Clean Hydrogen Partnership

Strategic Research Priorities for the next partnership.

Bart Biebuyck
Executive Director

03 February 2022

EUROPEAN PARTNERSHIP

Clean Hydrogen Partnership

Strong public-private partnership with a focused objective

A combined private-public of **more than 2 billion Euro** has been invested since 2008 to bring products to market readiness

Hydrogen Europe
Industry grouping
>350 members
50% SME

European Commission

Hydrogen Europe Research
Research grouping
100 members

Energy

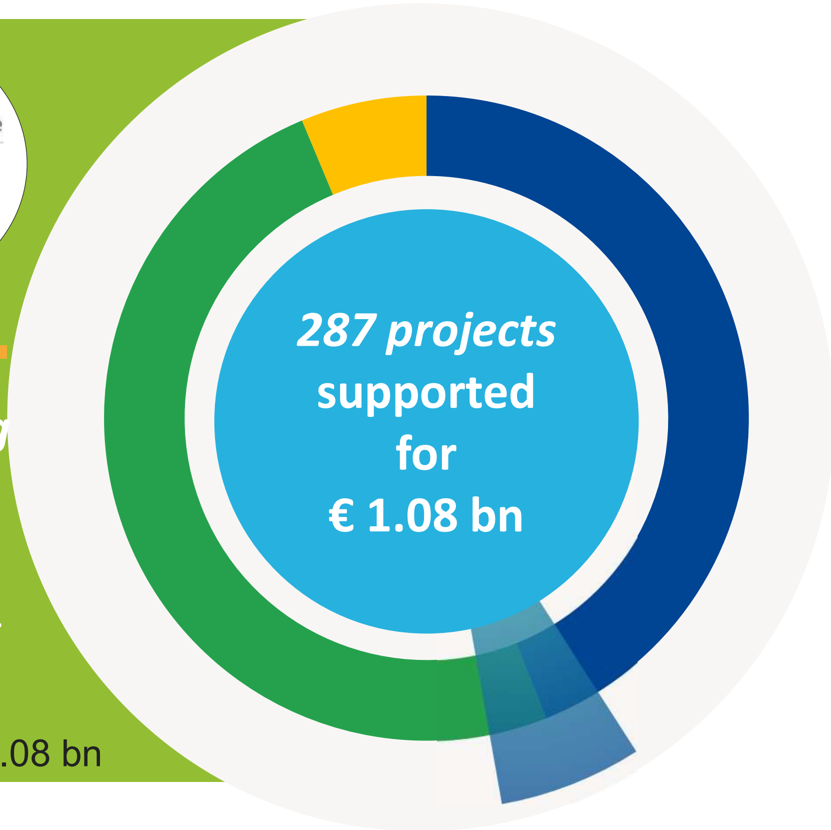
H_2 production and distribution
H_2 storage
F/C for CHP

Transport

Road vehicles
Non-road vehicles
Refueling infra
Maritime, rail and aviation applications

Cross-cutting

standards, safety, education, consumer awareness, GoO…



- Similar leverage of other sources of funding: € 1.08 bn

Co-funded by the European Union

Clean Hydrogen Partnership

Research and Innovation priorities in Clean Hydrogen JU

PILLAR H2 PRODUCTION

SO1 Low carbon H2 production
1. Electrolysis
2. Other modes of production

SO2 Integration of renewables
3. Role of electrolysis in the energy system

PILLAR H2 DISTRIBUTION

SO3 Storage & delivery of H2
4. Large scale storage
5. Pipeline transport (grid)
6. Liquid carriers
7. Non-pipeline transport
8. Key technos for distribution

SO4 Refuelling infrastructure
9. HRS for multiple applications

PILLAR H2 END USES

SO5 Transport vehicles
10. Building blocks
11. Trucks & large vans
12. Maritime (inc. ports)
13. Aviation
14. Rail
15. Coaches

SO6 Heat & Power
16. Stationery H2 fuel cells
17. H2 burners and turbines

SO7 Industry
18. H2 in industry

SO9 Supply Chain
Manufacturing & scale-up

Comms

Knowledge

Safety

Int'l coop.

