Making an impact on the clean energy transition

TRANSPORT

HYDROGEN TECHNOLOGY FOR CLEANER SKIES FROM 2035

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Green power in the air

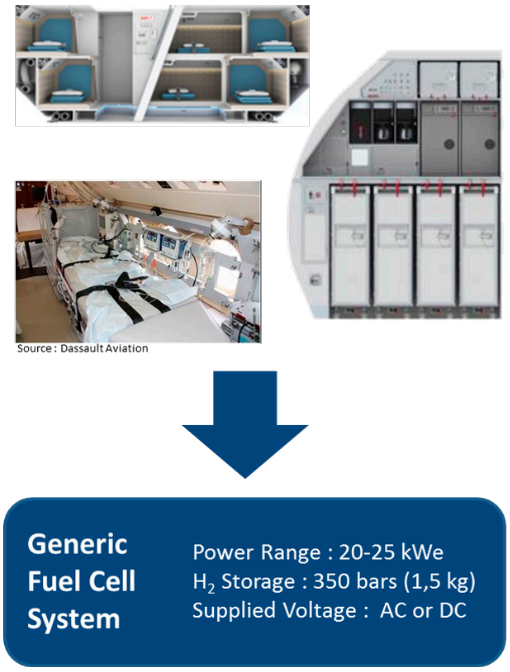
Modern aircraft, powered by polluting kerosene, emit more than 900 million tonnes of CO_2 globally each year, putting the aviation industry under intense pressure to decarbonise. Hydrogen, which can be produced sustainably using renewable energy, is emerging as a game-changing clean, green and viable solution, not just as an alternative to kerosene but also to synthetic fuels and biofuels. A Fuel Cells and Hydrogen 2 Joint Undertaking and Clean Sky 2 Joint Undertaking study predicts short-range hydrogen-powered aircraft could enter into service by 2035.

Significant progress towards using hydrogen to power aircraft, is being achieved in a series of FCH JU-supported projects. HYCARUS developed a flight-ready fuel-cell system, including a high-pressure hydrogen tank for pressurised passenger aircraft, while FLHySAFE is developing an auxiliary power unit for flight controls, linked hydraulics and flight-critical instrumentation in case of emergency. The HEAVEN project is producing a modular high-power fuel-cell system for small aircraft in combination with an innovative cryogenic liquid hydrogen storage system.

Innovating toward the first test flights

In the near future, planned flight tests and validation of the technology by these projects underpin expectations that the first prototype fully-hydrogen-powered aircraft could be approved for take-off by 2028. This will mark a watershed moment in aviation's green transition and will raise awareness in the aeronautics sector globally of the potential of hydrogen. FCH JU's progressive approach to supporting innovation spans key applications from propulsion and auxiliary power to safe hydrogen storage that are set to play a significant role in accelerating decarbonisation of the industry.

Hydrogen-powered commercial aircraft could come into service in just 15 years. The FCH JU has started the ball rolling with three research projects that will help reach this milestone.



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DECARBONISING AVIATION

The aviation industry needs commercially viable, green and clean alternatives to fossil fuel in order to decarbonise and reduce its environmental impact.

HYDROGEN-POWERED PLANES

To support the development and testing of hydrogen-powered aviation solutions, the FCH JU brought together research institutions and leading companies in aviation and hydrogen technology. **The goal?** To demonstrate the commercial viability of hydrogen-powered aircraft and raise awareness of hydrogen's potential to help the aviation industry decarbonise. **Key results?** New propulsion systems, emergency power units and hydrogen storage solutions that are putting hydrogen-powered aircraft on track to commercial deployment.

KEY ACHIEVEMENTS

HYCARUS

20 - 25 kW
fuel-cell power range achieved

46 %
target efficiency under airborne operating conditions

10
partners from 5 European countries

FLHySAFE

15 kW
modular fuel-cell system architecture

100 W/kg
power density of emergency unit

7
partners from 3 European countries

HEAVEN

2 kW/kg
expected power density of fuel-cell stacks

90 kW
powertrain of two 45 kW fuel-cell stacks

10 %
weight efficiency of cryogenic hydrogen storage system

7
partners from 4 European countries

IMPACT

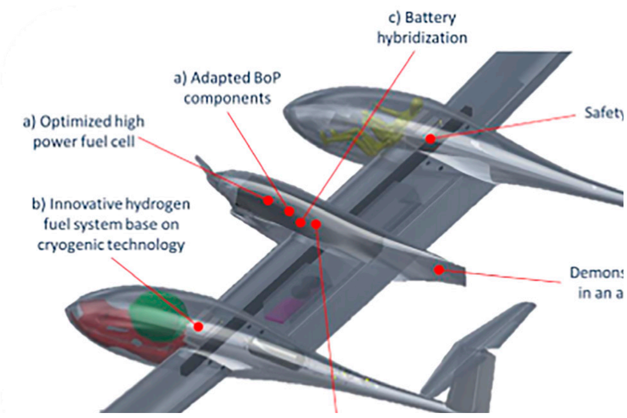
2030s
could see the introduction of commercial hydrogen-powered aircraft

50 - 90 %
reduction in global warming impact of flying

ZERO
CO_2 emissions if hydrogen demand met by renewable sources

40 %
of aircraft globally could by powered by hydrogen by 2050

5 - 10 % CHEAPER
than using synthetic fuels for short-range and regional flights



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

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Making an impact on the clean energy transition

TRANSPORT

FROM WASTE TO WHEEL: A CIRCULAR SOLUTION FOR HYDROGEN AS A CLEAN FUEL

© REVIVE, 2020

Garbage trucks fuelled from waste

Municipal waste incinerators produce energy for local heating and electricity networks, but during some seasons and times of day supply exceeds demand. This cheap excess electricity can be turned into green hydrogen to power fuel cell vehicles by deploying electrolysis technology at waste incineration plants. Heavy vehicles such as buses and trucks account for around 20 % of Europe's road transport CO_2 emissions, making them prime candidates for transitioning to clean hydrogen.

Powering garbage trucks with energy sourced from the municipal waste they collect is an innovative circular economy solution being demonstrated by the REVIVE project. The FCH JU-funded initiative will use electrolysers at waste incinerators in Roosendaal in the Netherlands and Gothenburg in Sweden to refuel clean and quiet FCH refuse trucks and plans to expand to other cities. Meanwhile, the JIVE project aims to operate 10 FCH-powered public buses refuelled at a waste-to-energy plant in Wuppertal, Germany. Other projects, such as H2ME2, are exploring similar technology as part of broader FCH infrastructure deployments.

Supporting the green transition

By supporting the development and testing of FCH technology at waste-incinerator sites, the FCH JU is aiming to demonstrate the commercial viability of waste-to-wheel solutions while raising interest and awareness among stakeholders and the public. These initiatives should stimulate the adoption of novel business models and investment in local FCH infrastructure by more towns and cities across Europe, supporting the broader transition to a green and circular economy.

A few towns and cities across Europe are trialling converting electricity generated from municipal waste into hydrogen to power buses, garbage trucks and other fuel cell vehicles. FCH JU projects are initiating the deployment of local 'waste-to-wheel' solutions that support the transition to green and circular economies.

© H2ME, 2020

EXCESS ELECTRICITY TO HYDROGEN ENERGY

Turning excess electricity generated from municipal waste incineration into green hydrogen to power local fleets of FCH buses or refuse trucks.

A LOCAL SOLUTION FOR FCH VEHICLES

To support the adoption of local waste-to-wheel solutions, some FCH JU projects have brought together municipal authorities, waste-incinerator plant operators and FCH technology providers. **The goal?** To demonstrate the commercial viability of converting excess electricity from waste incineration into hydrogen to power local fleets of FCH vehicles. **Key results?** A step towards local circular business models with several waste-powered FCH refuelling plants in operation and more planned across Europe.

