Fuel Cells and Hydrogen for Green Energy in European Cities and Regions

A Study for the Fuel Cells and Hydrogen Joint Undertaking

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Roland Berger

Sponsor of the study	The Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU)
Author of the study	Roland Berger
Coalition of the study	175 stakeholders
Regions and cities	Aberdeen (Aberdeen City Council); Agia Paraskevi; Akershus; Alimos (Municipality of Alimos); Aragon (Gobierno de Aragon); Assen; Auvergne-Rhône-Alpes; Barcelona (Barcelona Energy Agency); Birmingham; Bourgogne-Franche-Comté; Bremerhaven (H2BX); Bulgarian Ports; Cantabria (Dirección General de Innovación, Desarrollo Tecnológico y Emprendimiento Industrial); Castilla-La Mancha; Centre-Val de Loire (Chargé de Mission Recherche et Technologie, Direction de l'Enseignement Supérieur, de la Recherche et du Transfer de Technologie, Conseil régional du Centre-Val de Loire); Constanța (Ovidius University from Constanta, Institute for Nanotechnologies & Alternative Energy Sources); Cornwall (Cornwall Council); District of Steinfurt (Amt für Klimaschutz und Nachhaltigkeit); Dundee (Dundee City Council); East Germany HYPOS (Hydrogen Power & Storage Solutions); Emmen; Favignana (Favignana City Hall); Fife Region; Flanders (Waterstofnet); Gavleborg (Regional Office - Region Gavleborg); Grand Dole; Grenoble (Grenoble-Alpes-Métropole); Groningen (Gemeente Groningen); Guldborgsund (Guldborgsund Kommune); Hamburg (hySOLUTIONS); Heide Region; Helmond; Heraklion; Hydrogen Region Rhineland (HyCologne); Ieratpetra (City of Ierapetra); Kalymnos; Kokkola (City of Kokkola); Kozani (City of Kozani); La Roche-sur-Yon Agglomération; Lazio (Regione Lazio); Leeds; Lolland; London (Greater London Authority); Manchester (Manchester Metropolitan University); Mariestad (Utvecklingsstrateg & ansvarig Test- & demonstrationsplats Mariestad); Médio Tejo e Pinhal Interior Sul; Milos (Municipality of Milos); Møre og Romsdal (Region of Møre og Romsdal); Murcia Region (Oficina de Impulso Socioeconómico del Medio Ambiente); Newcastle (Newcastle City Council); Normandie (Service Transition Energétique – Caen); North Rhine Westphalia (Ministerium für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen); Occitanie-Pyrénées (TRIFYL); Oppland County Municipality; Orkney Islands (Orkney Islands Council); Orléans Métropole (Loire et Orleans Eco); Oxfordshire (Oxfordshire County Council); Papagou-Holargos (Municipality of Papagou-Holargos); Pays de la Loire; Pays de St Gilles; Perth and Kinross; POM West-Vlaanderen; Provincie Drenthe; Puertollano (Centro Nacional del Hidrógeno, City of Puertollano); Recklinghausen/Northern Ruhr area (H2-netzwerk-ruhr); Region of Crete (Crete regional office in Brussels); Reykjavik (City of Reykjavik); Riga; Saxony-Anhalt; Sofia; Sogn og Fjordane (Maritim Forening); South Tyrol (IIT – Institute for Innovative Technologies Bozen); Split (City of Split); Split-Dalmatia County; State of Baden-Württemberg

(State Agency for Electric Mobility & Fuel Cell Technology Baden-Württemberg, e-mobil BW); Swindon and Wiltshire (Swindon and Wiltshire Local Enterprise Partnership); Tallinn; Tirol; Tees Valley (Tees Valley Combined Authority); Torres Vedras; Toscana; Trutnov (City of Trutnov, Vedení města); Turin (Servizio Politiche per l'Ambiente); Port of Valencia (Valenciaport Foundation for Research, Promotion and Commercial Studies of the Valencian region); Valladolid (Fundación CIDAUT); Velenje (Municipality of Velenje); Venice; Vrilissia (Municipality of Vrilissia); Western Macedonia (Regional Development Agency Of West Macedonia)

Industry

ABB Marine & Ports; Ad Venta; AFC Energy; Air Liquide Advanced Business & Technologies Europe; Alstom; Amio Ingenieros; AREVA Energy Storage; ARIEMA Energy and Environment; Asahi Kasei Europe; Atawey; Auriga Energy; Ballard Power Systems; BMW Group; BOC; Bosch; Calvera; cEnergy; Ceres Power; Convion; Daimler AG; DCNS; Elcore; ElringKlinger; EMCEL; EPS Elvi Energy; Faun Umwelttechnik; FCP Fuel Cell Powertrain; Ferguson Marine; Fronius International; Galp; Genport; H2B2 Electrolysis Technologies; Helbio; Holthausen; Honda; Hydrogen de France; HydrogenHub; Hydrogenics; HyET; HyMove; Hyseas Energy; Hzwo; IDiCal - Calvo Construcciones y Montajes; IHT Industrie Haute Technologie; Intelligent Energy; iPower Energy; ITM Power; Logan Energy; Maritim Forening Sogn og Fjordane; Michelin; Nedstack Fuel Cell Technology; Nel Hydrogen; Nimbus Boats Sweden; Norsk H2; Persee; PitPoint; Plug Power; Powidian; Proton Motor Fuel Cell; S.A. CMI; Safra; Saga-Fjordbase; Sebastian Wider - Engineering Services; Seiya Consulting; SOLIDpower; Statoil; Storengy; sunfire; Swiss Hydrogen; Symbio Fcell; The Linde Group; Toyota; Uniper; VDL Bus & Coach; Viessmann; Wrightbus

Other organisations

Environment Park; EU Commission - Joint Research Centre, Institute of Energy and Transport; Fraunhofer; Hydrogen Europe; HyER; Research Centre CEA; Research Center Rez; Scottish Hydrogen and Fuel Cell Association; Sir Joseph Swan Centre for Energy Research; STRING Network; University of Split

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Legal notice:

Roland Berger GmbH
Sederanger 1
80538 Munich
Germany

Contact: Yvonne Ruf (yvonne.ruf@rolandberger.com)

Authors: Yvonne Ruf, Simon Lange, Johannes Pfister, Claudia Droege

Date of publication: September 2018

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Abstract

Fuel cells and hydrogen (FCH) technology can be a key enabler to reduce emissions and realise the green energy transition in European regions and cities. In 2017 the FCH JU launched an initiative to support regions and cities in this regard. Today, 89 regions and cities participate, representing about one quarter of Europe's population, surface area and GDP. These regions are pursuing ambitious plans to deploy FCH technology in the coming years. FCH investments totalling about EUR 1.8 billion are planned for these regions in the next 5 years. Potential for further growth is considerable. These planned investments can contribute significantly to further developing the FCH market in Europe and driving the sector towards commercialisation. To achieve the development of a large-scale commercial market, all relevant stakeholders must play their part, and the FCH deployment plans developed by participating regions will need to be brought to implementation. This report provides a detailed insight into the FCH investment plans of the participating regions and cities and points out next steps to be taken for realising a European FCH roadmap with a view to commercialising the technology.

Executive summary

Fuel cells and hydrogen are a viable solution for European regions and cities to reduce their emissions and realise their green energy transition

European regions and cities need to take action now to realise their ambitious emission reduction targets and improve local air quality. In line with greenhouse gas (GHG) emission targets set by the EU and its member states as well as in the landmark Paris Agreement, many European regions and cities aim to significantly reduce their GHG emissions in the coming years. Others are expected to follow suit. In the EU, GHG emissions will be reduced by 20% by 2020, by 40% by 2030 and by 80 to 95% by 2050, thus creating an immediate need to fully shift our energy systems to green, low-carbon technologies. In addition, the EU has introduced stringent regulation to improve air quality and alleviate the negative health impacts of polluted air. Many European cities face serious challenges because they are failing to comply with these EU air quality standards and need to take countermeasures now to avoid heavy penalties. European citizens are increasingly aware of these challenges and expect their local governments to take action at the local level. Regions and cities can play an important role in Europe's green energy transition as drivers of change that translate global ambitions into local action. Regions and cities must therefore take action now to initiate a consistent shift to green technologies that will help them achieve their emission reduction targets and improve local air quality.

Investing in fuel cell and hydrogen technology pays off for cities and regions, as it provides a mature, safe and competitive zero-emission solution for all their energy needs. Fuel cell and hydrogen (FCH) technology is technically mature and well-tested. Numerous successful deployments in Europe and beyond show that the technology is a viable and safe solution that works in practice. Technology performance has improved and costs have been reduced significantly in recent years, with many FCH applications demonstrating increasingly competitive, successful business cases compared to other zero emission and conventional technologies. Today, a broad range of FCH applications that are ready to be deployed exists for all energy and transport sectors. More applications are expected to become available as market uptake advances. FCH technology is the only option available today to store renewable energy on a large scale and use it for all energy needs – from transport to building heat and power to industry, thus enabling sector coupling. It also provides a green solution for energy uses that are otherwise hard to electrify. In addition, it provides the operational flexibility of conventional solutions with no need for long recharging and minor limitations in range or runtimes. Direct electrification and the use of battery technology alone will not be able to provide a reliable and efficient future supply of green energy across all sectors. For a full shift to a renewable energy system, European regions and cities will also need to rely on hydrogen and fuel cells.

Regions and cities can benefit from investing in hydrogen and fuel cells not only in environmental terms, but also by stimulating local economic growth and creating attractive places to live, work and visit. Above all, hydrogen and fuel cells are a green energy solution that can reduce local GHG and local pollutant emissions to zero. This will improve local air quality and create positive health impacts for the local population, thereby enhancing local quality of life. At the same time, FCH deployments can help regions and cities foster a "green" image and position themselves as attractive places to live, work and visit. Furthermore, the FCH sector in Europe is growing quickly and opening up new business opportunities for local companies. As the pace of the green energy transition accelerates in the years ahead, a large international market for fuel cells and hydrogen is expected to evolve. By investing in the FCH sector, regions and cities can support local innovation, stay competitive in the future, stimulate local economic growth and create new jobs.

Waiting is not an option – A growing coalition of 89 European regions and cities is working together to make hydrogen and fuel cells a green energy reality

89 regions and cities – representing one quarter of European population, surface area and GDP – invite others to join them in realising a green energy future with hydrogen and fuel cells. The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) launched an initiative in 2017 to help European regions and cities harness hydrogen and fuel cells to realise their energy transitions. 89 European regions and cities from 22 countries are currently taking part in the initiative, working together to realise major investment projects of around EUR 1.8 billion that will deploy hydrogen and fuel cell technology across Europe in the next five or so years. For 67% of these planned investments respective regions and cities see a very high likelihood for implementation so that it can be assumed that the large majority of these investments will actually be realised in the next years. In addition, almost half of envisaged projects have already entered into advanced stages of project development, thus underlining the clear ambition of the regions and cities to actually implement envisaged projects. A large number of companies from the FCH industry are actively supporting these efforts and helping regions and cities to realise their plans. These investments will help to further mature the technology, broaden the product portfolio and drive down deployment costs – to commercialise the technology, in other words, and to make it an everyday reality across European regions and cities. Only if such investments are realised now will a commercial market for FCH technology evolve with competitive costs: exactly what is needed to realise the ambitious emission reduction and energy transition goals of many European regions and cities. Waiting is not an option. If mature and competitive green energy solutions based on hydrogen and fuel cells are to be available for European regions and cities in the future, investments are needed now to push the technology to a genuine commercial breakthrough.

The Regions and Cities Initiative provides a unique opportunity to benefit from existing knowledge, draw on project development support and financing assistance to realise own FCH deployment projects. The 89 regions and cities currently taking part in the initiative represent a broad range of experience regarding FCH technology deployments: From regions having no experience at all that want to build up relevant knowledge and know-how to regions having already realized large scale FCH projects with a lot of hands-on experience. Thus one main goal of the initiative is to facilitate the dialogue with experienced regions, cities and industry players regarding valuable expertise, best practices and lessons learned from FCH project implementation. It provides up-to-date information on FCH applications and their business cases, as well as giving guidance on how to draw on a variety of European, national and other funding programmes to finance the cost premium that still exists for this technology. It provides regions and cities with support on FCH project development and helps them overcome typical challenges in FCH project implementation. It thus constitutes a unique opportunity for cities and regions to receive dedicated support as they realise their individual FCH deployment plans. All European regions and cities are invited to join and to collaborate in this joint effort to start the green energy revolution with hydrogen and fuel cells at the local level.

To enable the realisation of the envisaged FCH deployment plans of the regions and cities continued support will be required for individual projects as well as the coalition at large. Participants of the initiative have clearly stated that they require continued support to bring their deployment plans to implementation and to actually realise EUR 1.8 bn of investments in the FCH sector. This need for support includes both measures to facilitate individual project development (e.g. support in setting up implementable project concepts, developing financing concepts or aligning relevant stakeholders) as well as to continue facilitation of joint coalition work (e.g. in raising awareness for the technology, facilitating exchange between experienced and less experienced regions or with industry). It will be important to sustain a comprehensive support framework in this regard to realise the envisaged deployment plans and thus to contribute to technology commercialisation in Europe.

1. Introduction – Fuel cells and hydrogen for green energy in European cities and regions

Tackling emissions and establishing a sustainable green energy and transport system are key challenges for Europe in the 21st century

A drastic reduction in greenhouse gas (GHG) emissions is required to keep global warming to below 2 °C, as declared in the 2015 Paris Agreement. Accordingly, the European Union (EU) and its member states are pursuing ambitious GHG reduction targets: Compared to 1990 levels, the EU aims to reduce GHG emissions by 20% by 2020, by 40% by 2030 and by 80 to 95% by 2050.[1] Its member states have defined national targets in line with these goals. Consequently, today's use of fossil fuels across all energy sectors must be drastically reduced. Doing so will in return decrease dependency on energy imports to the EU and thereby enhance energy security.

Local emissions also need to be reduced to improve local air quality and alleviate negative health impacts. Fossil fuel use generates significant emissions of local pollutants such as nitrogen oxides, fine particulate matter and sulphur dioxide. It is estimated that air pollution in the EU is responsible for health costs of at least EUR 215 billion and around 487,000 premature deaths per year.[2] The EU has therefore set targets to reduce local pollutants in its Ambient Air Quality (2008) and National Emission Ceilings (2016) Directives, as well as in its vehicle exhaust emissions regulation. Nevertheless, local air pollution levels in many European cities still continuously fall short of local air quality standards. European citizens increasingly see climate change and local air pollution as serious problems. At the same time, their perception is that public authorities and local governments are not doing enough to improve local air quality and protect the environment.[3] Fighting local air pollution and mitigating climate change therefore rank among the most pressing environmental concerns in the EU, and regulatory pressure to take action in this regard is being stepped up.

To achieve global emission reduction goals, a consistent shift to a green energy system is necessary. Countries around the globe must cater for their energy needs mainly from renewable sources. Green energy will need to be available not only for the electricity supply, but also for transport, heating and industrial energy use. This poses significant challenges to governments, economies and societies around the world as they seek to finance and implement the necessary transition to green energy. Whereas the EU overall is on track to reach its 2020 GHG emission reduction target, the measures implemented to date will have to be significantly enhanced after 2020 to reach the targets for 2030 and beyond.

The FCH JU's Regions and Cities Initiative supports realisation of the green energy transition in European regions and cities with hydrogen and fuel cells

Against this backdrop, the FCH JU launched an initiative in 2017 to support European regions and cities in realising their green energy transition with fuel cells and hydrogen (FCH). The primary objectives of the FCH JU's Regions and Cities Initiative[4] include:

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[1] EU 2020 Climate and Energy Package (2009); EU 2030 Climate and Energy Framework (2014); EU 2050 Low-Carbon Roadmap (2011)

[2] Health and Environment Alliance (2017), European Environmental Agency (2017)

[3] Eurobarometer "Climate Change" (2017), "Attitudes towards the environment" (2017), "Urban Mobility" (2013), "Air quality"(2013),

[4] http://www.fch.europa.eu/page/about-initiative

> Supporting regions and cities in assessing the potential of various FCH applications
> Identifying and maximising the use of available funding sources for FCH projects
> Supporting regions and cities in engaging their local stakeholders to invest in FCH
> Developing a joint way forward, including the preparation and implementation of FCH deployment projects from 2018 onwards

As of today, 89 European regions and cities from 22 countries are taking part in the initiative. Together, they represent approximately one quarter of Europe's population, surface area and GDP. All participating regions and cities are actively working to shape their green energy transitions with hydrogen and fuel cells. Regions and cities can play an important role in creating a future FCH market in Europe by channelling public investments into the sector and supporting the build-up of a European FCH value chain with the potential for local economic growth and job creation.

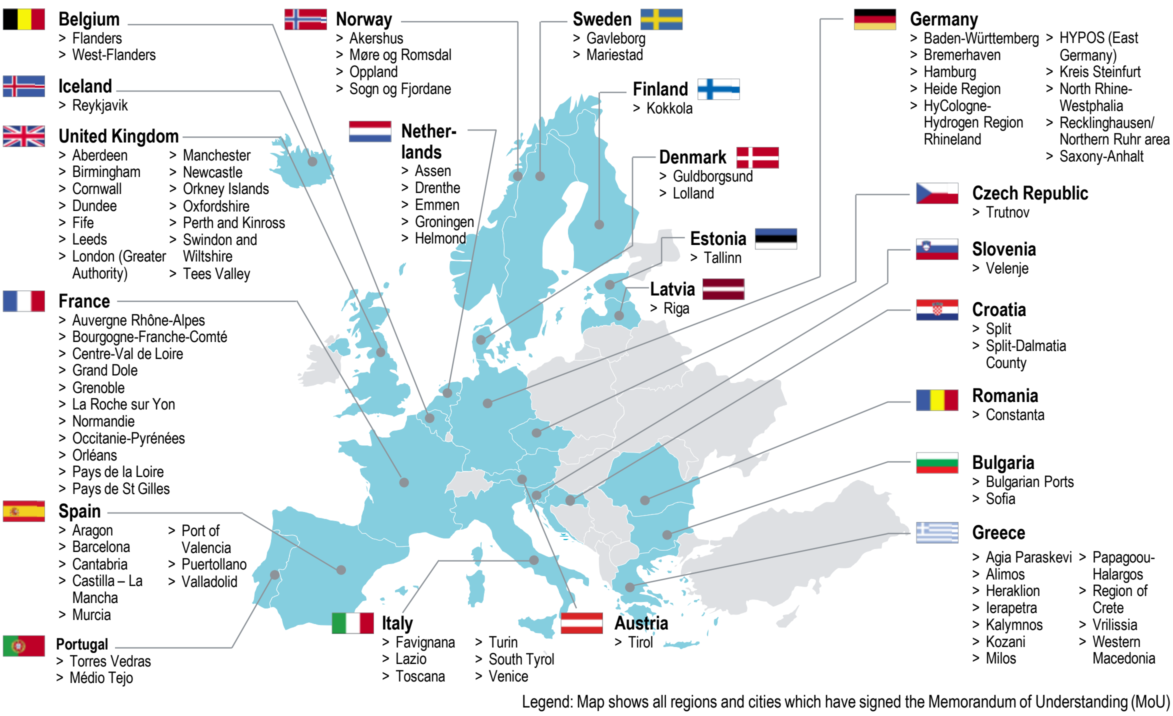

Figure 1: Overview of participating regions and cities as of May 2018

An even larger number of FCH projects is currently under development outside the scope of the study coalition that will considerably drive technology development in Europe.

A large number of FCH industry players are supporting the initiative, keen to engage in a joint effort with the regions and cities to develop the European FCH market. 76 companies in the FCH sector are taking part in the initiative, supporting its work with their expertise and first-hand knowledge.

European regions and cities can play a crucial role in reducing emissions and realising the green energy transition

An increasing number of European regions and cities have defined ambitious local emission reduction targets and are acting as drivers of change at the local level. In many cases, these local targets actually exceed national or EU targets, thereby paving the way for profound emission reduction measures to be implemented. Initiatives such as the "C40 Cities" network and the "Covenant of Mayors for Climate & Energy" represent an increasing number of regions and cities that are committed to taking climate and energy action and driving change on the local level.

Regions and cities are crucial stakeholders in the green energy transition, as it is they who translate global ambitions into local action. The EU and its member states need to and will further develop the policy framework for reducing emissions and for enhancing green energy use. This development must be complemented by action taken on the local level, where regions and cities can translate global ambitions into local action: This can include the development of local environmental strategies and policies, the establishment of local incentive schemes for green technology adoption, and the realisation of direct public investment in a number of areas – from improving building energy efficiency and renewable power generation to transforming public transport and municipal service fleets. Many European regions and cities are already committed to advancing Europe's green energy transition on the local level, but more are still needed to join.

Hydrogen and fuel cells can play a key role in helping regions and cities to achieve local emission goals and build the future green energy system

Hydrogen and fuel cells will be important cornerstones of the future energy system, as they enable renewable power generation to be integrated on a large scale. Already today, significant amounts of renewable electricity are being curtailed in Europe due to an imbalance between supply and demand. This imbalance will worsen as renewable energy generation increases in the future. Hydrogen is the only viable solution in this regard, as it can serve as a large-scale renewable energy store, thereby enabling renewables to be integrated in the energy system.

Hydrogen is also a versatile energy carrier that can be used in a variety of sectors, thus enabling sector coupling. Hydrogen can be used in all kinds of energy sectors, from power production to transport, building heat and power and industrial energy use. It can also be used as industry feedstock. It thereby enables sector coupling, i.e. linking renewable power generation to energy use in other sectors. Moreover, it can be a green energy solution for sectors that are otherwise hard to electrify. Hydrogen and fuel cell-based energy solutions exist today across a number of different sectors and for a variety of use cases. Advanced technology levels have been reached, as has commercial maturity to some extent.

The technology is mature and safe, so it provides a viable zero-emission alternative for regions and cities. Hydrogen and fuel cell-based energy solutions currently exist across a number of different sectors and for a variety of use cases at advanced levels of technological maturity. Significant advancements in recent years have improved technology performance and brought it close to commercialisation. The technology has been deployed in daily, real-world operations in countries across the globe and has demonstrated that it is mature, safe and works in practice. Hydrogen and fuel cells are thus a viable solution to help regions and cities realise their green energy transition.

This study presents the key results of joint work conducted in the first year of the initiative and the key lessons learned. It includes an overview of the potential and current status of hydrogen and fuel cell technology for European regions and cities (chapter 2); an overview of participants' FCH deployment plans and the associated market development potential (chapter 3); and a summary of the main challenges and a way forward to further develop the market and drive commercialisation (chapter 4). Additional, more detailed project results are publicly available on the FCH JU website. Furthermore, a comprehensive set of tools and materials is available from the FCH JU for members of the initiative. Information on joining the initiative is likewise available on the FCH JU website.

2. Hydrogen and fuel cell applications – Potential and current status

The following chapter provides a comprehensive overview on the future role of hydrogen and fuel cells in the green energy system, the local benefits that regions and cities can derive when investing in hydrogen and fuel cells, and the current development status for key hydrogen and fuel cell applications. It shows that hydrogen and fuel cells are a viable solution to address current emission reduction challenges and realise the green energy transition at local level.

2.1 The role of hydrogen and fuel cells in the future green energy system

The green energy transition will raise new challenges that need to be addressed

A future green energy system will require renewable energy sources (RES) to be integrated on a large scale. That in itself leads to new challenges. To reach the above mentioned GHG emission reduction targets, almost all energy production and consumption in the EU will have to stem from RES – a development that creates new challenges for the energy system. Electricity produced from RES is available only when the sun shines or the wind blows: RES energy supply fluctuates significantly and often does not match energy demand. At other times, RES energy demand is insufficient, with the result that production of this energy needs to be curtailed as it cannot be stored. This imbalance between supply and demand will worsen as more and more renewable energy is integrated in the energy system. Solutions will therefore need to be developed to better match energy supply and demand.

Hydrogen can serve as a flexible store of electricity from RES, thereby resolving the imbalance between energy supply and demand. Hydrogen can resolve the challenge of the imbalance in energy supply and demand, as it can be produced from renewable electricity using electrolysis and can be stored on a large scale over long periods of time, like any conventional gas, e.g. in large salt caverns. Direct electrification and the use of battery technology alone will not be able to overcome this challenge. Nor will the latter technologies be able to cater for all energy needs in a fully decarbonised energy system: Several energy-intensive sectors (such as heating and industrial energy use) are hard to electrify at all. In the mobility sector too, electrification will be difficult to achieve using battery technology only.

Hydrogen will play an important role in the future green energy system

Hydrogen can fulfil the following important roles in the future European energy system:

1. Hydrogen will help to overcome the imbalance between renewable energy supply and demand. By producing green hydrogen from RES, **it will enable** large-scale renewable energy storage and allow **renewables to be integrated in the energy system on a large scale.**
2. **Hydrogen offers flexible energy storage and distribution options**, as it has the same storage and distribution properties as any conventional gas in use today. It can easily be distributed to any point of end use at comparatively lower infrastructure cost.[5]

[5] In Germany, for example, a recent study by Robinius et al. (Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles, 2018) revealed that, given a larger market uptake for electric vehicles, system costs for hydrogen refueling infrastructure are a less expensive way to install the required charging infrastructure.

3. **Hydrogen provides flexible energy buffer capacity** to ensure a secure energy supply and energy system resilience. It is a viable carbon-free replacement for current energy buffer capacity, which covers about 15% of the world's total annual energy demand.