SO8 Hydrogen Valleys
Integrated H2 ecosystems combining multiple applications (ports, industrial hubs, cities, etc.)

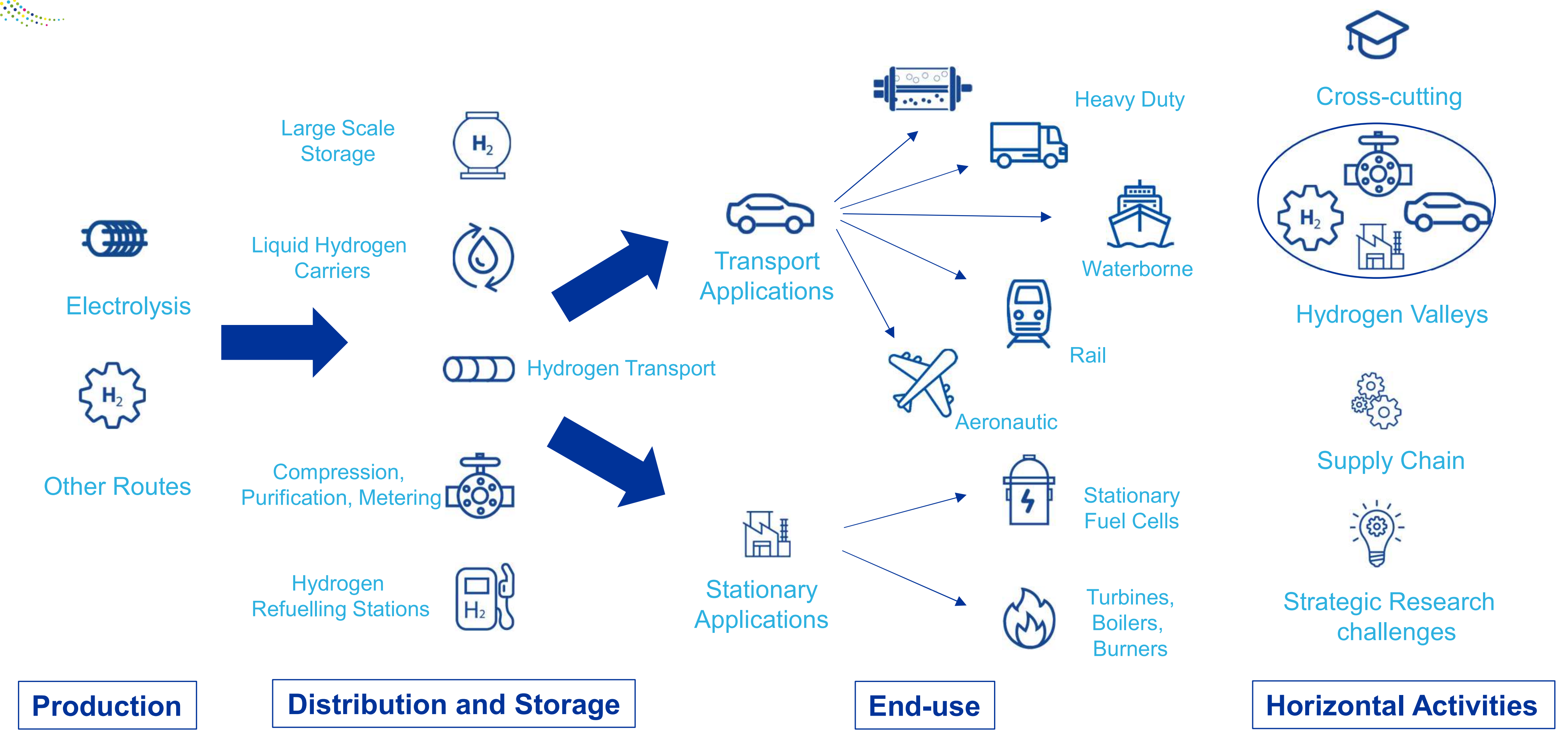
S10 Cross-Cutting
Regulations, Codes, Standards, Training, Safety, social, etc.