KEY ACHIEVEMENTS

REVIVE

2
electrolyser systems deployed at test waste-incinerator sites

15
FCH waste-collection vehicles to be trialled

8
cities and regions to participate in trials

50 %
Tank-to-wheel efficiency targeted for refuse-collection vehicles

800 - 1 000 kg PER DAY
potential for large-capacity hydrogen refuelling stations

UP TO 12 MONTHS
of trials using FCH refuse trucks

JIVE

10
FCH buses to refuel at a waste-to-energy plant in Wuppertal, Germany

IMPACT

REVIVE

20 %
of Europe's road transport CO_2 emissions produced by heavy vehicles such as buses and trucks which could transition to green hydrogen

COMPARABLE
driving range, refuelling time and payload capacity for FCH refuse trucks compared to diesel-powered trucks

LESS NOISE AND ZERO POLLUTION
from FCH garbage trucks, making them ideal for use in residential areas

MONITORING AND ANALYSIS
to explore the potential for waste-to-wheel business models

3
more EU countries to deploy FCH garbage trucks

JIVE

DEMONSTRATE
technological readiness of FCH buses and hydrogen refuelling stations and encourage further uptake

© H2ME, 2020

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
https://h2revive.eu/
https://www.fuelcellbuses.eu/projects/jive
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Making an impact on the clean energy transition

TRANSPORT

MASS FUEL-CELL PRODUCTION IN LINE FOR A BOOST


© Fronius, 2019

Bottleneck breakers

Fuel cells and hydrogen (FCH) technologies are key in the EU's switch to low-carbon energy to protect the climate and environment. For adoption across Europe, fuel cells must be cheaper to produce, perform better and last longer, and be made in large enough volumes to meet market demand.

INLINE is one of eight FCH JU projects improving fuel-cell manufacturing and quality control. The project has increased the capacity of a 100-unit PEMFC production line to up to 50 000 fuel cells each year, with better-quality output. Each unit can be made 27 % faster, thanks to a redesign of two components – the media supply unit and tank valve – while automated quality-control processes correct faults during production, reducing waste.

Industry-ready technology

Fuel cells from the project have been integrated into 20 commercial HyLog-Fleet fuel systems for industrial forklifts. Other fuel-cell industries could follow. INLINE has produced a list of key exploitable results with good market potential and projected return on investment. For one quality-control tool, an endoscopic inspection sensor, the project consortium has produced a business plan to encourage adoption. All results help manufacturers to develop a competitive European PEMFC supply chain that contributes to a greener, cleaner world.

Mass fuel-cell manufacturing is a step closer in Europe. The FCH JU project INLINE has designed a large-volume, flexible production line for high-quality proton-exchange fuel cells (PEMFC), the most common type of fuel cell. These innovations drive forward a stronger European PEMFC industry and a lower-carbon, more sustainable economy.


© INLINE, 2020

MASS FUEL-CELL PRODUCTION IN LINE FOR A BOOST

KEY ACHIEVEMENTS

500
times more capacity in a single manufacturing line

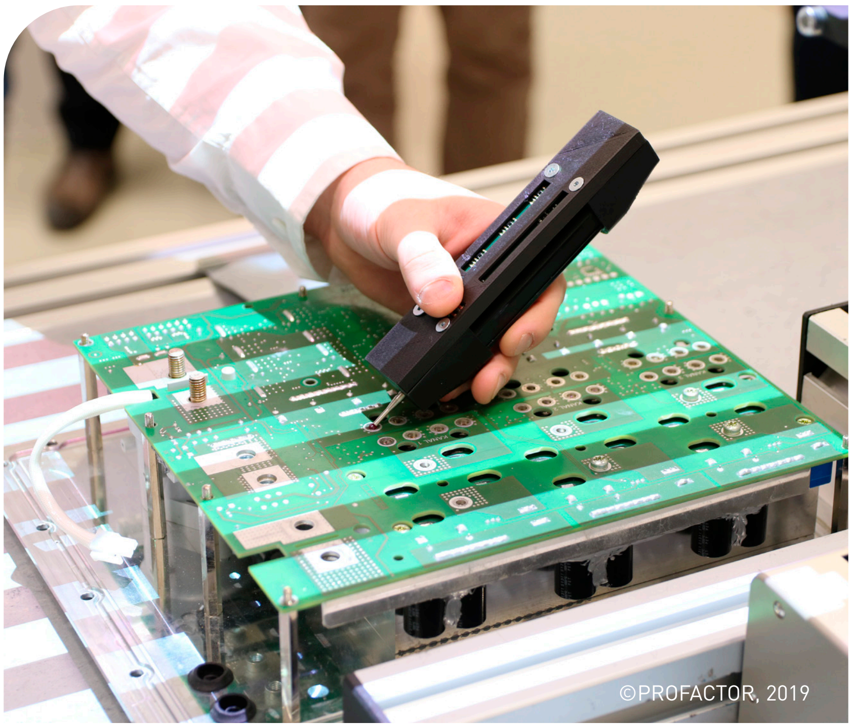
27 %
faster production time

2
key components redesigned for faster production and assembly

20
units in industrial forklift trucks using HyLog fuel systems

20
innovations and processes ready for industry adoption

1
business plan for an endoscopic quality-control sensor



IMPACT

INCREASED CAPACITY
to produce fuel cells that help to reduce carbon emissions

FASTER
manufacturing of high-quality PEM fuel cells

MORE COMPETITIVE
EU-based fuel-cell supply chains

ADOPTABLE
solutions for industry, for a quicker return on the EUR 3.2 million public investment

REDUCED WASTE
thanks to improved in-line quality control technology

250
potential new jobs from the technology

FASTER, CHEAPER, HIGH-QUALITY FUEL-CELL PRODUCTION

European manufacturers need scalable, efficient processes to manufacture high-quality PEM fuel cells for a more competitive fuel-cell industry in Europe.

COMPONENT AND PROCESS UPGRADE

Research organisations and technology companies have analysed and redesigned a PEMFC production line and key components to scale up the manufacturing process. **The goal?** To develop flexible technology and processes fuel-cell manufacturers can integrate to reduce bottlenecks, quality issues and end-of-line rejections. **Key results?** Innovative component designs, manufacturing and quality-control technology and processes. Results can be adapted to other lines, supporting a more secure, competitive supply of fuel cells in Europe.

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
https://www.inline-project.eu
https://digiman.eu/
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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

A partnership dedicated to clean energy and transport in Europe

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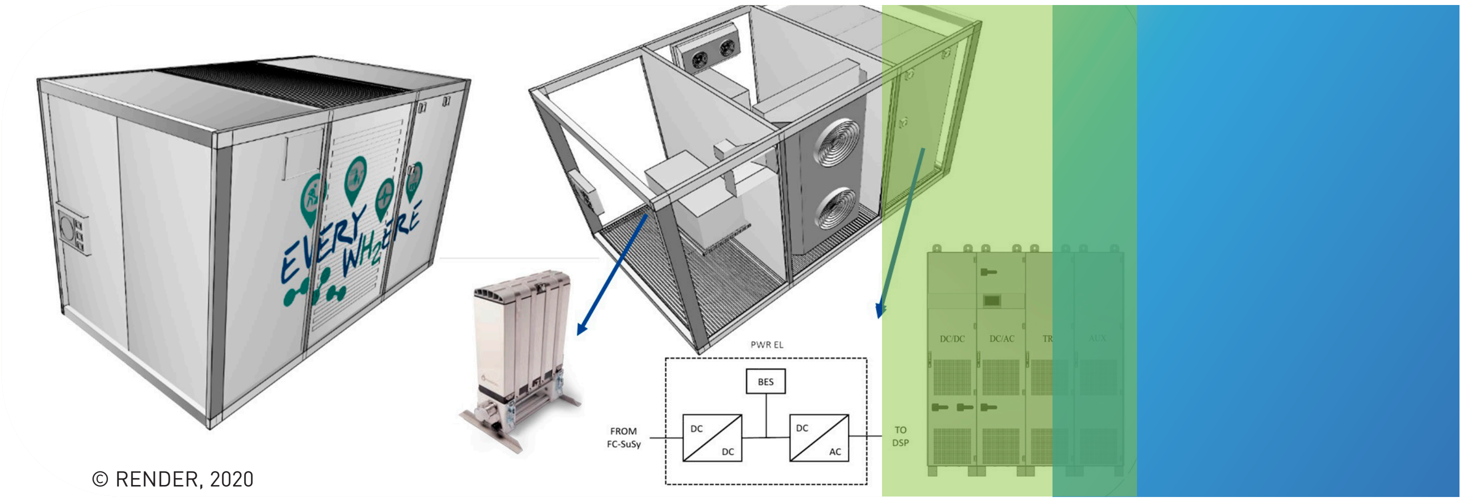
Making an impact on the clean energy transition

