions, the FCH JU is moving Europe into pole position in electrolyser technologies.

**Electrolysers generate renewable hydrogen through a process whereby renewable electricity splits water into hydrogen and oxygen, to the benefit of the environment and fighting climate change. The FCH JU is supporting the development of cutting-edge research projects in the field, turning Europe into a global leader in the field of renewable energy technologies**

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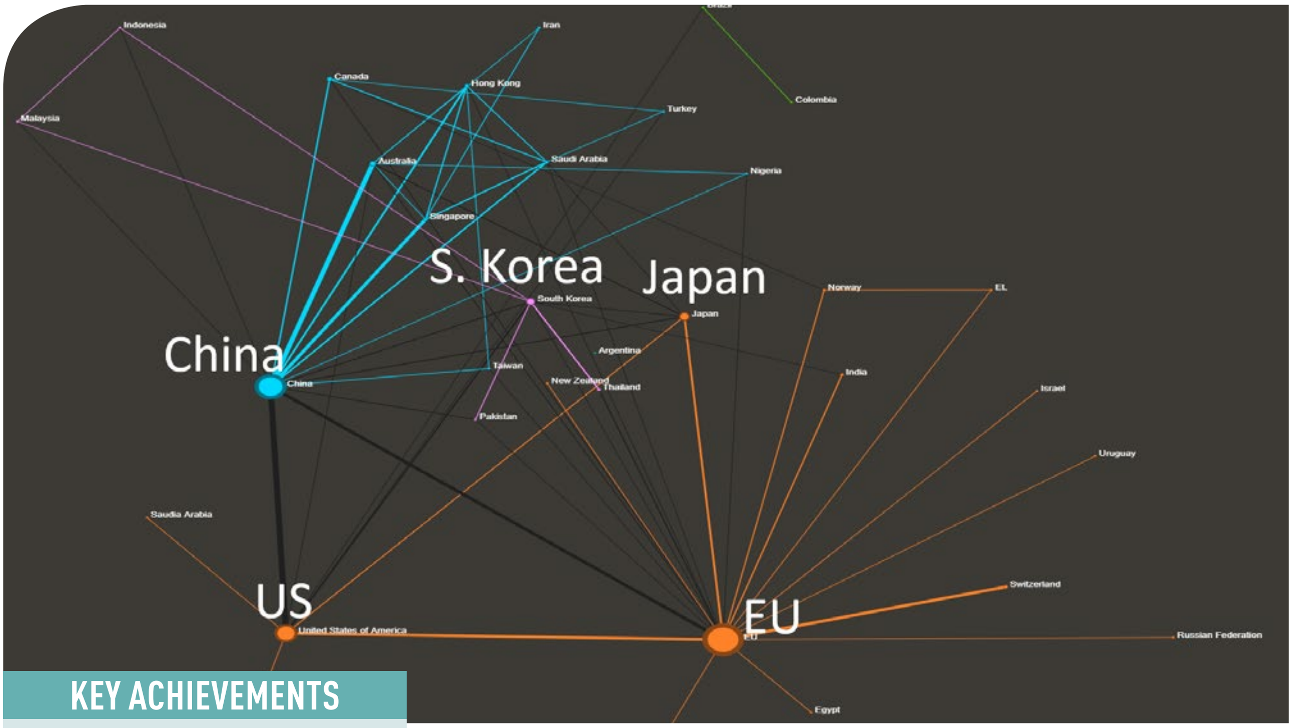


## KEY ACHIEVEMENTS

**UP TO 8 A/CM2**
electrolyser current density targeted in projects

**AT LEAST 11 000 HOURS**
total duration of electrolyser operation across the various research projects

**LESS THAN 50 kWh PER kg HYDROGEN**
energy requirement target in NEPTUNE

## IMPACT

**823**
PEM electrolysis publications and patents in EU 2004-2017

**508**
solid oxide electrolysis publications and patents in EU 2004-2017

## AFFORDABLE, EFFICIENT AND RELIABLE

In light of the growing potential for renewable energy to combat climate change, electrolyser technologies must become more affordable, efficient and reliable before they can be rolled out on a large commercial scale.

## PUSHING LIMITS

FCH JU-supported projects are seeking to go beyond the current mix of state-of-the-art technologies for the commercial production of clean energy from electrolysers. By tackling issues currently limiting the full potential of electrolysers, the research is making a significant contribution to the EU's transition to a low-carbon economy. **The goal?** To ensure Europe continues to lead the world when it comes to innovative electrolysers and pushing the technology beyond what is currently possible. **Key results?** The plan is to further increase capacity, safety and performance and drive down the cost of electrolysers.

FIND OUT MORE

**NEPTUNE** http://www.neptune-pem.eu/
Will develop a self-pressurising 100 bar PEM electrolyser system of 48-115 kW

**PRETZEL**: http://pretzel-electrolyzer.eu/
Will develop a PEM electrolyser cell concept capable of 100 bar, with a system of 25 kW

**GAMER** https://www.sintef.no/projectweb/gamer/
Will develop a tubular proton ceramic electrolyser at 30 bar, with a system of 10kW

**REFLEX** http://www.reflex-energy.eu/

www.fch.europa.eu/page/fch-ju-projects

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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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ENERGY

# HYDROGEN FROM RENEWABLES: GREEN BACK-UP POWER

© WaterstofNet VZW

## Powerful, efficient electrolysis

Using excess electricity from renewables to split water molecules via electrolysis, the resulting green hydrogen can be stored in fuel cells to supply power as needed. For green hydrogen to be used as efficient back-up energy-storage, electrolysis technology must become flexible enough to be coupled with renewables in real world-conditions, and costs need to be cut. To address these challenges, the FCH JU is focusing on developing more powerful and efficient electrolysers, and demonstrating industrial applications for the technology to open up new markets. HPEM2GAS, ELY4OFF, PRETZEL and NEPTUNE are among 30 co-funded projects aiming to improve electrolysis technology. Other initiatives, such as H2FUTURE, have demonstrated the increasing power of electrolysers, highlighting their suitability particularly for energy-intensive heavy industries, and HyUnder which worked on efficient hydrogen-storage solutions.

## Clean energy storage

The European Commission's Energy Roadmap 2050's ambitious renewable energy targets could result in a 10-fold increase in demand for energy storage, with green hydrogen expected to play a key role. The FCH JU has put in place the building blocks to smooth the transition to renewables, showing that back-up power using green hydrogen is technically feasible and increasingly financially viable. Amid growing interest from industries, cities and regions, the point is now being reached where electrolysis is being adopted more widely as a clean energy-storage solution.