Goal: Maintain and strengthen **EU's global leadership role**
How: Clean Hydrogen Partnership a 2.0b EUR program

Clean Hydrogen Partnership

Research & Innovation activities

Building Blocks



Co-funded by the European Union

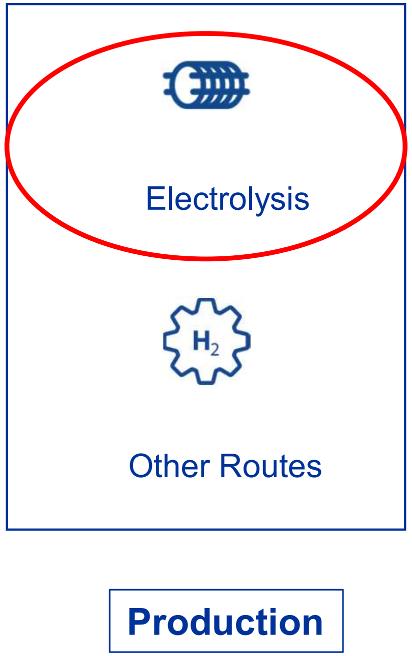
Clean Hydrogen Partnership

Pillar 1: Renewable Hydrogen Production

1.A Electrolysis

OBJECTIVES

1. Reducing electrolyser costs;
2. Improving dynamic operation, durability, reliability and efficiency;
3. Increasing current density and decreasing footprint;
4. Demonstrate their ability to provide flexibility to the electricity system;
5. Ensure circularity by design for materials and for production processes;
6. Increase the scale of deployment;
7. Improved manufacturing for both water and steam electrolysis.

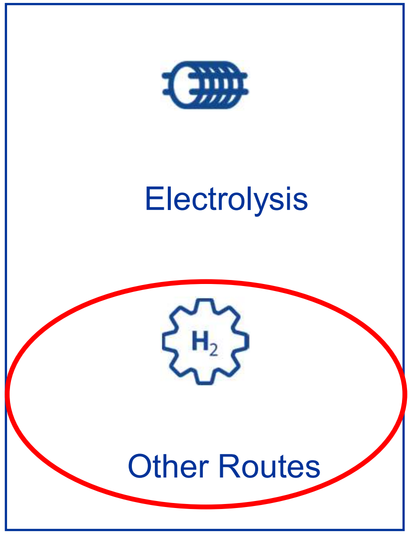


Pillar 1: Renewable Hydrogen Production

1.B Other Routes

OBJECTIVES

1. Reducing costs;
2. Improving the efficiency of the process;
3. Increasing carbon yield for processes based on biomass/raw biogas;
4. Increase the scale of deployment;



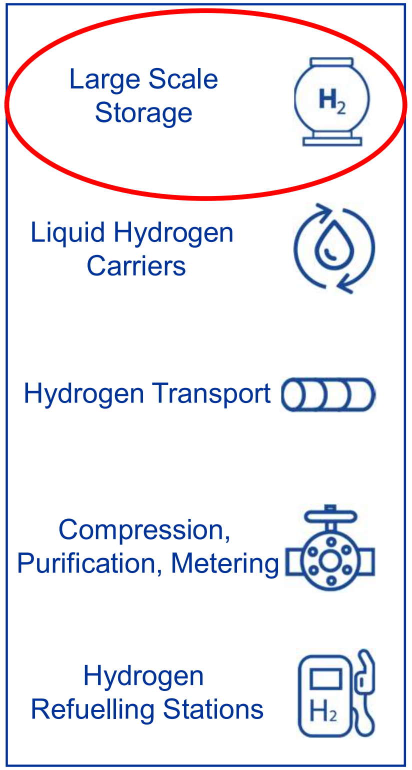
Production

Pillar 2: Hydrogen Storage and Distribution

2.A Large Scale Storage

OBJECTIVES

1. Improving cost and efficiency of aboveground storage solutions;
2. Demonstrate distributed aboveground storage solutions available at a low capital cost;
3. Validate the performance of underground storage in different geologies, to identify better materials and to encourage improved designs;
4. Demonstrate the large-scale underground storage across various media at a low capital cost.