ENERGY

CLEAN AIR EVERYWH2ERE WITH HYDROGEN POWER



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Zero-pollution generators

Although most urban air pollution comes from transport, other activities make a significant contribution. Diesel generators – or gensets – used for construction sites, outdoor events and off-grid locations are one such polluting source, producing harmful particles, greenhouse gases and noise. Fuel cells can be a disruptive solution, providing clean, silent mobile power.

The EVERYWH2ERE project, funded by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), has designed light, low-pollution 25-kWe and 100-kWe generators with proton-exchange membrane (PEM) fuel cells and safe pressurised-hydrogen technology. The consortium is integrating EU-manufactured components into four low-carbon 'plug and play' gensets for each size. In the ALKAMMONIA project, FCH JU-funded researchers have produced components for a European version of efficient alkaline-fuel-cell mobile generation. The project's transportable cost-effective units use hydrogen they 'crack' from high-energy density ammonia and are 60 % recyclable, making them a sustainable source of zero-carbon power, particularly in remote areas.

Demand demonstration

EVERYWH2ERE plans to tour its eight gensets around construction sites, music festivals and events in Europe to demonstrate their economic viability and safety. Project partners will use the results to fine-tune the prototype devices before moving to commercialisation in 2025. Meanwhile, a life-cycle analysis by ALKAMMONIA has demonstrated a business case for different applications of alkaline fuel-cell generators. Project partner AFC Energy has since launched and demonstrated a scalable 20-kW electric-vehicle fuel cell charger using alkaline fuel-cell technology capable of using hydrogen from cracked ammonia to provide affordable off-grid power.

Events, construction sites and off-grid infrastructure could soon run on quiet, clean power. Two FCH JU projects are paving the way to the deployment of fuel-cell generators that can replace mobile diesel generators, for less polluted, quieter cities and events and sustainable low-carbon energy in remote areas.


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CLEAN AIR EVERYWH2ERE WITH HYDROGEN POWER

LOW-IMPACT MOBILE POWER

Safe, accessible alternatives to mobile diesel generators, to reduce the significant amounts of harmful air and noise emissions they produce.

READY-TO-USE SOLUTIONS

The approach? Research, industry and local authority partners joined forces in two FCH JU projects for mobile power generators, one based on PEM fuel cells, the other on alkaline fuel cells using hydrogen from ammonia. **The goal?** To develop and demonstrate sustainable, cost-efficient, hydrogen-fuelled gensets using 100 % European technology. **Key results?** Zero-carbon, silent mobile generators that can supply clean, quiet 'plug and play' power in cities and off-grid regions, with PEM models ready for demonstration at construction sites and festivals, and ammonia-fuelled models close to commercialisation.

KEY ACHIEVEMENTS

EVERYWH2ERE

2 SIZES
of generator – 25 kWe and 100 kWe

20 000 HOURS
targeted generator lifetime

50 %
targeted genset power efficiency

COMPARABLE OPERATING COSTS
relative to diesel gensets

ALKAMMONIA

EUROPEAN WORLDWIDE LEADERSHIP
in alkaline fuel-cell technology

60 %
stack power efficiency

> 90 %
ammonia cracker efficiency

<150kg / kW
stack weight

60 % FUEL CELL WEIGHT

80 % MATERIALS
can be recycled or reworked

IMPACT

EVERYWH2ERE

EUR 5 500/kWe
predicted capital expenditure

EUR 110 MILLION/YEAR
potential EU market

150-200 UNITS
expected to sell in Europe 2025-2030

ALKAMMONIA

< EUR 3 000/kWe
forecasted supporting system costs

< 100 % PURE
hydrogen tolerated for more flexible and cheaper source

COMMERCIAL ALKALINE FUEL CELL SOLUTIONS DEVELOPED
for a diverse range of applications

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
http://www.everywh2ere.eu/
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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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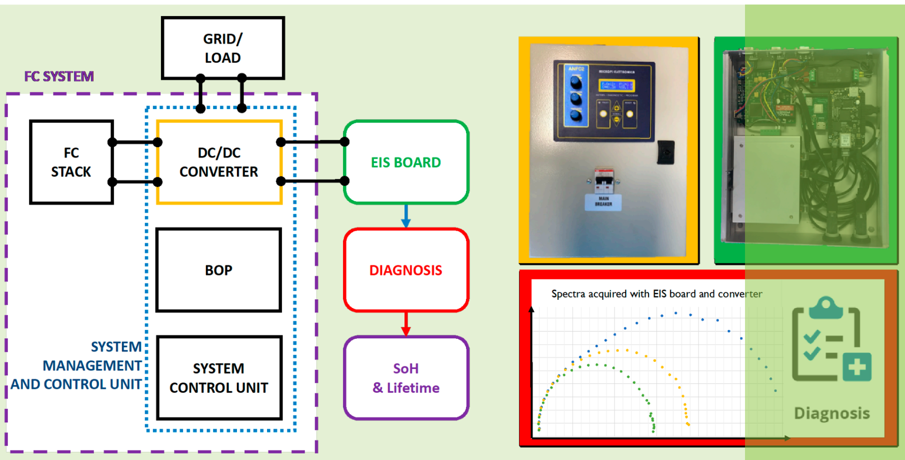
Making an impact on the clean energy transition

ENERGY

ADVANCED TOOLS FOR BETTER-PERFORMING STATIONARY FUEL-CELL SYSTEMS



Early diagnosis, lower costs

Stationary proton-exchange membrane (PEM) and solid-oxide fuel cells could increase their market appeal if they last longer and require less care and repair downtime. Above all, there is scope to reduce maintenance costs – currently up to 20 % of total operating expenditure – and to detect and fix faults faster.

In the INSIGHT project, researchers have developed IT-based tools that can be fitted into SOFC micro combined-heat-and-power (μCHP) systems to detect early-stage critical faults and weak stack components, using electrochemical impedance spectroscopy (EIS)-based tools to propose mitigation strategies.

In parallel, the HEALTH-CODE project has designed an EIS-based monitoring and diagnostic tool to identify faults that impact the performance of micro combined-heat-and-power (μCHP) and back-up power PEM systems. Hardware and software for implementing the tools in commercial systems were developed by embedding all functions in a unique box linked to the main fuel-cell system controller. All tools can estimate a unit's remaining useful lifetime and operate with the aforementioned advanced techniques, in addition to conventional diagnostic tools. They build on results from the GENIUS, DESIGN, DIAMOND and D-CODE projects and use entirely European technology.

A series of projects funded by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) have developed IT-based tools that monitor the health of fuel-cell stacks and quickly detect and isolate faults. The technologies will make stationary fuel-cell systems more reliable and easier to maintain, to drive increased uptake of clean, on-site power generation.