**Green hydrogen, produced by harnessing surplus electricity from wind and solar sources, is an important back-up power solution. The FCH JU is playing a central role in making this clean energy-storage technology more efficient and cost-effective.**

© WaterstofNet VZW

## KEY ACHIEVEMENTS

**5 900 %**
increase in power output of advanced, highly efficient, high pressure electrolysers from 2011 to 2016

**1 000 %**
forecast increase in demand for energy storage as a result of EU renewable energy targets

**142 M EURO**
FCH JU support for the development and demonstration of electrolysers

## IMPACT

**53**
projects to improve electrolysers

**30**
projects developing electrolysis for energy applications

**2.8 GW**
electrolysers potential to be installed in Europe by 2025 with a market value of 4.2 b Euro

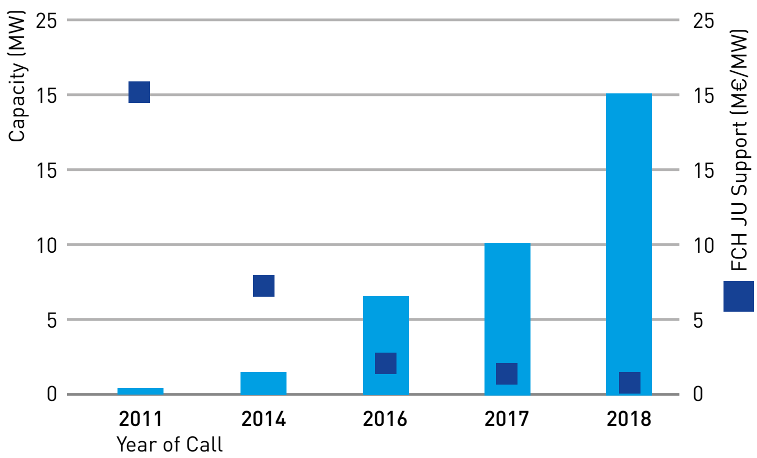
## ENERGISING ADOPTION OF CLEAN ENERGY STORAGE

Developing more powerful and efficient electrolysers and demonstrating the potential applications of green hydrogen will encourage the adoption of the technology as an emission-free energy-storage solution.

## DRIVING DEPLOYMENT THROUGH GREATER EFFICIENCY

To support wider deployment of green hydrogen as back-up energy storage, FCH JU projects use a unique public-private partnership structure enabling suppliers and end-users to work together, while promoting a long-term, strategic perspective on the sector. **The goal?** To increase sectoral interest and boost confidence in the technology by developing more powerful and more efficient electrolysers, alongside demonstrations of transport and industrial applications to open up new markets. **Key results?** A 5 900 % increase in the power output of advanced, dynamic electrolysers from 100 kW in the Don Quichote project in 2011 to 6 MW in H2FUTURE in 2016.

## USING GREEN HYDROGEN FOR ENERGY STORAGE AND SECTOR COUPLING

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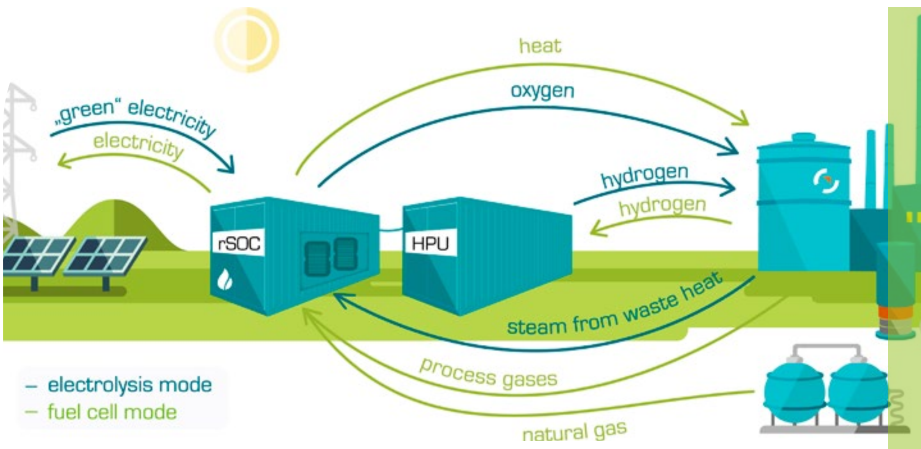
ENERGY

# MAKING STEEL GREEN THROUGH HYDROGEN




© FCH JU project H2FUTURE

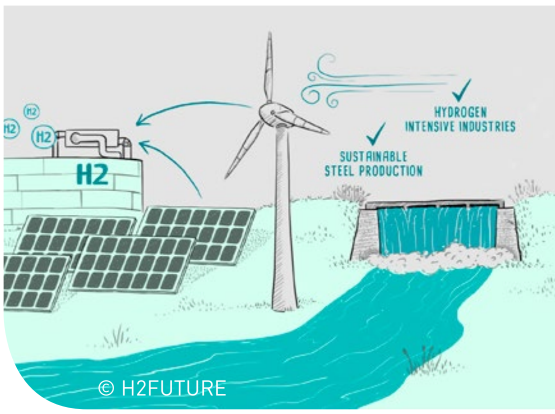
## Hydrogen in action

With global steel demand set to increase by around 6 % by 2030, greening the steel industry is essential for the energy transition. This will require the integration of highly volatile renewable energy resources, through the use of hydrogen technologies. For this reason, the European Hydrogen Roadmap identifies steel as the leading sector for new feedstock applications of hydrogen.
The FCH JU-funded GrInHy project spent three years developing the largest reversible solid oxide electrolyser in the world, and demonstrating its use for producing hydrogen for the surface treatment of steel. Additionally, project H2FUTURE has developed the largest low-temperature proton exchange membrane (PEM) electrolyser of 6 MW, and is using the resulting hydrogen for direct iron-ore reduction.

**Greening steel production will mean replacing fossil-based energy cycles with green hydrogen. By supporting technological advancements and demonstrating how hydrogen applications can be used for cleaner steel production and processing, the FCH JU is playing a pivotal role in decarbonising the industry.**

## Changing the landscape

The FCH JU is establishing the prerequisites for market uptake by creating reference sites, proving the feasibility of large-scale green hydrogen, and upscaling important technologies like high-temperature electrolysis.
By demonstrating the capacity of solid oxide electrolysers to produce high-efficiency hydrogen, the GrInHy2 project is paving the way for European industries to exploit waste industrial heat. H2FUTURE is assessing barriers to deployment with a view to discussing solutions with national and EU level policymakers. The long-term goal is to enable green electrolytic hydrogen to completely replace coke oven gas, making hydrogen a cost-effective solution for the steel industry.




© H2FUTURE

## TIME TO CHANGE

The steel industry accounts for 7% of global $CO_2$ emissions, making it an urgent target for decarbonisation.

## LET HYDROGEN HELP

The complex nature of steel production makes green hydrogen the most fitting solution for decarbonising the industry. The FCH JU is developing scaling and replication scenarios for environmentally friendly steel production using new electrolyser concepts. **The goal**? Facilitating broad-based and intense cooperation between steel and energy sectors, scientific and industrial partners, and national and European stakeholders, to demonstrate and upscale green hydrogen solutions for the steel industry. **Key results?** Proof that environmentally friendly steel production is possible using innovative hydrogen technologies.

## KEY ACHIEVEMENTS

### GrInHy

**FIRST HIGH-TEMPERATURE ELECTROLYSER (HTE)**
implemented in an industrial environment

**84 %**
electrical efficiency based on LHV of hydrogen for HT electrolysis system utilising steam from waste heat

**10000+ HOURS**
of operation for HT electrolysis system

**90 000 Nm3**
of hydrogen produced

**10 MINUTES**
time to switch from electrolysis to fuel cell (reversible) operation, showing the dynamic operation capabilities of solid oxide cell technologies.