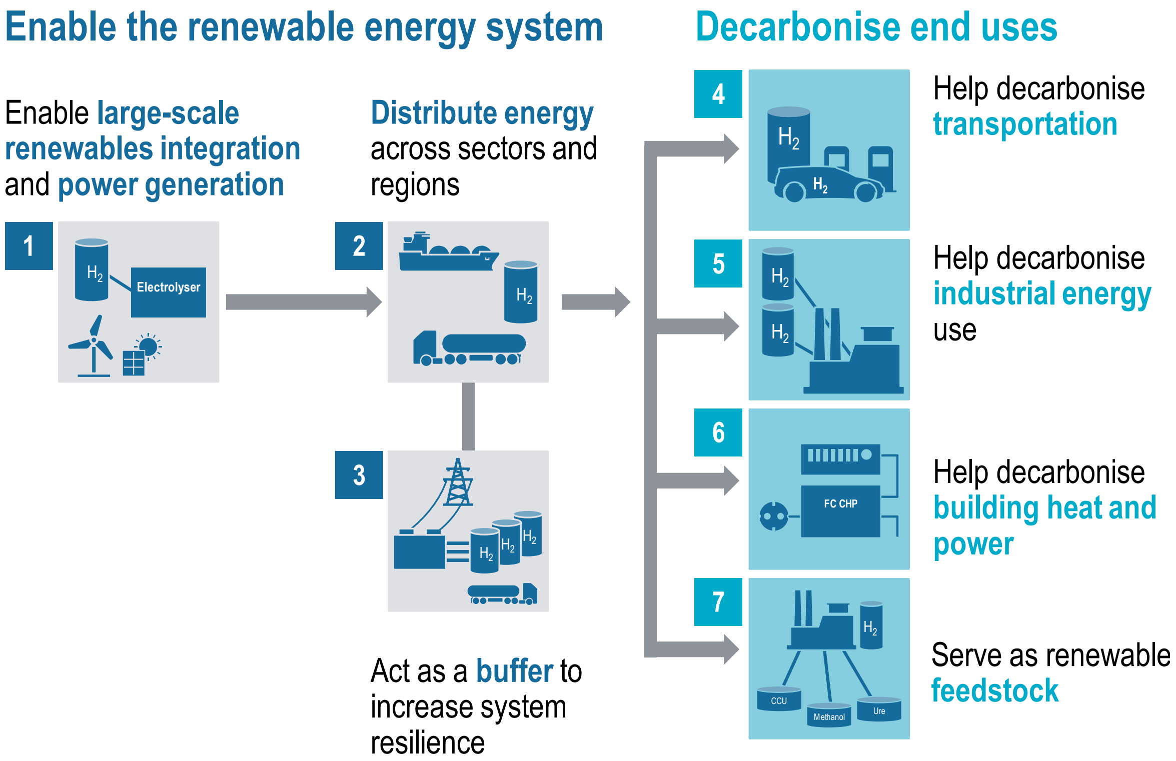

Figure 2: The roles of hydrogen in the future green energy system

Additionally, hydrogen and fuel cells can decarbonise energy use across different energy sectors:

4. **Transport:** Hydrogen-based mobility offers flexibility and operational performance similar to conventional vehicles and can also cater for demanding use cases (e.g. trains, buses, trucks).
5. **Industrial energy use:** Hydrogen can supply green energy to energy-intensive industries where using electricity is not a viable option.
6. **Building heat and power:** Today, around 80% of residential energy demand stems from the provision of heating and hot water.[6] Hydrogen can provide clean residential heat and power, e.g. with FC CHP systems, as direct electrification is not a viable option for decarbonisation.
7. **Industry feedstock:** Where industrial production processes rely on hydrogen as feedstock, the "grey" hydrogen currently in use can be replaced by green hydrogen to drive decarbonisation at scale.

In addition, hydrogen will help keep energy supply secure and shift value creation to Europe. At present, the EU relies heavily on fossil fuel imports. Yet fossil fuel resources are limited and will become increasingly contested in the future. Enabling local energy production from RES with hydrogen will largely reduce EU energy imports, thus making energy supply more secure in the future. At the same time, local energy production will shift value creation back to Europe.

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[6] Eurostat (2017): Electricity and heat statistics for the EU

2.2 The benefits of hydrogen and fuel cells for European cities and regions

Regions and cities can benefit significantly from investment in the FCH sector

Hydrogen and fuel cells can deliver multiple benefits for regions and cities. On the one hand, deploying FCH technology yields multiple local benefits and helps create the growing market for FCH technology that is needed to achieve commercialisation. On the other hand, regions and cities can invest in local FCH industrial and research capacity to cultivate local economic growth and job creation in the FCH sector. Development of both the demand and supply sides is needed in Europe to advance the sector overall.

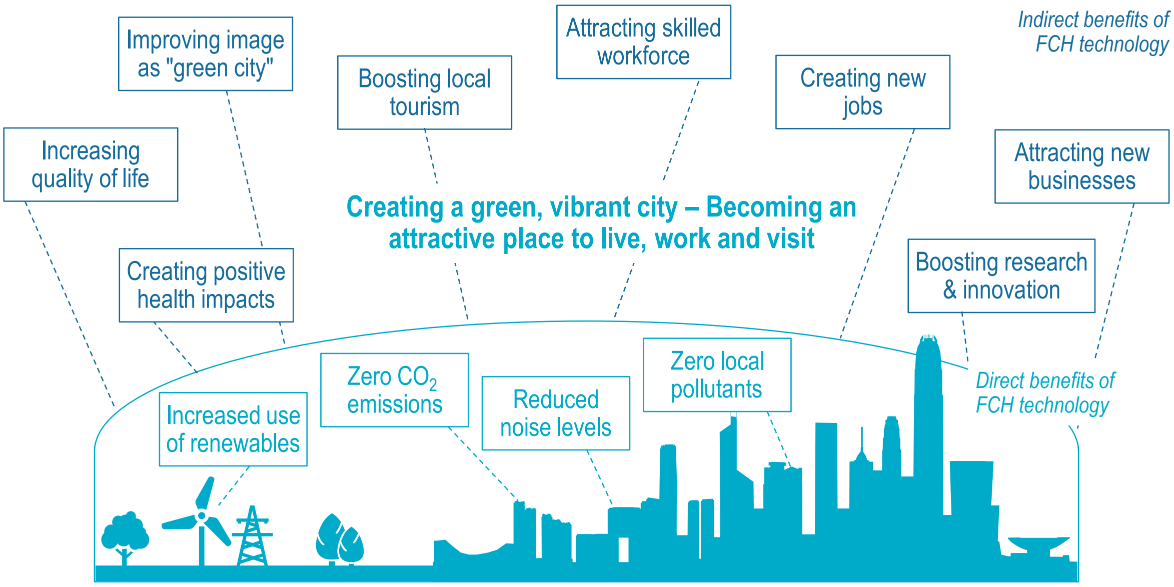

Figure 3: Local benefits of hydrogen and fuel cells for regions and cities

FCH applications combine high operational performance with flexibility

FCH applications provide operational performance which compares favourably with conventional solutions, thus providing high user comfort. FCH applications provide the benefits of long runtimes and long ranges without refuelling. Refuelling times are comparable to conventional applications. FCH applications can also service more demanding operational requirements, such as for public transport buses or trucks, where battery technology reaches its limits. In this way, FCH vehicles provide considerable operational flexibility while possessing the same advantages as any electric drivetrain (e.g. reduced noise, smooth driving experience, quick and continuous acceleration).

Deploying FCH applications yields significant local environmental benefits

Hydrogen can be produced from 100% renewable energy sources and therefore has the potential to completely decarbonise energy use. Even if hydrogen is produced from conventional steam methane reforming (SMR) using natural gas, GHG emissions can be reduced. If hydrogen is produced from electrolysis using electricity from renewable energy sources, associated GHG emissions can be reduced to zero.[7]

In addition, hydrogen causes no local pollutants. For example, FCH transport vehicles emit nothing but water and completely avoid any harmful local emissions such as nitrogen oxides (NOx). If all transport were to run on electric energy (e.g. with hydrogen and fuel cells), regions and cities could significantly improve local air quality and comply with the EU's air quality standards. On top of that, local noise pollution would be considerably reduced.

The environmental benefits of using hydrogen improve local quality of life

Beyond environmental effects, regions and cities can gain a number of additional benefits:

> **Improved local air quality has positive health impacts**. Improved air quality and reduced noise will contribute to the well-being and good health of the local population.
> **Clean air and reduced noise levels improve local quality of life**. Cities will become more attractive to local residents, but also to potential new arrivals moving into the area.
> **FCH deployments will help foster the image of a 'green city'.** By investing in green technologies, regions and cities can position themselves as clean and environmentally friendly.
> **A 'green city' image and high local quality of life can substantially boost local tourism**. Green tourism is an ongoing trend. A 'green city' can attract new visitors and boost local tourism.
> **An attractive city attracts new businesses that create new jobs.** Attractive living conditions are of tremendous importance to competitive industries and make it easier to attract them.
> **Enhanced city attractiveness and reduced air and noise pollution can positively impact property values**, thus increasing technology deployment benefits for the local population.

Additionally, investing in the FCH sector opens up huge potential for local economic growth and job creation in an advanced industry sector

Regions and cities can support local industrial development in the FCH sector, thus facilitating local economic growth. Increasing the local capacity of the FCH sector is an attractive option to tap into a growing market, drive local economic growth and create new jobs. In the German state of Baden-Württemberg, for example, the potential value added by the FCH sector is estimated at around EUR 680 million through 2030.[8] Opportunities for local economic growth arise along the entire FCH value chain. In the long term, a large international market is expected to evolve that is projected to create 30 million jobs and USD 2,000 billion in annual sales worldwide by 2050.[9] Today, the European FCH sector already harbours significant potential for local SMEs to create additional business. Developments in other green technology sectors show that substantial economic benefits can be expected from investing in fuel cells and hydrogen (see figure 4). Investing in the local FCH economy pays off: Up to 15 jobs are expected to be created for every EUR 1 million of revenue generated in

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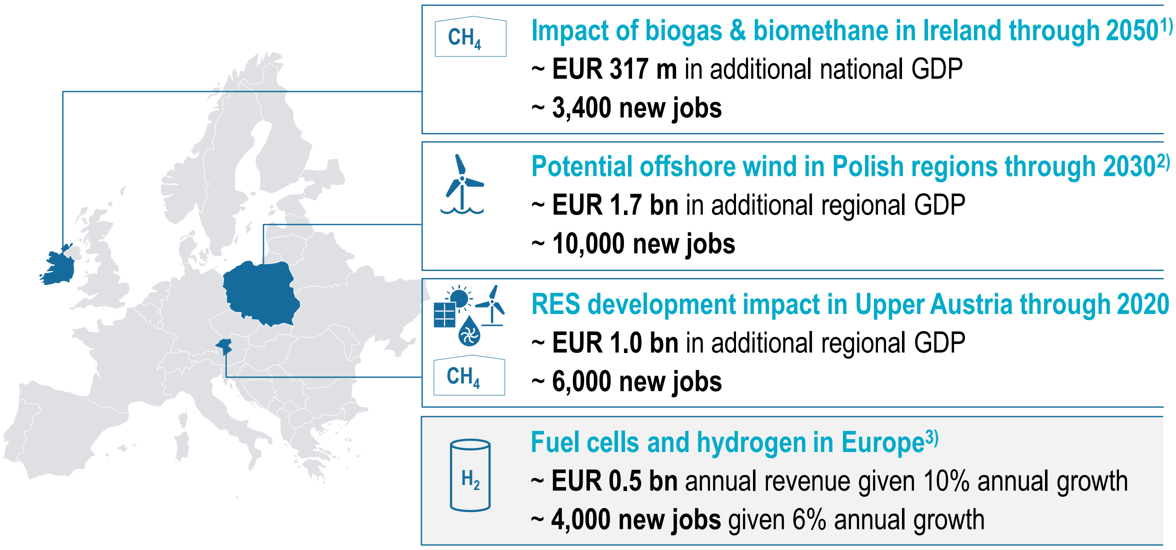
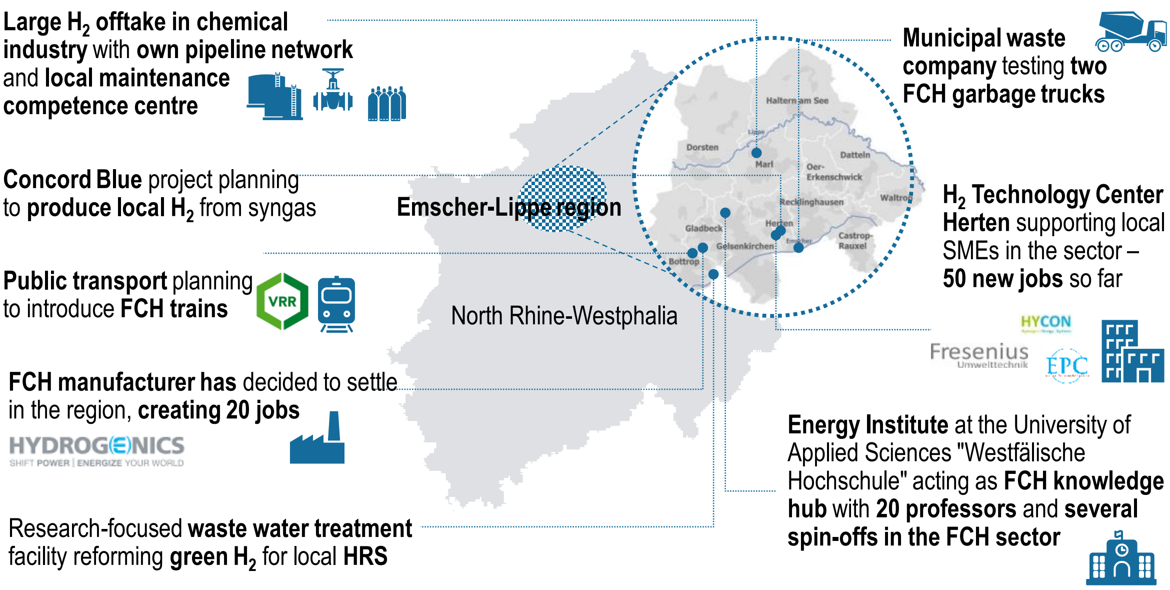
[7] Assuming no additional emissions arise from hydrogen distribution (e.g. by on-site production) or other sources (e.g. using conventional grid electricity to power refueling stations etc.)
[8] Assuming the widespread roll-out of hydrogen infrastructure; see e-mobil Baden-Württemberg (2016): Commercialisation of the hydrogen technology in Baden-Württemberg
[9] Hydrogen Council (2017): Hydrogen Scaling up

the sector by local businesses.[10] That is why regions and cities are among those investing in local FCH research and production capacity, supporting local companies in their R&D efforts and realising joint demonstration projects. Numerous examples of focused local development support for the local FCH sector exist throughout Europe, e.g. the H_2 Region Emscher-Lippe in Germany's Ruhr region (see figure 5), the Auvergne-Rhône-Alpes region in France and the Province of Drenthe (including Groningen) in the Netherlands.



1) Operational impact only, excluding construction; impact on gross value added 2) Regions Pomorskie and Zachodniopomorskie 3) Through 2012
GDP = Gross domestic product; RES = renewable energy sources

Figure 4: Economic effects of green technology developments (selected examples)



*) In the wider regional context, the hydrogen and fuel cell center ZBT GmbH in Duisburg should also be mentioned as an important knowledge and technology hub
Sources: h2-netzwerk-ruhr e.V., Roland Berger

Figure 5: FCH activities and investments in the H_2 Region Emscher-Lippe

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[10] Hydrogen Council (2017): Hydrogen Scaling up

To summarize: Investing now in fuel cells and hydrogen will yield enormous benefits for European regions and cities. Hydrogen and fuel cells have vast potential to be the keystones of the green energy transition in European regions and cities. Investing in this technology now offers enormous local benefits – for the local environment, to create an attractive city to live in and to boost the local economy. Numerous pioneering cities and regions have already started to make hydrogen and fuel cells their green energy solution of the future, and more are expected to follow suit.

2.3 FCH applications – Technological readiness, economic and environmental performance, deployment potential for regions and cities

A large portfolio of FCH applications with high levels of technological maturity are available for deployment today

FCH technology has made significant advances in recent years. Numerous FCH applications are available today that feature impressive levels of technological maturity, safety and reliability and are ready for deployment. Substantial real-world operational experience has been gathered with different applications in Europe over the past few years. FCH technology works in practice and is thus ready to be deployed to reduce emissions and enhance green energy use.

FCH experience		Achievements	
20,000,000+ km travelled globally with FC vehicles	**1,000+** fuel cell vehicles operating in Europe	Car driving range improved to **600 km**	Refuelling time for cars reduced to **3 min**
300 new fuel cell buses to be deployed in Europe	**200+** H_2 refuelling stations installed globally	Fuel cell bus costs reduced by about **80%**	Bus fuel cell system lifetime improved by **350%**
15,000+ Fuel cell forklifts in operation globally	**120,000+** FC micro-CHP systems installed in Japan	**50%** cost reduction for FC stacks and HRS	**99.4%** reliability for stationary FCs achieved

Figure 6: Experience gained and development achievements for selected FCH applications (examples)

Many FCH applications are close to commercialisation today and are expected to become fully commercially available with further market uptake in the years ahead. Other applications are still at earlier development stages, but are expected to advance quickly. Today's cost premium for the technology compared to conventional solutions is expected to decrease significantly with further market development and as the volume of deployed FCH applications increases.

Different FCH applications with the greatest relevance to deployment by regions and cities were analysed in detail during the project. The exhaustive findings of the analysis are published and can be accessed on the FCH JU website.[11]

1 Heavy-duty transport

- Trains
- Buses
- Heavy-duty trucks

2 Light & medium-duty transport

- Cars
- Delivery vans
- Garbage trucks
- Sweepers
- Mobile construction equipment
- Material handling
- Bikes
- Scooters

3 Maritime & aviation

- Ferries
- Boats
- Ships
- Port operations equipment
- Aircraft
- Airport ground operations

4 Stationary

- Residual use/ FC micro-CHP
- Commercial buildings
- Industrial use cases
- Back-up power
- Off-grid power
- Gensets

5 Energy-to-hydrogen

- Hydrogen production
- "Hydrogen-to-X"
- Energy storage
- Hydrogen injection into the gas grid
- Electricity grid services

Figure 7: FCH application clusters within the project scope

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[11] Extensive documentation is provided at: http://www.fch.europa.eu/page/presentations-2

Different FCH applications have reached varying levels of technological readiness and commercial availability, and this affects their readiness for deployment. Some FCH transport or stationary applications are already very mature today and can already fully replace conventional solutions. Other applications are still in their development and prototype stages, with less technological maturity and limited commercial availability.

		1 Tech, readiness level (TRL)	2 Economic competi-tiveness	3 Environ-mental benefits	4 USP	5 Ease of deploy-ment	6 Direct pro-curement	7 "Show-case" visibility
Transport appli-cations	(Urban) buses	High	Medium	High	High	Medium	High	High
	Cars	High	Medium	High	High	High	Medium	High
	Delivery vans	Medium	Low	High	Medium	Medium	Low	High
	Heavy-duty trucks	Medium	Low	High	Medium	Medium	Low	High
	Trains	Medium	High	High	High	Medium	Medium	High
	Port operations	Low	Medium	High	Medium	Low	Low	Low
Stationary appli-cations	Power to H_2	High	Medium	Medium	High	Low	Medium	Low
	H_2 injection into gas grid	High	Low	Medium	High	Low	Medium	Low
	Residential mCHP	High	Medium	Medium	Medium	High	Medium	Medium
	Off-grid power	High	Low	High	High	Medium	Medium	Medium

High Medium Low

Figure 8: Assessment of application maturity based on key evaluation criteria

Heavy-duty FCH transport applications will play a key role in the future e-mobility market, as there are hardly any other zero-emission alternatives available

Urban FCH buses are one of the most mature FCH applications. Extensive operational experience has been gathered in Europe and they are on the verge of commercialisation. Overall, urban FCH buses are one of the most viable FCH options for regions and cities, as they are among the most mature FCH applications and are close to commercialisation. Multiple large-scale demonstration projects have tested the technology in Europe and led to high maturity levels. Costs have also been reduced significantly since the first prototypes were launched.

Regional FCH passenger trains have just gone into service in the first demonstration project in Germany, with substantial potential for rapid commercialisation. From a present perspective, FCH trains are the only viable zero-emission alternative for regional train services operating on non-electrified lines. Even though the first FCH train demonstration is only just starting, ambitious plans exist to scale up FCH train deployments in the coming years, especially in Germany and France, thus potentially driving swift commercialisation. Besides FCH passenger trains, the potential use of FCH technology is also being explored in other rail segments, although related activities are still in their early stages.

Heavy-duty trucks could potentially be well-suited to the use of FCH technology. So far, however, only initial prototypes have been developed and larger-scale roll-out is yet to begin. Even though energy-hungry transport use cases such as heavy-duty trucks are often seen as the most promising areas of application for FCH technology, commercial development of relevant products has only just started. A few pioneering OEMs are currently working on prototypes, of which a few have yet been tested. The heavy cost pressure that private sector companies typically face when operating heavy-duty trucks means that it is still a challenge to develop commercial market offerings for FCH trucks.

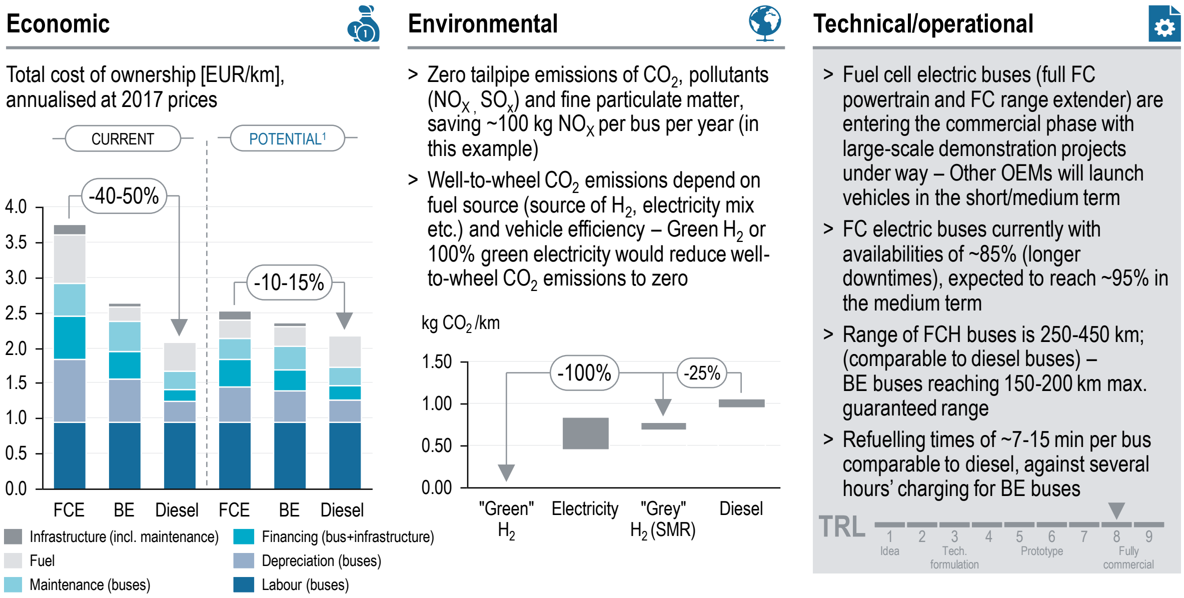

Figure 9: Main findings of FCH bus assessment

Light and medium-duty transport applications cover a wide range of market segments with different levels of technical and commercial readiness

FCH cars with high maturity levels are available mainly from Asian OEMs, but commercial availability is currently limited. FCH cars have reached very high levels of technological maturity and have acquired substantial operational experience in Europe and other key international markets. Nevertheless, one of the biggest hurdles for an accelerated European market uptake is the current lack of availability of commercial products from OEMs. The limited number of OEMs offering products and relatively low production volumes/shipments to Europe create a shortage of vehicles for deployments larger than current projects.

FCH delivery vans (below 3.5 tons) can potentially service multiple use cases in municipal fleets and in the private sector, but the product portfolio is currently limited. A sizable proportion of traffic in inner cities is serviced by delivery vans. FCH delivery vans could cover a large chunk of this segment where operational requirements are demanding. Despite this large potential, only one range-extended FC vehicle model is commercially available at the present time.

Garbage trucks and sweepers are currently being demonstrated in several early projects as pre-commercial stages with a clear use case for public sector deployments. Garbage trucks are at an early development stage. Initial larger demonstration projects are currently being realised, but these are using different technological solutions. The FCH sweepers deployed so far are mainly based on a retrofitting approach and are likewise at an early development stage. Regions and cities are becoming more interested in deploying such vehicles, however, so technology development will advance and costs will be reduced in the future.

FCH forklifts are very mature FCH applications which potentially present a more positive business case than other solutions. FCH forklifts already provide an attractive use case for warehouse operators who require indoor material handling equipment. Short refuelling times for FCH forklifts dramatically increase the operational availability and, hence, the capacity of forklift equipment, which in turn leads to labour productivity gains. However, forklifts are mainly used in private warehouses and the logistics sector. Potential for direct public sector deployment projects is currently limited.

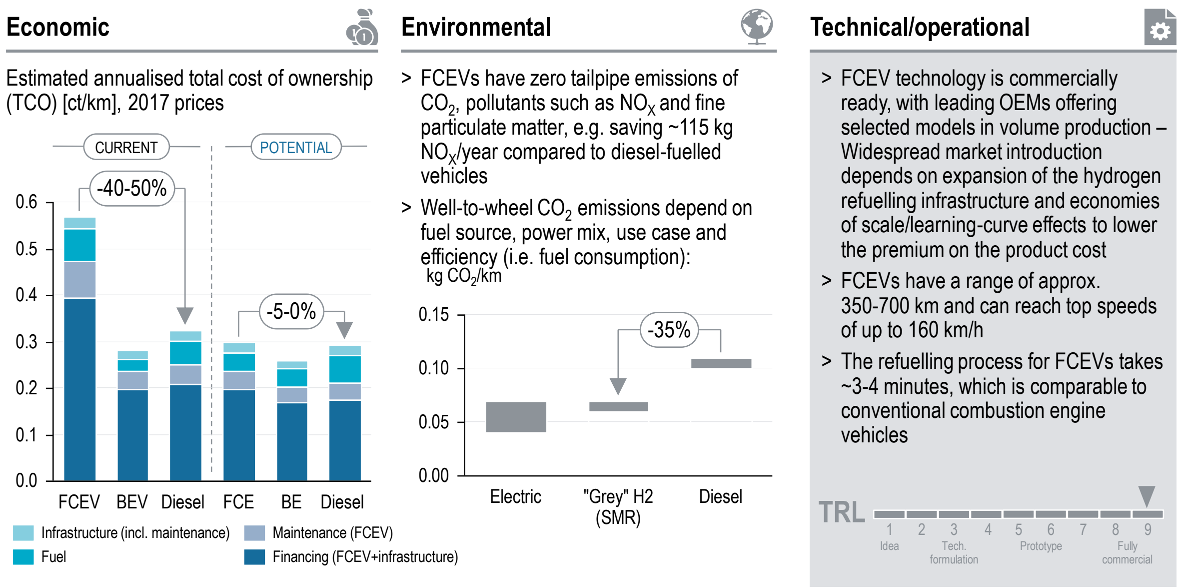

Figure 10: Main findings of FCH car assessment

Maritime and aviation applications are mostly at the conceptual or prototyping stages, with initial demonstrations currently being realised

Maritime FCH applications are still in the prototyping and developing stage, even though the maritime sector is under huge pressure to reduce emissions. Fuel cell-powered maritime transport applications – including different types of boats, ferries and ships – are currently in the prototyping phase. Most vessels are being developed as fuel cell hybrids: Only a small minority of developments include full fuel cell propulsion. In some cases, fuel cells are used as auxiliary power units for on-board energy needs above and beyond pure propulsion, e.g. for the extensive auxiliary power needs on cruise liners. It is expected that further tightening of regulations on maritime emissions such as noise, as well as SO_2, CO_2 and NO_x emissions, will promote the deployment of zero-emission solutions on larger scales in the future.