Wider applications

Building on the work to date and on physical boards developed by INSIGHT and HEALTH-CODE, a follow-up project, RUBY, is developing a generic monitoring and diagnostic tool that can operate with both solid-oxide and PEM fuel-cell systems, for broader roll-out. Another follow-up project is being considered to extend the EIS-based approach to other fuel-cell technologies such solid-oxide electrolyser cells and reversible solid oxide cells. Interoperable tools also increase the possibility of standards for such technologies, enhancing access to fuel cells. A HEALTH-CODE exploitation analysis has identified transport as one sector with much to gain from EIS-based monitoring and early fault diagnosis.

ADVANCED TOOLS FOR BETTER-PERFORMING STATIONARY FUEL-CELL SYSTEMS

INCREASE FUEL-CELL APPEAL

Longer-lasting, high-quality stationary fuel cells that are cheaper to maintain could encourage more consumers to adopt low-carbon power generation.

OPTIMUM POWER PRODUCTION

Approach: Industrial and research partners have developed advanced monitoring, diagnostic, control and lifetime assessment tools for stationary fuel cells. **The goal?** To detect faults faster and earlier than current technology so that systems operate closer to their nominal conditions and last longer. **Key results?** A range of EIS-based tools that could streamline maintenance, reduce ownership costs and improve the performance and lifetime of diverse fuel-cell systems, increasing their market appeal.

© INSIGHT project Engen for Insight test, 2020

KEY ACHIEVEMENTS

INSIGHT

3 TOP FAULTS
identified for solid-oxide fuel cells

10 % EARLIER
detection of fuel starvation during operation

1 TOOL BOARD
holding software and hardware innovations installed on a micro CHP fuel cell unit for validating real conditions

HEALTH-CODE

6 KEY FAULTS
detectable using the tool

4 ALGORITHMS
developed to identify faults

1 DIAGNOSTIC BOX
for µCHP and back-up systems

IMPACT

INSIGHT

BETTER UNDERSTANDING
of faults and their impact on stack lifetime

TAILORED MONITORING
of the most critical faults

COMMERCIAL APPLICATION
validated in a marketed µCHP system

HEALTH-CODE

EXPLOITABLE RESULTS
for research and early system-status detection

LONGER-LASTING, MORE RELIABLE
PEM fuel cells for wider appeal

HIGH TECHNOLOGICAL READINESS
encouraging commercial investment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https://cordis.europa.eu/project/id/875047 - **RUBY**
https://cordis.europa.eu/project/id/671486 - **HEALTH-CODE**
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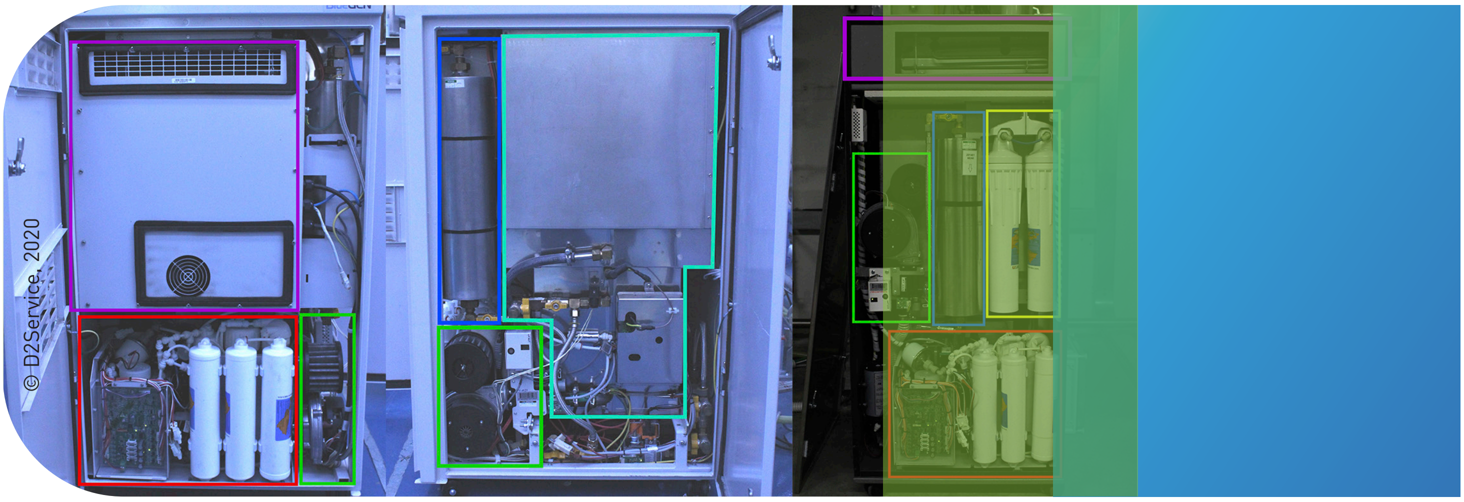
Making an impact on the clean energy transition

ENERGY

LOW-MAINTENANCE FUEL-CELL SYSTEMS FOR WORK AND HOME



New generation of products offer streamlined servicing

Micro-combined heat and power (μCHP) systems operated by fuel cells can convert 95 % of input natural gas or hydrogen into reliable heat and power supplies. Similarly, back-up power systems using fuel cells offer a zero-emission solution to securing power supply to essential infrastructure. They can also reduce heat and power CO_2 emissions by 30-50 %. In addition, back-up power systems using fuel cells offer a zero-emission solution to securing power supply to essential infrastructure. However, units are still expensive and require frequent maintenance, increasing their total cost of ownership.

Solid-power fuel-cell (SOFC) and proton-exchange membrane fuel-cell (PEMFC) systems have been adapted in the FCH JU-funded D2Service project to make them cheaper and easier to maintain. Modular layouts enable technicians to replace defective sections easily, while individual components have been improved and standardised to last longer and be faster to replace. Simpler manuals also allow non-specialised technicians to install and maintain the units. Finally, a remote monitoring system detects failures early, for fewer service visits and unit breakdowns, and supports customers to perform service tasks. Field tests of four improved SOFC μCHP systems at commercial sites in Italy and two PEMFC back-up power systems at critical telecommunications infrastructure sites in Denmark have shown that the units are easy to install, reliable, and require fewer and cheaper services.

Fuel-cell systems that generate heat, power or back-up energy in homes, SMEs and essential infrastructure are becoming cheaper to service and maintain, thanks to the FCH JU project D2Service. Design and service innovations make the low-emission systems more affordable for homeowners and businesses alike.

Carbon-efficient technology for all

The reduced operation costs and increased efficiency make climate-friendly μCHP and back-up power fuel-cell systems more accessible to customers. By enabling more non-specialist technicians to install and service units, the FCH JU is helping to better disseminate the technology. Manufacturers are adapting the project enhancements to their next generation of products, with one improved and cheaper μCHP unit already commercially available throughout Europe.

LOW-MAINTENANCE FUEL-CELL SYSTEMS FOR WORK AND HOME

KEY ACHIEVEMENTS

>12 MONTHS
operation in trials for each of the units tested

100 %
availability and reliability throughout the test period

20 % AND 30 %
lower service frequency and costs thanks to remote monitoring

60 000 HOURS
possible operating time for critical components for SOFC

1 YEAR
service interval for SOFC – 2 to 4 times longer

<4 HOURS

SOFC SERVICE TIME

48 HOURS
total SOFC service downtime

>40 %
total service cost reduction for SOFC

IMPACT

MORE READILY AVAILABLE
products that reduce carbon emissions by 30-50 %

LOWER COSTS
of ownership for homes and businesses

LONGER SERVICE LIFE
from more efficient systems

NON-SPECIALISED TECHNICIANS
can install and service systems using simplified manuals *

CUSTOMERS
can perform some service tasks with remote support

* https://project-d2service.eu/documents/

CUTTING OWNERSHIP COSTS

Fuel-cell systems must become cheaper to service and maintain if they are to attract more consumers.