**VERY LOW DEGRADATION RATE**
less than 1 % degradation per thousand hours of operation

### H2FUTURE

**6 MW**
largest atmospheric pressure PEM electrolyser to be developed and demonstrated

**1 200 CUBIC METRES**
of green hydrogen to be produced per hour

**26-MONTH-LONG TRIALS**
of the 6 MW electrolysis power plant

**80 % STACK EFFICIENCY**
reached for converting electricity into hydrogen

## IMPACT

### GrInHy

**10 % OF CURRENT HYDROGEN CONSUMPTION DISPLACED**
4 million m3 required per year for the annealing process on-site in the GrInHy project

**FIVE-FOLD SCALE-UP**
of electrolyser capacity in GrInHy2.0 planned

**LESS THAN 1 000 EUR / kW COST**
within five years based on comprehensive scale-up study

**150 MILLION TONNES OF $CO_2$ ABATEMENT PER YEAR IN THE EU**
now possible when using green hydrogen in the reduction process during steel production

**NOMINATED FOR 'BEST PROJECT INNOVATION'**
FCH JU Awards 2018

### H2FUTURE

**WINNER**
at FCH JU Awards 2018

**REPLICABILITY**
A 1 GW electrolyser would be required to provide the amounts of hydrogen necessary to fully convert a steel plant for direct iron ore reduction through hydrogen

**REINFORCED PLAUSIBILITY**
of the Hydrogen Roadmap

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
www.green-industrial-hydrogen.com
www.h2future-project.eu

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ENERGY

# HOME-MADE HEAT AND POWER

© Viessmann Group

**Fuel cell micro combined heat and power (μCHP) units enable homes to produce much of their own electricity, heat and hot water. The FCH JU has been instrumental in the development, testing and commercialisation of this cutting-edge clean and low-emission technology.**

## Low-emission, big benefits

Fuel cell μCHP units enable energy to be generated at the point of consumption by transforming natural gas into hydrogen to power the fuel cells. They can achieve combined heat and power efficiencies as high as 95 %, whilst cutting overall $CO_2$ emissions by 30-80 % with a reduced impact on local air quality. However, until recently, the technology faced several limitations: the fuel cells were large, expensive and required regular maintenance.
The FCH JU has supported the development of fuel cell μCHPs suitable for any home connected to the gas network, while demonstrating the benefits of the technology to consumers and industry on a wider scale. The co-funded project ene.field installed over 1 000 residential fuel cell μCHPs in nine EU countries. Furthermore, the PACE initiative is bringing domestic fuel cells closer to mass commercialisation by installing 2 800 units, enabling manufacturers to scale up production and reduce costs. These activities are encouraging national initiatives, which are supporting wider adoption of the technology – for example, Germany is aiming to have hundreds of thousands of units installed by 2025.

## In-demand decentralised energy

The decarbonisation of heating in the building sector – an EU energy policy priority – coupled with the roll-out of financial incentives for decentralised energy generation solutions are building confidence in the market and driving additional private investment. Thanks to the FCH JU's early support for research, the domestic deployment of fuel cell μCHPs is now a reality. A solid EU-based industry has been established, and new business models are being implemented, offering consumers innovative home energy solutions and driving growing demand for fuel cell μCHPs from manufacturers.

© Solid Power

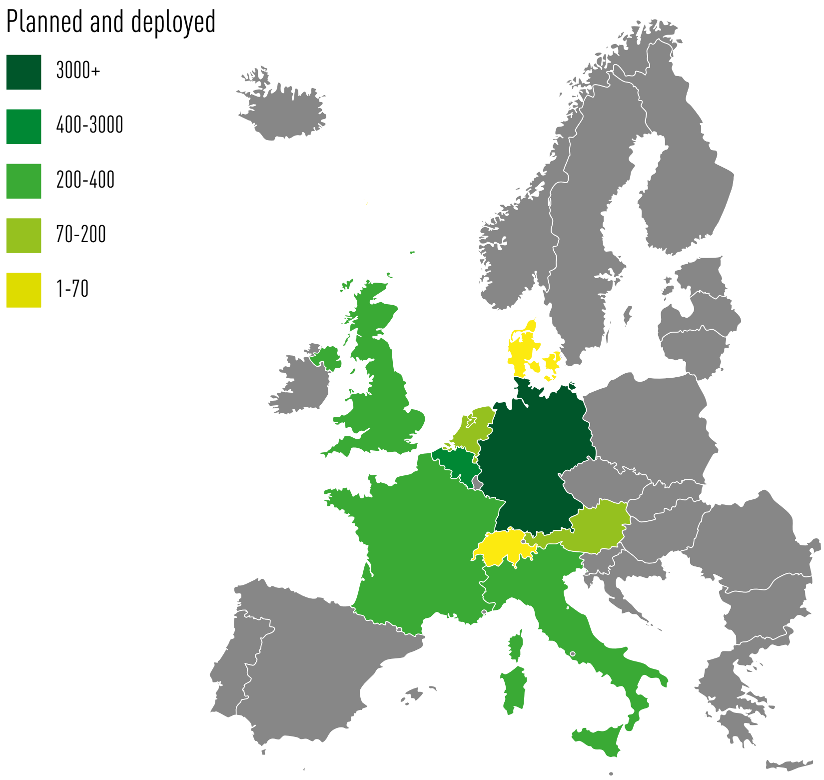
## DEVELOPING THE DOMESTIC FUEL CELL MARKET

The limitations of domestic fuel cell µCHP units are being tackled to build consumer confidence and drive down costs leading to the wider adoption of this clean and low-emission heat and power solution.

## BUILDING CONSUMER AND INDUSTRY CONFIDENCE

The FCH JU public–private partnership model allows SMEs to engage with key partners: utilities, energy services companies, house builders and local governments. This has enabled large-scale trials and demonstrations of domestic fuel cell µCHP technology. **The goal?** To address fuel cell µCHP cost, size and maintenance challenges, broadening the technology's appeal and increasing consumer confidence. **Key results?** Thousands of fuel cell µCHPs deployed in homes across Europe, a 30 % reduction in manufacturing costs through the scale-up of production and the development of innovative business models to drive market demand.

## MICRO-CHP DEPLOYMENT GEOGRAPHY




## KEY ACHIEVEMENTS

**95 %**
heat and power combined efficiencies of fuel cell µCHPs

**60 %**
electrical efficiencies of fuel cell µCHPs

**98 %**
availability with low maintenance and minimal downtime in ene.field

**UP TO 15-YEAR LIFETIME**
providing a secure supply of power and heat

**30 % REDUCTION IN FUEL CELL µCHPS CAPITAL COSTS**
achieved within the PACE project

**600+ INSTALLERS TRAINED ACROSS EUROPE**
preparing blue-collar workers for the energy transition

**EUR 149 MILLION**
total budget of FCH JU fuel cell µCHP projects

## IMPACT

**30-80 % REDUCTION IN $CO_2$ EMISSIONS**
compared to conventional boiler and grid power

**UP TO 40 % SAVINGS ON ENERGY BILLS**
thanks to efficient on-site generation of heat and power

**10 000+ UNITS SOLD IN EUROPE**
thanks to a combination of European and national initiatives

**ADDITIONAL INVESTMENT IN THE SECTOR**
a single OEM secured EUR 40 million investment to expand its production capacities in Europe and leading European heating equipment suppliers are offering FCH JU fuel cell µCHP solutions

**700,000 UNITS COULD BE DEPLOYED IN EUROPE BY 2030**
equivalent to EUR 400 M European production value

**FIND OUT MORE**

www.fch.europa.eu/page/fch-ju-projects
http://enefield.eu/
http://www.pace-energy.eu/