Airport noise emissions and pollutants can be significantly reduced by FCH auxiliary power units for non-propulsive aircraft systems. Today, fuel cell-powered flights are not regarded as feasible. Auxiliary power units for non-propulsive systems on the ground and in flight are therefore the only application case for FCH that is within reach in the aviation sector in the years ahead. However, further research and development efforts are still needed even for this use case, as the application is still at a pre-commercialization stage with initial demonstration projects ongoing. Airports also provide a variety of possible use cases for fuel cells and hydrogen in the aviation sector, including ramp, passenger and cargo handling, catering services, facility management and other services.

Stationary FCH applications have already reached high maturity levels and are commercially available, especially for residential use

Combined heat and power (CHP) systems can be deployed in different use cases for local heat and power provision. Micro-CHPs (mCHPs) for residential are the most advanced market segment to date. Micro-CHP systems for residential buildings are the most advanced market segment for stationary FCH applications in Europe as things stand. Upscaled CHP systems can be used in larger public or commercial buildings (e.g. office buildings, public schools etc.). They can also be deployed for industrial use to replace less efficient turbines or combustion systems. Stationary systems mainly run on natural gas today, but CHP systems are already a viable solution to reduce CO_2 emissions from heat and electricity generation. Right now, mCHP systems emit around 25% less CO_2 than boilers[12] due to their higher energy efficiency levels. These emission savings can be further improved if hydrogen is added to the natural gas grid, or if systems run on green hydrogen alone in the future.

The use of larger CHP systems for commercial or public buildings still needs to be developed in Europe to create a larger market. A well-established product portfolio for larger CHP systems (5-100 kW_{el} up to 400 kW_{el}) is commercially available only in North America and Asia. European manufacturers are slowly starting to develop products. In the industrial use case CHP segment (> 400 kW_{el} up to multi-MW_{el} power output), larger-scale trial projects are being conducted across Europe. Commercial offerings are already well advanced.

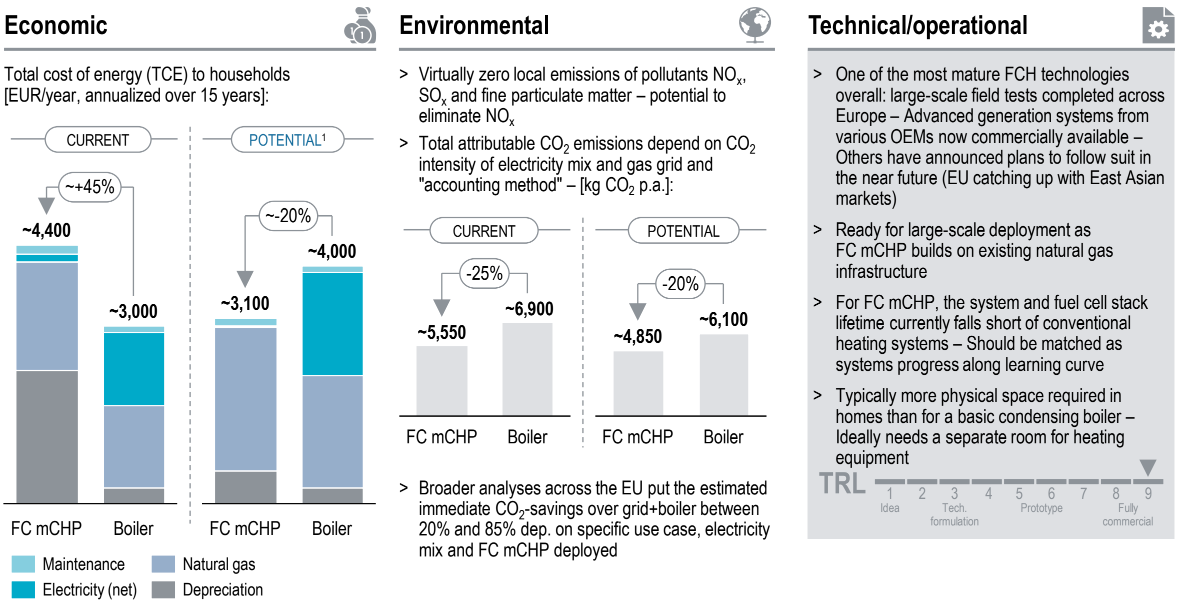

Figure 11: Main findings of FC mCHP assessment

Back-up power, off-grid power and gensets are additional FCH application areas in the stationary sector. Fuel cell powered back-up electricity systems are a very reliable low-emission alternative for critical infrastructure (e.g. data centres, hospitals, public security facilities, telecommunication infrastructures). Fuel cells and hydrogen can also provide off-grid power supply for remote areas such as islands, mountain refuges, industrial sites, mining facilities and telco infrastructures. FCH gensets offer a reliable power source for the remote operation of smaller applications (e.g. generators for construction, cooling for refrigerated containers).

[12] Broader analyses across the EU put the estimated immediate CO_2 savings over the grid and boilers at between 20 and 85% depending on the specific use case, the electricity mix and the FC mCHP deployed

Power-to-hydrogen and associated secondary applications are becoming better and better established to produce green hydrogen from RES electricity

Power-to-hydrogen based on electrolysis is an established technology that enables the large-scale production of hydrogen from renewable energy sources. Producing green (i.e. carbon-free) hydrogen from electrolysis using RES electricity will enable hydrogen to assume an important systemic role in the future energy system (see chapter 2.1). Considerable experience has been accumulated in Europe, where a range of OEMs provide commercial market offerings for electrolysis systems. Further major cost reductions are expected to materialise in the years ahead. Produced hydrogen can be sold for use in a variety of energy sectors and FCH applications, as seen above. In addition, secondary revenue streams exist that can help to create a viable business case for power-to-hydrogen projects: hydrogen injection into the gas grid, for example, as well as grid balancing services.

Advancing technological development and growing market uptake with increased deployments will be required to establish a commercial FCH market

In the years ahead, efforts to achieve the commercialisation of different kinds of FCH applications must be stepped up in Europe. Although several FCH applications are readily available for deployment today, others still require further technological development. For all applications, achieving substantially higher deployment volumes to cut costs and drive commercialisation is the main challenge to overcome in the coming years in Europe.

3. Towards a European FCH roadmap – The FCH deployment plans and ambitions of European cities and regions

This chapter outlines the insights gathered from three surveys during the course of the project[13]. The surveys focused on the local FCH deployment plans of the participating regions and cities, the implementation status in each case and the challenges they face. In effect, this chapter thus provides an aggregated overview of what the participants plan to contribute to FCH market development in Europe in the coming years. Given the nature of the initiative, this market assessment focuses primarily on public sector investments (such as the deployment of FCH vehicles in public transport or municipal fleets), but also includes public-private and private sector projects.

Realising these planned FCH investments will

- Significantly increase the FCH market volume in Europe
- Bring new FCH products to market and improve both the technological maturity and commercial availability of existing products
- Contribute to further reducing costs for FCH components and applications
- Establish a hydrogen production, storage and distribution infrastructure as a necessary basis for further market uptake across numerous European regions

Support for the realisation of these FCH deployment plans is important to drive FCH commercialisation in Europe. The FCH industry, the EU, its member states and the regions and cities themselves must make a collaborative effort if these plans are to materialise (see chapter 4).

3.1 Drivers of investment in hydrogen and fuel cells for regions and cities

Members of the Regions and Cities Initiative are pursuing a strong environmental agenda and see hydrogen and fuel cells as key pillars of their future energy systems

The large majority of regions and cities in the initiative are committed to realising EU targets for emission reduction and renewable energy use and have in most cases mapped out their own concrete targets. While most of these objectives are in line with EU and/or national emission reduction and renewable energy targets, some pursue even more ambitious goals. Some include plans for the 100% use of renewable energy sources even in the short term. Others have plans to become carbon-neutral regions or cities between now and 2030. Most regions and cities have made these targets part of their political agenda, thereby securing broad and long-term stakeholder commitment. This constitutes a strong basis on which to invest in green technologies such as hydrogen and fuel cells and to realise large-scale deployments in the years ahead.

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[13] 1st self-assessment survey (June 2017, N=79); 2nd self-assessment survey (October/ November 2017, N=63); FCH Deployment Plan Survey (March/April 2018, N=53)

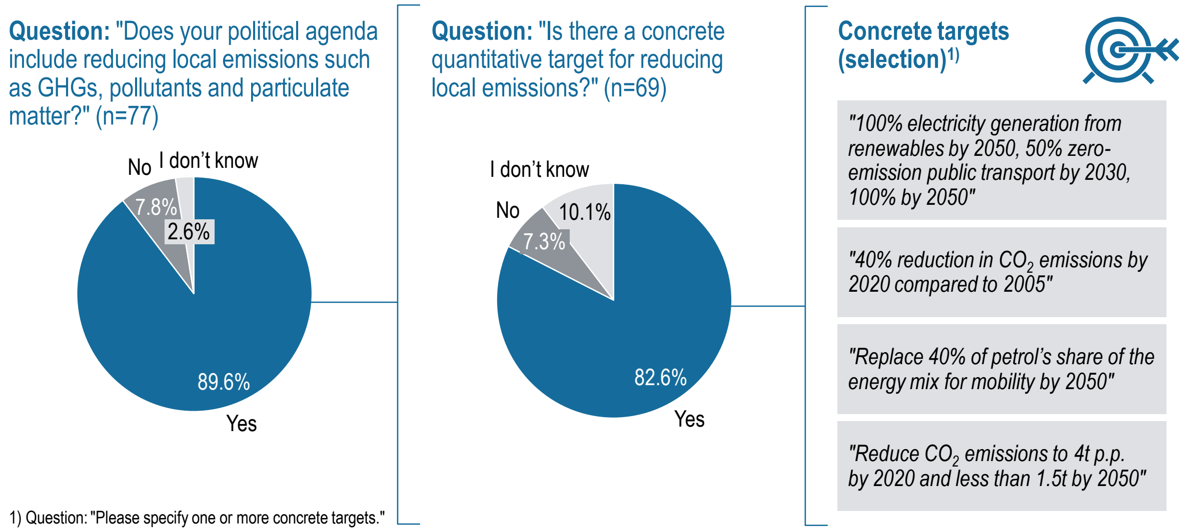


Figure 12: Levels of ambition to reduce local emissions among participants (1st self-assessment, June 2017)

Most participants have developed local strategies to implement their environmental agendas. The level of concrete proposals varies. Strategies typically include a long-term vision for a local green energy transition and define its main objectives. They usually determine the main areas of action and the next steps to take, as well as outline the next projects to be realised. In many cases, however, these local strategies are still being fleshed out in detail. Only a few regions and cities have already developed a complete transition roadmap that defines all the steps to be taken, sets clear milestones and quantifies targets. Most strategies do not focus on one green technology alone, but envisage a combination of different technologies that complement each other. Even though detailed strategies are in most cases still under development, a large number of green energy projects are currently under development or have been implemented in the majority of participating regions and cities. This number will grow significantly as more and more green energy transition strategies are put into practice. One predominant focus of these projects lies on the transport sector, while a smaller number of projects focus on renewable energy production.

London Be a zero-carbon city by 2050	**Torres Vedras** Reduce CO_2 emissions by 29% by 2020	**Aberdeen** Reduce carbon emissions by at least 50% by 2030	**Oslo** Reduce climate emissions by 95% by 2030
Riga Reduce CO_2 emissions by 55% by 2020	**Hamburg** Reduce CO_2 emissions by 40% by 2020	**Venice** Reduce CO_2 emissions by 20% by 2020	**Pays de la Loire** Reduce CO_2 emissions by 23% by 2020

Figure 13: Selected emission reduction goals of participating regions and cities

Regions and cities increasingly see hydrogen and fuel cells as an integral part of their green energy agendas, and some have a dedicated FCH strategy in place. Participating regions and cities acknowledge the important role that hydrogen and fuel cells can play in their future green energy systems and transition strategies. In some cases, participants have even mapped out dedicated FCH strategies complete with specific targets and the steps to take to drive local FCH uptake.

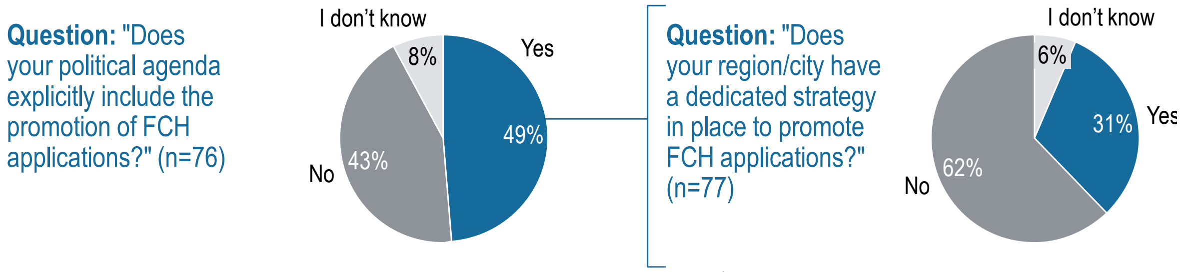
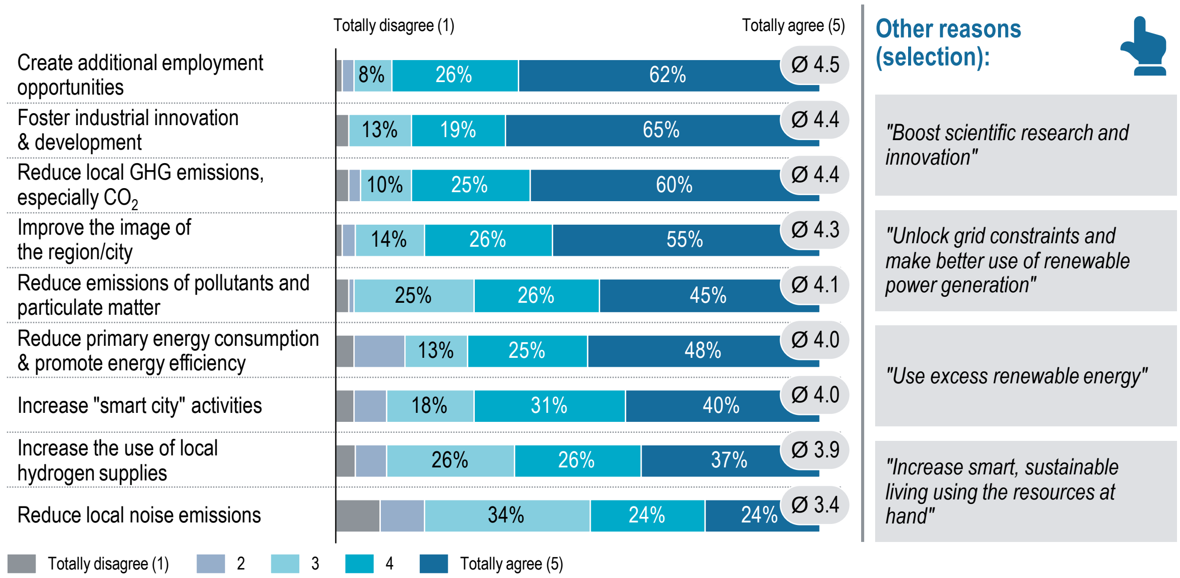


Figure 14: FCH applications as part of the local political agenda (1st self-assessment, June 2017)

For regions and cities, nurturing local economic growth is just as important as the need to exploit environmental benefits as a reason for investing in hydrogen and fuel cells

Supporting the local economy is high on the political agenda of many regions and cities. It is also one of the main policy goals of the EU's 2020 strategy for smart, sustainable and inclusive growth. Accordingly, many regions and cities are not only pursuing plans to deploy hydrogen and fuel cell technology to reduce emissions, but also to support local businesses and R&D activities in this sector (see also chapter 2.2). Through funding from the European Regional Development Fund (ERDF) regions can realize strategies to invest in research and innovation in the green energy sector (e.g. low-carbon and zero emission technologies etc.). Investments in hydrogen and fuel cell technology can be part of these strategies and hence ERDF funds may be used to build local H_2 economies. A few regions even specifically include hydrogen and fuel cells in their smart specialisation (RIS3) strategies[14].



1) Question: "What are your region's/city's main reasons for pursuing FCH applications? How relevant and important are typical drivers for FCH technologies to you, also compared to one another?" (n=76-77)

Figure 15: Main reasons why regions and cities pursue investments in the FCH sector (1st self-assessment, June 2017)

[14] For more information visit the Smart Specialisation Platform (http://s3platform.jrc.ec.europa.eu/)

3.2 The FCH deployment plans and ambitions of the regions and cities

The majority of participants plan to implement FCH projects in the coming years, based on different levels of experience and ambition

The level of experience with deploying FCH applications varies between participants, thus resulting in different levels of ambition for projects in the pipeline. About one third of participants have already gathered substantial experience in deploying FCH applications and the requisite infrastructure in recent years. However, the majority of participating regions and cities still have no experience in deploying FCH applications and are yet to take their first steps in this direction.

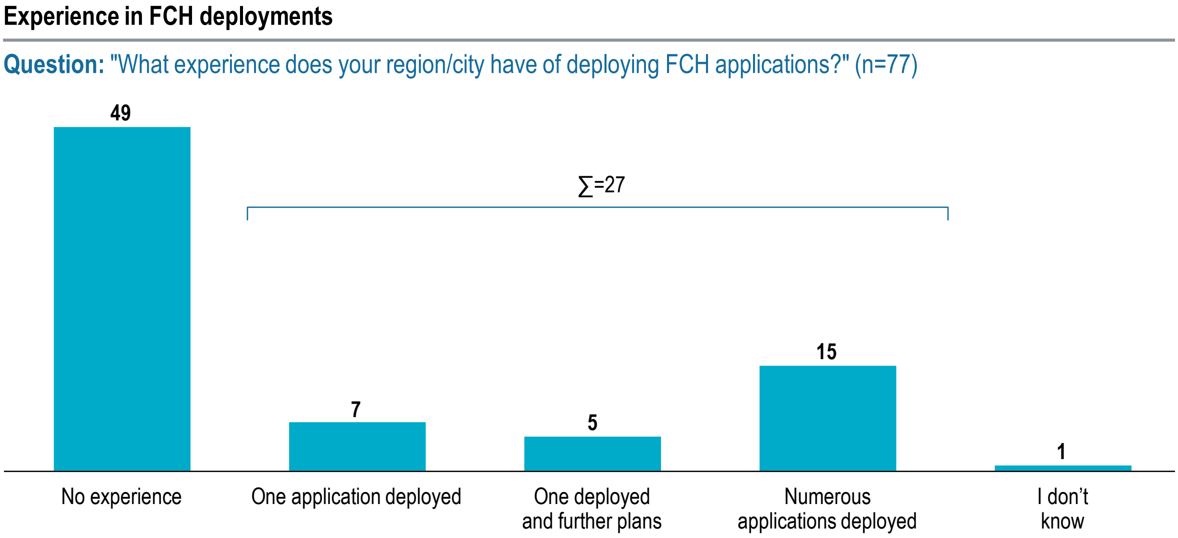


Figure 16: Levels of experience in deploying FCH applications among participating regions and cities (1st self-assessment, June 2017)

The majority of participants are planning to realise their first FCH deployment projects in the next few years. Typically, these regions and cities are planning to start with individual deployments of one low-volume FCH application before scaling up. In most cases, a local hydrogen infrastructure for H_2 supply and refuelling is yet to be established. These participants still need to address typical challenges to the implementation of initial FCH projects, such as convincing local stakeholders and securing political support. Given that this situation applies to a majority of the coalition members and, probably, to the majority of regions and cities in Europe, supporting these regions and cities as they take their first steps will be important to the large-scale roll-out of the technology in Europe.

A number of experienced and ambitious regions and cities are planning to realise large-scale local FCH roll-outs and establish "H_2 Valleys" in the years ahead. These regions and cities have defined ambitious FCH deployment plans on larger scales and at higher levels of complexity. They intend to establish local hydrogen infrastructure for production, storage and distribution, as well as to deploy larger-volume FCH applications for different use cases. In so doing, they intend to demonstrate the future role of H_2 in a green energy system as an enabler of sector coupling. By going beyond the scope of individual FCH deployment projects, they envisage initiating the development of a local H_2 economy. Such ambitious projects are referred to within the initiative as "H_2 Valleys". They are seen by participants as the necessary next developmental step for the sector. The concept has attracted significant interest both within and outside the initiative: Long-term ambitions and concrete short-term plans alike exist to establish several local "H_2 Valleys" across Europe (see chapter 3.4).

53 regions and cities have submitted detailed FCH deployment plans,[15] providing more detailed insights into their future FCH ambitions.[16] Almost all of these regions (92% have defined concrete environmental targets, e.g. to reduce emissions, as part of their political agendas, while 83% have defined or are currently developing local strategies on how to reach these targets. About two thirds of the regions either have a dedicated FCH strategy in place or have ambitions to make hydrogen and fuel cells part of their long-term energy transition strategies. Others are pursuing FCH deployment plans without any such long-term perspective. 87% of the regions have submitted quantified FCH deployment plans outlining the specific FCH applications they envisage deploying in what volumes and over what timeframe. Existing FCH deployment plans differ considerably in the degree to which they have been fleshed out: Some are already very mature, with an advanced implementation status. Others are still in a conceptual stage which foresees FCH project implementation in the future, but which has not yet concretised individual projects or volumes for the applications to be deployed. In several cases, ambitious targets exist where hydrogen and fuel cells could play an important role (e.g. "make all public transport zero-emission by 2030", "convert all municipal service vehicles to zero emissions by 2035"), but without having defined the exact share that FCH applications will have in future deployments. Consequently, these cases are not reflected in the quantified FCH deployment plans. It is nevertheless reasonable to assume that the future market potential for FCH applications extends well beyond the aggregated deployment figures discussed in the next chapter. In the years ahead, one of the major tasks for regions and cities across Europe will be to add further detail to local environmental strategies and define the concrete measures to be implemented, including measures for hydrogen and fuel cells. Only then will a comprehensive and detailed market assessment be feasible.

94% of regions and cities plan to implement FCH projects in the next five years, though the level to which plans have been detailed varies considerably

The wide majority of these planned projects can be categorised as substitutive deployments, i.e. where FCH applications will replace conventional applications and will go into regular daily operation. Regions and cities expect the technology to be able to fully replace conventional solutions and deliver comparable performance, also in terms of technical availability. Only few regions plan to realise local R&D and demonstration projects with prototypes or pre-commercial types of applications, especially where there is a clear objective to support the establishment of a local FCH industry. In some cases, a combined approach – pursuing substitutive deployments together with R&D projects – can be observed, especially in more ambitious "H_2 Valley" projects. Only in very few cases do projects focus solely on building up a local hydrogen infrastructure (such as establishing local hydrogen production facilities or refuelling stations). More typically, infrastructure developments accompany deployments of applications that create the required offtake for locally produced or distributed hydrogen. As experience in recent years has shown, investing in infrastructure alone does not necessarily trigger increased local deployment of FCH applications. Instead, deployments must be actively developed hand in hand with the local hydrogen infrastructure. Many regions and cities are therefore planning to implement "captive fleet" projects, i.e. installing local hydrogen infrastructure together with initial deployments of a sufficient number of FCH vehicles to ensure sufficient utilisation of infrastructure capacity.

[15] Two additional FCH deployment plans were submitted after the analysis was conducted. Overall, they are in line with the results presented below.
[16] Except where otherwise indicated, all the following statements and figures refer to this group of regions and cities.

Overview of regions and cities with submitted FCH deployment plan outlines

Aberdeen (United Kingdom)
Agia Paraskevi (Greece)
Akershus (Norway)
Alimos (Greece)
Auvergne-Rhône-Alpes (France)
Baden-Württemberg (Germany)
Barcelona (Spain)
Bulgarian Ports (Bulgaria)
Cantabria (Spain)
Castilla – La Mancha (Spain)
Centre-Val de Loire (France)
Cornwall (United Kingdom)
Drenthe (Netherlands)
Dundee (United Kingdom)
Emmen (Netherlands)
Fife (United Kingdom)
Flanders (Belgium)
Groningen (Netherlands)
Guldborgsund (Denmark)
Halland (Sweden)
Hamburg (Germany)
Heide (Germany)
HYPOS – East Germany (Germany)
Kozani (Greece)
La Roche sur Yon (France)[1]
Lolland (Denmark)
London (United Kingdom)
Médio Tejo (Portugal)
Milos (Greece)
Møre og Romsdal (Norway)
North Rhine-Westphalia (Germany)
Orkney Islands (United Kingdom)
Pays de la Loire (France)
Pays de St. Gilles (France)[1]
Perth and Kinross (United Kingdom)
Port of Amsterdam, North Holland and Flevoland (Netherlands)
Port of Valencia (Spain)
Puertollano (Spain)[2]
Recklinghausen/ Northern Ruhr (Germany)
Saxony-Anhalt (Germany)
Sofia (Bulgaria)
Sogn og Fjordane (Norway)
South Tyrol (Italy)
Swindon and Wiltshire (United Kingdom)
Tees Valley (United Kingdom)
Trutnov & Krkonoše (Czech Republic)
Valladolid (Spain)
Velenje and Savinjsko-Šaleška (Slovenia)
Venice (Italy)
Vrilissia (Greece)
Western Macedonia (Greece)
West Flanders (Belgium)
Zuid-Holland (Netherlands)

[1] As part of the Vendée Region (France)
[2] As part of the Castilla – La Mancha Region (Spain)

24 regions (45%) indicate that they also have long-term ambitions for local FCH roll-out, with 13 more regions (25%) currently discussing such plans. Whereas a large majority of regions say they have plans to realise FCH deployment projects in the next five years, ambitions for FCH roll-out beyond that period are less frequently stated. Nevertheless, almost 70% of the regions indicate that they already have or are currently developing long-term plans to use FCH technology. Concrete milestones or targets to be achieved (e.g. establish a certain number of hydrogen refuelling stations (HRS) across the region by a certain year) have been defined in 17 regions (32%). In terms of concrete deployment plans, 33 regions (62%) have indicated expected deployment volumes in the long-term, i.e. after 2022. This shows that there is sustainable long-term demand for hydrogen and fuel cell technology in these regions that is likely to increase further.