SIMPLER TECHNOLOGY FOR HIGHER UPTAKE

To reduce total costs of owning fuel-cell systems, the FCH JU brought together commercial manufacturers and research organisations. **The goal?** To identify ways to reduce service and maintenance expenses. **The results?** Simplified components, unit layouts and service manuals, along with remote monitoring, that are being adopted by industry to increase uptake of fuel-cell technology.

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Making an impact on the clean energy transition

ENERGY

RELIABLE GREEN POWER FOR OFF-GRID COMMUNITIES

© ELY4OFF, 2020

Overcoming variability

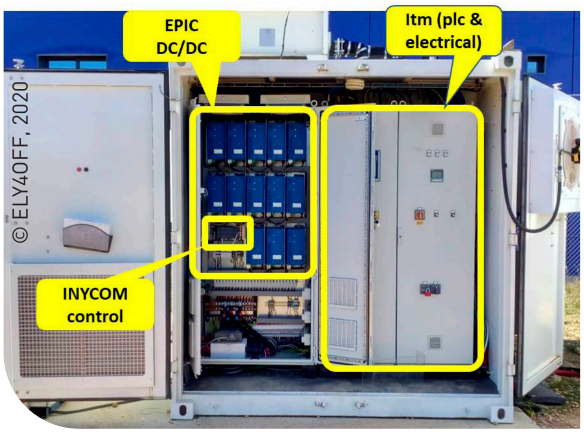
Solar panels and wind turbines are emblems of the clean energy transition, although they themselves cannot provide a stable energy supply. In locations where grid power is unavailable or unreliable, stand-alone systems producing green hydrogen could help to compensate for the variability of these renewable energies and phase out fossil fuels as a fallback solution. They could also boost the uptake of wind and solar energy in general.

Proton exchange membrane water electrolysis (PEMWE) has shown particular promise for use in the type of dynamic, adaptable operation required for hydrogen production powered by variable renewable energy. The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) project ELY4OFF focused on developing this technology into a more competitive proposition.

What happens when the sun does not shine? Hydrogen holds promise even in remote locations: autonomous electrolyser systems could help to reduce the reliance on diesel generators which are widely used as back-ups. Research funded by the FCH JU has produced an innovative prototype.

A system for all seasons

The solar-powered autonomous 50-kW system devised and demonstrated by ELY4OFF produces more than 1.5 tonnes of hydrogen per year. Key features include a robust, innovative control system designed to ensure safe, efficient operation under varying environmental conditions. A back-up component combining batteries and a fuel cell maintains the electrolyser system when solar power is unavailable. The project also innovated by connecting the photovoltaic power source and the electrolyser through a DC bus, achieving higher conversion efficiencies. In addition, the partners explored a wide variety of potential business cases.



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STRINGENT REQUIREMENTS

Green hydrogen can be generated without grid power, for uses as varied as remote electrification, mobility and the production of fertiliser – but a system designed to do so autonomously using variable renewable energy must be particularly flexible and robust.

PROMISING STAND-ALONE TECHNOLOGY

Self-sufficient off-grid systems transforming intermittent renewable energy into a versatile, storable, sustainable energy carrier could help to phase out fossil fuels – and revolutionise the lives of communities worldwide that currently cannot access electricity. **The goal?** To improve the case for stand-alone PEMWE technology as a way of tapping this potential. **Key results?** The ELY4OFF project developed a prototype of a highly efficient system powered by a photovoltaic (PV) field, paving the way for scale-up to the megawatt range.

IMPACT

62 % REDUCTION IN GREENHOUSE GAS EMISSIONS
achievable compared to hydrogen from steam methane reforming

530 kg OF GREEN HYDROGEN
produced in the project, during one year of intermittent operation

GREEN HYDROGEN SUPPLIED TO OTHER PROJECTS
e.g. for research on hydrogen refuelling stations and hydrogen drones

IMPROVED UNDERSTANDING
of the economic aspects and potential business cases

LEADS FOR FURTHER ADVANCES
such as development of a hydrogen-producing wind turbine involving direct connection of an electrolyser located inside the tower, potentially offshore

KEY ACHIEVEMENTS

AUTONOMOUS 50-kW PEM ELECTROLYSER

MORE THAN 1.5 TONNES OF HYDROGEN PER YEAR
(potential output capacity)

FUEL-CELL GRADE HYDROGEN PURITY

DIRECT DC CONNECTION TO A PV POWER SOURCE

97.4 % AVERAGE EFFICIENCY
achieved for the power supply unit

56.33 kWh/kg EFFICIENCY AT SYSTEM LEVEL*

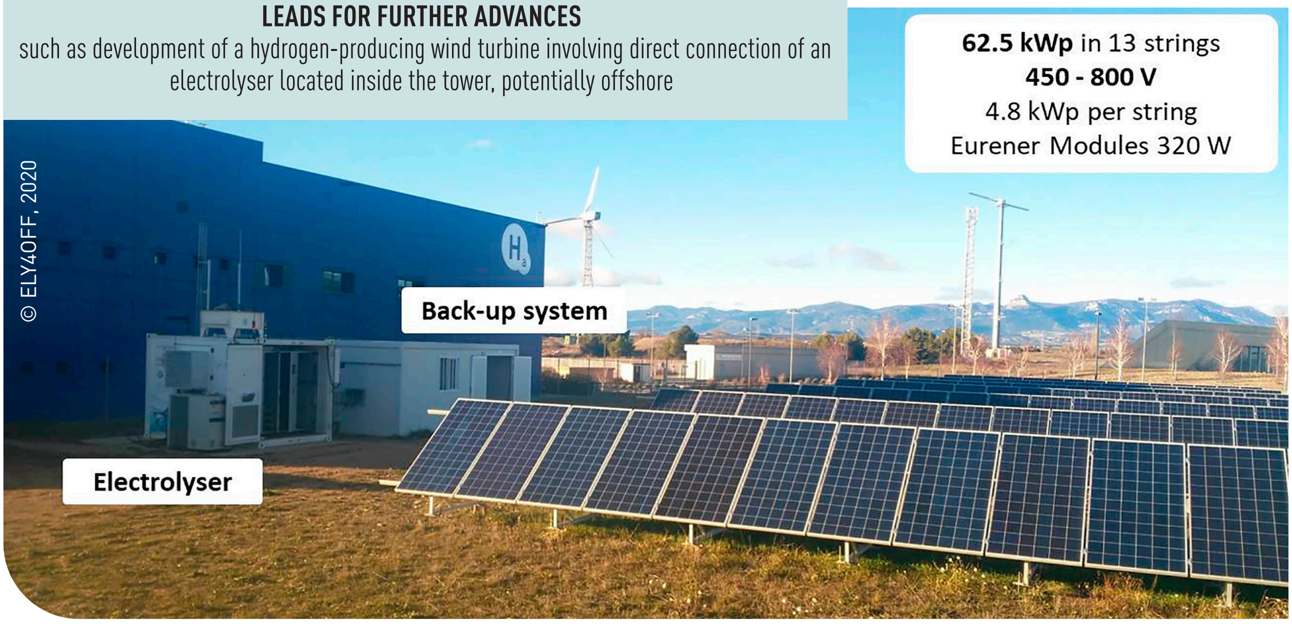
46.3 kWh/kg EFFICIENCY AT STACK LEVEL*

150 % MAXIMUM OVERLOAD CAPACITY

210 S COLD START RAMP TIME
(from idle)

0.2 S RAMP-UP
(to full load)

* at 77.48 % load



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

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Making an impact on the clean energy transition

ENERGY

GATHERING STEAM: GREEN HYDROGEN FOR ENERGY-INTENSIVE INDUSTRIES

© GrInHy, 2018

Demonstrating the case ...