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@PACEmCHP

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

A partnership dedicated to clean energy and transport in Europe

ENERGY

# FAREWELL TO FOSSILS

© FCH JU project REMOTE

## The missing piece

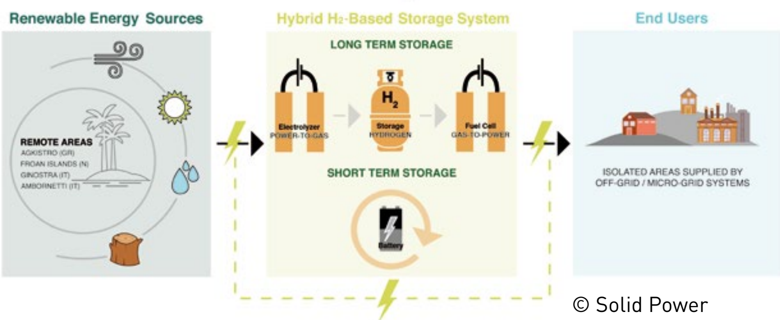
Many remote regions cannot be adequately integrated into a larger energy grid and must use alternative systems for energy storage and distribution. This means that those using renewables often rely on fossil-fuel generators to balance supply and demand. Producing hydrogen is a cleaner alternative for storing excess energy.

Two major projects are exploring and demonstrating this route. In a remote region of Norway, the FCH JU-funded Haeolus project is creating a new-generation electrolyser for installation inside the fence of a wind farm experiencing grid bottlenecks. With demonstrations in four isolated micro-grid or off-grid sites, the REMOTE project will showcase the technical and economic feasibility of using FCH energy storage solutions to create completely sustainable energy systems.

**The deployment of intermittent energy sources, like wind and solar, requires a system for balancing supply and demand. For regions that are not part of a larger energy system, this can be particularly problematic. The FCH JU is demonstrating how flexible hydrogen technologies can offer an environmentally friendly solution.**

## Microcosm

With the potential to compensate for fluctuations in renewable sources, FCH technologies could enable the EU-wide replacement of fossil fuels. To advocate for this, the FCH JU is not only showing how these technologies can revolutionise energy systems in remote regions, but publicly presenting the business case for electrolysers in wind farms as a means to avoid electricity distribution fees. The Haeolus project is exploring a number of operating strategies and creating a business case for hydrogen production that can be replicated in remote wind farms across the world.

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## LIGHTHOUSES BURN BRIGHT

The use of renewable energy resources presents specific challenges for remote regions, but the solutions can be applied across Europe.

## SHOWCASING SOLUTIONS

By resolving energy-storage challenges in remote regions, the FCH JU is demonstrating key tools for stabilising the energy grid. **The goal?** Bringing together FCH product manufacturers, both small and large, with renewable energy suppliers, energy storage providers, researchers and regional authorities, to show that sustainable energy systems can be developed. **Key results?** Demonstrating the use of hydrogen to create entirely sustainable energy systems based on renewables.

## KEY ACHIEVEMENTS

### HAEOLUS

**2.5 MW**
polymer electrolyte membrane (PEM) electrolyser, with a unique single cell stack, to be developed and deployed

**52 kWh per kg $H_2$**
energy consumption in line with FCH JU KPIs for 2020

**2 SECONDS**
for hot start-up, enabling effective grid balancing inside a wind park fence

### REMOTE

**4 REMOTE LOCATIONS**
Ginostra, southern Italy; Agkistro, Greece; Ambornetti, northern Italy; Froan Island, Norway

**4 DIFFERENT RENEWABLE ENERGY SOURCES**
solar PV, biomass CHP, hydroelectric, wind

**50 – 100 kW SCALE**
4 proof-of-concept power-to-power solutions

**4 USAGE CASES**
electrical power to communities, electrical power to industry, battery electrical storage, power to heat

## IMPACT

**3 CONTROL SYSTEMS DEVELOPED**
to address the challenges of the 3 main modes of operation identified by the International Energy Agency: electricity storage; mini-grid; fuel production

### REMOTE

**TOTAL 584 MWh ANNUAL ENERGY DEMAND ACROSS 4 SITES**
met entirely using renewable energy with the help of hydrogen storage

**65 000 LITRES PER YEAR FUEL SAVINGS**
on the island village of Ginostra in southern Italy

**100 % ENERGY AUTONOMOUS AGRIFOOD PROCESSING UNIT**
independent from the grid using the hydro plant and a hydrogen-based storage system in Agkistro, Greece

**100 % RENEWABLE POWER GENERATION**
provided for the mountain community of Ambornetti in northern Italy

**> 98 %**
power availability when wind energy is combined with hydrogen storage on the island of Froan, Norway

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
www.haeolus.eu
www.remote-euproject.eu

@fch_ju

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ENERGY

# DEMANDING A SUPPLY

© Elcogen

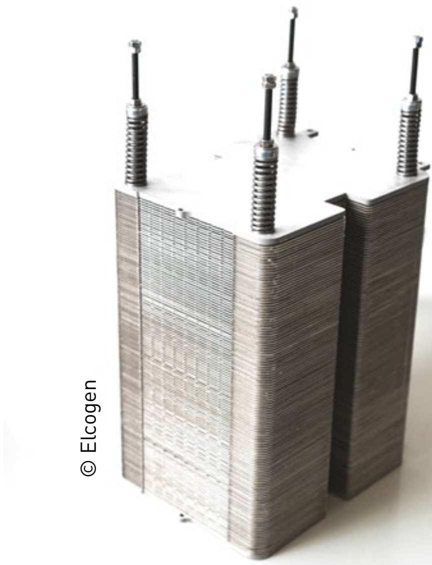
## Ready to roll

Power-to-gas and gas-to-power technologies play a key role in the energy transition. As the most efficient, flexible, durable and environmentally friendly of these technologies, solid oxide fuel cells (SOFC) and solid oxide electrolyser cells (SOEC) are valuable decarbonising tools for Europe. However, costly and time-intensive manufacturing processes are impeding their mass deployment and preventing them from reaching their full potential.
By 2017, the FCH JU-funded NELLHI project had developed a mass-producible, high-performance SOFC stack. More recently, projects like SOSLeM have increased performance and production speed, while the qSOFC project has reduced the cost of SOFC stacks by automating the manufacturing process. Now, the HEATSTACK project is working to cut the cost of the two most expensive components – the stack and the heat exchanger – by 60 %.

## The knock-on effect

The developments made in the solid oxide fuel cell industry has also led to the establishment of European companies as leaders in the sector of solid oxide electrolysis. Projects such as GrInHy are bringing the new technologies to the steel industry, while CH2P is using them in clean transport. Project breakthroughs have enabled manufacturers like SOLIDPOWER and Elcogen to expand production, further cutting costs. Leading manufacturer, Sunfire, plans to produce thousands of micro-CHP systems using new automated processes, while the REFLEX project uses new reversible solid oxide cell (rSOC) technology in a renewable energy storage solution. Looking more into the future, with the use of 3D printing, the Cell3Ditor project could enable the manufacture of SOFC stacks at unprecedented speed and scale.