FCH deployment plans have a clear focus on the transport sector, within which the focus applications are public transport buses, trains, garbage trucks, cars and delivery vans. This can be explained by the fact that the technological maturity and commercial development of FCH transport applications is particularly advanced. Numerous deployments of such applications have already been realised. Additionally, reducing transport emissions plays an important role in public debate and in European policy. Furthermore, regions and cities have several levers to take direct action in the transport sector, e.g. by converting public fleets, greening public transport, investing in local HRS networks and establishing different kinds of incentives for zero-emission vehicle use. Activities in other sectors, such as residential heat and power provision and industrial use for energy supply or as feedstock, but also in private sector mobility, are by nature more difficult to realise for regions and cities.

Nevertheless, FCH deployment plans also give due consideration to other sectors and the entire variety of FCH applications that are available today. The entirety of local FCH deployment plans covers most FCH use cases and applications in different sectors where hydrogen and fuel cells can play a role (see chapter 2.3). Several regions are currently looking at projects with mobility applications that are in their early development stages (e.g. maritime applications, heavy-duty trucks and special-purpose vehicles for construction work, fire services, port operations etc.). Beyond this, projects using hydrogen as industry feedstock are being pursued in several regions to green existing production processes and improve their GHG emission footprint (e.g. in refineries, steel production or various production processes in the chemical industry). Such cases create the opportunity to implement hydrogen use on very large scales where small-scale use, e.g. in mobility, can potentially also be realised more economically. Whereas deployment projects for stationary CHP systems are under discussion to a more limited extent, e.g. for use in public buildings, the large-scale use of hydrogen for heating has attracted particular interest in some regions, even though ambitious plans are mostly still in the feasibility assessment phase and initial projects still need to be realised. This broad variety of ongoing activities showcases the versatility of hydrogen and fuel cells for use in different sectors and applications.

The level of concrete detail in FCH implementation projects differs widely, with 87% of regions indicating quantified FCH deployment plans. For other regions, the exact scopes of projected FCH deployment activities still need to be defined – often in locations that are in a very early stage of project development. 85% of regions (including all 46 regions which have submitted quantified deployment plans) indicate that they have already taken concrete preparatory steps to implement projects. However, the level to which these steps have been completed again differs widely between the participants. Whereas only a draft concept for the project scope exists in some cases, concrete preparatory steps (such as detailed feasibility and design studies for refuelling stations, development of staff training and maintenance concepts, preparation of tendering processes and documents etc.) have already been completed in others. The figure below assesses the plans submitted for forthcoming FCH implementation projects, assigning them to four project status categories throughout the project lifecycle:

> **Scoping** – Projects are still in an early project definition phase. Regions have not yet decided which exact project(s) will be realised in the coming years.

> **Early planning** – Regions have started to prepare implementation but are still at an initial planning stage, e.g. discussions with stakeholders are underway, feasibility studies, detailed concept preparations and analyses of potential funding sources have been initiated etc.

> **Advanced planning** – Projects are already close to implementation, e.g. they are supported by all required stakeholders, procurement and tendering are underway, project budget and financing concepts have been set up etc.

> **Implementation** – Projects have already entered the first stages of actual realisation, e.g. equipment has been procured, infrastructure is being installed, staff is being trained etc.

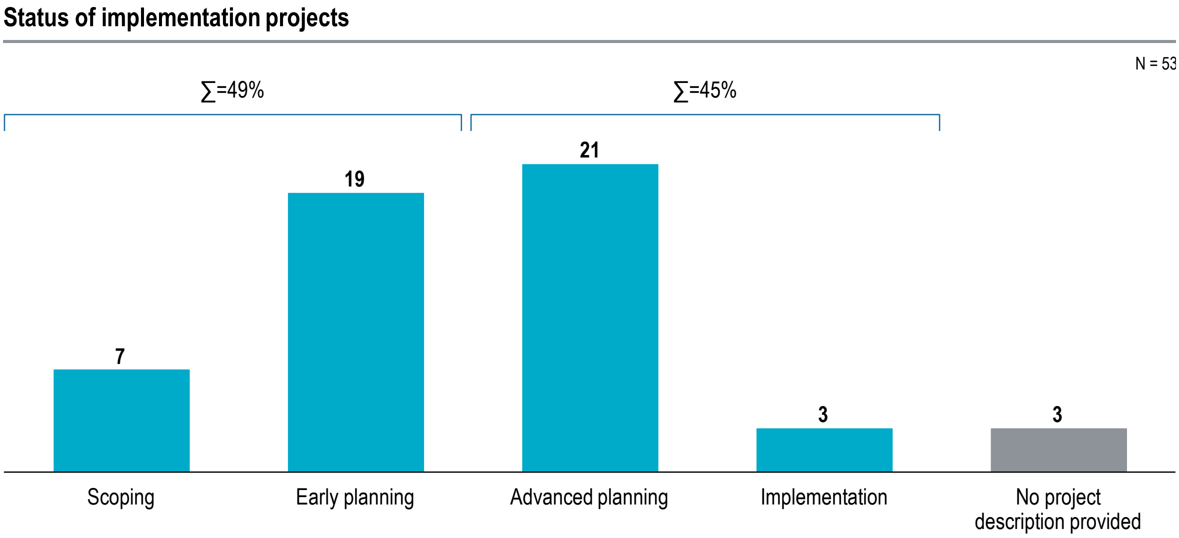


Figure 17: Status of forthcoming implementation projects

Almost half of the FCH deployment projects mentioned are still in the early phases of project development and will require further substantial project development work in the coming months and years to become ready for implementation. The other half are already well advanced in terms of project development, or are already under implementation. There is therefore the definite prospect of implementation for a large number of planned projects in the very near future as their preparation is already well advanced.

Securing stakeholder support is an important precondition for project implementation, but it has not yet been secured by all regions which plan to implement FCH projects in the next years. 47% of regions indicate that they have already secured the necessary political and other stakeholder support for the implementation of their FCH projects. 30% say that they are currently working in this regard, but discussions have not yet been concluded. 15% still lack the required stakeholder support and are unsure whether it can be obtained. (The remaining regions are not pursuing any concrete project plans at the moment). In most cases where stakeholder support has not yet been secured, final political decisions at the local level have not yet been made to go forward with proposed projects and make a local budget available for project funding.

Be that as it may, the majority of regions rate the likelihood of project implementation as high. 60% of regions see the likelihood of project implementation as "certain" or "very likely", with another 21% assessing it as "possible". Only 4% of regions are uncertain whether their planned projects will be implemented at all. (9% did not submit an assessment and 6% are currently not developing any

FCH project). Even though stakeholder support still needs to be secured in some cases and projects need to be further developed, participating regions are generally confident that they will ultimately be able to realise their planned projects.

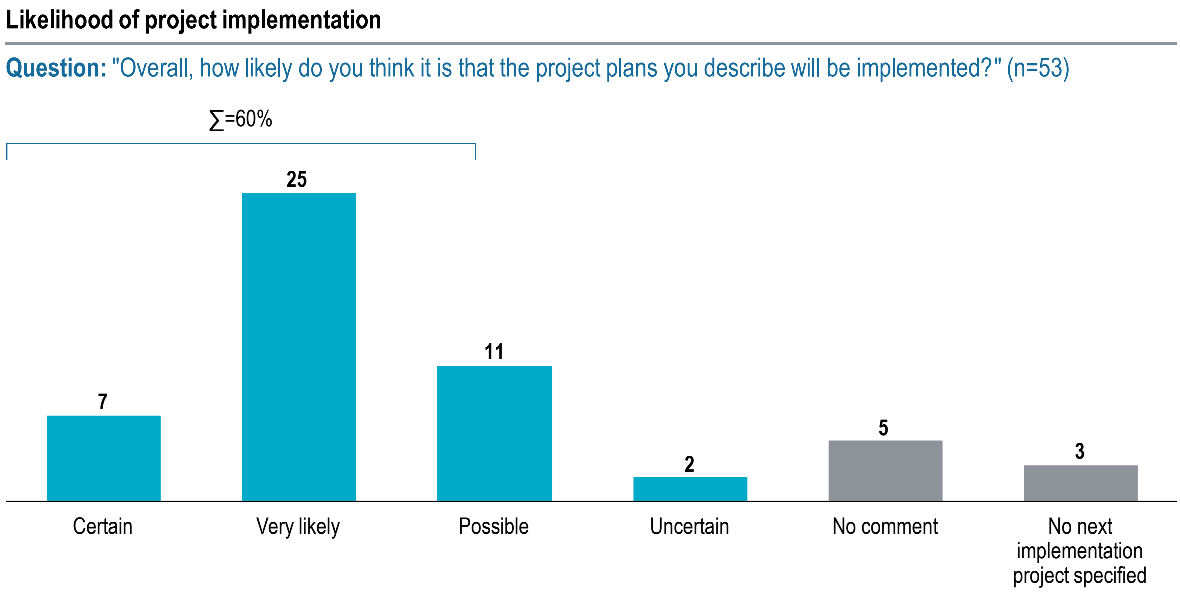


Figure 18: Likelihood of project implementation indicated by regions and cities

Project funding is seen as the most critical challenge to project implementation, with a number of other aspects following close behind

For participants, the most critical challenges and hurdles that face FCH project implementation include:

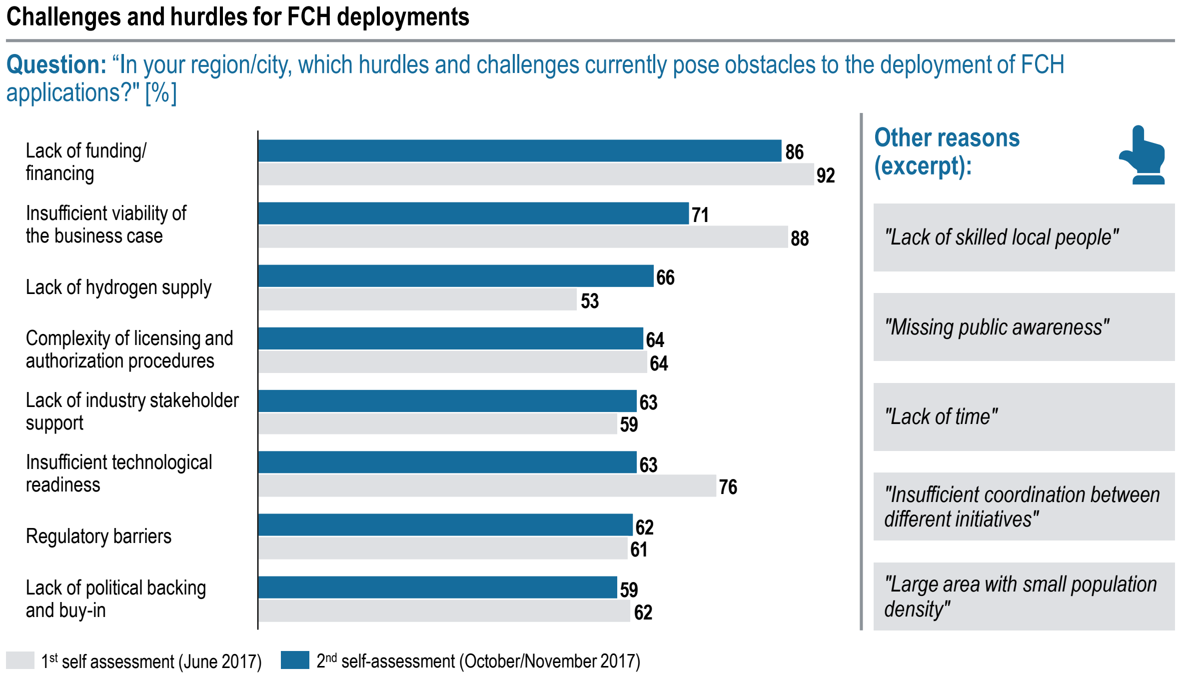


Figure 19: Main hurdles and challenges to FCH deployments

High technology costs and the resultant need for additional project funding are seen as the most critical challenges to project implementation. Whereas the perception of certain typical challenges of FCH projects has changed for participants during the first year of the initiative (i.e. business case viability, insufficient technological readiness), lack of funding and financing is continuously seen as the most critical challenge for project implementation. These perceived challenges are also seen as the most relevant ones by the regions which have outlined their FCH deployment plans. In addition to project financing and technology costs (indicated by 62% of these regions as major challenges), the following other main challenges were outlined in the submitted FCH deployment plans:

- Lack of awareness/knowledge of FCH technology among political decision-makers (15%)
- Complex and costly permitting/approval procedures (15%)
- Commercial availability of required FCH applications (13%)
- Technological readiness of FCH applications (11%)
- Regulatory/legal issues (11%)
- Local H_2 logistics/distribution (6%).

In addition, regions frequently point to their own organisations' lack of the resources needed to advance project development as a major hurdle to project implementation. This problem is even more pressing where ambitions exist to develop the kind of complex H_2 Valley projects which require various individual sub-projects to be put into place, numerous stakeholders to be aligned and complex financing structures to be set up. Considering the early development stage of many of the FCH projects outlined, having sufficient project development capacity in place could become a major challenge to the implementation of these projects in the years ahead. This is even more so given that all the other challenges outlined above contribute to a complexity that needs to be addressed with suitable project development capacity.

Most regions have analysed potential financing sources and are planning to rely chiefly on public grant schemes and regional/local budgets. The project funding sources they envisage range from different kinds of EU funding programmes to national government budgets or funding programmes, regional/federal or municipal budgets and private financing, thus encompassing the full spectrum of potential project funding sources. Participants did indicate an interest in also investigating more innovative project financing approaches. As things stand, however, the project financing concepts envisaged today mainly rely on established channels of FCH project funding, i.e. public grants. In this regard, participants plan to specifically rely on EU funding programmes such as Horizon 2020 (via the FCH JU) and on other programmes such as CEF, ERDF and INTERREG, but also on smaller and more specific EU programmes such as ELENA, LIFE, Civitas, Urbact and others. While it is unclear which precise EU funding programmes will be available in the next multi-annual financial framework period after 2020, references to the EU funding instruments available today can be understood to mean that comparable support schemes are again expected to be available in the future. National, regional and municipal government funding is expected to complement these funds. The figure below shows what share of their total envisaged FCH investment volume participants plan to finance from which main sources.[17] As can be seen, the majority (more than 60% in total) of project funding is expected to stem from public sources; most notably EU funds (29%, or more than EUR 500 million). Private funding only plays a smaller role. For about 7% (or EUR 133 million) of the total envisaged investment volume, regions indicated that they have not yet identified a potential funding source. A funding gap therefore remains. Across all the indications given in this regard, it should be stressed that they only represent initial planning indications by the participating regions. Only in very few cases have budgets already been finalised and concrete funding commitments made. In seven cases, typically at early planning stages, it is clear that envisaged project funding cannot be realised as planned at the moment, because funding rates (e.g. for EU or national grant contributions) exceed the maximum funding rates available at the present time. In these cases, currently planned project financing will need to be revised. Throughout the project, participants have received guidance to help them identify available funding sources, understand the eligibility criteria and find ways to combine different sources. Furthermore, current examples of successful and innovative project financing concepts have been presented to serve as best practice examples. Based on this information, participants are now required to advance the financial engineering needed for their individual projects. That said, it became obvious during the course of the study that continued support will be required in this regard to bring projects to financial closure and actual implementation.

[17] "Other" includes the sum of all project budgets for which specific funding sources have been stated (e.g. EU, national, regional and/or local funding), albeit without indicating the planned budget share for each funding source.

Funding sources [EUR m]

Question: "Please indicate your envisaged funding sources" (n= 36)

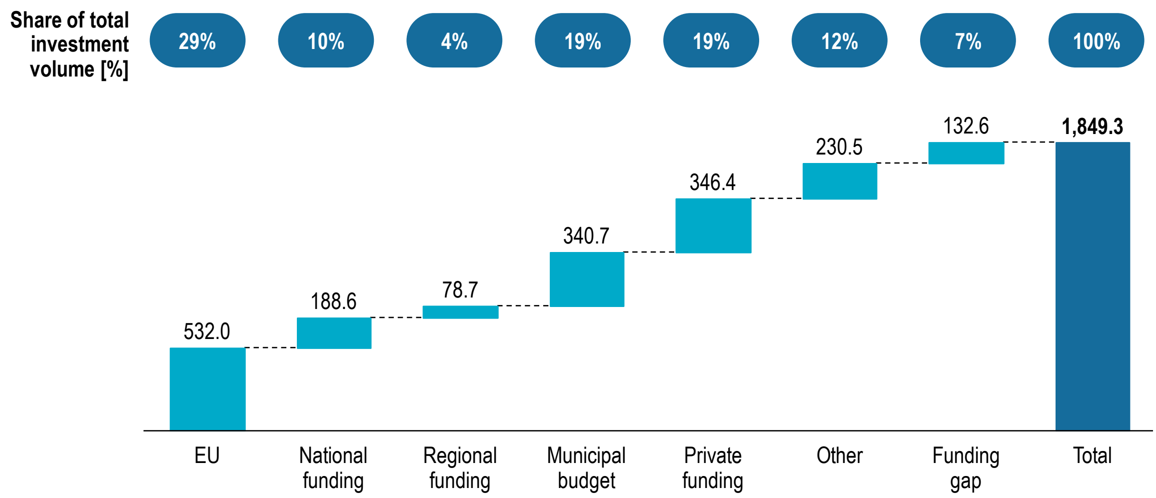


Figure 20: Envisaged project funding in each category and share of total investment volume

To realise their project funding plans, the critical issue for regions and cities will be to maximise and combine the use of different funding sources. Whereas the remaining budgets for existing public funding programmes should in principle be able to provide the required co-financing in line with participants' plans (see table above and details of EU funding programmes below), gaining access to funding for individual projects remains a complex challenge. To realise all their planned investments and raise the co-financing they need, it will be crucial for regions and cities to tap the entire range of available funding sources, identify the programmes or instruments which best suit their individual projects and wisely combine the different sources. The public funding landscape at the EU and national levels is complex, with an abundance of different programmes in place that have different objectives and priorities, different application procedures and eligibility criteria, and different individual calls for proposals with individual timelines and selection criteria. Two important caveats therefore apply to the above statement on sufficient public funding support being available in principle: First, suitable calls for proposals with conditions that fit the individual projects have to be available at the time when these projects reach the financing stage. Even when looking at existing funding programmes that are in principle available to fund planned FCH projects in the next couple of years, it is impossible right now to say whether individual calls which fit all participant project plans will indeed be published within the framework of these programmes. Yet suitable calls are needed to support participants' plans. Second, overall indications of investments totalling about EUR 1.8 billion are spread over a timeframe of roughly the next five years, in some cases also beyond that period. At the EU level, the current financial framework covers only the period until 2020- Some funding programmes at the national levels have similar or even shorter timeframes. As a result, it is currently unclear whether investments planned beyond these periods can obtain the currently envisaged public funding support. Whatever the case, it is to be expected that continued public funding support will be required beyond 2020 if FCH investment projects are to be realised, even though the use of other financing instruments and private funding will likewise need to be enhanced.

In principle, there are three ways for FCH projects to approach financing at the moment, although grant funding will still play the principal role in the next years. Regions and cities can use different approaches to fund their projects and increasingly face the need to combine different sources and forms of financing to fund their projects, especially when it comes to more complex and large investments. (For a categorisation of the most suitable funding tools for different kinds of projects, see the section below).

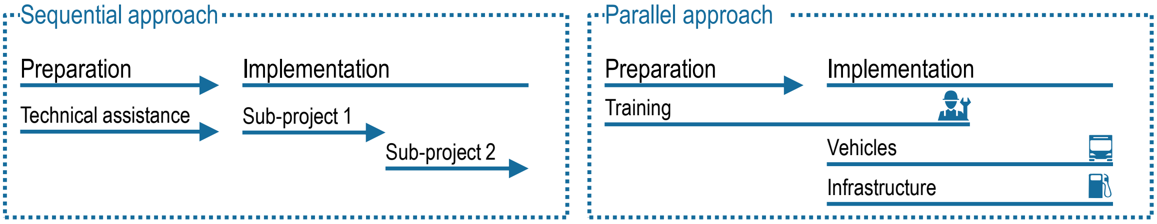
	Public	Public-private (PPPs)	Private
Brief description	> **Public grants** (EU, national, regional), budget financing, comprehensive subsidies and tax incentives – with co-financing from project promoters > **Non-repayable** finance	> **Combination** of public and private finance, e.g. (development) bank loans and government grants/subsidies > **Partially repayable** finance	> **Financing from private intermediaries**, i.e. commercial bank loans, other debt finance, mezzanine, (private) equity > **Repayable** finance
Project bankability/ commercial viability	> **Low** > Pilot, prototype & pre-commercial deployment phase of new technologies – Typically gap to purely commercially funded and viable business cases	> **Medium** > Bridgeable gap to viable business case, hence revenue support, CAPEX relief mechanisms etc.	> **High** > Typically available for applications that are commercially developed with a defined use/business case (TRL[1] 8-9)
FCH examples (selection)	> FCH transport project in South Tyrol/Bolzano, Italy	> Public transport renewal and FCH bus deployment in Riga	> Amazon procurement of Plug Power FCH Forklifts

Technology readiness, commercial viability

1) Technological readiness level

Figure 21: Different approaches to financing innovative technology projects

Using different funding programmes to finance one and the same project is possible but requires a well-defined project structure and strict compliance with funding rules. Public funding programmes at the EU and national levels typically prescribe a number of conditions to avoid excessive use of funds and the duplicate funding of projects via different programmes. Limits are normally imposed on the combined use of different funding sources, and a certain co-funding rate must be covered by other means than public grants. In addition, the cumulative use of different grants to fund the same activity or cost item within one project is usually prohibited. Nevertheless, two ways remain for regions and cities to make use of different funding programmes within one project and to realise synergies between different funding programmes:



Sequential approach

- > Synergies between different EU funding programmes can come into play if separate project lifecycle stages are clearly differentiated
- > Dividing clearly differentiated work packages into a modular project set-up can make different packages eligible for different funding instruments
- > Example: Preparatory work can be funded from different sources than implementation of the same project

Parallel approach

- > Synergies between EU funding sources can be realised by clearly differentiating separate complementary project components
- > Setting up a project framework in which different components can be traced to individual but complementary work packages is key for parallel funding
- > Example: HRS deployment can be funded from different sources than vehicle deployment and training activities

Smart structuring of your FCH projects is the key to securing funding from different EU funding programmes – Complexity (timelines, eligibility criteria, accounting) must be addressed

Note: A combination of funds within one project is possible only between Horizon 2020 and ESIF, but each cost item can only be funded from one programme

Figure 22: Ways to realise synergies across different public funding programmes

A wide range of potential funding sources are available at the EU and national levels to support the FCH investments envisaged by regions and cities. One important success factor for the realisation of planned projects will be not focusing on using one particular funding programme alone or just waiting for suitable calls to be published for particular programmes. Instead, regions and cities should assess the entirety of potential funding sources and identify those that are best suited to their own requirements. Some funding opportunity is almost always available for every project at any time: It simply needs to be identified and applied for. Several institutions and initiatives, such as the Regions and Cities Initiative, provide information and orientation for regions and cities to help them navigate the funding landscape. Some programmes even provide assistance in developing individual project financing concepts. The most important funding sources for FCH projects in Europe include:

- **European Regional Development Fund (ERDF)**: This is the largest EU funding programme to support investments in areas such as research and innovation and in supporting the shift towards a low-carbon economy. With an overall budget of nearly EUR 300 billion through 2020 and a budget utilisation of 52% to date, it provides vast potential to support different kinds of FCH investments. For each country or region, individual operational programmes administered by individual managing authorities define individual funding priorities and eligibility criteria. Regions and cities can reach out to their managing authority to assess opportunities for ERDF funding for their projects.[18]
- **Cohesion Fund**: This fund provides an extra roughly EUR 75 billion of funding through 2020 for investments in Europe's structurally less developed regions particularly in the EU-13 countries (new member states) and southern Europe. 64% of the budget has been used so far. The available budget is disbursed via the respective operational programmes of the ERDF or via calls published by the Connecting Europe Facility (CEF).[19]
- **INTERREG Programme**: INTERREG is also financed via the ERDF and has a total budget of about EUR 12.5 billion through 2020. Budget utilisation currently stands at 58%. The programme is designed to improve EU cohesion policy and interregional cooperation. It includes 56 cross-border, 16 transnational and 4 interregional programmes that can support FCH projects in eligible regions. The INTERREG operational programmes specify individual funding opportunities in regular calls for proposals.[20]
- **Connecting Europe Facility (CEF)**: This facility is the EU's key funding programme to support investments in the transport, energy and ICT infrastructures along the TEN-T/E corridors to improve European market integration. The CEF has a total budget of EUR 30 billion through 2020, 91% of which has already been used. It mainly supports Projects of Common Interest (PCIs) and projects in horizontal priorities/key thematic areas, normally only in the core network corridors. Although its remaining funding potential is limited by these two factors, upcoming calls, centrally managed by the INEA, may still be of relevance to support selected FCH projects.[21]
- **Fuel Cells and Hydrogen Joint Undertaking (FCH JU)**: The FCH JU provides the only funding programme at the EU level that is dedicated to hydrogen and fuel cell technology alone. With a total budget of approximately EUR 1.3 billion through 2020, it mainly supports research and innovation activities in the FCH sector and issues annual calls for proposals on selected topics. As an industry-led public-private partnership, the FCH JU will only be able to support FCH projects envisaged by coalition participants to a limited extent. The

[18] The managing authorities responsible and details of their operational programmes can be found at http://ec.europa.eu/regional_policy/en/atlas/managing-authorities
[19] For more information, see http://ec.europa.eu/regional_policy/en/funding/cohesion-fund/
[20] For more information, see https://www.interregeurope.eu/
[21] For more information, see https://ec.europa.eu/inea/en/connecting-europe-facility

organisation also provides dedicated support regarding the funding and financing of FCH projects.[22]

> **Technical assistance (TA) programmes**: Programmes run by the European Investment Bank (EIB) and other EU institutions support the preparation of investment projects before actual implementation, e.g. by providing support with feasibility studies, business case development, de-risking and developing a financing structure. Typically, such programmes focus on larger-scale investment projects and expect a certain leverage factor between the funding support provided and the total investment volume realised. Most established TA offers include ELENA, JASPERS, EPEC, InnovFin or EIAH provided by the EIB as well as EASME PDA or the European City Facility.