Distribution and Storage

Clean Hydrogen Partnership

Pillar 2: Hydrogen Storage and Distribution

2.B Hydrogen in the Natural Gas Grid

OBJECTIVES

1. Development of technologies and materials to explore and support the transportation of H2 via the natural gas grid.
2. Enable through research and demonstration activities the transportation of hydrogen through the natural gas grid either by blending or via repurposing to 100% hydrogen.

Large Scale Storage

Liquid Hydrogen Carriers

Hydrogen Transport

Compression, Purification, Metering

Hydrogen Refuelling Stations

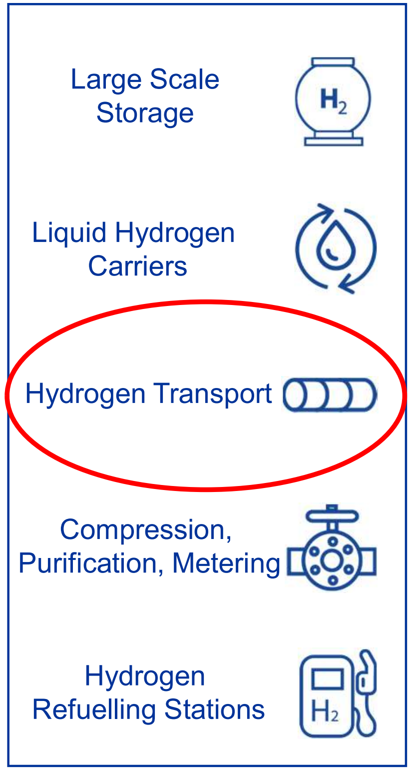
Distribution and Storage

Pillar 2: Hydrogen Storage and Distribution

2.C Liquid Hydrogen Carriers

OBJECTIVES

1. Increase efficiency and reduce costs of hydrogen liquefaction technologies;
2. Contribute to the roll-out of next generation liquefaction technology;
3. Continue research on carrier cycling performance, chemistries, catalysis and reactors, which show potential for improved roundtrip efficiency and life cycle assessment;
4. Develop a range of hydrogen carriers that will be used commercially to transport and store hydrogen, while improving their roundtrip efficiency and lowering their cost.



Distribution and Storage

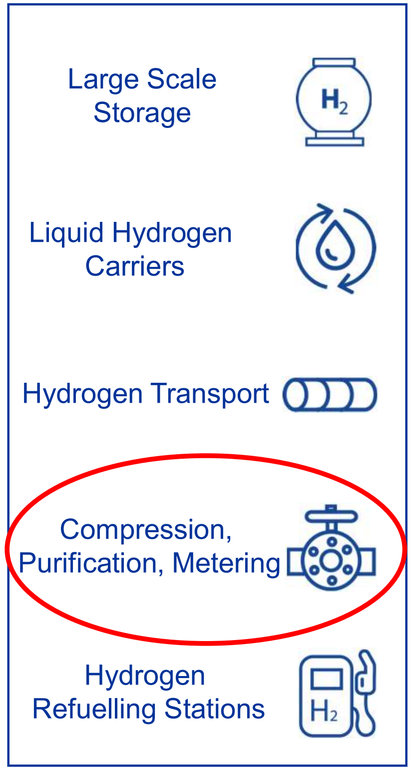
Clean Hydrogen Partnership

Pillar 2: Hydrogen Storage and Distribution

2.D Improving Existing Hydrogen Transport Means

OBJECTIVES

1. Increase the pressure and capacity for new built pure hydrogen pipelines, while reducing their cost;
2. Reduce road transport costs of compressed hydrogen by increasing the capacity of tube trailers;
3. Improve the efficiency of road transport of liquid hydrogen, while reducing costs;
4. Enable scale-up of solutions for shipping of bulk liquid hydrogen and support its commercialisation.