**Solid oxide technology presents one of the most promising routes to a low-carbon economy. By funding the development of increasingly marketable, cost-effective and efficient technologies, the FCH JU is nourishing a thriving supply chain for the European solid oxide industry.**



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## TOOL FOR CHANGE

Although solid oxide technology is a valuable tool for decarbonising Europe's industry, transport, heating and energy sectors, it has yet to reach mass deployment.

## TAKING THE LEAD

The FCH JU is ensuring that Europe stays at the forefront of solid-oxide-based technologies by accelerating the development towards cost-effective mass production. **The goal?** To bring together leading technology providers in the supply chain with extensive industrial experts to advance the design and industrialisation of core manufacturing processes and exploit the results to open up new markets. **Key results?** European SOFC and SOEC manufacturers are expanding and upscaling.

## IMPACT

### Heatstack

**1 000 MICRO-CHP SYSTEMS**
to be produced using automated production from 2020

### qSOFC

**1-2.5 GW**
potential power from existing biogas using SOFC

**50 MW/YEAR EXPANSION**
of Elcogen production facilities

**Succesfull projects qSOFC and NELLHI contributed to Elcogen signing 12 million loan from European Investment Bank to expand manufacturing facilities to 50MW/year**

## KEY ACHIEVEMENTS

### Heatstack

**INCREASE IN MANUFACTURING SPEED AND QUALITY**
of the Cathode Air Pre Heaters

**REDUCTION IN STACK MANUFACTURING COST**
due to process improvements developed by Sunfire

### qSOFC

**RESEARCH & INNOVATION DAYS**
disseminating qSOFC's optical-recognition system for quality control

**500 €/kW STACK COST REDUCTION**
potential at 2 000 MW/year production volume

**200 €/kW CELL COST REDUCTION**
potential at 2 000 MW/year production volume

### SOSLeM

**70 % REDUCTION IN MANUFACTURING COSTS**
for fuel-cell cassettes

**CAPITAL COST DECREASED TO 3 700 €/kW**
The SOSLeM project was a key factor contributing to the new production plant currently under construction in Italy by SOLIDpower which will increase production capacity to 25MW/y initially and potentially up to 50MW/y, creating many new high quality employment opportunities.

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects

www.soslem.eu
www.heatstack.eu
www.qsofc.eu
www.demosofc.eu
https://ch2p.eu/

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ENERGY

# RESOURCEFUL WAYS WITH WASTE HYDROGEN

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## Home thoughts from abroad

Although fuel-cell applications have the potential to transform by-product hydrogen from some industry processes into energy that can replace fossil fuels, the cost of electricity in Europe is still too low to incentivise the implementation of this practice. The FCH JU is bypassing this by funding EU-led projects in regions with more favourable market conditions and supporting research leading to the next generation of fuel-cell power plants.
Located in a chlor-alkali factory in China, the DEMCOPEM-2MW project has helped European industry players to develop and demonstrate a successful system for converting industrial by-product hydrogen into electricity, heat and water for use in the production process. Similarly, the ClearGenDemo project is demonstrating a 1 MWe fuel cell at a refinery in the French overseas territory of Martinique using spare hydrogen in a refinery. With these flagship projects, the FCH JU intends to demonstrate large stationary fuel-cell systems for clean and efficient power and heat production in industry applications.

## Greener prospects

By demonstrating the successful use of waste hydrogen and developing lower-cost technologies, these overseas projects are helping fuel cells to become cost-effective choices in European industry. The technology developed by DEMCOPEM-2MW has been advanced by European companies. The 2 MWe fuel-cell system demonstrated in China has provided experience and know-how to support other applications in the maritime sector, for example. The Martinique refinery project has led to follow-up projects in other territories. To reduce costs further to make the technology commercially feasible in Europe, the FCH JU-funded Grasshopper project is developing the next generation of cost-effective multi-MW fuel-cell power plants.

**Some chemical and petroleum industries produce significant quantities of by-product hydrogen which could be transformed into energy using fuel-cell technology. By creating reference sites and developing increasingly efficient and cost-effective European technologies, the FCH JU is making energy from redundant hydrogen, that would otherwise have no value, a feasible solution for European and worldwide industry.**

## KEY ACHIEVEMENTS

### DEMOCOPEM-2MW

**MULTI-MWE FUEL CELL SUCCESSFULLY INSTALLED IN A CHLOR-ALKALI PRODUCTION PLANT**
first-of-its kind installation in a successful partnership with Chinese industry

**2 MWe FUEL CELL RECOVERING BY-PRODUCT HYDROGEN DEMONSTRATED OVER 2 YEARS**
870 tons hydrogen recovered
13+ GWh electricity,
7 GWh heat produced
15000 $tCO_2$ emissions avoided
50% net electrical conversion efficiencies and 85% overall net conversion efficiencies
availability of 95%+ for over 16 000 hours

**27 000 NEW MEAS**
designed and produced by European manufacturer

**TARGETED EXCHANGES WITH DECISION-MAKERS**
replication potential of 1+GWe in the chlor-alkali sector in China; viable business in other French overseas territories identified

**OPEN-SOURCE CALCULATION TOOL**
preliminary economical assessment of using by-product hydrogen with fuel cells

## IMPACT

**INCREASED COMPETITIVENESS OF EUROPEAN INDUSTRY**
new and improved MEA manufacturing process with lower platinum demands and longer lifetimes; stack platform developed also suitable for transport applications

**POTENTIAL TO ACHIEVE POWER PRODUCTION OF ~0.04 €/kWh**
at CAPEX <2 500/kWe

**OPENING-UP NEW MARKETS FOR HEAT AND POWER PRODUCTION WITH FUEL CELLS**
maritime, district heating and chemical industry; today, $H_2$ produced by chlor-alkali plants worldwide would be sufficient to produce about 3 GWe with fuel cells

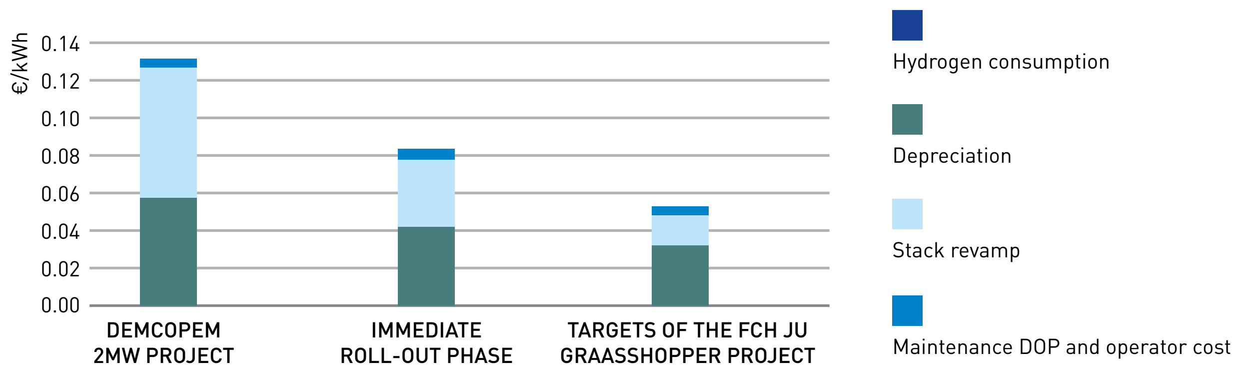
**REPLICATIONS ALREADY STARTED AND PARTNERSHIPS SET UP**
General Electric with Nedstack and Ballard Power with ABB to develop hydrogen fuel-cell power systems for cruise vessels; 100 % renewable power for plant generating green $H_2$ planned in French Guiana with zero subsidies and private financing

## WASTE NOT WANT NOT

Harnessing redundant hydrogen as a resource for heat and power at large scale has yet to become cost-effective for industry in Europe.