> **National funding programmes**: Several European countries have national funding programmes in place that are either devoted specifically to FCH investments (such as e.g. the NIP 2.0 in Germany) or have a broader scope that also covers FCH projects (e.g. funding programme for zero-emission vehicles of the Office for Low Emission Vehicles in the UK and the National Energy Efficiency Fund in Spain). Depending on individual conditions and available budgets, these national programmes are important to provide co-funding alongside EU funds, or can even fund FCH projects without the need to rely primarily on EU funding. Information on such funding opportunities can usually be obtained from the relevant national ministries or agencies.

Realisation of the FCH deployment plans referred to by the participating regions and cities will only succeed if the full range of available funding support from different kinds of programmes and instruments (available at the webpage stated in footnote 22) is tapped to co-fund the estimated EUR 1.8 billion in total investments. To provide more detailed orientation in this regard, a comprehensive database of available funding and financing sources has been compiled for the participants. In addition, focused support will be needed to facilitate financial engineering for FCH investments planned by the regions and cities. Without such support to maximise the use of available funding, it is likely that only a part of the total investment volume envisaged today will actually be realised.

Based on these findings, regions and cities can be clustered into four groups with similar characteristics, as well as specific challenges and support needs

Despite pronounced variance in local framework conditions, project concepts and challenges, it is possible to identify certain common patterns between the participants. The 53 detailed FCH deployment plans that have been jointly developed during the course of the project can be assigned to four distinct groups of regions and cities:

1. **Orientation seekers**: Regions and cities in this group consider FCH as one technology option to realise their green energy and emission reduction ambitions, but have only just started to investigate its local feasibility. Typically, these regions and cities have not yet developed any FCH projects, but are exploring whether this could be an option for the future.
2. **Early-stage newcomers**: Regions and cities in this group typically also have no experience with FCH deployments so far, but are pursuing concrete plans to realise such projects in the future. To gather experience with the technology, they plan to realise small-scale projects (e.g. 5-10 FCH buses) first and to potentially scale up later. Even though FCH project development has started, they are in an early development stage and still need to solve major challenges.
3. **Ambitious newcomers/experienced FCH users**: These regions and cities either already have significant experience with FCH deployments which they would like to expand or are pursuing ambitious large-scale FCH deployment plans even though they have not yet gathered any

[22] For more information, see http://www.fch.europa.eu/page/funding-financing

experience. Their projects are typically more advanced and usually have the political backing and stakeholder support needed for implementation.

4. **H_2 Valley developers**: These regions and cities are pursuing very ambitious plans to realise large-scale FCH deployments as a local "H_2 Valley", typically associated with plans to migrate to a local H_2 economy in the long run (for a detailed description of the concept, see chapter 3.4). Even though this group is very heterogeneous in terms of existing levels of experience and the concrete nature of their plans, they have typically secured broad stakeholder support and face specific challenges in terms of developing their projects.

Even though local framework conditions, stages of FCH project development and specific challenges vary considerably, these four groups describe the typical patterns observed among participating regions and cities. Similar support needs thus arise for each cluster and will need to be addressed. The section below provides a more detailed examination of the common characteristics and challenges for each group as well as the next steps towards FCH project implementation.

1. Orientation seekers: Initial interest, but need to broaden knowledge of technology and its deployment – and to convince local stakeholders to invest

"Orientation seekers" have an initial interest in FCH technology, but have only now started to explore it as one option to realise their environmental objectives. Regions and cities in this group typically have no own experience with the technology so far and have just started to investigate its value proposition, technical specifications, status of development and deployment implications to develop a better understanding of its feasibility for local deployment. They generally have local objectives to reduce emissions and to initiate a green energy transition in place, but have not yet decided whether and how FCH technology should play a part in reaching these targets. They have internal resources available to work on emission reduction and green energy topics, but no dedicated resources for FCH project developments are in place. Since these regions and cities are currently in a stage where they intend to develop a basic understanding of the technology as a basis to assess its local feasibility, no decisions have yet been made to go forward with the technology in general and with any potential deployment projects in particular. Local stakeholders and decision-makers still need to be convinced that FCH technology is a viable option for local deployment and can greatly contribute to realising the local green energy transition. In some cases, initial project ideas exist, but are typically in an early scoping phase with major questions regarding the project concept, the decision about its implementation and its financing still to be resolved.

About 20 project participants from across Europe can be attributed to the "orientation seekers" group. Participants that can be attributed to this group have typically not yet developed any concrete FCH deployment plans, but are considering doing so in the future. During regional workshops organised with regions and cities from outside the project coalition, it became clear that a large number of other European regions and cities is in a similar situation. Participants in the workshops said that many regions and cities are still not aware of the technology and its potential as a feasible zero-emission option. They would, however, be ready to consider the option once initial awareness had been created and opportunities to get acquainted with it existed. It became evident in this context that raising awareness for the technology among more European regions and cities and supporting their activities to explore local deployment feasibility of FCH technology can greatly contribute to paving the way to more FCH deployment projects.

The orientation seeker group thus has the following needs for specific support:

> **Raise general awareness of FCH technology as a viable zero-emission option** – Inform more regions and cities about the technology, its development status and local feasibility, e.g. by organising more regional workshops in cooperation with local stakeholders or participating

in relevant regional conferences or events (e.g. on green energy topics, meetings of municipal associations etc.)

> **Facilitate knowledge dissemination on FCH technology** – Satisfy basic information needs regarding deployment implications and facilitate dialogue with industry and/or experienced users, for example by developing and making available dedicated information material on FCH technology and its deployment potential (e.g. on a central website), organising workshops with industry and experienced user participation etc.

> **Support efforts to convince local stakeholders and decision-makers to invest** – Inform decision-makers directly or enable local FCH proponents to secure required stakeholder support, e.g. by providing support material including key arguments for FCH deployments, providing training sessions and details of lessons learned in stakeholder management, supporting local efforts towards direct engagement with local decision-makers etc.

To gain support for the development of their individual local strategies and action plans to implement the green energy transition, orientation seekers can obtain support from a variety of programmes. "Orientation seekers" are typically in the process of developing local emission reduction strategies, green energy or e-mobility concepts and action plans. They are looking to define the role of fuel cells and hydrogen in this regard. Many initiatives or competence centres at the national level in several European countries are supporting such strategy and action plan development processes by providing experience-based advice and/or financial support to develop these strategies and action plans on the local level. The programmes are typically available at the national or regional level, with only few exceptions at the European level. Sample programmes with potential for orientation seekers include:

> European level:

– Relevant operational programmes of the European Regional Development Fund (ERDF)
– URBACT III programme
– Urban Innovative Actions (UIA)
– JPI Urban Europe
– URBIS
– LIFE

> Specific national programmes, e.g.:

– Service and competence centre: Communal climate protection (Service- und Kompetenzzentrum: Kommunaler Klimaschutz (SK:KK) – Germany)
– HIER opgewekt (Netherlands)

2. Early-stage newcomers: Ambition to implement initial FCH deployment projects with the need to advance project development and secure final stakeholder commitment

"Early-stage newcomers" are in the early stages of developing their first, typically small-scale FCH deployment projects. In contrast to orientation seekers, early-stage newcomers have already made the decision to realise their first FCH deployment projects to test their feasibility for reaching local emission reduction and green energy goals. 18 regions that have developed a detailed FCH deployment plan can be attributed to this group, plus an additional eight regions from the coalition (i.e. about 30% of all coalition members) on top. Such regions can be found all across Europe, but have a particularly strong presence in the EU-13 countries (new member states) and in southern European countries, where experience with FCH deployments is generally scarce. These regions typically have no prior experience with FCH deployments, but do have relevant basic knowledge of the technology and have developed concrete project ideas that they deem feasible under local conditions. All participants in this group plan to implement FCH projects in the coming years. For such first projects, fairly small-scale deployments with limited scopes (i.e. focusing of one FCH application alone) and budgets (below EUR 5 million or, in many cases, not yet defined) are typically envisaged as a way to gather initial experience. Applications planned for deployment are typically mature and established transport applications (e.g. cars, vans, buses etc.) and present the opportunity to start with smaller deployment volumes (e.g. up to 10 vehicles at most). Internal resources are typically available to develop green energy projects, but to a limited extent that is usually sufficient to develop such smaller-scale projects. Most of these projects are still in their early development stages – i.e. concrete project ideas have been developed and first preparatory steps have been undertaken, but major steps towards implementation have yet to be taken: About 75% of the participants in this group are still in the "scoping" or "early planning" project development phase. Regions and cities in this group need to develop solutions for typical challenges when implementing initial FCH deployment projects, e.g. establishing the H_2 supply and installing required infrastructure, successfully completing approval procedures, preparing concrete operational setups, exploring funding options and developing a project financing concept etc. In addition, final stakeholder and decision-maker support for implementing concrete projects has typically not yet been secured. Final decisions are still to be made and are under discussion (this is the case for about 60% of participants in this group). Consequently, a higher share of participants in this group assesses the likelihood of project implementation as "possible" or "uncertain", compared to the other groups which are planning to realise FCH deployment projects (45% of participants from this group, compared to 28% overall).

The early-stage newcomers group thus has the following needs for specific support:

> **Provide knowledge about FCH project development** – Provide best practices and lessons learned regarding the main building blocks for FCH deployment projects, facilitate dialogue with experienced cities and industry on developing solutions for project implementation, e.g. by developing and making available dedicated information material on FCH project development (e.g. on a central website or information repository), organising workshops or regular working groups with industry and experienced user participation etc.

> **Obtain support for FCH project concept development** – Provide tailored advice for regions and cities, addressing their specific challenges and local obstacles, help to develop workable project concepts, e.g. by providing technical assistance and project development support

> **Support access to funding** – Provide guidance on potential funding sources and their eligibility criteria and application procedures (e.g. in a funding manual, information website, dedicated workshops), help regions and cities access to funding by reaching out to relevant donors (e.g. managing authorities of ERDF funds), as well as supporting the set-up of individual project financing concepts as part of technical assistance for project development

> **Support local stakeholder engagement** – Provide advice and best practice approaches to secure local stakeholder support (e.g. regarding local political decision-makers, project sponsors and potential project partners), e.g. by providing supporting material including key arguments for FCH deployments, providing training sessions and lessons learned in stakeholder management, supporting local efforts in direct engagement with local decision-makers etc.

Early-stage newcomers can gain funding support from available regular project calls for small-scale deployments from national or EU level grant programmes. Early-stage newcomers can benefit from a variety of funding programmes that support implementation of small to medium-sized investment projects. In particular, newcomers should engage in dialogue with the managing authorities that administer the relevant operational programmes of the European Regional Development Fund in their region in order to discuss potential funding opportunities. Sample programmes that could potentially support early-stage newcomers include:

- Annual calls for specific topics from the Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
- Calls and ongoing funding support from the relevant operational programmes of the European Regional Development Fund (ERDF)
- Calls as part of the INTERREG programme for eligible regions
- Specialised European support programmes such as CIVITAS, Urbact, LIFE, Urban Innovation Actions etc.
- National funding calls, e.g. published by the National Organisation Hydrogen and Fuel Cell Technology in Germany, the Department for Business, Energy & Industrial Strategy in the UK and other comparable national agencies and programmes

3. Ambitious newcomers/experienced FCH users: Goal to implement large-scale FCH deployments with the need to complete final steps towards implementation

Regions and cities in this group aim to realise more ambitious FCH investments based on either prior deployment experience or ambitious local plans to start investing in the technology. Eight regions with a detailed FCH deployment plan can be attributed to this group, while seven more regions or cities from the coalition can also be included based on dialogue with local stakeholders (i.e. about 17% of all coalition members). Regions in this group mainly stem from countries in Europe which already have substantial experience in FCH deployments, in particular from Scandinavia, the UK, Belgium, the Netherlands, Germany and France. Regions and cities in this group have either already realised FCH deployments in the past or have thoroughly investigated the feasibility of FCH deployment. On this basis, they have fleshed out well-scoped deployment plans to realise local emission reduction and green energy goals using FCH technology. Their deployment plans are typically more diverse in terms of the applications in scope. Some also include less-developed transport applications (e.g. trucks or ships/ferries), as well as stationary or industrial use applications. Deployment volumes are typically higher (several dozen applications in total), thus triggering project budgets for envisaged investments from around EUR 10 million to EUR 50 million. They typically show a high degree of local commitment to FCH deployments, e.g. they have a local H_2 strategy or a clear ambition to continue using the technology in place in the long term. They have also largely secured stakeholder support for their planned FCH deployment projects – as reflected in the fact that they invest substantial internal resources in their large-scale FCH project developments. At the same time, they typically rate project implementation likelihood as "certain" or "very likely". It follows that project development is, in most cases, already relatively advanced (in "advanced planning" or even the "implementation" stage). In most cases, an initial financing concept for planned investments has been set up, including an investigation of potential funding sources, advanced talks with potential donors and aspects of the financing concept already closed.

The ambitious newcomers/experienced FCH user group thus has the following needs for support:

- **Obtain support for individual FCH project concept development** – Provide individual advice on more complex project development challenges (i.e. not basic input on typical FCH project issues, but rather focusing on complex project development support)
- **Facilitate cooperation projects across locations, e.g. including joint procurement** – Provide a platform for interested regions to cooperate on their project developments and accumulate demand to accelerate market development, e.g. through joint procurement
- **Support access to funding and developing individual financing concepts** – Support developing more complex project financing concepts, potentially making use of more innovative financing approaches and private sector financing contributions

Ambitious newcomers/experienced FCH users draw on a variety of programmes to fund their projects. They also leverage project development assistance to prepare their investments. As investment volumes increase, project development becomes more complex and requires dedicated resources and knowledge. Several European support programmes are therefore dedicated to facilitating the development of large-scale investment projects from which ambitious newcomers/experienced FCH users can benefit:

- European Local Energy Assistance - ELENA
- Joint Assistance to Support Projects in European Regions - JASPERS
- Executive Agency for SMEs Project Development Assistance - EASME PDA
- InnovFin Advisory by the European Investment Bank
- European Investment Advisory Hub - EIAH

To fund their concrete investment projects, ambitious newcomers/experienced FCH users can rely on different grant programmes as well as on financial instruments or alternative financing schemes:

- Calls and ongoing funding support from the relevant operational programmes of the European Regional Development Fund (ERDF)
- Calls from the Connecting Europe Facility (CEF)
- Calls as part of the INTERREG programme for eligible regions
- National funding programmes
- European Investment Bank (e.g. Municipal Framework Loans or InnovFin offering)
- Alternative financing schemes such as green municipal bonds, revolving loan funds, guarantees

4. H_2 Valley developers: Ambition to realise very large-scale and complex H_2 Valley projects with specific challenges in complex project developments

24 participating regions and cities have expressed an ambition to become an "H_2 Valley" in the future, with ten regions pursuing concrete plans for implementation in the years ahead. Regions with ambitions to become H_2 Valleys are again mainly in countries which already have substantial experience in FCH deployments, in particular the UK, Belgium, the Netherlands, Germany and France. A significant number of project participants have expressed their intention to become such H_2 Valleys in the future. Typically, these regions have a clear commitment to making hydrogen a cornerstone of their future green energy systems and are pursuing a clear ambition to realise large-scale deployments of the technology. In many cases, these ambitions are documented in existing local H_2 strategies or roadmaps that also highlight existing stakeholder support to develop and realise relevant FCH deployment projects. Accordingly, H_2 Valley developers typically rate the likelihood of project implementation in the years ahead as "very likely" or "certain". These projects typically encompass a broad range of different FCH applications foreseen for deployment across different use cases or sectors. Most of these regions are building on prior FCH deployment experience and have already reached advanced stages of project development. Nevertheless, project development still remains the source of their principal challenges: First, they need to develop and structure a coherent local approach for their planned projects that reflects the overall H_2 Valley approach (see chapter 3.4). Second, they need to have substantial local capacity available to advance complex project development, i.e. coordinating several large sub-projects and all relevant stakeholders to bring projects to implementation. Third, implementing H_2 Valleys is associated with realising substantial local investments that need to be financed. Typically, H_2 Valley projects include investment volumes from around EUR 50 million to as much as EUR 400 million. In these dimensions, raising the required project funding is a significant challenge.

The H_2 Valley developer group thus has the following needs for specific support:

> **Obtain support for tailor-made H_2 Valley project concept development** – Provide individual assistance with very complex project development and bringing projects to implementation, e.g. by providing dedicated technical assistance for project development, and by organising regular meetings between H_2 Valley regions to facilitate dialogue and mutual learning from other approaches and solutions
> **Support developing financing concepts** – Support developing individual and more complex project financing concepts, potentially making use of more innovative financing approaches and private sector financing contributions, e.g. by providing dedicated support in this regard as part of technical assistance for project development, establishing links to existing PDA platforms that can suitably support such large-scale projects etc.

H_2 Valley developers can benefit from grant programmes, innovative financing offerings and the stronger leverage of private financing. H_2 Valley concepts should build a bridge between grant-subsidised business cases and an increasing share of both regular project finance and private financing contributions. H_2 Valley developers can likewise benefit from technical assistance programmes for complex project development in this regard (see section above). In addition, one focus of the H_2 Valley developers should be on instruments that help to de-risk large-scale, complex projects and leverage private financing. This can, for example, be achieved by leveraging public equity to facilitate external debt financing, or by using public guarantees to de-risk the operations phase (e.g. offtake agreements). Several EU institutions and national promotional banks can provide financing instruments and soft loans on favourable terms. Sample programmes and instruments of relevance to H_2 Valley developers include:

> Calls from the Connecting Europe Facility (CEF), ERDF or national programmes
> European Fund for Strategic Investments (EFSI)
> European Investment Bank (e.g. Municipal Framework Loans or InnovFin offerings)
> National promotional banks
> Natural Capital Financing Facility
> Alternative financing schemes such as green municipal bonds, revolving loan funds, guarantees

3.3 Associated market potential for the FCH sector

The market potential represented by the participating regions and cities is significant – and has plenty of room for further growth

The current project coalition of 89 European regions and cities harbours significant market potential for the FCH sector in the coming years. The participating regions and cities represent approximately one quarter of Europe's population, surface area and GDP – a large share of the European market. Nevertheless, the planned FCH deployment volumes shown below only reflect the plans of the participating cities and regions. By consequence, the aggregated deployment volumes presented below mainly comprise direct public sector investment projects or projects with strong public sector involvement. The existence of even greater market potential that is only covered to a limited extent by the FCH deployment plans of the regions and cities, i.e. public authorities is anticipated – especially in the long-term – if recourse is made to the private sector. Nevertheless, due to the current development stage of the sector it is reasonable to assume that, especially in the short term, further market uptake will largely be driven by public sector investments. Ultimately, large-scale private sector involvement will be needed to develop a commercial FCH market. The first private sector projects have recently been initiated, but further public sector support will be required in the next years to achieve a significant private market uptake in the long run.

Of the project coalition members, 53 regions have submitted a detailed FCH deployment outline and 46 regions have provided a quantified deployment schedule for their projects. These 46 submitted FCH deployment schedules lay the basis for the aggregated deployment volumes as shown below. In many cases, however, existing policy ambitions have not yet been fully translated into concrete and quantifiable FCH deployment plans, with the result that they are not reflected in these aggregated figures – even though concrete perspectives for an increased FCH deployment volume do exist. For example, some cities and regions have defined concrete policy objectives (e.g. "make all public transport zero-emission by 2030"), albeit without having defined the role FCH applications will play in this regard and which precise volumes of such applications will be deployed in which years. It can nevertheless be assumed in many of these cases that FCH applications will play an important role in achieving these targets. As already stated, regions and cities will, in the coming years, need to continue translating their policy objectives into concrete measures that will shape a growing FCH project pipeline and drive further market uptake.

Envisaged FCH investments accumulate to around EUR 1.8 billion for planned FCH deployment projects in the next years

Envisaged budgets for planned FCH projects range from around EUR 1 million to EUR 400 million, with an average budget of about EUR 51 million. Indicative project budgets for planned FCH deployment projects again show the different levels of ambition that exist among participants planning to implement projects in the next five or so years. Whereas regions planning to realise their first steps in terms of FCH deployments typically envisage realising projects with a total budget of up to EUR 10 million, other projects go well beyond this figure. Several locations envisage realising projects with a total budget of up to EUR 50 million, including both more ambitious regions making their first deployments and regions with the ambition to develop "H_2 Valleys". The group of projects with an envisaged project budget of more than EUR 50 million includes only ambitious regions aiming at developing "H_2 Valley" projects. By contrast, very few regions foresee realising total investments of EUR 100 million or more. If all submitted indicative project budgets for forthcoming FCH implementation projects are added together, a significant total investment volume of around EUR 1.8 billion will be realised by the 36 regions and cities from 13 different European countries that have indicated an envisaged investment budget.

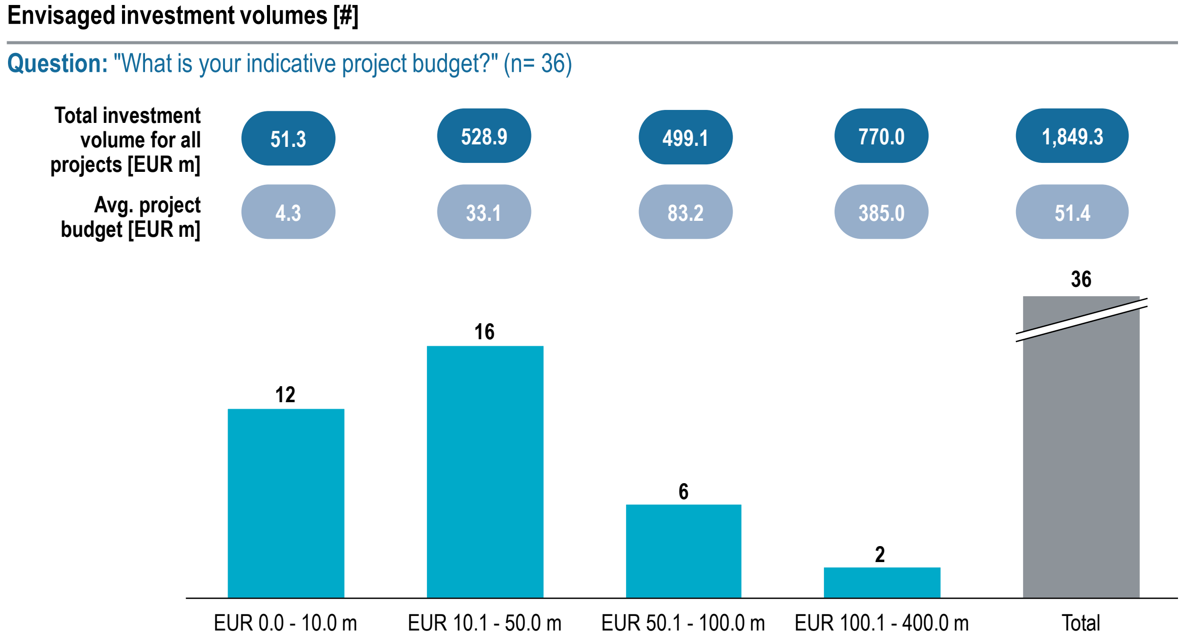


Figure 23: Envisaged total and average investment volumes per group and number of projects

Even if we restrict ourselves to investment volumes that are the most likely to be realised according to indications given in the FCH deployment plans, a total investment volume of more than EUR 1 billion will still be realised in the coming years:

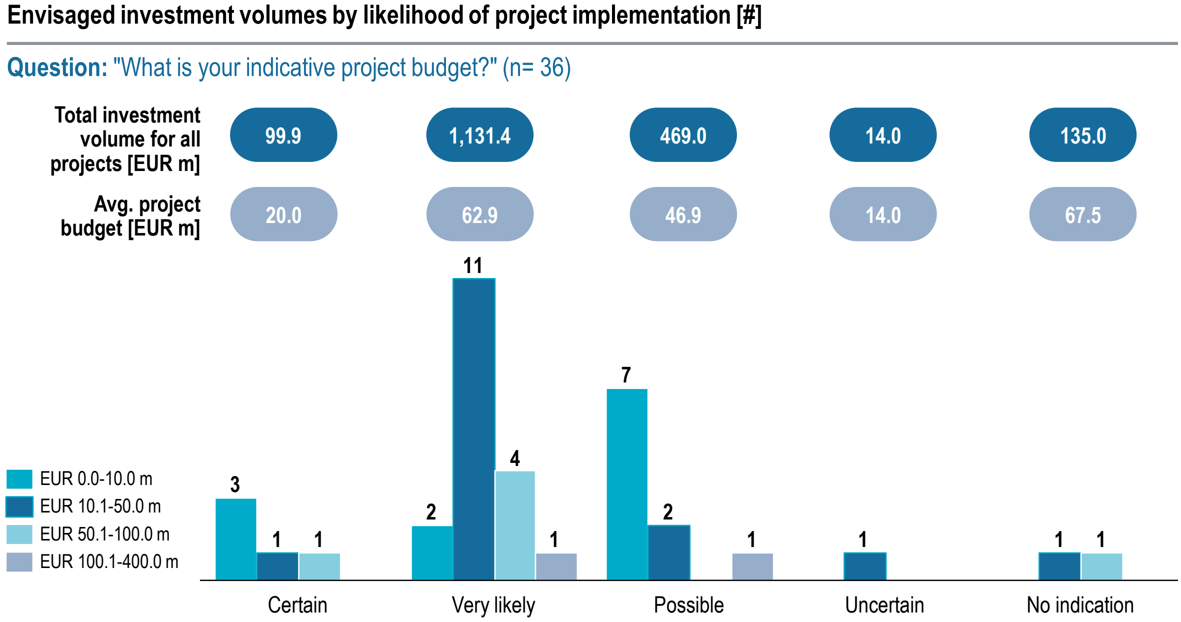


Figure 24: Envisaged investment volumes according to likelihood of project implementation

Indicated investments are well spread across Europe. However, by far the largest share will be realised in Central Europe, especially in Germany. Very high planned investments in two regions in this country account for about 40% of the total indicated investment volume.