Using solid oxide electrolysers, hydrogen can be produced from steam rather than from water in liquid form. Although this has the potential to boost the efficiency of the process, until recently, this technology had only been demonstrated on a small scale. Just a few years on, it is already being used for a concrete application in steelmaking.

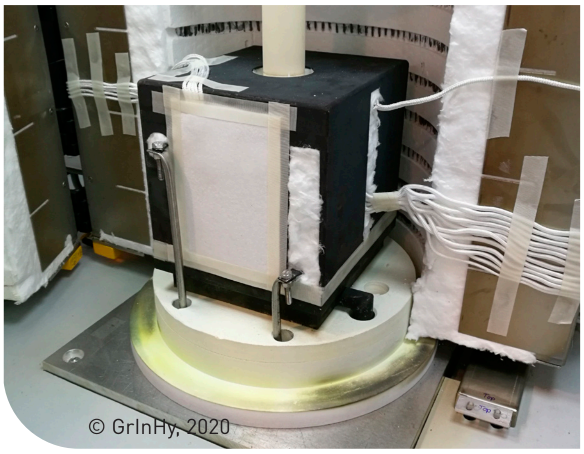
This demonstrator, a 150-kW reversible electrolyser developed by the FCH JU project GrInHy, was set up at a plant in Germany. It uses waste heat from the plant to produce hydrogen for annealing processes carried out on-site. The unit can be used in reverse mode, as a 30-kW solid oxide fuel cell operating on hydrogen or natural gas. Follow-on project GrInHy2.0 is about to replace this with a 720-kW prototype. The new demonstrator, which will not be reversible to further boost efficiency, is due to go into operation in September 2020.

... for high-temperature electrolysis

The advances already achieved rely on the broad collaborations mobilised in these successive projects, which have led to a number of strategic partnerships. One such partnership involves application in a different sector: the new FCH JU project MultiPLHY is developing a solution on an even larger scale for a biorefinery in Rotterdam, the Netherlands.

This system will be the world's first HTE demonstrator in the megawatt range. Significant reductions in capital cost are achievable at this scale, according to insights from GrInHy and GrInHy2.0, which also explored the business case.

High-temperature electrolysis (HTE) is a compelling proposition for the efficient production of green hydrogen and subsequent decarbonisation of many industrial processes. Research backed by the Fuel Cells and Hydrogen Joint Undertaking has been scaling up this technology in view of the capacities required by industry. Work is now under way on the world's first demonstrator of an HTE system in the multi-megawatt class.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POWERING AHEAD

To enable high-temperature electrolysis (HTE) to play a key role in the decarbonisation of industry, the technology must be scaled up quickly.

FROM HYDROGEN DREAM TO HYDROGEN STREAM

R&I supported by the FCH JU is harnessing the power of HTE for concrete applications in real-life industrial settings. **The goal?** Unlocking the potential of HTE and, in the process, helping to build strong partnerships to take the technology forward. **Key results?** Rapid scale-up reflected in the construction of the world's largest reversible solid oxide electrolyser, which is already showing impressive performances, with two even bigger demonstrators to follow soon; and consolidation of European leadership in the field.

KEY ACHIEVEMENTS

GRINHY

150-kW HTE CAPABLE OF OPERATING IN REVERSE MODE AS 30-kW FUEL CELL
a world first!

DIRECT UTILISATION OF WASTE HEAT
from energy-intensive industrial processes
78 % efficiency
a 25 % improvement on electrolysis at lower temperatures

~10 000 HOURS OF OPERATION
in electrolysis, fuel cell or hot-standby mode

LOW DEGRADATION RATES
less than 1 % per 1 000 hours of operation

GRINHY2.0

720-kW HTE DEMONSTRATOR

MULTIPLHY

2.4-MW HTE DEMONSTRATOR PLANNED

IMPACT

STRATEGIC PARTNERSHIPS FORMED
to exploit the projects' results

FEASIBILITY DEMONSTRATED
at industrial scale

GRINHY

HIGH SYSTEM EFFICIENCIES ACHIEVED

GRINHY2.0

NEXT-LEVEL OBJECTIVES TARGETED
e.g. efficiency increase to 84 %
and production of >100 t of hydrogen at <7 €/kg

FURTHER CONTRIBUTION TO LOW-CARBON STEELMAKING EXPLORED
more specifically, use of green hydrogen as a reducing agent

MULTIPLHY

REDUCTIONS IN MANUFACTURING COST EXPECTED
to advance the technology's market readiness

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
https://www.green-industrial-hydrogen.com
http://multiplhy-project.eu.

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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING
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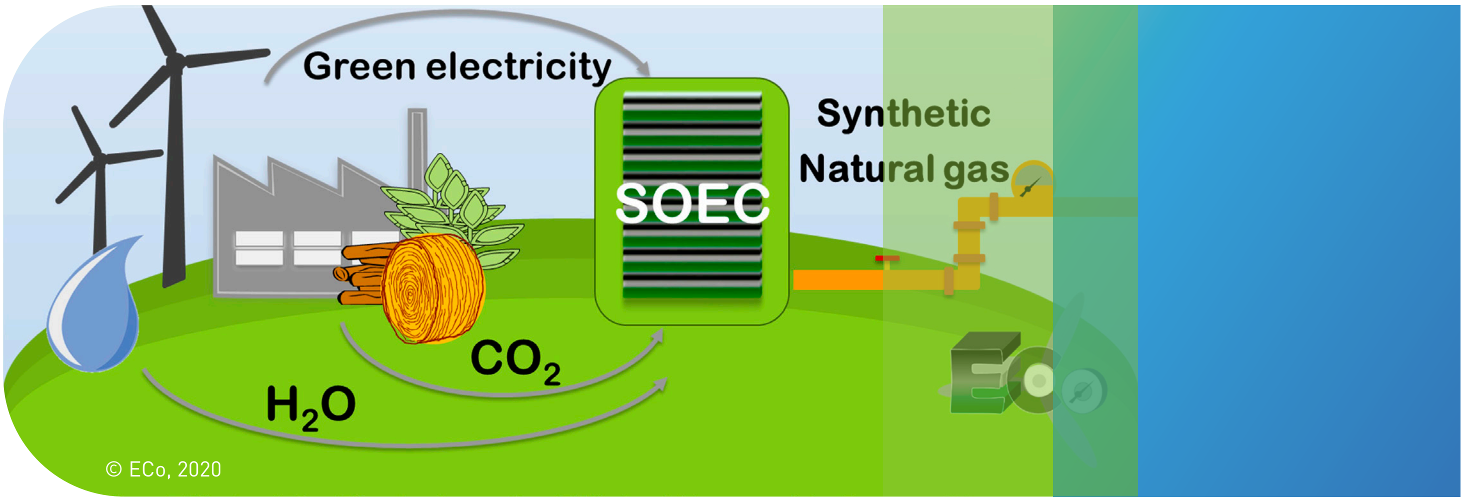
Making an impact on the clean energy transition

ENERGY

GREEN SYNGAS FOR A GREENER FUTURE



From sunshine to synthetic natural gas

Decarbonising our electricity supply is only part of the green energy challenge – 80 % of the energy we use is supplied in the form of molecules. Sustainable syngas could add the momentum on both fronts by helping to green our fuels and facilitating the integration of variable renewable energies such as wind and solar power.

The Fuel Cells Hydrogen Joint Undertaking project Efficient Co-Electrolyser for Efficient Renewable Energy Storage (Eco) has brought the technology closer to commercialisation. It has improved its performance and the overall business case, produced designs and laboratory-scale prototypes for a power-to-methane plant operating on intermittent electricity, and developed the wider vision by performing techno-economic analysis for three potential industrial applications.

Harnessing the potential of co-electrolysis

The ECo project notably improved the design of the electrolysis cells that underpin the process, achieving remarkable performances. These advances were made using existing materials and established manufacturing paths in a bid to facilitate large-scale production.