## GETTING MARKET READY

The FCH JU is implementing projects in suitable markets, developing lower-cost technologies and demonstrating how waste hydrogen can be fed back into production as electricity, water and heat. **The goal?** To bring European manufacturers, operators, engineers and project developers together to develop and showcase fuel-cell technologies fit to enter the European market. **Key results?** The first multi-MW-scale combined heat and power PEM fuel cell has been demonstrated using recuperated hydrogen to generate power and heat for two years. Market prospects: applications abroad are already viable and replication of similar concepts have been planned.

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www.fch.europa.eu/page/fch-ju-projects
www.demcopem-2mw.eu/
www.cleargen.eu
www.grasshopperproject.eu

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MARKET UPTAKE

# KEEPING HYDROGEN GREEN


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## Untapped potential

Environmentally sustainable hydrogen is essential for decarbonising the energy system. However, FCH technologies have yet to be used as widely or effectively as the energy transition demands. With a series of important guidance documents, a hydrogen roadmap, and green hydrogen certification, the FCH JU is ensuring that hydrogen and fuel cell (FCH) technologies constitute an environmentally friendly solution for Europe.

In 2019, the FCH JU-funded initiative, CertifHy, marked the start of a new green hydrogen market by launching the first-of-its-kind EU-wide guarantees of origin (GO) pilot scheme for green and low-carbon hydrogen. Other FCH JU projects are providing a framework to support the market as it expands. Launched in 2010, FC-HyGuide is considered the reference for life-cycle assessment (LCA) tools, while HyTechCycling has been establishing environmentally sustainable recycling and dismantling processes for fuel cells.

## Ready to roll

The 2019 FCH JU Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition outlines the importance of hydrogen for achieving a zero-carbon Europe and its potential to decarbonise difficult sectors like long-haul transport, chemicals, and iron and steel. By 2050, hydrogen energy could account for 24 % of final energy demand. By creating an LCA tool and a European framework for green hydrogen GOs, while introducing sustainable practices for precious metal and rare earth use, FCH JU-funded projects are paving the way for widespread commercial uptake and ensuring that FCH technologies are an environmentally sustainable choice.

**Hydrogen and fuel cell technologies have a lot to offer the energy transition. The FCH JU is ensuring the environmentally friendly use of these technologies, with a number of cross-cutting aspects embedded throughout its project portfolio and complemented by several initiatives.**


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## A PILLAR FOR CHANGE

Hydrogen is essential for decarbonising the energy system, but it can only play its part if clean production and application methods are used.

## FIT FOR THE FUTURE

To ensure FCH technology fulfils its role in the energy transition, the FCH JU is building a guidance and certification framework for green hydrogen. **The goal?** It aims at increasing market uptake and helping FCH technology to reach its full decarbonising potential by putting in place guidelines and best practices for environmentally friendly FCH use. **Key results?** The hydrogen roadmap outlines the importance of FCH for decarbonisation, while piloted green hydrogen certification has demonstrated a high demand for environmentally sustainable FCH.

## KEY ACHIEVEMENTS

### FC-HyGuide

**19 EU EVENTS**
in one year, increasing awareness of sustainable FCH

**9 HIGH-LEVEL ORGANISATIONS**
worked together to create invaluable LCA documents

### HyTechCycling

**FCH RECYCLING AND DISMANTLING GUIDELINES**
created in line with the circular economy

### HYDROGEN ROADMAP

**17 LEADING INDUSTRIAL ACTORS**
worked together to build a hydrogen future

**STRATEGY AND ROADMAP**
developed for handling critical materials and components

**FIRST**
comprehensive quantified European perspective for deployment of FCH technologies

### CertifHY

**900+ STAKEHOLDERS**
collaborating to create green hydrogen standards

## IMPACT

### FC-HyGuide

**70+ LCAS**
carried out across the entire hydrogen value chain by FCH JU projects

### CertifHY

**76 000+ GOs ISSUED**

**4129 GOs**
already proving that customers are receiving green hydrogen

### HYDROGEN ROADMAP

**50 M TONNES**
expected global demand for hydrogen by 2025

**1 M JOBS**
by 2030 via the Hydrogen Roadmap

**EUR 820 B PER YEAR**
market potential for hydrogen in Europe

**24% OF FINAL ENERGY DEMAND**
could be met by hydrogen by 2050

**560 MT $CO_2$**
savings can be achieved by following the Hydrogen Roadmap

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
www.certifhy.eu
www.fc-hyguide.eu
www.hytechcycling.eu

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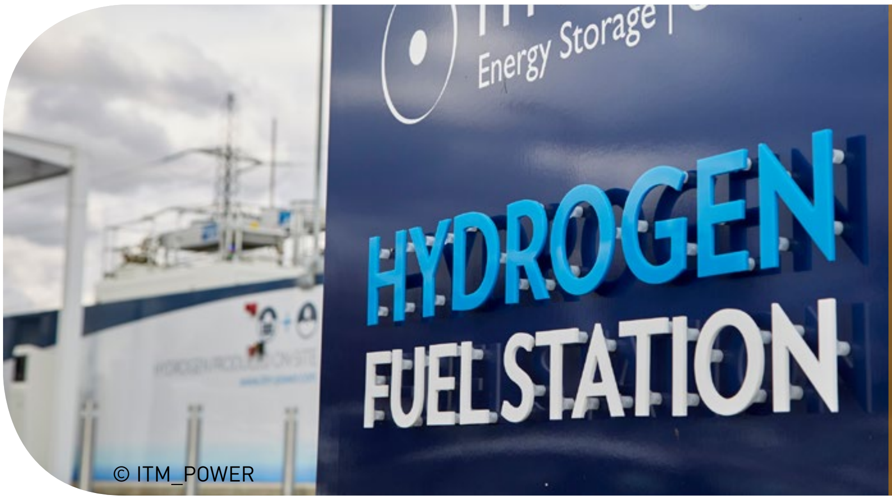
MARKET UPTAKE

# BIG RESULTS FOR SMES

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## Small in size, large in numbers

Illustrating the significant role played by small and medium-sized enterprises (SMEs), these key industrial concerns comprise half of the membership of Hydrogen Europe, a group of FCH JU companies working to make hydrogen power an everyday reality in the energy and transport sectors. The FCH JU financial programme has set aside 27 % of its EUR 77.7-million budget for SMEs, exceeding the Horizon 2020 target of 20 %.
The FCH JU has been a key instrument for SMEs, providing a stable regulatory environment as well as the long-term stability that comes with public-sector funding. The leverage effect means public money also triggers additional private investment. Working alongside larger companies in the same field enables SMEs to tap into the expertise, distribution networks, support and customer pools of those organisations.

## Investment that counts

Continued investment in SMEs and rising industry confidence has been underpinned by the above-mentioned pooling of resources, both within the industrial sector, and between research, industry and the European Commission. The European Hydrogen Roadmap has enabled the acceleration of technological development to the point where real-world fuel cell hydrogen solutions are on the verge of wide-scale distribution. The FCH JU already boasts many impressive examples of achievements by funded SMEs, up to and including successful market deployment.