Total budget for pending implementation projects per cluster [EUR m]

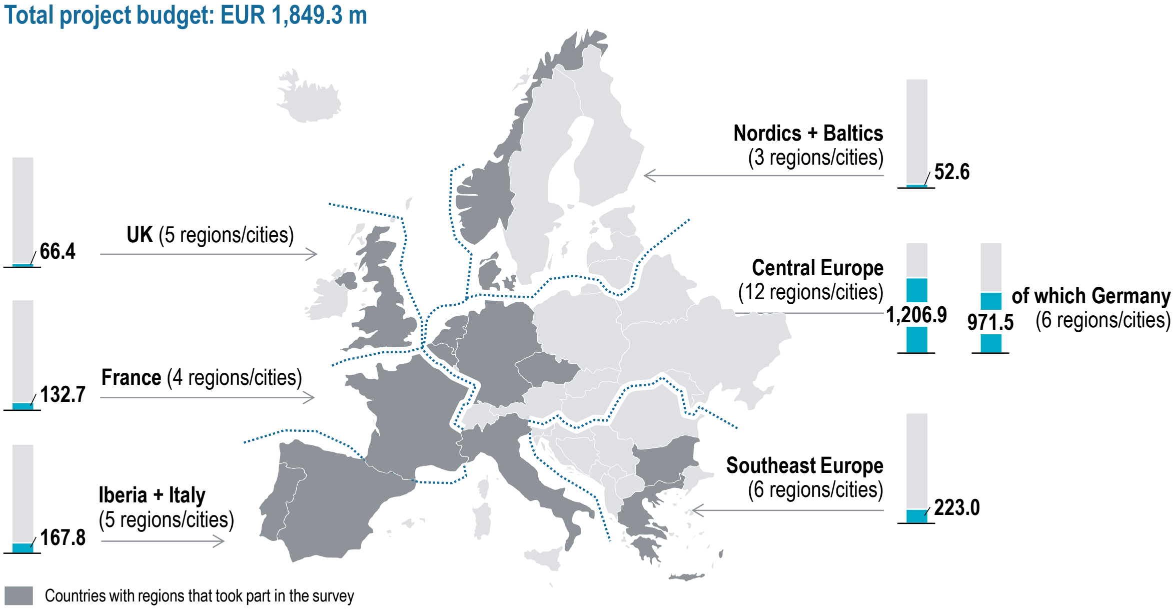


Figure 25: Geographical overview of envisaged FCH investments

These planned investments will lead to significant volumes of FCH applications planned for deployment

Deployments of different FCH applications and related infrastructure will significantly increase in the years ahead. The table below shows the total aggregated deployments of FCH applications as planned by the participating regions and cities in the short term (implementation projects pending in 2018 to about 2022) and in the long term (from 2023 to 2030+). The long-term outlook represents only the current view of potential levels of FCH deployments by the participating regions and cities. It is likely to change in the future. Figures for pending implementation projects should be more reliable, as they refer to concrete projects that participants are currently planning or developing. Especially figures for at least the next two, if not three years should be very reliable, as associated deployment projects must already be fairly advanced today if they are to be implemented in that timeframe.

Considering the likelihood of project realisation for pending implementation projects, significant deployment volumes are indicated as "certain" or "very likely" by participants. In the additional tables below, deployment volumes for FCH applications in the years to about 2022 ("pending implementation projects") are presented based on the likelihood of project implementation as indicated by the participants. Differences between total aggregate deployment volumes and the accumulated deployment volumes in the four tables referring to the different levels of project implementation likelihood stem from projects where no indication of the likelihood of project implementation was given.

	Applications	Next implementation projects					Long-term outlook			
		2018	2019	2020	2021	2022	Until 2025	Until 2030	2030+	Total
Heavy-duty transport applications	**Trains**		**52**	**2**	**3**	**29**	**189**	**161**	**102**	**538**
	Buses	**8**	**109**	**300**	**218**	**244**	**1.003**	**1.659**	**1.665**	**5.206**
	Solo	2	50	65	15		137	280	500	1.049
	Articulated		2		9		50	100	35	196
	Minibuses			1	1		5	8		15
	Not specified	6	57	234	193	244	811	1.271	1.130	3.946
	Heavy-duty trucks	**3**	**17**	**18**	**24**	**8**	**274**	**9.110**	**35.520**	**44.974**
Light- and medium-duty transport applications	**Cars**	**103**	**327**	**488**	**776**	**780**	**17.405**	**191.585**	**1.023.850**	**1.235.314**
	Vans	**49**	**167**	**121**	**263**	**355**	**1.565**	**21.140**	**20.400**	**44.060**
	Large vans			5		7	20	50	150	232
	Small vans		35	36	100	107	25	60	200	563
	Not specified	49	132	80	163	241	1.520	21.030	20.050	43.265
	Garbage trucks	**6**	**10**	**60**	**112**	**42**	**144**	**206**	**485**	**1.065**
	Sweepers	**1**	**6**	**10**	**9**	**11**	**2**	**5**	**10**	**54**
	Construction mobile equipment/ tools	**3**	**3**	**3**	**3**	**3**				**15**
	Material handling/ forklifts			**41**	**88**	**110**	**80**	**70**	**50**	**439**
	Bikes	**42**	**35**	**25**	**25**	**11**	**115**	**50**	**75**	**378**
	Scooters		**5**	**5**		**3**			**100**	**113**
Maritime applications	**Ships/ ferries/ boats**	**3**	**5**	**6**	**4**		**8**	**57**	**501**	**584**
	Port operations equipment			**2**				**21**	**32**	**55**
	Yard tractors			1				19	30	50
	Reach stackers			1				2	2	5
Stationary applications	**CHP**		**20**	**12**	**1.010**	**1.007**	**10.102**	**50.161**		**62.312**
	Residential use/micro CHPs		1		1.000	1.000	10.000	50.000		62.001
	Commercial CHPs			1	1	1	2	1		6
	Not specified		19	11	9	6	100	160		305

Figure 26: Aggregate deployment plans for the FCH applications of participating regions (n=46)

	Next implementation projects					Long-term outlook			
	2018	2019	2020	2021	2022	Until 2025	Until 2030	2030+	Total
Infrastructure									
HRS	**27**	**63**	**46**	**73**	**73**	**306**	**319**	**721**	**1.628**
700 bar	15	26	8	28	12	177	101	500	867
350 bar	4	14	15	18	19	62	74	208	414
combined		6	3	4	10	19	4	4	50
Not specified	8	17	20	23	32	48	140	9	297
Production facilities	**10**	**24**	**18**	**23**	**17**	**64**	**31**	**9**	**196**
Electrolysis	8	15	16	22	13	60	21	8	163
Other			1	1	3		4	1	10
Not specified	2	9	1		1	4	6		23

Figure 27: Aggregate deployment plans for the FCH infrastructure of participating regions (n=46)

		Next implementation projects: Certain					
		2018	2019	2020	2021	2022	Total
	Applications						
Heavy-duty transport applications	**Trains**						
	Buses	**2**	**50**	**86**	**30**		**168**
	Solo	2	40	65			107
	Articulated				5		5
	Minibuses						
	Not specified		10	21	25		56
	Heavy-duty trucks		**12**	**5**			**17**
Light- and medium-duty transport applications	**Cars**	**16**	**105**	**290**	**350**	**250**	**1.011**
	Vans	**15**	**15**	**20**			**50**
	Large vans						
	Small vans						
	Not specified	15	15	20			50
	Garbage trucks	**2**	**2**	**21**	**75**		**100**
	Sweepers	**1**	**2**				**3**
	Construction mobile equipment/ tools						
	Material handling/ forklifts						
	Bikes	**0**	**10**				**10**
	Scooters						
Maritime applications	**Ships/ ferries/ boats**	**2**	**1**		**2**		**5**
	Port operations equipment						
	Yard tractors						
	Reach stackers						
Stationary applications	**CHP**						
	Residential use/micro CHPs						
	Commercial CHPs						
	Not specified						
	Infrastructure						
	HRS	**11**	**33**	**7**	**28**	**10**	**89**
	700 bar	7	20		20		47
	350 bar	4	7				11
	combined		1				1
	Not specified		5	7	8	10	30
	Production facilities	**9**	**15**	**1**	**10**		**35**
	Electrolysis	7	6		10		23
	Other						
	Not specified	2	9	1			12

Figure 28: Aggregate deployment plans for the FCH applications and infrastructure of participating regions for which the likelihood of project implementation is deemed "certain"

		Next implementation projects: Very likely					
		2018	2019	2020	2021	2022	Total
	Applications						
Heavy-duty transport applications	**Trains**		**1**			**25**	**26**
	Buses		**39**	**169**	**180**	**198**	**586**
	Solo		10		15		25
	Articulated		2		4		6
	Minibuses			1	1		2
	Not specified		27	168	160	198	553
	Heavy-duty trucks	**3**	**5**	**13**	**24**	**8**	**53**
Light- and medium-duty transport applications	**Cars**	**77**	**171**	**163**	**406**	**530**	**1.347**
	Vans	**34**	**139**	**45**	**104**	**118**	**440**
	Large vans			5		7	12
	Small vans		35	36	100	107	278
	Not specified	34	104	4	4	4	150
	Garbage trucks		**5**	**22**	**28**	**18**	**73**
	Sweepers		**4**	**10**	**9**	**11**	**34**
	Construction mobile equipment/ tools	**3**	**3**	**3**	**3**	**3**	**15**
	Material handling/ forklifts			**35**	**80**	**100**	**215**
	Bikes	**20**	**25**	**25**	**25**	**11**	**106**
	Scooters		**5**	**5**			**10**
Maritime applications	**Ships/ ferries/ boats**		**2**	**1**	**1**		**4**
	Port operations equipment			**2**			**2**
	Yard tractors			1			1
	Reach stackers			1			1
Stationary applications	**CHP**		**6**	**10**	**9**	**6**	**31**
	Residential use/micro CHPs						
	Commercial CHPs				1	1	2
	Not specified		6	10	8	5	29
	Infrastructure						
	HRS	**11**	**18**	**26**	**39**	**48**	**142**
	700 bar	8	6	8	8	12	42
	350 bar		6	12	16	17	51
	combined		1	1	2		4
	Not specified	3	5	5	13	19	45
	Production facilities	**1**	**8**	**13**	**11**	**14**	**47**
	Electrolysis	1	8	12	10	11	42
	Other			1	1	3	5
	Not specified			0		0	

Figure 29: Aggregate deployment plans for the FCH applications and infrastructure of participating regions for which the likelihood of project implementation is deemed "very likely"

Category	Applications	Next implementation projects: Possible 2018	2019	2020	2021	2022	Total
	Applications						
Heavy-duty transport applications	**Trains**		51	2	3	4	60
	Buses		20	4	8	46	78
	Solo						
	Articulated						
	Minibuses						
	Not Specified		20	4	8	46	78
	Heavy-duty trucks						
Light- and medium-duty transport applications	**Cars**	5	30	15	20		70
	Vans		3	6	9	12	30
	Large vans						
	Small vans						
	Not Specified		3	6	9	12	30
	Garbage trucks	2	3	17	9	24	55
	Sweepers						
	Construction mobile equipment/ tools						
	Material handling/ forklifts			6	8	10	24
	Bikes	22					22
	Scooters					3	3
Maritime applications	**Ships/ ferries/ boats**	1	1	2	1		5
	Port operations equipment						
	Yard tractors						
	Reach stackers						
Stationary applications	**CHP**			2	1		3
	Residential use/micro CHPs						
	Commercial CHPs			1			1
	Not Specified			1	1		2
	Infrastructure						
	HRS	3	8	12	6	9	38
	700 bar						
	350 bar		1	2	2	2	7
	combined		1	2	2	4	9
	Not Specified	3	6	8	2	3	22
	Production facilities			2		1	3
	Electrolysis			2			2
	Other						
	Not Specified					1	1

Figure 30: Aggregate deployment plans for the FCH applications and infrastructure of participating regions for which the likelihood of project implementation is deemed "possible"

		Next implementation projects: Uncertain					
		2018	2019	2020	2021	2022	Total
	Applications						
Heavy-duty transport applications	**Trains**						
	Buses			**21**			**21**
	Solo						
	Articulated						
	Minibuses						
	Not Specified			21			21
	Heavy-duty trucks						
Light- and medium-duty transport applications	**Cars**						
	Vans						
	Large vans						
	Small vans						
	Not Specified						
	Garbage trucks						
	Sweepers						
	Construction mobile equipment/ tools						
	Material handling/ forklifts						
	Bikes						
	Scooters						
Maritime applications	**Ships/ ferries/ boats**						
	Port operations equipment						
	Yard tractors						
	Reach stackers						
Stationary applications	**CHP**		**1**		**1.000**	**1.000**	**2.001**
	Residential use/micro CHPs		1		1.000	1.000	2.001
	Commercial CHPs						
	Not Specified						
	Infrastructure						
	HRS			**1**			**1**
	700 bar						
	350 bar			1			1
	combined						
	Production facilities			**1**			**1**
	Electrolysis			1			1
	Other						
	Not Specified						

Figure 31: Aggregate deployment plans for the FCH applications and infrastructure of participating regions for which the likelihood of project implementation is deemed "uncertain"

Continuous installations of hydrogen refuelling stations (HRS) are expected in the coming years, with a significant increase in deployments after 2022. With their clear focus on deploying FCH transport applications, participating regions and cities also anticipate developing the required HRS infrastructure: 282 HRS are planned for deployment by 2022, followed by a significant increase in the pace of roll-out after that. Envisaged installations include 350 bar, 700 bar and combined stations, though the clear focus is on 700 bar stations. This illustrates that planned station installations are determined not only by the need to service deployed public fleets of FCH vehicles, but also by the intention to develop local HRS networks as a basis for FCH vehicle use in the private sector too. It is to be expected that these envisaged HRS deployments partly overlap with targets defined in other programmes (such as the various national initiatives to develop HRS networks such as H_2 Mobility in Germany, UK H_2 Mobility and Mobilité Hydrogène France), as well as with the national plans to develop HRS networks that have been submitted by several EU member states in response to the Alternative Fuels Infrastructure Directive (2014/94/EU). So far, hydrogen has been included in the national alternative fuels infrastructure plans of 14 EU member states, with a total of 747 HRS to be deployed by the end of 2025.[23] This number of HRS is about 25% higher than the number to be deployed according to the FCH deployment plans in the same timeframe, thus underlining the ambitious targets that participants are pursuing in this regard. Some of the submitted HRS deployment plans are from countries which have not submitted a national plan for HRS build-up. Some of the plans clearly exceed national ambitions for HRS roll-out in their respective countries.

Planned hydrogen refuelling station (HRS) deployments

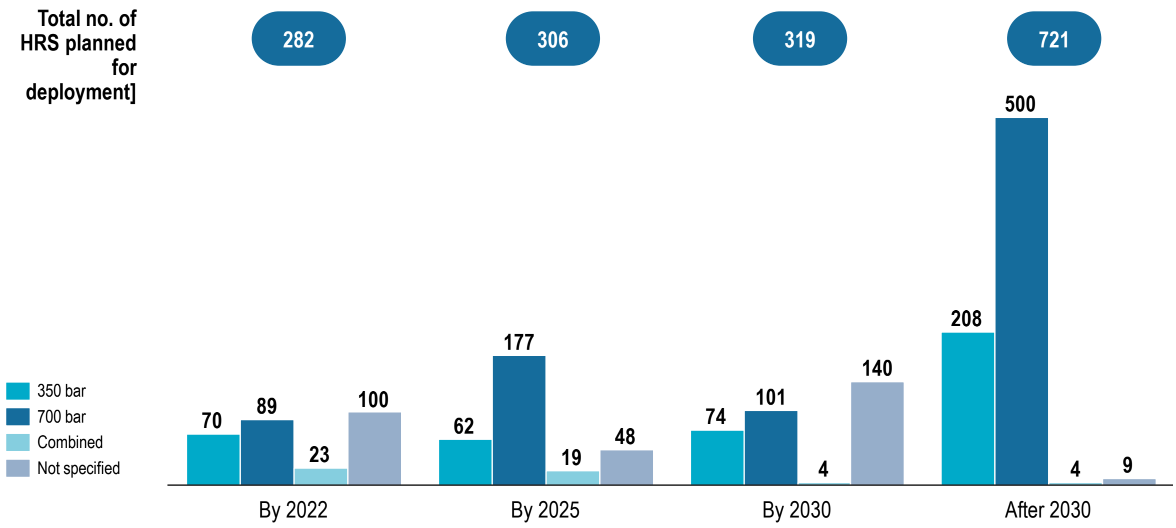


Figure 32: Planned HRS deployments by HRS type

Whereas participants have in most cases indicated the type of HRS to be deployed (350 bar vs. 700 bar), very few statements have been made regarding the projected daily refuelling capacity of these stations (in kg H_2/day). Naturally, there is an observable tendency towards deploying stations with lower daily capacity earlier (i.e. up to 100 kg H_2/day) and larger stations later (i.e. after 2022). Nevertheless, planned HRS capacity is also heavily dependent on the main envisaged type of

23 These member states are Austria, Belgium, Bulgaria, the Czech Republic, Estonia, Finland, France, Germany, Hungary, Italy, the Netherlands, Spain, Sweden and the UK. For a detailed assessment of the respective national plans, see European Commission (2017): Commission Staff Working Document – Detailed Assessment of the National Policy Frameworks.

application deployment: Buses and trains, for example, consume significantly larger amounts of hydrogen than fleets of cars or delivery vans. If such deployments are planned in the next few years, the regions and cities concerned will need to install higher-capacity HRS in the short term as well. Similarly, few indications have been given about whether planned HRS are to comprise on-site H_2 production facilities to supply the required hydrogen. Again, there is an observable tendency that the deployment of HRS with on-site production is planned in the coming years. Later on, when local hydrogen use has been scaled up significantly, large-scale centralised production facilities will most likely produce the required hydrogen that will then be distributed to local HRS.

Many regions also foresee installing local hydrogen production capacity with a focus on harnessing electrolysis to make use of local RES. There is a tendency among developed FCH deployment plans to focus on renewable carbon-neutral hydrogen production pathways even in the short term, despite potentially higher costs, with the largest share of participants focusing on using electrolysis technology. In many cases, making use of local excess RES electricity is a key driver for participants to invest in hydrogen, so it also boosts interest in electrolysis technology.. Most regions and cities do not seem to have a clear preference in this regard, but most will likely select the technology that best fits local requirements.[24]

Electrolyser capacity planned for installation totals more than 3,521 MW, with individual projects significantly increasing their capacity after 2020. In terms of hydrogen production capacity too, continuous deployments will be made until 2022, with a further increase in deployments afterwards. The installed capacity (in MW) of planned installations significantly increases over time, with large-scale installations (in excess of 20 MW) primarily planned for deployment after 2020. Up to 2030 and beyond, there are plans for individual projects with total production capacity of 2,000 MW. Considering all projects for which indications of planned capacity have been made, total installed capacity of 3,521 MW will be realised within the framework of the participants' plans by 2030 and beyond. That said, not all FCH deployment plans give an indication of detailed capacity, so the total accumulated capacity for all projects can be expected to be even higher. In addition to realising local hydrogen production with electrolysis, a number of regions are also looking at other supply sources. Especially in the short term, some regions plan to rely on hydrogen sources which exist today, such as conventional hydrogen production facilities, or to make use of industrial by-product hydrogen that is available locally. Only in a few cases have plans been indicated to use other hydrogen production pathways than electrolysis, e.g. organic waste or biogas reforming, steam methane reforming with carbon capture and storage (CCS) or gasification. Since the technology for some of these production pathways is less mature and needs further development, corresponding projects are not planned until after 2020.

[24] For a detailed account of the current state of electrolyser technology, expected performance development and associated business cases, see FCH JU (2017): Study on early business cases for H_2 in energy storage and more broadly power to H_2 applications.

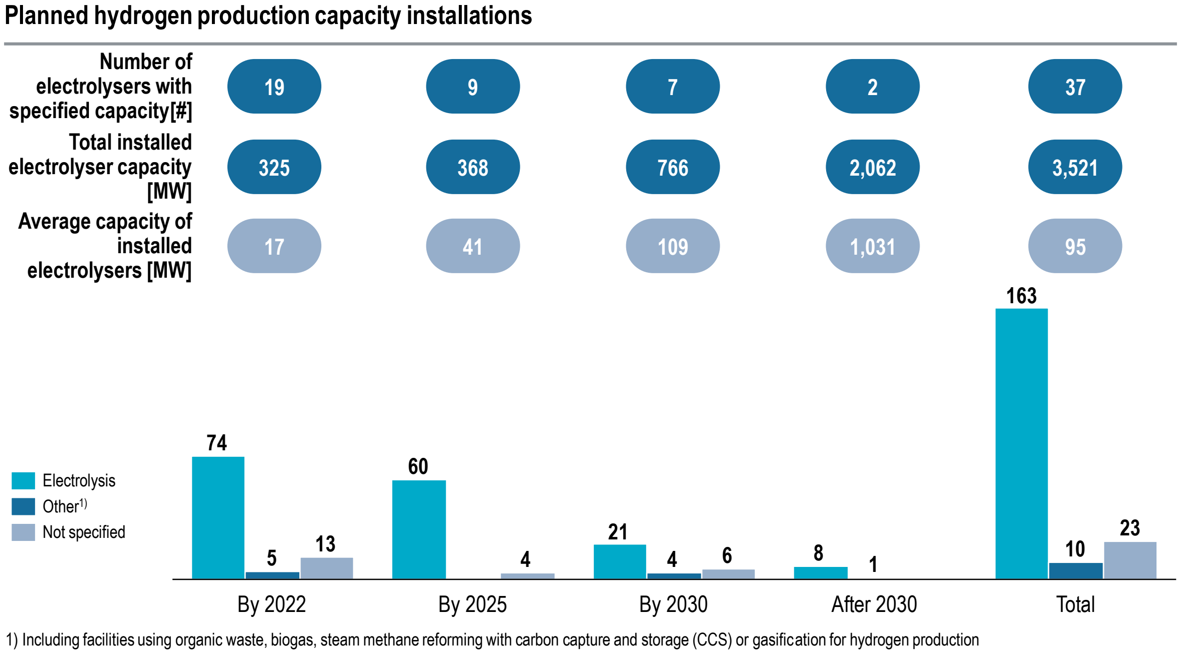


Figure 33: Planned hydrogen production capacity installations by type and planned total, plus average electrolyser deployments by capacity

Participating regions expect average hydrogen prices of EUR 7.50 per kg to materialise in the next years, reducing the operating cost of FCH deployments. Hydrogen prices currently differ significantly between European regions. Hydrogen production methods, the availability of existing production facilities vs. the need to realise new investments, the cost of distribution and logistics, utilisation levels for installed infrastructure and guaranteed offtake volumes are the main factors influencing local hydrogen prices. Stated future price expectations per kilogram of hydrogen (to be understood as final customer prices, including all costs for infrastructure capex and opex, hydrogen production and logistics etc.) reflect this wide variance in current price levels: Indicated expected prices range from a minimum of EUR 2 to a maximum of EUR 13 per kg H_2, the average being EUR 7.50 per kg. Typically, participating regions indicate a certain individual price range which they expect to materialise. Looking at the lower end of these indicated price ranges, the average expected H_2 price would be about EUR 6 per kg. For many European regions, that would be a significant improvement over today's price levels and would constitute an important lever to reduce overall FCH application deployment costs.

3.4 Achieving scale – Implementing "H_2 Valleys" as the next development stage for the FCH sector

Several ambitious regions and cities are planning to establish local "H_2 Valleys" in the coming years to move towards establishing a local H_2 economy

Local "H_2 Valleys" will demonstrate the important role that hydrogen can play in the future energy system, going beyond the scope of individual deployment projects. Many regions and cities in Europe have already deployed individual FCH applications and started to build up local hydrogen infrastructure. While substantial efforts have been made in this regard, activities in most cases have only been realised on a project-based approach with a limited project lifetime. They have also only included individual applications or have only established parts of the hydrogen value chain locally. The next development stage for regions and cities with the long-term goal of building up a local hydrogen economy is to link individual projects to each other and start creating a dedicated local hydrogen ecosystem, or H_2 Valley. Establishing such initial local H_2 ecosystems can then serve as a basis from which further roll-out and uptake of local H_2 use can start, with the establishment of a local H_2 economy as the ultimate goal. In addition, establishing H_2 Valleys will be important to demonstrate to key stakeholders the systemic role that hydrogen can play as a future energy carrier.

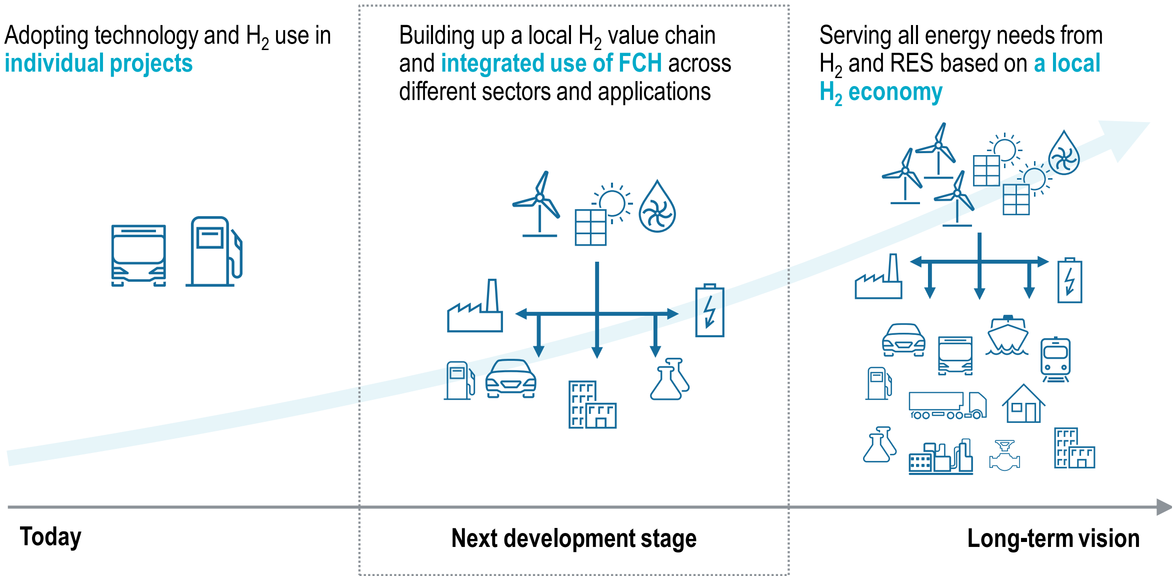


Figure 34: H_2 Valleys as the next development stage for the FCH sector

H_2 Valleys will showcase the future role of hydrogen in the energy system and serve as nuclei for growth in this sector

H_2 Valleys will show the potential of hydrogen and fuel cells as key enabling technologies for the green energy transition in Europe. By using electrolysis to produce hydrogen locally from RES electricity and channel it into a variety of local use cases for different FCH applications, H_2 Valleys will establish concrete examples of sector coupling and the potential future role of hydrogen as a flexible energy storage medium. By using hydrogen in different applications, they will showcase the versatility of hydrogen as an energy carrier and the wide variety of its potential use cases. Such real-world examples will demonstrate to key stakeholders and the general public that hydrogen and fuel cells can become key pillars of the green energy transition in Europe.