Research building on ECo's achievements will begin in a follow-on project in 2021, again with support from the FCH JU. This new initiative will focus on demonstrating the technology's potential contribution to reducing carbon emissions in the chemicals industry. It will involve scaling up the technology to suitable dimensions for this sector, with the goal of building and operating the world's largest co-electrolyser.

Syngas has many uses – notably as an energy carrier that can be transformed into resources such as synthetic natural gas or biofuel. The FCH JU is supporting the development of co-electrolysis technology to produce it sustainably from steam and carbon dioxide using renewable electricity, thereby helping to harness its potential to advance decarbonisation.

KEY ACHIEVEMENTS

4 IMPROVED SOEC VERSIONS
delivered and tested at cell and stack level

94 % IF STEAM IS AVAILABLE
high levels of efficiency reached: 74 % if steam is to be generated

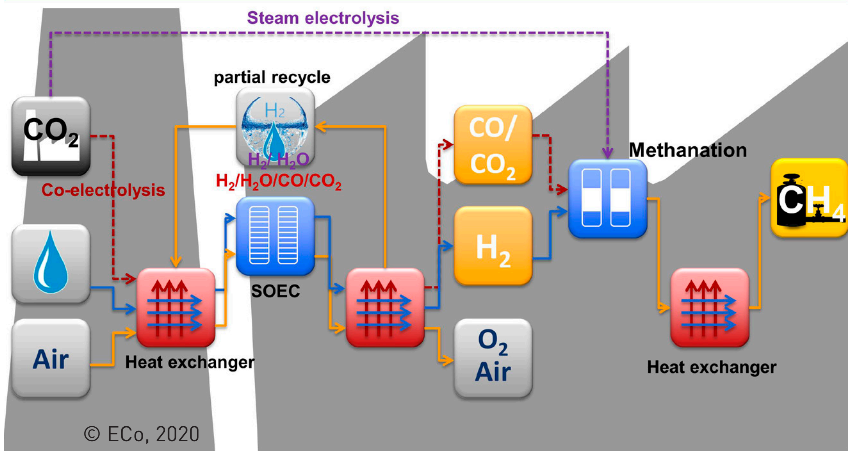
100 °C REDUCTION
operating temperature lowered (from ~800 to ~700 °C) – without affecting the gas output

3 -> 5
technology readiness level raised

<1 %/1 000 HOURS OF OPERATION
very low degradation rates achieved even under dynamic operation

A PIONEERING DESIGN
for a methane-producing co-electrolysis plant operating with fluctuating electricity input

SOEC Plant - Illustration



A COMPELLING PROPOSITION

High-temperature co-electrolysis can produce syngas – a blend of hydrogen, carbon monoxide and CO_2 – directly from steam and CO_2, but further development is needed.

IMPACT

BETTER UNDERSTANDING
of operation and durability under relevant conditions

VALIDATION AT SYSTEM LEVEL
confirming that SOE is an efficient technology solution for the storage of energy from intermittent sources

A STRONGER BUSINESS CASE
e.g. with regard to durability and cost

ADDED INSIGHT
as to the perspectives, impacts and requirements

A STRONG MESSAGE
favourable conditions for this technology already exist!

SOLID SUPPORT FOR SUSTAINABLE SYNGAS

Research and innovation backed by the FCH JU is helping to advance the technology and pave the way for commercialisation. **The goal?** Via the production of green syngas and its transformation into energy carriers such as synthetic natural gas, electricity from intermittent sources could be transformed into a storable supply. **Key results?** The ECo project has achieved significant progress, including refinements of the solid oxide electrolysis cells (SOECs) on which the process relies, exploration of the business case and studies of potential applications.

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
https://www.eco-soec-project.eu
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Making an impact
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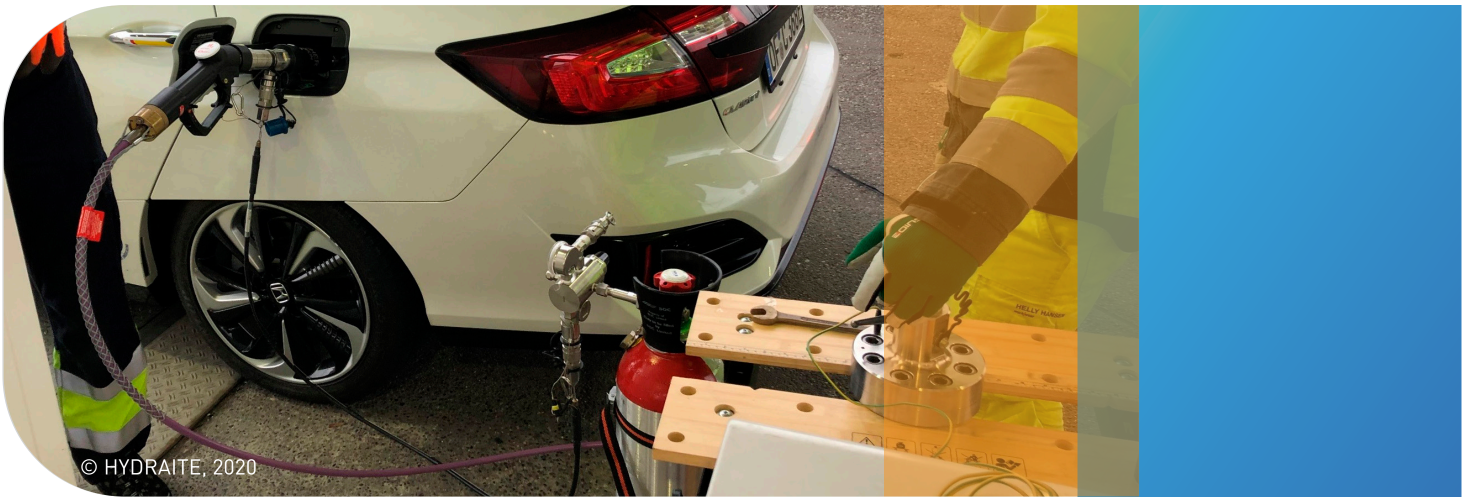
MARKET UPTAKE

HIGH-QUALITY HYDROGEN, COST EFFECTIVELY PRODUCED



© HYDRAITE, 2020

Production purity with quality assurance

The composition of hydrogen depends on how it is sourced and produced. Feedstock, whether water, natural gas or biogas, and production methods, such as electrolysis, steam methane reforming or natural gas partial oxidation, can influence levels of pollutants.

However, ensuring hydrogen meets minimum quality standards and purity levels above 99.9 % for fuel cell and other applications entails higher production costs and additional quality assurance throughout the process.

The FCH JU is tackling these challenges with initiatives aimed at increasing purity, optimising standards and reducing costs. The HYCORA project conducted landmark research into maximum pollutant thresholds, reducing the cost of purification and contributing to updated international quality standards.

Building on that achievement, HYDRAITE has set up the first three laboratories in Europe to test for all contaminants covered by the standards, and implemented a method for in-line continuous monitoring of fuel quality at hydrogen dispensers.

Meanwhile, MEMPHYS focused on optimising an electrochemical hydrogen purification system, while the HYGRID project is scaling up and demonstrating a hybrid system for the direct and cost-effective separation of high-quality hydrogen from natural gas grids. The successes so far have led to two patent applications and the creation of a commercial spin-off.

High-quality, high-purity and cost-effective hydrogen is essential for the commercial take off of fuel cells and other applications. The FCH JU is addressing this cost-vs-quality challenge through innovative projects to advance hydrogen quality assurance and purification technologies.