**The FCH JU-recognises SMEs as key industrial sector actors and is helping some of those involved in fuel cell and hydrogen technologies to develop and market cutting-edge technologies. The emphasis is on collaboration with policymakers, larger companies, research partners and others.**

### WHAT'S AT STAKE?

Although SMEs have been and continue to be central players making vital contributions to within the FCH JU community, they need targeted support to expand and develop innovative technologies.

## GENERATING SUCCESS

The FCH JU has been a key supporting financial instrument for SMEs in the fuel cell and hydrogen sectors, providing funding in excess of the H2020 target of 20 % of its total budget. **The goal?** SMEs are widely recognised as dynamic and innovative power houses, but access to funding and investment remains a key challenge. Through its support to SMEs, the FCH JU is seeking to break that barrier. Participating SMEs also gain numerous advantages by linking with larger companies. **Key result?** Through financial and networking support, FCH JU has helped many SMEs in the fuel cell and hydrogen sectors to achieve their business goals, from obtaining private investment to the marketing of new products and services.

## KEY ACHIEVEMENTS

**50 %**
of all Hydrogen Europe members are SMEs

**27 %**
share of FCH JU budget is going to SMEs

**74 % STACK ELECTRICAL EFFICIENCY**
world record achieved by Estonian SME Elcogen for solid oxide fuel cells (SOFCs)

**60% SEASONAL ELECTRICAL EFFICIENCY**
achieved by Solid Power kWe scale fuel cell micro-cogeneration unit, matching and exceeding the power efficiencies achievable by centralised large power stations

**IMPROVED AND CHEAPER $H_2$ TANKS FOR LIGHT-DUTY VEHICLES**
80 % cheaper, half the weight and able to store more hydrogen

**10 MW**
world's largest high-pressure PEM electrolyser is being developed by UK company ITM Power and will be installed in a Shell refinery in Germany greening the hydrogen utility

## IMPACT

### ATTRACTING INVESTMENTS TO THE SECTOR

**EUR 9 MILLION**
private funding recently secured by Norwegian SME NEL Hydrogen

**EUR 40 MILLION**
private investment obtained by French SME Sylfen

**EUR 40 MILLION**
investment secured by Solid Power to expand its production capacities in Europe leading to new jobs and cost reductions

**EUR 12 MILLION**
loan provided by the EIB to ELCOGEN to increase production volumes and start mass-manufacturing processes

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**FUEL FOR HYDROGEN VEHICLES**
Norwegian SME NEL Hydrogen is building around 300 hydrogen refuelling stations per year, enough to serve 200 000 hydrogen vehicles

**UTILITY-SCALE STORAGE SYSTEMS**
Italian SME Electro Power Systems (now part of Engie Group) offers turnkey power-to-power systems using hydrogen as energy storage

**INDUSTRY-SCALE ELECTROLYSERS**
advanced electrolysers are reaching the 10s of MWs scale relevant to industrial applications

**MORE RESILIENT GRIDS AND LOWER $CO_2$ EMISSIONS**
French SME Sylfen is solving the problem of energy spikes in renewable energy production using $H_2$ as energy storage

**INTERNATIONALISATION OF SMES**
Belgium SME Optimum CPV, an on-board hydrogen tank manufacturer, developed innovative performing tanks and expanded activities abroad, now part of Plastic Omnium

**FIND OUT MORE**

**H2 LOGIC / NEL HYDROGEN** https://nelhydrogen.com/
Low-cost, reliable and user-friendly hydrogen refuelling stations

**ELCOGEN** https://elcogen.com/
The world's most efficient solid oxide fuel cell (SOFC) technology

**SYLFEN** http://sylfen.com/en/home/
Decentralised production and management of energy

**SOLID POWER** https://www.solidpower.com
Highly efficient micro-cogeneration solution with fuel cells

**ITM POWER** https://refhyne.eu/
Advanced high-pressure PEM electrolysers, in this case applied to a refinery environment.

www.fch.europa.eu/page/fch-ju-projects

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MARKET UPTAKE

# PROMOTING INTERNATIONAL COOPERATION


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## Sharing knowledge, globally

The FCH JU works closely with other stakeholders, research programmes and organisations worldwide involved in the exploration, development, deployment and regulation of fuel cell hydrogen technology. These players include the US Department of Energy's Hydrogen and Fuel Cells Program, Japan's New Energy and Industrial Technology Development Organization, the United Nations Industrial Development Organization and the International Energy Agency, etc. Many FCH JU-funded projects focusing on areas such as safety or pre-normative research include national partners or international contributors. For instance, the HySEA project included two Chinese academic partners, while the DEMCOPEM-2MW project is sharing European technology and expertise to help to green Chinese industry. The HyCoRA and H2Sense initiatives involved collaboration with laboratories in the US, while HyResponse worked with firefighters from different non-EU countries to establish the world's first comprehensive training programme for first responders.

## Collaborative priorities

Besides supporting international cooperation through projects and programmes, the FCH JU is identifying priority areas, at policy and technology level, where coordinated and collaborative international activities are of interest. In Europe, it coordinates work with the European Commission's science research service, the Joint Research Centre, and national bodies such as Germany's National Organisation Hydrogen and Fuel Cell Technology. After Japan, Germany has the highest number of hydrogen refuelling stations worldwide and is the most advanced European market for fuel cell micro-cogeneration – achievements largely due to the involvement of national partners in FCH JU-funded projects.

**The transition to fuel cell hydrogen technology as a clean, low-emission energy solution necessitates a global effort. To that end, the FCH JU is establishing and expanding cooperation with international partners.**

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## KEY ACHIEVEMENTS

**127 PROJECTS**
with Non-EU participants

**73.5 MIL EUR**
Funding to Non-EU participants

**95 NON-EU PARTICIPANTS**
In FCH JU projects

## IMPACT

**COOPERATION WITH THE US FOR THE IDENTIFICATION OF TOPICS FOR INTERNATIONAL COLLABORATION**

**CLOSE COLLABORATION WITH INTERNATIONAL ORGANIZATIONS SUCH AS THE IPHE, IEA H2, UN UNIDO, ETC.**

**PARTICIPATION IN GLOBAL INITIATIVES LIKE THE MISSION INNOVATION INITIATIVE**

## A WORLDWIDE EFFORT

Establishing and maintaining links with major research programmes and stakeholders globally is an important part of the FCH JU's work to develop and deploy commercially viable fuel cell hydrogen energy solutions.

## WIDENING THE HORIZONS

By building links and sharing knowledge with international partners and programmes, the FCH JU is broadening research into FCH technologies worldwide while supporting science and technology cooperation internationally in line with the Europe 2020 strategy for smart, sustainable and inclusive growth, and the Horizon 2020 programme. **The goal?** To drive innovation and support uptake of FCH technology globally. **Key results?** Ongoing collaborative initiatives with partners and organisations around the world.


FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
https://demcopem-2mw.eu/
http://www.hyresponse.eu/
http://www.hysea.eu/
http://hycora.eu/

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MARKET UPTAKE

# LAYING THE GROUNDWORK FOR A NEW HYDROGEN MARKET

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## Building the scaffolding

Hydrogen is an essential component of the future energy system, but adequate commercialisation will depend on the right legal environment and regulations, codes and standardisation (RCS) frameworks. To help boost market deployment, the FCH JU funds a variety of pre-normative research (PNR) activities.