H_2 Valleys can improve the business case for FCH deployments by achieving significant scale. Current individual FCH deployment projects often face significant economic challenges, e.g. due to uneconomical small-scale infrastructure installations and deployments, low asset utilisation (e.g. for HRS) or expensive hydrogen distribution and logistics, all of which results in high FCH deployment costs. While all FCH deployment projects could be designed in a way to overcome those challenges, specifically, H_2 Valleys have the potential to improve the business case for FCH deployments:

- by reducing initial capex costs as larger deployment volumes are realised for applications, thereby reducing purchase prices, or as larger-scale infrastructure installations are implemented with lower relative investment costs
- by ensuring reasonable levels of infrastructure asset utilisation, e.g. by ensuring sufficient base-load offtake of H_2 for refuelling stations, thus creating a commercial business case for them
- by reducing H_2 costs as lower prices for green electricity can be realised on the spot market
- by generating additional revenue streams, e.g. by offering grid balancing services.

In this way, they can demonstrate how the local business case for FCH deployments can be improved and prove that FCH deployment costs can be reduced with large-scale market uptake.

Furthermore, H_2 Valleys will foster H_2 roll-out with increased impact and visibility. Establishing several H_2 Valleys in pioneering regions and cities in Europe will increase the impact and visibility of local H_2 deployments, establishing them as local nuclei for growth in this sector in Europe. H_2 Valleys can also serve as role models for other regions and cities, and can develop solutions to realise the large-scale roll-out of FCH technologies that can pave the way for similar roll-outs in other locations. In other words, they can significantly contribute to the ongoing market development and cost reduction that is needed to achieve commercialisation and establish hydrogen and fuel cells as a viable and also economically feasible future energy solution.

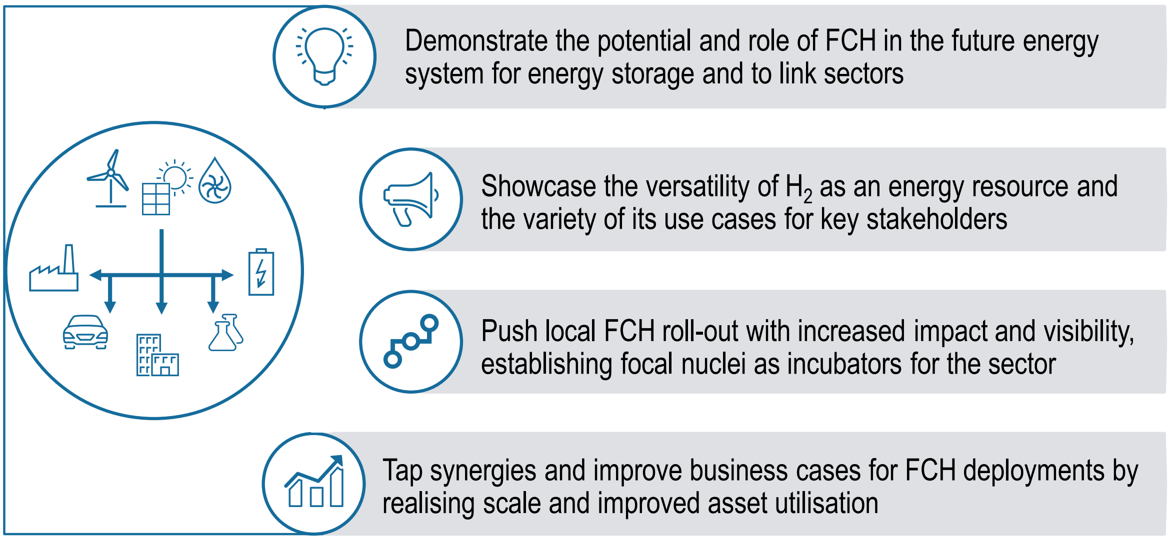


Figure 35: Overarching objectives for setting up H_2 Valleys

"H_2 Valleys" are local hydrogen ecosystems which span the entire hydrogen value chain, plus a variety of use cases and applications. H_2 Valleys are not yet established as a common concept or approach, and are currently also referred to as H_2 "communities", "territories" or "regions" in other contexts. Whereas the concept is still under development and more concrete examples for concept implementation will be required for further concretisation, some common principles are at the core of the concept:

1. **Coverage of the entire value chain** – Establishing a complete local H_2 ecosystem covering hydrogen production, storage, distribution, refuelling and end use in several FCH applications
2. **Demonstration of sector coupling** – Showcasing how the use of hydrogen produced from renewable energy sources using electrolysis can enable sector coupling and increase the use of renewable energy sources
3. **Different FCH use cases** – Demonstrating different FCH use cases and applications, potentially from different energy sectors, in a single coherent project
4. **Integrated approach** – Linking individual sub-projects to each other to demonstrate their systemic interaction in a clearly defined local setup
5. **Scaling** – Allowing for large-scale hydrogen use and application deployments, thus potentially enabling an improved business case for FCH

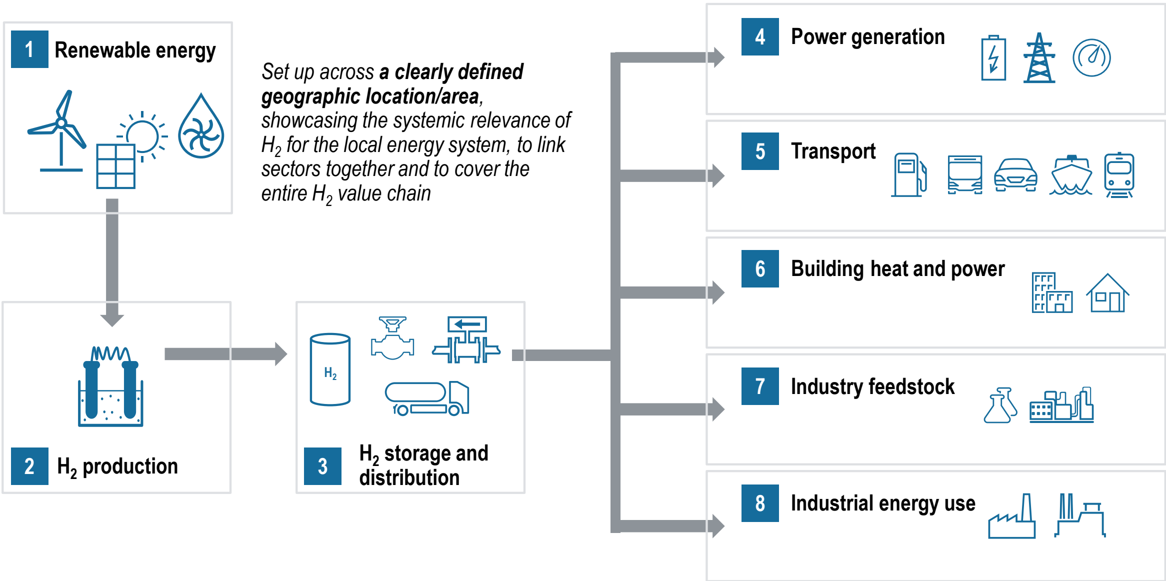


Figure 36: Conceptual overview of an H_2 Valley

There is obviously no "one-size-fits-all" approach for developing local H_2 Valleys. Instead, a number of individual setups and configurations can potentially be implemented, depending on local framework conditions and existing FCH activities. Individual H_2 Valley concepts can focus on deployment alone or also include R&D or technology demonstration activities. They can build on locally available expertise and industrial capacity, or they can introduce the technology to a region. They can build on and integrate existing hydrogen infrastructure and deployed applications or initiate a greenfield development. They can cover different energy sectors and include numerous potential configurations of FCH applications to be deployed. They can vary and develop individual solutions for a number of other aspects, such as volume/scale, geographic coverage, public/ private sector involvement, implemented operational/ business models, funding/financing concepts etc. Ultimately, it is up to the implementing regions and cities to come up with coherent but distinctive approaches to developing local H_2 Valleys. At the same time, these approaches should always reflect the basic principles stated above. Some potential configurations of H_2 Valleys can be illustrated following the basic archetypes depicted below. Whereas an H_2 Valley archetype is defined by the main focus of its FCH deployments and associated investments, smaller-scale deployments in other sectors should complement deployments in the focus sector of each archetype:

Archetype 1
Focus: Energy/heat

- Injection of H_2 into local gas grid
- Heat and power generation for buildings, e.g. with CHPs
- Back-up power supply, e.g. for data centres, ICT infrastructure
- Off-grid power supply, microgrids, gensets etc.

Archetype 2
Focus: Industrial use

- Large scale H_2 use for industrial processes, e.g.
  - Refineries
  - Chemical industry
  - Steel production
- Combined with small-scale use in other sectors, e.g. transport

Archetype 3
Focus: Transport

- Public transport, e.g. buses, trains, taxis, ferries etc.
- Public service vehicles, e.g. garbage trucks, sweepers etc.
- Captive fleets of cars, vans etc. in public or private sector
- Other vehicles, e.g. forklifts etc.

Local H_2 production and distribution infrastructure (e.g. production facilities, pipelines, refuelling stations etc.), potentially allowing grid balancing services to be offered as an additional revenue stream

Individual H_2 Valley concepts can follow the above archetypes, include elements of all or only two archetypes – **Individual local concepts must be developed that coherently reflect the overarching approach**

Figure 37: Potential H_2 Valley archetypes

Regarding the potential scale of future H_2 Valleys, it is expected that pending projects will have sufficient ambition to clearly exceed the scope of existing projects and realise large-scale deployments of FCH applications and hydrogen use at substantial volumes. That will enable synergies to be realised and business cases to be improved. The figure below gives an indication of the deployment volumes, indicative investment volumes and annual H_2 consumption levels that are associated with some potential model H_2 Valley configurations:

Current example: Orkney Islands (BIG HIT / Surf'n'Turf Projects)

- 2 electrolysers (1.5 MW total)
- 75 kW FC for port power supply
- 2 H_2 heating systems (60 kW)
- 5 Symbio FC vans
- 5 H_2 trailers (260 kg each)
- 5 H_2 storages
- 1 HRS (20 kg H_2/day)

CAPEX: ~ EUR 13 m
Annual H_2 consumption: ~ 10.5 t

Potential future case: Industrial use focus

- 1 electrolyser system (10 MW, on-site refinery plant to which H_2 is primarily supplied)
- 1 HRS (200 kg H_2/day)
- 10 solo FC buses
- 20 FC cars

CAPEX: ~ EUR 26 m
Annual H_2 consumption: ~ 1,300 t

Potential future case: Transport focus

- 20 solo FC buses
- 10 FC garbage trucks
- 30 small FC delivery vans
- 1 HRS (420 kg H_2/day)
- 1 electrolyser system (2.5 MW, on-site production at HRS)

CAPEX: ~ EUR 26 m
Annual H_2 consumption: ~ 115 t

Figure 38: Examples of deployment, investment and H_2 consumption volumes in H_2 Valleys

Initial examples of H_2 Valley concepts already exist, and participants in the initiative are pursuing ambitious plans to develop further H_2 Valleys across Europe

On the Orkney Islands (in Scotland), a pioneering example of an H_2 Valley concept is currently under implementation. The FCH JU is contributing EUR 5,000,000 to help fund this development as part of the "BIG HIT" project ("Building innovative green hydrogen systems in an isolated territory: A pilot for Europe"). The project builds on installations from its predecessor, "Surf'n'Turf", which was funded by the Scottish government. It entails the implementation of a fully integrated concept for hydrogen production from renewables, hydrogen storage, distribution and transportation on tube trailers, as well as utilisation for heat, power and mobility applications. Locally produced renewable electricity from wind and tidal turbines is used to produce local green hydrogen in two electrolysers on two different islands with a total capacity of 1.5 MW. Stationary hydrogen stores and a small-scale hydrogen refuelling station have been installed. Five tube trailers for compressed gaseous hydrogen are used to transport hydrogen between the islands and use sites. The hydrogen produced is used to heat school buildings with two catalytic hydrogen boiler systems, to heat and power buildings and ferries at the port with a stationary CHP system, and to fuel five vans equipped with fuel cell range extenders. Annual H_2 demand is estimated at about 10-15 tons for the applications currently deployed, while total annual H_2 production capacity already goes as high as 100-150 tons, but has the potential to be ramped up to 200 tons. Plans exist to further expand currently installed infrastructure and use cases/applications, which would significantly increase H_2 consumption and make greater use of existing production capacity. Furthermore, it is planned to exploit the replication potential of the concept in other locations. The concept reflects all the basic principles of H_2 Valleys as stated above: establishing a complete local H_2 value chain, demonstration of sector coupling by featuring local hydrogen production from renewables, establishing different FCH use cases and pursuing an integrated approach to link individual sub-projects. Even though future H_2 Valleys will likely aim for larger scales, the Orkney Island concept can serve as a role model for future H_2 Valleys.

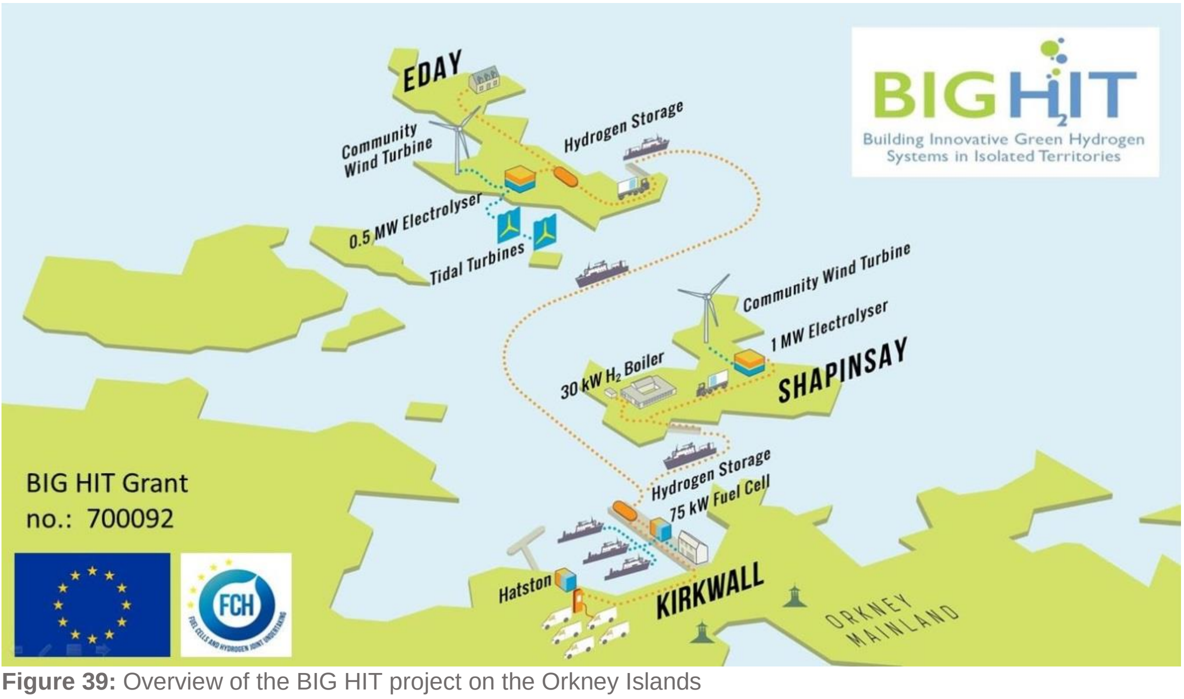


Figure 39: Overview of the BIG HIT project on the Orkney Islands

Within the initiative's participant coalition, 24 ambitious regions and cities currently aim to develop their own local H_2 Valley approaches. More regions have also indicated ambitions to develop a local H_2 economy in the long term. These too could potentially become H_2 Valleys, though only the first 24 regions have so far stated a clear ambition to become H_2 Valleys. These regions are the most ambitious in terms of absolute investment and deployment volumes within the coalition: Investments totalling EUR 1,366 million are planned in these regions alone (for aggregate deployment volumes in these regions, see the table below). About 10 of these locations are pursuing implementation of their H_2 Valley plans in the immediate future (i.e. in the next 1-3 years). In most cases, first FCH deployments and infrastructure installations already exist that will be complemented by additional activities to become a H_2 Valley. Significant efforts are currently being made by these pioneering regions and cities to develop their individual H_2 Valley concepts, secure local stakeholder support and initiate project realisation. Other locations are pursuing plans that are planned for implementation after 2020. In a very few cases, a general ambition to develop a regional H_2 Valley in the future has been aired, but without providing any clear indication of when such a development will become feasible.

		Next implementation projects					Long-term outlook			
		2018	2019	2020	2021	2022	Until 2025	Until 2030	2030+	Total
	Applications									
Heavy-duty transport applications	**Trains**		**51**	**0**	**0**	**25**	**129**	**111**	**2**	**318**
	Buses	**6**	**59**	**203**	**206**	**210**	**668**	**1.280**	**1.475**	**4.107**
	Solo	0	10	0	15		37	80	500	642
	Articulated		2		4		10	20	35	71
	Minibuses			0	0		0	0		0
	Not specified	6	47	203	187	210	621	1.180	940	3.394
	Heavy-duty trucks	**3**	**13**	**18**	**23**	**7**	**270**	**9.100**	**35.500**	**44.934**
Light- and medium-duty transport applications	**Cars**	**102**	**307**	**482**	**772**	**734**	**7.105**	**190.975**	**1.023.100**	**1.223.577**
	Vans	**49**	**164**	**115**	**254**	**343**	**1.545**	**21.110**	**20.350**	**43.930**
	Large vans			5		7	20	50	150	232
	Small vans		35	36	100	107	25	60	200	563
	Not specified	49	129	74	154	229	1.500	21.000	20.000	43.135
	Garbage trucks	**6**	**7**	**40**	**98**	**27**	**98**	**120**	**435**	**831**
	Sweepers	**1**	**2**	**0**	**0**	**2**	**2**	**5**	**10**	**22**
	Construction mobile equipment/ tools	**3**	**3**	**3**	**3**	**3**				**15**
	Material handling/ forklifts			**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Bikes	**20**	**15**	**5**	**5**	**5**	**15**	**50**	**75**	**190**
	Scooters		**0**	**0**		**0**			**0**	**0**
Maritime applications	**Ships/ ferries/ boats**	**2**	**3**	**4**	**3**		**3**	**57**	**501**	**573**
	Port operations equipment			**0**				**0**	**0**	**0**
	Yard tractors			0				0	0	0
	Reach stackers			0				0	0	0
Stationary applications	**CHP**		**13**	**1**	**2**	**2**	**2**	**20.001**		**20.021**
	Residential use/micro CHPs		0		0	0	0	20.000		20.000
	Commercial CHPs			0	1	1	2	1		5
	Not specified		13	1	1	1	0	0		16
	Infrastructure									0
	HRS	**18**	**32**	**27**	**61**	**47**	**145**	**289**	**708**	**1.327**
	700 bar	9	10	8	28	12	76	100	500	743
	350 bar	2	4	4	9	8	36	50	200	313
	combined		5	1	2	0	15	0	0	23
	Not specified	7	13	14	22	27	18	139	8	248
	Production facilities	**7**	**15**	**11**	**6**	**6**	**12**	**10**	**4**	**71**
	Electrolysis	5	6	9	6	5	12	9	4	56
	Other			1	0	1		1	0	3
	Not specified	2	9	1		0	0	0		12

Figure 40: Aggregate deployment plans for regions with ambitions to establish "H_2 Valleys"

Existing H_2 Valley concepts have a clear focus on FCH deployments in the transport sector and can therefore be attributed to the "transport focus" H_2 Valley archetype. Considering the current state of technological maturity and commercial availability of some FCH transport applications this focus does not seem surprising. Nevertheless, it should be stressed that it would be desirable for any future H_2 Valley projects not to focus on the transport sector alone, but to demonstrate the use of hydrogen across different energy sectors. Besides FCH deployments in transport, a number of H_2 Valley plans also include large-scale projects in the (petro)chemical industry, where hydrogen is already used as feedstock. Making such activities part of H_2 Valley projects has the advantage that they are technically not complex, can realise very large volumes of hydrogen offtake and can get close to or create a viable business case. FCH applications in other sectors with smaller hydrogen offtake volumes could then potentially benefit from lower-priced hydrogen. To a lesser extent, domestic energy and heat provision with CHPs are also part of some H_2 Valley concepts. Looking in more detail at the H_2 Valley plans submitted (more concrete short-term and long-term ambitions at a more conceptual stage), the following characterisations can be made:

> **20 H_2 Valley concepts have a clear focus on FCH deployments in transport**, including 11 concepts that foresee only FCH transport deployments. These concepts can clearly be attributed to the "transport focus" H_2 Valley archetype. Two concepts can be classified as the "industrial use focus" archetype, with large-scale plans to produce "green" H_2 as feedstock for industrial production. The two remaining concepts have not yet defined a clear scope and focus. **However, FCH transport deployments are definitely foreseen in all concepts.**

> **Typical FCH transport applications envisaged for deployment are the currently the most advanced FCH vehicles and are already available**. They include buses (part of 16 concepts[25]), cars (16) and delivery vans (8). These also led to the highest planned deployment volumes. Submitted concepts further include a number of other transport applications such as garbage trucks (7), trains (3), ships or ferries (5), trucks (5), bicycles (2), special-purpose vehicles for public services, ports and construction 83), sweepers (2) and forklifts (1). Aggregate deployment volumes for all applications as part of H_2 Valley projects are depicted in the figure above (see figure 40).

> For FCH deployments without a specific focus, **industrial use cases** using H_2 as feedstock for different kinds of production processes **are part of five H_2 Valley concepts**. **Domestic energy and heat provision with hydrogen is part of nine H_2 Valley concepts**, albeit mostly on very small scales and in many cases only highlighted as a long-term goal for H_2 use, with no concrete deployment plans in the short term.

> **Required H_2 infrastructure developments are foreseen in all H_2 Valley concepts**, typically on larger scales than would be required for initial deployments in order to create the basis for upscaling deployments later on. **All concepts include H_2 production with electrolysis using RES electricity**, as well as installations of HRS to refuel FCH vehicles. Five concepts explicitly mention the ambition to install larger-scale infrastructure, e.g. in terms of P2G facilities with extended storage options, H_2 pipelines and H_2 storage in salt caverns.

> **21 concepts include deployments in both public and private sector use cases**, although public sector deployments are the clear focus in nine of these cases and will lead to the majority of investments. Only three cases envisage a majority of investments in the private sector. In three additional cases, indicated deployments will be realised in the public sector alone. Also unlike other submitted FCH deployment plans, H_2 Valley concepts thus show a clear ambition to involve the private sector to a greater extent. This is reflected in the envisaged financing of H_2 Valley projects, where private sector contributions are foreseen in the majority of cases (18 out of the 20 that specify funding sources).

[25] In the following, numbers in brackets indicate the number of H_2 Valley concepts which foresee the deployment of the respective FCH transport application

The majority of participants indicate that implementation of their H_2 Valley projects is certain or very likely, and that detailed project planning is underway. 19 of the regions planning to implement a local H_2 Valley (roughly 80%) indicate that project implementation is certain or very likely. This represents an even higher share than that for all submitted FCH deployment plans. 13 of these regions (about 54%) have already entered the detailed planning stage for their H_2 Valley projects. Nevertheless, in all such cases, substantial preparatory work remains to be done to refine individual H_2 Valley concepts, secure necessary stakeholder support (and project financing in particular) and advance detailed project planning for all sub-projects. Detailed project development for such complex projects is a major challenge for all these regions, as it requires substantial capacity and dedicated knowledge. Many of the regions see a lack of project development capacity and complex project financing as the main obstacles to implementation. It therefore seems advisable to provide regions with dedicated support in this regard if initial H_2 Valley projects are to be ready for implementation within the next 2-3 years.

4. The way forward to realise a European FCH roadmap towards commercialisation of the technology

Realisation of the regions' and cities' FCH deployment plans as outlined in the previous chapter can significantly advance market development and, ultimately, the commercialisation of FCH technology in Europe. At the regional and city levels, these plans are "bottom-up" initiatives that represent the first significant demand and short-term market volume for FCH technology in Europe.

Besides the measures outlined below to support the realisation of the described deployment plans, more action is needed on an overarching level (e.g. by industry, the European Commission, member state governments etc.) to foster FCH technology commercialisation in Europe. Due to the current state of market and technological development, substantial contributions must be made by all the relevant stakeholders: political decision-makers and regulators, the industry, regions and cities, and other demand-side stakeholders besides. A roadmap towards the commercialisation of the technology should consist amongst others of at least three areas of action:

1. Demand-side market development initiatives
2. Supply-side technology development initiatives to ensure product availability
3. Conducive framework conditions on an overarching level

The section below briefly outlines these main areas of action and provides recommendations on their implementation. These actions cannot be implemented by the FCH JU alone, but action is also required by the FCH industry (represented by Hydrogen Europe) as well as the European Commission and national governments. Renewed pressure to reduce emissions and the concrete plans put forward within this initiative show that interest in FCH technology has sparked. We are observing momentum that can achieve a decisive step towards FCH technology commercialisation. However, **this momentum requires commitment and action in the areas described below within the next 2-3 years to substantially support the plans of those cities and regions that foresee FCH deployments in the next 1-5 years**. If they all materialise, showcases and success stories will significantly contribute to bringing the technology forward.

4.1 Demand-side market development initiatives (by the FCH JU / EC)

As discussed in detail above, the FCH projects planned by regions and cities represent the lion's share of the demand side today. However, they are mainly public-sector-driven initiatives, and potential from the private sector in Europe still remains largely untapped.

Public side: Organising the work in the cities and regions coalition (by the FCH JU or other suitable platforms on European level)

As regards the public side, which has been laid out in detail in this report, it will be crucial to nurture and further support the project implementation initiatives of the current group and continue growing it. The section below provides recommendations as continuing the work in the coalition.

There is a broad consensus among project participants that the joint work should be continued to further support ongoing FCH project development activities. Participants have continuously stated that the continuation and consistency of the support structures for FCH project preparation activities is very important. Within just one year, the cities and regions initiative has not only doubled the number of participating locations, but also directly supported the stakeholders in developing their project plans and roadmaps in various dimensions (see chapter 3). The framework and the support provided by the initiative and its experts were considered instrumental in project preparation. All participants have expressed a clear willingness to continue working within the framework of this joint platform and highlighted their need for further support in advancing their local FCH deployment projects.