Distribution and Storage

Co-funded by the European Union

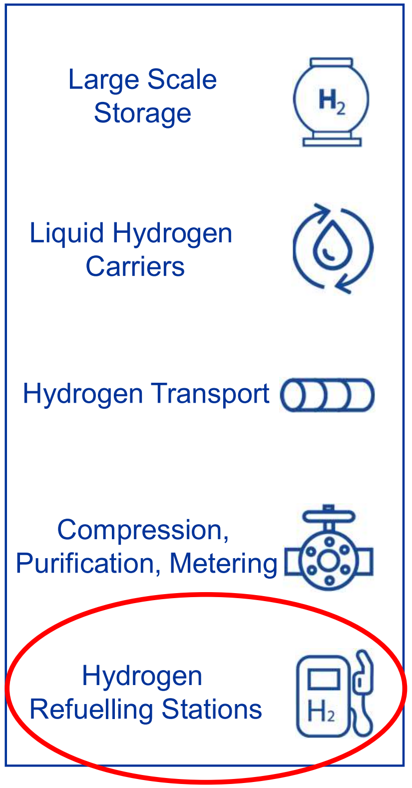
Clean Hydrogen Partnership

Pillar 2: Hydrogen Storage and Distribution

2.E Compression, Purification and Metering Solutions

OBJECTIVES

1. Develop more efficient compressor and purification technologies;
2. Reduce total cost of ownership of compression and purification technologies;
3. Reduce energy consumption and increase the recovery factor of purification technologies;
4. Increase the reliability and lifetime of compression and purification technologies;
5. Improve metering technologies and standards, especially in terms of accuracy and protocols.



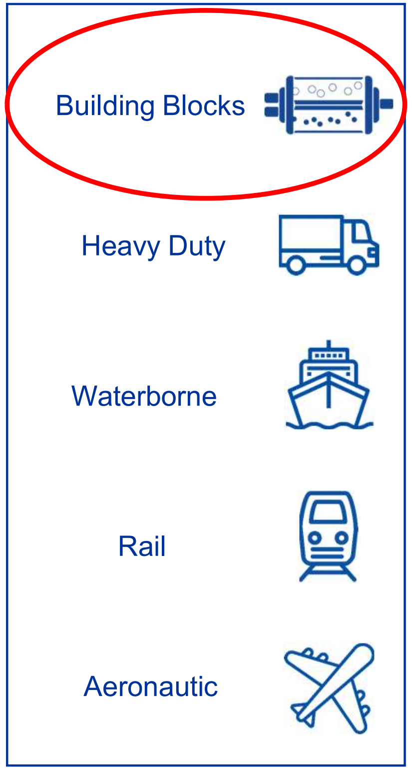
Distribution and Storage

Pillar 3: Hydrogen End-Uses: Transport Applications

3.1.A Building Blocks

OBJECTIVES

1. Improving overall system performance for fuel cell stack technology in terms of power density, reliability and durability;
2. Reduction or replacement of PGM loadings and development of new materials advancing the performance of on-board storage technology;
3. Improvements in design, health monitoring and manufacturability of core components for fuel cell stacks and on-board storage technology;
4. Extending the EU leadership on FC production from automotive to maritime and aviation, given the high pressure for decarbonisation of these sectors.



End-use: Transport Applications

Clean Hydrogen Partnership

Pillar 3: Hydrogen End-Uses: Transport Applications

3.1.B Heavy Duty Vehicles Applications

OBJECTIVES

1. Reducing the cost of core components ,such as modules and stacks, in order to foster the competitiveness of FC heavy-duty applications;
2. Improving overall system performance of FC systems, in order to improve the availability and durability and meet the needs of FCH HDV end users;
3. Improvements in design and monitoring procedures of FC systems;
4. Supporting and accelerating the wide roll out of FC HDVs.

End-use:
Transport Applications

Pillar 3: Hydrogen End-Uses: Transport Applications

3.1.C Waterborne Applications

OBJECTIVES

1. Scaling up FC designs towards commercially relevant applications;
2. Reducing the CAPEX of PEMFC or SOFC systems for maritime applications;
3. Improving overall system performance for FC and stacks, especially in terms of power density, bunkering rate and operational flexibility;
4. Improvements in ship design and safety procedures, both for ships and ports bunker terminals;
5. Supporting the wide roll out of FC ships.