© HyCoRA, 2020

From innovation to commercial adoption

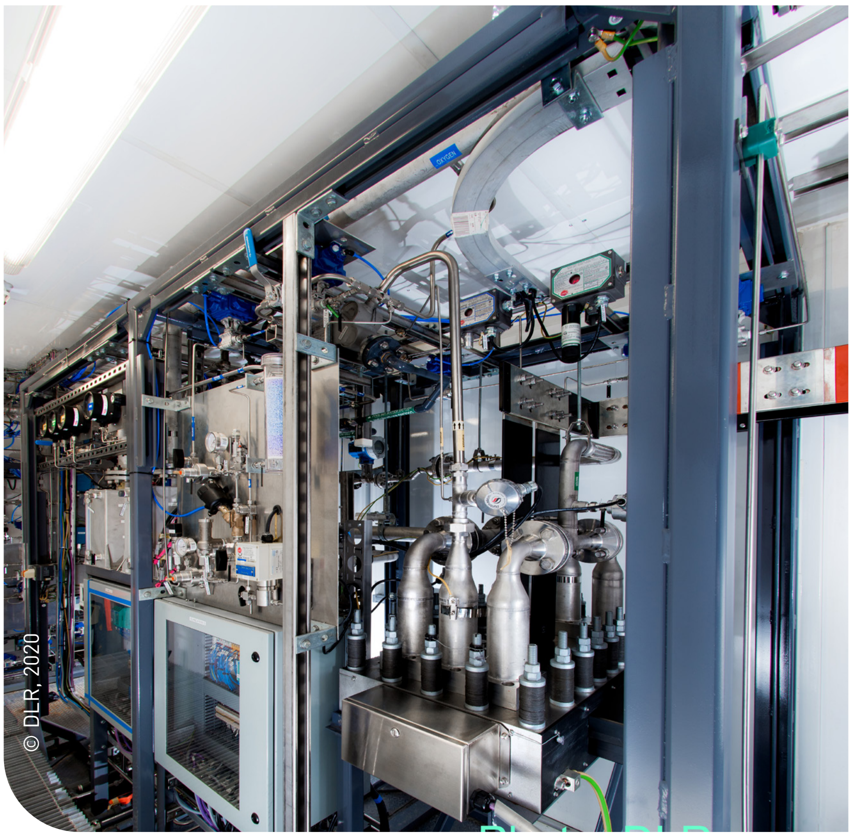
The FCH JU is supporting ongoing research into cost-effective solutions, including innovative technologies capable of extracting and purifying hydrogen from hydrogen-natural gas blends and gas streams with different compositions and origin. With an expanding market for hydrogen technologies, especially fuel cells for transportation, purity and quality assurance will be fundamental factor in driving widespread commercial adoption.

COST-EFFECTIVE SOLUTIONS TO MEET QUALITY AND PURITY STANDARDS

Hydrogen composition can vary depending on how it is produced, but complying with international standards on purity and quality for use in fuel cells and other applications must be achieved cost-effectively.

SETTING THE HYDROGEN QUALITY STANDARD

To address the challenge of meeting hydrogen quality and purity requirements cost-effectively, the FCH JU brought together leading hydrogen technology research institutions and companies across Europe. **The goal?** To contribute to the evolution of international standards, provide quality assurance solutions and support commercially viable high-purity hydrogen production. **Key results?** Optimised international standards on hydrogen quality, novel purification technologies and Europe's first hydrogen testing facilities that are supporting the commercial deployment of hydrogen for transportation and other applications while boosting the competitiveness of the European hydrogen industry.



KEY ACHIEVEMENTS

HYCORA

ISO14678
international standards optimised based on HYCORA research

2 500
individual measurements of hydrogen pollutants

41
days of continuous testing

7
partners from across Europe

HYDRAITE

3
European laboratories capable of measuring all contaminants according to ISO14687 standards

8
partners from across Europe

HYGRID

NEW
stable, high performance and long durability membranes for hydrogen recovery

12.5 kg/DAY
production of prototype hydrogen recovery system

LESS THAN EUR1.5/kg
target cost of recovered hydrogen

TWO
patent applications

IMPACT

ISO
recommendations for optimisation of hydrogen quality standards

1ST
hydrogen quality testing laboratories in Europe

99.97%
purity of hydrogen recovered from natural gas

FIND OUT MORE

www.fch.europa.eu/page/fch-ju-projects
http://hycora.eu/
https://hydraite.eu/
https://www.hygrid-h2.eu/
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Making an impact
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MARKET UPTAKE

ESSENTIAL EDUCATION FOR A SKILLED FCH SOCIETY

© NET-Tools, 2019

FCH innovation fuels demand for talent

Rising commercial adoption of innovative fuel cell and hydrogen technologies for applications as diverse as transport, home energy and industry is generating a growing demand for qualified workers. By 2030, tens of thousands more researchers, engineers and other workers will be needed to fill a rapidly increasing number of skilled jobs in the sector in Europe.

Education programmes focused on providing dedicated training in FCH technologies are thus essential today to meet this forecast future demand. The Fuel Cell and Hydrogen Joint Undertaking is addressing the challenge with initiatives targeting students of all ages, starting with primary and secondary education in the FCHGO project, which developed a 'ready to teach' toolkit aimed at inspiring interest and awareness of FCH technologies among 8 to 18-year-olds. For undergraduate and graduate education, TEACHY2020 is building a pan-European network of universities with FCH curricula, including a complete MSc course on FCH technologies, available in multiple languages. NET-TOOLS, used by TEACHY2020, is providing an internet-based e-learning platform, featuring networking, e-science and e-laboratory components to expand multilingual online education, training and research around FCH.

A knowledge-based green transition

Developed in collaboration with education institutions, research organisations and businesses along the fuel cells and hydrogen value chain, the FCH JU-supported education and training programmes are tailored to multiple target groups and accessible across different formats, from in-person learning to e-learning and blended learning. The approach will support European leadership in FCH technologies and promote a knowledge-based FCH society, benefitting all Europeans in the green transition.

The expanding fuel cell and hydrogen industry needs qualified workers, skilled in the development, deployment and maintenance of FCH technologies. The FCH JU is bolstering European talent with far-reaching initiatives to promote excellence in education and training, and to develop a well-educated workforce and FCH society prepared for a low-carbon, low-emission future.

© Unsplash, 2020

KEY ACHIEVEMENTS

FCHGO

8-18 YEARS OLD
students learning about the basic principles and applications of FCH technology

6
presentations and videos for teaching students aged 13-18

5
teaching tools for students aged 8-13

7
partner universities and organisations

TEACHY2020

75
educational and training institutions participating in the network

200
target number of partner educational and training institutions

7
languages in which course materials will be offered

20 % / 80 %
any university able to offer 20 % of course content locally can benefit from 80 % supplied by the project

NET-TOOLS

1
collaborative online platform offering e-Learning, e-Science, e-Laboratory and e-NETwork applications

3
languages in which learning materials are offered, with more to be added

4
live workshops and educational schools

INTENSE DEMAND FOR QUALIFIED EMPLOYEES

The expansion of the fuel cells and hydrogen industry will create intense demand for qualified employees, and education institutions need to be prepared to meet this demand.

COLLABORATIVE ONLINE AND OFFLINE TRAINING PROGRAMMES

Forecasts for future talent needs in the fuel cells and hydrogen industry led the FCH JU to launch education and training initiatives across Europe, bringing together universities, education and research institutions, businesses and social enterprises. **The goal?** To provide future generations of engineers, researchers and other skilled employees with the qualifications needed and bolster European competitiveness in FCH technologies. **Key results?** Tools for primary and secondary education activities around FCH, a network of universities offering FCH-relevant training undergraduate and graduate programmes, and e-learning materials in multiple languages that are already preparing thousands of students across Europe for the dynamic FCH sector.

IMPACT

466 HOURS
average length of training

1 200 HOURS
maximum length of training

1 837
number of trainees in nine countries, 2016-2018

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FIND OUT MORE

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