The need for dedicated support becomes particularly evident when considering the development stages of individual FCH projects among the participating regions and cities (see chapter 3.2). Many European regions and cities (especially those that have not participated in the initiative) are still not aware of the technology as a viable zero-emission option. Others have only just started to explore FCH technology as a potential alternative, or are in the early stages of developing projects for FCH deployment. Even in locations where projects are already more advanced and participants have greater experience in deploying the technology, specific support needs still persist, especially in terms of complex project development support (see chapter 3 for more detailed information). Hence, it cannot be assumed that, after a year of working together within the initiative, all participants are now on the verge of project implementation, and that all outlined FCH investments will materialise without further support. On the contrary, it has become evident that continued and dedicated FCH project development support is required to help participants realise their FCH deployment plans and establish FCH technology broadly as a viable zero-emission energy alternative.

The section below therefore provides recommendations on how the work which started in the cities and regions initiative can be further organised to enable swift project implementation.

The support needs discussed within the coalition can be clustered into two groups: First, general cross-cutting activities to support sector development; and second, concrete support for individual project development.

1. General cross-cutting support activities

1 **Initiate intensified dialogue with industry on further market development needs**

> Discuss in a joint dialogue with industry how the commercial availability of FCH applications can be improved and how further market development can be accelerated

> Define concrete next steps and potential projects/initiatives required to reach these objectives

2 **Facilitate knowledge dissemination**

> Establish a central repository of relevant information material, project experience etc.

> Compile material summarising key topics for easy access and distribution

> Facilitate more knowledge sharing with experienced regions and industry

3 **Launch marketing/communication activities**

> Develop and implement a broad and visionary communication campaign to promote FCH

> Engage in meetings with key decision-makers (EU, national, local) to promote FCH use

> Support regions in promoting FCH at the local level (e.g. with materials, events etc.)

4 **Engage in FCH policy development**

> Engage in policy dialogues at the EU/national levels to create a more favourable FCH framework

> Develop an overall EU FCH sector development strategy/roadmap

> Support regions in developing their own individual FCH policies and strategies

2. Individual project development support

5 **Support individual project concept development**

> Help to structure/review project concepts, provide advice on challenges (H_2 Valleys, others)

> Identify promising business models and help to develop individual local approaches

> Provide ongoing/needs-based coaching/advice on key topics, e.g. stakeholder management

6 **Support access to funding**

> Support development of individual financing concepts for local FCH projects

> Investigate innovative financing approaches, including attracting more private financing

> Support in identifying and applying for the most suitable funding programmes for projects

> Support gaining access to ERDF funds for projects, e.g. by lobbying with managing authorities

7 **Support realising cooperation projects and joint procurement**

> Facilitate matchmaking for participants working on similar projects (e.g. in working groups) or looking for project partners, as well as with suitable industry partners

> Structure large-scale projects incl. several locations, potentially conducting joint procurement

Support in both areas will be necessary to further advance sector development and greatly contribute to making envisaged FCH investment a reality in the years ahead. The general cross-cutting support activities outlined above address some of the most pressing challenges and areas for action in the FCH sector. Individual project development support measures are designed to directly support participants in taking their FCH projects from vision to reality, thus supporting actual implementation of large planned investments. It is of the utmost importance that any future FCH support framework should provide tangible and concrete support to individual project developments by the regions and cities, to help them overcome the typical barriers to entry for FCH deployments, but also to lead projects to successful implementation – especially in the form of direct service and support to those cities and regions with less experience in FCH technologies.

An FCH Project Advisory Hub can provide the platform for consistent support in the next 1-2 years: Participants have continuously expressed the need for a dedicated structure, e.g. an "FCH Project Advisory Hub" that combines capacity for technical project development assistance with dedicated FCH knowledge, project implementation knowledge and financing expertise that addresses the specific challenges associated with this particular technology.

Against this backdrop, it seems advisable to continue providing an organisational framework or platform under which a potential offer of future support can be organised on a medium-term basis. It would seem beneficial to bundle all potential support activities for the FCH sector within this framework, to establish it as a single point of contact for interested regions and cities with potentially high visibility. The existing coalition of cities and regions would be the starting point.

Based on the experience gained from this project, potential future FCH support offerings should include the following work streams and scopes:

1 H_2 Valley Support

> Prepare and bring to financing stage fully integrated valley projects to start implementation from 2019 onwards
> Provide individual support for each valley

2 FCH Project Implementation Support

> Prepare demo projects (for 1-2 applications)
> Support detailed business cases, project organisation, joint procurement etc.
> Potentially, help to launch large-scale pan-European projects on selected applications

3 Joint Platform Work – Supported by secretariat, study, FCH technology partnership etc.

> Networking, exchange, information sharing (e.g. in regular meetings)
> Outreach, communication and visibility (e.g. through communication campaign, letter of intent)
> Development of general concepts and tools (e.g. business cases, cost assessment, funding/financing)
> Technology discussions and dialogue with industry

Value proposition and work streams in the Advisory Hub

We suggest three core work streams and a relevant scope of work for the platform or hub. This proposal is based on the next steps outlined above to realise cities' and regions' projects and on the needs assessment that has been conducted.

H_2 Valley Support: On the one hand, the platform should directly support those 24 cities and regions that have the ambition and plans to develop H_2 Valleys. Since Valleys face the specific challenges inherent in a more complex set-up (see chapter 3.4.), it makes sense to create a dedicated workstream for this group of pioneering stakeholders who plan to scale up their projects.
As explained in more in detail in chapter 3.4, the most critical issues for the realisation of H_2 Valleys are:

- Finalising any open commercial and financial assessments
- Conducting integrated planning for a complex system of interlinking application/technology deployments that depend on each other in terms of timing, technology and commercialisation
- Securing financing and funding, which is often very complex due to the increased project scale, the span across various sectors and applications/technologies which bankers often find difficult to evaluate in a classical due diligence and bankability check
- Supporting the structuring of complex business cases and financing arrangements, including the use of innovative financing instruments and private financing contributions

We expect a number of the planned H_2 Valley projects to become reality in the next 2-3 years if the necessary support structures can be provided. Since most cities and regions which intend to establish a Valley are fairly experienced with FCH projects, focused support in the area of financial engineering should be at the centre of this workstream. We suggest bi-annual meetings of all Valley stakeholders to share lessons learned and progress made, and also to draw on ongoing technical support (e.g. in coaching calls, workshops, dedicated meetings with individual Valleys) on a regular basis.

FCH Project Implementation Support: This workstream should mainly target those cities and regions with less experience in FCH projects (i.e. orientation seekers, early-stage newcomers) and that are planning to implement demonstration projects with 1-2 FCH applications. As outlined in chapter 3.4, support in this group should focus on guiding the stakeholders in all necessary steps to further plan and realise their projects, including:

- Further technological and commercial/cost assessments for their projects within the specific framework conditions – based on the cost assessment model developed during the course of this initiative
- Fleshing out the project concepts that have already been developed and refining the steps going forward
- Securing funding and financing and maximising the use of existing funding sources to maximise the realisation of envisaged investments

Since this group is expected to need more dedicated individual support, we suggest 3-4 individual sessions per year with each location, as well as joint coaching calls to explain financing concepts and answer detailed questions in between.

For both H_2 Valley and individual FCH deployment projects, it is advisable to provide participating regions and cities with dedicated support in gaining access to either the national or regional operational programmes of the ERDF or to other national funding programmes that can support the funding of planned FCH projects. Such support should be provided on demand based on the needs expressed by the cities and regions. It should also include direct talks and exchange with responsible national authorities regarding ways to support FCH project implementation. Such dialogue should ideally be initiated by the FCH JU in its capacity as the sponsor of the initiative and the main body promoting the deployment of FCH technology at the European level.

Joint Platform Work: The framework for all activities will be provided by the overarching and ongoing Joint Platform workstream. This workstream will keep the coalition together, facilitate networking and ensure that work continues on the overarching areas of action outlined above, e.g. on technology discussions with the industry, regulation, awareness and campaigning. It should be a workstream that organises annual (or semi-annual) general assemblies as well as knowledge generation and conceptual development from which all participants can benefit.

Duration, set-up and working mode of the hub

Ideally, such a platform will provide ongoing support to FCH projects for an extended period of time to maximise its impact and reach across all European countries and regions. That will also maximise its potential to bundle ongoing initiatives, projects and activities that are being realised in parallel today by different stakeholders in the field. Establishing a central and well-structured long-term FCH support framework would greatly contribute to overcoming this situation and to providing European regions and cities with the support they need to realise their green energy transition with fuel cells and hydrogen.

Judging from the status of preparation of the various project concepts, it will be crucial to maintain consistency over a longer period of time, e.g. 2-3 years. Whereas it can be expected that some projects will be realised in the short term, the majority of projects will need to prepare for more or less this time-span before becoming a reality.

Overall, the work could be organised by a dedicated team of 3-4 experts in the various technical fields mentioned above. Since the intensity of support needed will vary depending on the project stages and judging from the experience of the cities and regions initiative, this capacity set-up seems reasonable. While it would make sense to link the platform to an existing institutional structure (e.g. the FCH JU), we expect only limited physical space requirements.

The general working mode should be that of a coaching and peer learning approach in which knowledge is shared among the group. Individual support needs (especially those of the orientation seekers) should be met by offering dedicated advisory and technical assistance services to the cities and regions that need more support. As chapter 3 noted, support needs span all typical project-related technical areas, e.g. financing, project preparation, stakeholder engagement, technological assessments, cost assessments etc.

Interaction within the groups and between the experts and cities/regions should receive digital support to minimise travel costs for participants and the platform's experts. It should include formats such as telephone and video conferencing, joint electronic file systems (potentially with non-disclosure agreements) and so on.

Private side: Mobilising commercial potential to achieve an uptake of FCH technology (as part of the joint platform work of the FCH JU/EC and the regions and cities)

The market potential in Europe from an uptake of FCH technology in the private sector is in principle much larger than in the public sector. It is of relevance to companies in all sectors in which hydrogen and fuel cells can be applied, e.g. commercial transportation, heating, energy, chemicals/feedstock (see chapter 2.1). As mentioned, the commercial sector was not the focus of the initiative. However, most cities and regions are working closely together with the private sector to demonstrate and support the uptake of the FCH technology in this domain, e.g. in refineries, at logistics companies and in the heating sector.

Some projects demonstrate that the commercial sector is increasingly becoming aware of the need to reduce emissions and is therefore analysing the potential of FCH technology. These first initiatives must be strengthened. Success stories must be written to raise awareness and stimulate smart project development (including financing) that ensures the commercial viability of the deployed applications.

We suggest that all cities and regions use their demonstration projects to engage in dialogue with the private sector in their vicinity to explore options for uptake and define local measures that could incentivise uptake by the private sector. On the other hand, national and EU-wide policies and incentives to foster the technology need to be strengthened. A large number of public financing facilities already exist today from which the private sector can benefit directly (see previous chapter).

4.2 Supply-side technology development initiatives to ensure product availability (by the FCH industry and Hydrogen Europe)

One major challenge for many FCH deployment projects is the limited commercial availability of FCH products on the European market. A significant number of FCH applications with high levels of technological maturity are already ready for large-scale deployments. Many regions and cities are ready to realise such deployments in the years ahead, even at higher deployment costs compared to conventional solutions. At the present time, however, many FCH applications are simply not available. The production capacity of European FCH OEMs is still very limited (or non-existent). Many products are still made to order, or are only developed for specific demonstration projects. In some market segments, demand can currently not be catered for. In others, significant delivery times must be taken into account. If growing demand from regions, cities and the private sector cannot be serviced, this can potentially lead to negative customer perceptions that undermine the current growing willingness to deploy the technology. Such bottlenecks in product availability can therefore hamper the rapid market uptake that is required to drive the FCH market to commercialisation. This mainly applies to transport applications, as there are no significant bottlenecks in the field of infrastructure.

The portfolio of available FCH products needs to be broadened and commercial availability needs to increase within the next 1-2 years. The FCH deployment plans submitted by the participants demonstrate that regions and cities are interested in implementing a broad variety of FCH applications. To cater for this demand, more FCH products need to be developed and commercial availability needs to be enhanced significantly in the short run:

> In sectors in which FCH applications do not yet exist (or only as prototypes in demonstration projects), technology and product development need to be further advanced to make them ready for large-scale deployment. That includes heavy-duty and maritime transport applications.

- In sectors in which FCH applications exist at high maturity levels but available product options are limited, the available product range needs to be increased to cater to different use cases and operational needs. That includes light-duty vehicles such as delivery vans and smaller commercial vehicles.
- In sectors in which FCH applications exist at high maturity levels but product availability is currently limited (because only small volumes can be delivered, for example), production volumes must be increased and applications must be made commercially available at larger scales to cater to demand. That includes cars and buses.

For a large FCH market to develop in Europe, attractive market offerings need to be established where products can be ordered and deployed. This is even more important to avoid losing momentum compared to battery technology. The latter alternative zero-emission option has developed quickly in recent years and already boasts a sizeable product range in different market segments (though still with certain shortcomings in product availability). While regions and cities are increasingly willing to invest in FCH deployments, these investments can only be realised if suitable product offerings are established by the FCH industry.

In addition, FCH technology costs must continue to decrease substantially. Joint efforts in recent years have already driven costs down considerably. Significant private investments and public funding support have been made available to decrease technology costs and increase deployment volumes. Even so, FCH deployment costs are still a major obstacle to further technology roll-out – especially because of the high capex costs for applications and infrastructure, but also due to the high cost of hydrogen fuel (opex). It follows that efforts to decrease overall deployment costs must continue unabated: On the one hand, further research and development can achieve more improvements and optimise costs at the component level, for example by using less expensive materials. On the other hand, realising economies of scale by achieving larger production volumes is a main lever to further reduce costs on the road towards establishing a large-scale commercial market. Whereas continued efforts are required in both regards, scaling up deployments and production volumes will be the principal lever to reduce costs in the next years, especially in market segments which have already achieved high technological maturity levels. Substantial public funding schemes will therefore be needed in the years ahead to support large-scale deployments of the technology and cover the decreasing cost premium as long as it persists. Regions and cities will need to contribute in this regard by investing now in FCH technology deployments that later create the volumes needed to reduce costs. If these investments are not made today, cost reductions will fail to materialise and lower technology deployment costs will not be achieved in the mid-term to long-term future.

We recommend that the dialogue that has continued throughout the initiative over the past year be strengthened such that the demand side stays in very close contact with the supply side. Concrete projects are on the table. If cities and regions continue to communicate with the industry regarding the requirements for applications, then concrete impact and progress can be made – especially with those applications that are currently at the demonstration stage. As highlighted in chapter 4.1, we therefore advocate maintaining a platform to enable the demand and supply sides to work together on technology development.

4.3 Conducive framework conditions at an overarching level (by the EC / national governments as well as regions and cities)

A new technology can easily fail if it is introduced before the right framework conditions are in place. Hence, policies, incentives and financial support are of the utmost importance.

Conducive policies, incentives and regulatory framework

Besides the demand and supply side actions that need to be taken by project developers and the industry, let us also provide a brief overview of overarching challenges and action areas that need to be tackled to advance the sector towards commercialisation. These issues were raised by all the participating stakeholders and need to be addressed on multiple levels. The bottom-up initiatives set in motion by the regions and cities must be complemented by top-down measures and initiatives launched by national governments and the EU.

European and national policymakers must provide a coherent, long-term policy framework to enable hydrogen to play a key role in the green energy transition. Whereas several regulatory and policy measures have already been or are planned to be implemented at the EU and national levels, a more comprehensive policy approach and corresponding measures are needed to significantly promote the green energy transition with hydrogen and fuel cells. This should cover all sectors and technologies, establish reliable and adequate incentives to invest in green technologies and create a level playing field with conventional technologies. The most relevant policy areas are:

> **Reducing fossil fuel subsidies** (e.g. tax breaks) and both tightening and enforcing current emission regulations: Taxing CO_2 emissions effectively, beyond the current EU Emission Trading System (ETS), can be a valuable lever to incentivise green energy use. It would also internalise the high societal costs of using fossil fuel. Furthermore, effectively enforcing current vehicle emission limits for cars as well as tightening emission limits across all sectors can have a major impact.

> **Promoting the use of hydrogen as a renewable energy carrier**: The current EU regulatory framework to promote renewable energy does not sufficiently incentivise the use of hydrogen and green electricity. Future relevant legislations needs to explicitly acknowledge the role that hydrogen can play, and to establish strong incentives to invest in the technology.

> **Enabling affordable green hydrogen production**: So far, a conducive investment framework for a Power2Gas (P2G) market is lacking, as the legal status of electrolysers in the energy system is currently not favourable for the business case as electrolysers are considered loads on the grid and thus have to pay connection fees. It needs to be ensured that hydrogen production based on electrolysis is not categorised as energy consumption. Otherwise, it will become subject to regular taxes and levies for electricity consumers. Achieving a favourable price for renewable electricity is the most powerful lever to bring hydrogen costs down to a commercially appealing level.

> **Establishing the regulatory basis for secondary hydrogen revenue streams**: A regulated market for grid balancing services and a coherent framework for the injection of hydrogen into the natural gas grid in all member states would de-risk the business case for Power-to-Gas projects by tapping additional revenue streams.

> **Closing regulatory gaps and easing regulatory requirements**: Regulatory gaps still exist in certain areas for the use of hydrogen and fuel cells, for example regarding codes and standards, safety requirements and green hydrogen certification. In addition, approval

requirements for installing hydrogen refuelling stations and other items of infrastructure are often strict, complex and costly. They need to be streamlined.

Besides these EU and national-level levers, regions and cities can also take action on a local level. In Europe, pioneering regions and cities have already successfully implemented a broad range of local policies and incentives that support both local green energy and the use of FCH. Here are a few examples:

> **Implementing local incentives** – Potential measures range from establishing low/zero-emission zones with tolls or charges or local driving bans to granting benefits such as free public transport use, free parking or the use of bus lanes to drivers of zero-emission vehicles.

> **Realising direct public sector investments** – Transforming public transport or other public fleets and investing in the local refuelling infrastructure are common examples of direct public investments that can leverage private investment.

> **Providing local financial support schemes** – Regions and cities can set up their own financial support schemes such as purchase or lease grants and loan programmes, or they can provide other financial incentives such as exemptions from local taxes for local FCH users and projects.

> **Implementing support and engagement measures** – Raising local awareness for green energy use and providing advice to local stakeholders who plan to invest in green technology are potential soft policy measures that create an enabling environment.

> **Raising awareness for implementation of additional measures at the EU and national levels** – Regions and cities can raise their voices at the EU and national levels to push for a more stringent general policy and regulatory framework.

More European regions and cities will need to develop and implement such measures to promote local green energy use and create a conducive environment for FCH technology deployment 'from the bottom up'.

Looking at FCH deployment ambitions from a regional perspective, important differences between European countries need to be addressed

When comparing the EU-15 and the EU-13 (the new member states), it becomes apparent that there is large potential to develop FCH deployment projects in the EU-13 countries. Overall, project participation in the initiative for the EU-13 countries was not as high as for the EU-15 countries. Some EU-13 countries were not represented at all, while the majority of represented countries had only one participating region or city as a member of the coalition. Even though raising awareness for FCH technology as a viable zero-emission technology option is also relevant for EU-15 countries, it seems particularly important in EU-13 countries, as witnessed by participants' feedback. Whereas significant efforts have already been made, the energy systems in these countries still remains largely fossil-fuel-based, while few investments are made into renewable technologies. In addition to a lack of awareness for the technology, concrete FCH deployment experience hardly exists yet on which to build in these countries. Furthermore, most regions covered by project participants from EU-13 countries are part of the orientation seeker or early-stage newcomer groups that still have a lot of work to do before actual FCH project implementation. Project financing in particular can be a major challenge in these countries according to participant feedback. Whereas the ERDF and Cohesion Fund in principle provide well-dimensioned funding opportunities in these countries, participants report challenges in accessing these funds. From a cohesion policy point of view too, implementing dedicated support activities to advance FCH deployments in EU-13 countries will be required to ensure FCH market roll-out in these countries as well. Whereas a basic interest in developing FCH projects also exists in these countries, dedicated support is required in the framework of the FCH Advisory Hub (supported by the FCH JU / EC) to increase the number of projects and help individual regions and cities to overcome "first mover" challenges and bring their project plans to implementation. Such support can take the following forms:

- Liaising directly with national and regional governments on high levels to raise awareness of the technology and support its deployment, e.g. in direct talks or by organising high-level events such as the celebration of the 10th Anniversary of the FCH JU in Sofia this year
- Organising regional workshops or events to inform more regions and cities about the technology and its potential, as well as about the FCH Advisory Hub
- Provide an increased level of support for individual project developments, including support for conceptual development and stakeholder alignment, as well as for setting up project financing concepts and accessing various potential funding sources

Among the EU-15 countries, interest in FCH technology is picking up in southern European countries, but FCH projects have been implemented only to a limited extent so far. A significant number of project participants stem from southern EU-15 countries (particularly Greece and Spain, but also Italy and Portugal). They all have a clear and solid interest in deploying the technology. On the other hand, concrete experience with such deployments is only available to a limited extent, and many regions are still in the early stages of project development (again, mostly the orientation seekers and early-stage newcomers, although there are exceptions). Nevertheless, renewable energy projects do already exist in these countries and efforts are now being taken to convert national energy systems. This general openness to investing in green technologies should be built on to prepare the ground for implementation of FCH deployments. Again, project financing is seen as a particular challenge in these countries, according to participant feedback. These countries thus represent a second focus for dedicated support activities from the FCH Advisory Hub that should engage in talks with national governments and potential funding bodies on how FCH deployments can be supported in these countries.

Even though there are some regions and cities in the northern EU-15 countries that fall in the category of "orientation seekers" and "early-stage newcomers", the overall level of experience with the technology is considerably more advanced with multiple and/or large-scale FCH projects in existence today. Firm commitments have been expressed by national governments to considerably expand these activities, particularly in France, Germany, the UK, the Benelux countries and Scandinavia – see the list of local initiatives presented above. In these countries, the focus of the FCH Advisory Hub's work should be on providing specific support for large-scale deployments, such as in H_2 Valleys to help participants accessing national government funds in order to realise their ambitious project plans.

Funding support and financing schemes

Realising significant investments in the FCH sector in the coming years will require substantial funding support on various levels. The regions and cities participating in the initiative point to planned investments in FCH technology totalling approximately EUR 1.8 billion in the next five years. Sizeable additional FCH investment potential also exists within the initiative and beyond. More investments in further research and development and in commercial deployment projects are needed. If the green energy transition in Europe is to succeed, even more significant investments will need to be made in the decades ahead. It will need to become a clear investment focus. These investments can only be realised as a joint effort by all relevant public and private stakeholders who see the benefits of green technologies (such as FCH) and are therefore ready to pay a cost premium for their deployment:

- The EU and national and regional governments will need to continue to provide and increase dedicated funding support schemes for investments in FCH and other green technologies.
- Regions and cities will need to make substantial parts of their own local budgets available for investment in local green energy projects in public infrastructure and services.
- The private sector needs to become increasingly involved in green energy projects, and to start investing.
- The FCH industry needs to continue investing in bringing FCH products to market maturity and in expanding its production capacity.

These investments must be realised in the next few years. They are indispensable to enable a large-scale roll-out of FCH technology and establish a commercial market in Europe.

Continued public funding support will be required to facilitate FCH market development. As things stand, this technology still implies a cost premium compared to conventional technologies. Significant public funding support on all levels – EU, national and regional/local – will need to be available in the years ahead. In their FCH deployment plans, European regions and cities stated that they expect to receive at least around EUR 670 million from European and national budgets to realise their FCH projects, which add up to a total planned investment volume of EUR 1.8 billion between now and 2022. For an additional EUR 130 million, no funding sources have yet been identified but will ultimately have to be catered for. This funding support will predominantly be required in the form of grant funding programmes. Yet it will increasingly also need to cover commercial deployment projects, i.e. projects that do not only focus on research and innovation, but on the commercial roll-out of mature applications. In these cases, the cost premium for FCH application deployment is still too high for large-scale deployments to be realised without dedicated public funding support. At the same time, such large-scale deployment projects are vital to increase production volumes and realise economies of scale, thereby achieving further cost reductions that will drive commercialisation. Particularly at the EU level, the majority of the funding schemes available today have a strong focus on research and innovation. While these will remain important in many FCH market segments, increased attention will have to be paid to supporting deployment projects that drive large-scale technology roll-out and market development. First steps in this direction have been supported by the FCH JU or the Connecting Europe Facility (CEF), but substantially increased public investments are still required.

Better coordination between public funding programmes and reducing complexity in accessing funding support will facilitate project development. The current landscape of public funding programmes that can potentially support FCH investments encompasses an extensive number of individual schemes with different eligibility and funding criteria, application requirements, timelines and budgets. It is reportedly a major challenge for regions, cities and private sector investors to navigate this abundance of existing programmes and put together a project financing concept. It would significantly reduce project implementation complexity if these funding programmes were to become fewer in number and less complex. Significant capacity that project developers currently need to devote to this area could hereby be reduced and thus invested to develop more projects. Besides optimising the design of potential future funding programmes, providing dedicated support to regions and cities in this regard would be an alternative option. For example, during the course of the project, a comprehensive database including over 100 regional, national and European funding programmes that can potentially be accessed to fund FCH projects was developed to provide initial orientation and deal with the broad range of available funding sources. Nevertheless, identifying suitable sources for individual projects and preparing applications requires substantial additional work that regions and cities will need to undertake and for which they require more detailed guidance.

Lastly, the use of public funding will need to leverage more private participation in FCH investment projects. Constrained public budgets alone will not be able to bear the significant investments required to establish a European FCH market. Substantial private investments will therefore need to be mobilised. To this end, public funding instruments can be leveraged to secure private buy-in. For example, by providing a first-loss piece or guarantee as a de-risking component, the public side brings equity into the project as a basis to attract private engagement. Recent innovative examples – such as the FCH bus project in Riga that is financed by the EIB and the Zero Emission Valley in the Auvergne-Rhône-Alpes region in France that is financed by the CEF – highlight that FCH projects have the potential to leverage private funds by strategically drawing on public funding programmes. Continuing incentives must thus be set to attract more private investments, particularly in market segments that are close to commercialisation or to offering viable business cases. The EU has already sought to set such incentives, for example in its recent CEF Blending Call. Increased efforts are needed nevertheless. Dedicated support will be required by regions and cities to develop innovative financing concepts that include an increased share of private financing.

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