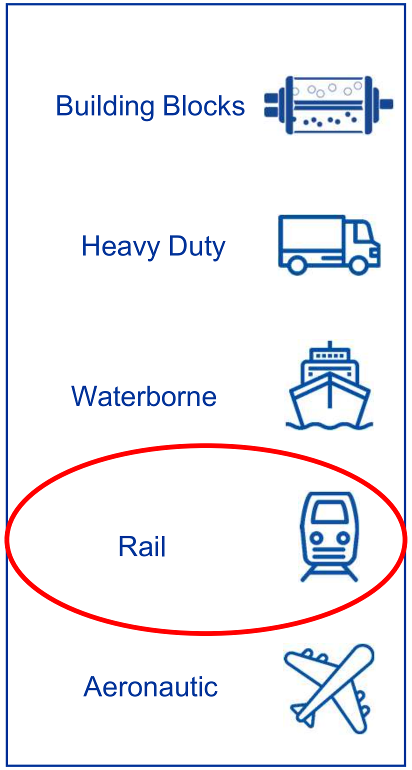
End-use:
Transport Applications

Pillar 3: Hydrogen End-Uses: Transport Applications

3.1.D Rail Applications

OBJECTIVES

1. Reducing the cost of stacks;
2. Improving reliability and durability at stack and FC system;
3. Improving power output while reducing weight and dimension of the module;
4. Improvements in train design and safety procedures;
5. Supporting the roll out of FC trains, by providing the viability of the FCH solution in the train transport segment.



End-use: Transport Applications

Clean Hydrogen Partnership

Pillar 3: Hydrogen End-Uses: Transport Applications

3.1.E Aeronautic Applications

OBJECTIVES

1. Improving overall system and stack performance for scalable FC in terms of power density, durability and availability;
2. Reducing NOx emissions of turbines;
3. Addressing Airport infrastructure (of both liquid and compressed hydrogen) and refuelling tech / procedures;
4. Developing aviation dedicated technological bricks, focusing on on-board storage, distribution components and systems of liquid hydrogen.
5. Addressing safety and regulation, specific to hydrogen for aviation applications

Building Blocks

Heavy Duty

Waterborne

Rail

Aeronautic

End-use: Transport Applications

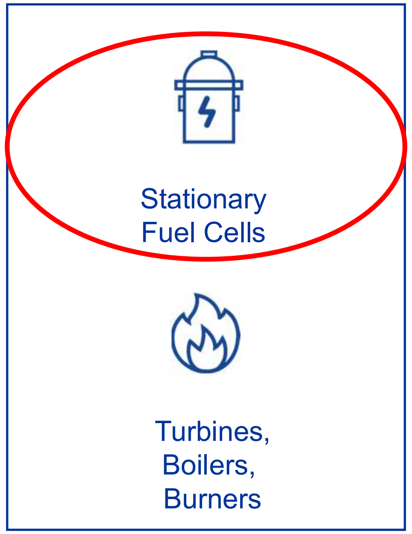
Co-funded by the European Union

Pillar 3: Hydrogen End-Uses: Clean Heat and Power

3.2.A Stationary Fuel Cells

OBJECTIVES

1. Reducing costs of stationary fuel cells;
2. Prepare and demonstrate the next generation of fuel cells for stationary applications, able to run under 100% H_2 and other H_2-rich fuels;
3. Improve flexibility of systems in operation, in particular with reversible fuel cells and integration with thermal storage;
4. Reducing use of critical raw materials and recycling them for further usage;
5. Support development of processes suitable for mass manufacturing.



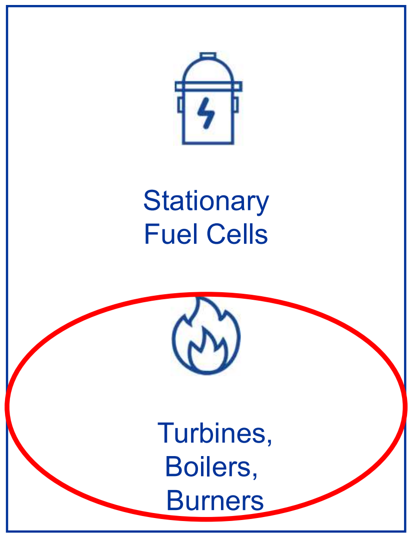
End-use: Stationary Applications

Pillar 3: Hydrogen End-Uses: Clean Heat and Power

3.2.B Turbines, Boilers and Burners

OBJECTIVES

1. Allow turbines to run on higher admixtures of H_2, up to 100% whilst keeping low NOx emissions, high efficiencies and flexible operation.
2. Develop concepts on safety and plant integration and demonstrate the retrofitting of turbines, boilers and burners, so that they are able to run up to 100% H_2.