These include 14 projects aimed at filling knowledge gaps and providing recommendations to put in place suitable RCS frameworks, covering the entire hydrogen chain and addressing aspects such as safety, quality and sustainability standards.

Between 2014 and 2016, the FCH JU-funded CertifHy project developed a definition for green and low-carbon hydrogen, resulting in the launch of the first EU-wide guarantee of origin (GO) scheme for green and low-carbon hydrogen in 2019. Meanwhile, the HyLaw project has been analysing the LAPs of 18 national legal systems as well as the EU's legal system, with a view to identifying the barriers to FCH deployment and advocating for their removal.

**Out-of-date legal and administrative processes (LAPs) and a lack of information are deterring investors and clients from using hydrogen fuel cell (FCH) applications. By providing the knowledge needed to develop a supportive framework for the new hydrogen market, the FCH JU is playing a fundamental role in removing these barriers.**

## Tools for change

To coordinate the RCS strategy within the FCH JU, the Strategy Coordination Group (SCG) provides evidence-based analyses of urgent priorities for PNR and standardisation needs. In collaboration with the EC's Joint Research Centre (JRC), the FCH JU responds to these findings and proposals with actions ranging from supporting the formulation of RCS strategy, to direct implementation of its proposals. Projects such as Hylaw have been disseminating their findings and advocating for public authorities to remove barriers, while CertifHy's green hydrogen certification marks the start of a new green hydrogen industry for Europe.


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## BLOCKING POTENTIAL

The full potential of FCH technologies is being restricted by the lack of harmonised and suitable RCS, which are essential for the mass roll-out of FCH technologies across Europe and worldwide.

## KNOWLEDGE IS KEY

To enable a supportive environment for widespread FCH technology uptake, the FCH JU is funding the pre-normative research needed to create the right regulations, codes and standards. **The goal?** To collaborate with industry and other stakeholders to remove this barrier to market deployment by ensuring that the necessary information is gathered and disseminated to policymakers, administrations, clients and investors. **Key results?** The development of green hydrogen certification, harmonised test protocols and an information database outlining current legal and administrative barriers to commercialisation.

## KEY ACHIEVEMENTS

**EUR 29 M FUNDING FOR 14 PNR PROJECTS**

**COLLABORATION WITH THE JRC**
to support the formulation and implementation of the RCS strategy

**NATIONAL ASSOCIATION ALLIANCE**
unites stakeholders in removing legal barriers

### HyLaw

**23 PARTNERS**
are investigating FCH legislation and regulations

**18 COUNTRIES**
analysed for legal and administrative barriers to FCH uptake

**EUROPEAN AWARENESS-RAISING WORKSHOP**
disseminating findings and pressing policymakers to remove legal barriers

**18 NATIONAL AWARENESS-RAISING WORKSHOPS**
disseminating findings and pressing policymakers to remove legal barriers

### CertifHy

**900+ STAKEHOLDERS**
working together to create green hydrogen standards

## IMPACT

More than **100** contributions to conferences and journals

### COLLABORATION WITH JRC

**EU HARMONISED TEST PROTOCOLS**
for PEMFC MEA in single cell configurations made in agreement with the main European manufacturers and research centres and backed by the EC

### HyLaw

**ONLINE DATABASE**
providing benchmarks and recommendations for removing barriers to FCH uptake in 18 countries

**30 PUBLIC AUTHORITIES**
provided with country-specific benchmarks and recommendations on how to remove barriers to FCH

**17 NATIONAL POLICY PAPERS**
highlighting best practices, identifying legal barriers and providing policy recommendations

**A PAN-EUROPEAN POLICY PAPER**
targeting European decision-makers

### CertifHY

**FIRST EU-WIDE GUARANTEES OF ORIGIN FOR GREEN AND LOW-CARBON HYDROGEN**

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
www.certifhy.eu
www.hylaw.eu

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MARKET UPTAKE

# SAFETY FIRST FOR HYDROGEN FUEL CELL TECHNOLOGY


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**Hydrogen fuel cell technology must be safe if it is to be used commercially. From drafting safety standards and training technicians to raising public awareness, FCH JU projects have been instrumental in ensuring the safety and acceptance of this clean energy solution.**

## Supporting safety standards

Public distrust can arise around any new technology, and hydrogen fuel cells are no exception. Addressing these concerns through the development of safety measures, rigorous testing procedures, research and education are key to developing hydrogen's central role in the transition towards a low-carbon, low-emission future. These challenges are being tackled by FCH JU projects, complemented by several initiatives such as the industry-led Regulations, Codes and Standards Strategy Coordination Group, the cooperation with the Joint Research Centre of the European Commission, or the European Hydrogen Safety Panel, among others.

FCH JU projects like PRESHLY, which is conducting pre-normative research on liquid hydrogen aimed at cost-efficient safer design and developing international performance-based standards. HySEA, which sought to facilitate the safe introduction of hydrogen energy systems by introducing harmonised venting requirements for enclosures and containers. Other projects, such as HyResponse, KnowHY and NET-Tools, focus on education and awareness – from training first responders and technicians working with hydrogen to providing e-learning tools for students and professionals.

## Maximising awareness

These FCH JU initiatives, alongside cooperation with international bodies, are helping to maximise the safety of fuel cell hydrogen technology, not least through the development of rigorous research-led standards and the training of relevant professionals. And by conveying important safety information to all concerned – whether they are workers, firefighters, researchers or students – and broadening awareness of the safety of the technology, these efforts are helping to build public and industry support for the wider deployment of hydrogen fuel cells.

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## KEY ACHIEVEMENTS

**30+**
Cross-cutting projects addressing safety aspects directly or indirectly

**200+**
completed vented deflagration tests in HySEA

**70+**
firefighters trained in HyResponse from about 15 countries, 21 international observers

**EUROPEAN HYDROGEN SAFETY PANEL**
set up to manage and promote a hydrogen safety culture

## IMPACT

**EN 14994**
European standard for gas explosion venting protective systems to be extended based on HySEA results

**EUROPEAN EMERGENCY RESPONSE GUIDE**

**1 200+**
technicians trained using KnowHy e-learning tools

## ENSURING SAFETY AND BUILDING TRUST

The commercial deployment of hydrogen fuel cell technology must go hand in hand with the introduction of rigorous safety standards as well as education and training, which in turn helps to raise public awareness and trust in the technology.

## KNOWLEDGE SHARED, EDUCATION GAINED

Bringing together a diverse array of stakeholders, including research and educational institutions, standards bodies and professionals, FCH JU projects generate and share knowledge about hydrogen fuel cell safety and support the development of international standards, while expanding access to education and training related to the technology. **The goal?** To ensure the commercial deployment of hydrogen fuel cells meets rigorous safety standards, while raising public awareness. **Key results?** The safe introduction and scale-up of hydrogen as an energy carrier, aligned with European scientific-technological interests and decarbonisation strategies. Education and training related to hydrogen fuel cell technology is critical for the current and future workforce as well as for furthering commercial implementation.

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects

http://www.hysea.eu/
https://preslhy.eu/
http://www.hyresponse.eu/
https://knowhy.eu/
https://www.fch.europa.eu/page/european-hydrogen-safety-panel

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# A collection of success stories from FCH JU projects

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50 YEARS
Publications Office
of the European Union