**End-use:
Stationary Applications**

Clean Hydrogen Partnership

Horizontal Activities (1)

1. Cross-cutting issues

1. Sustainability, LCSA, recycling and eco-design

a) Develop life cycle thinking tools addressing the three dimensions of sustainable development: economic, social, and environmental.

b) Develop eco-design guidelines and eco-efficient processes.

c) Develop enhanced recovery processes in particular for PGMs/CRMs and per- and polyfluoroalkyl substances.

2. Education and public Awareness

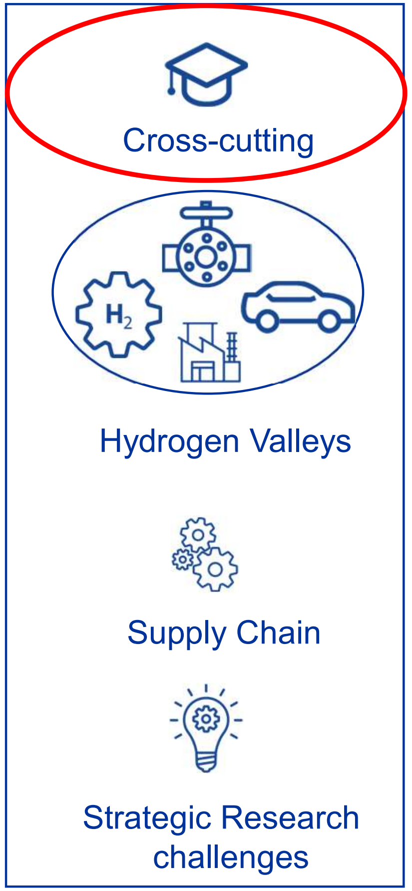
a) Develop educational and training material and building training programs for professionals and students on hydrogen and fuel cells.

b) Raise public awareness and trust towards hydrogen technologies and their system benefits.

3. Safety, Pre-Normative Research and Regulations, Codes and Standards

a) Increase the level of safety of hydrogen technologies and applications

b) Support the development of RCS for hydrogen technologies and applications, with the focus on standards



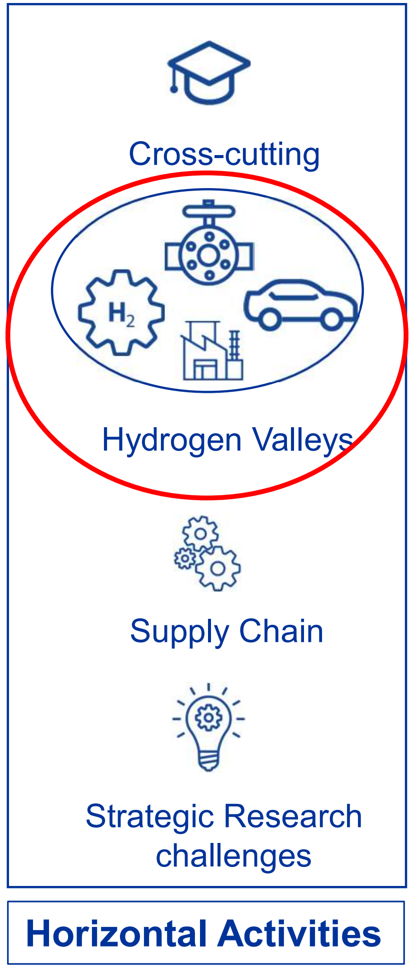
Horizontal Activities

Horizontal Activities (2)

2. Hydrogen Valleys

MAIN OBJECTIVES

1. Innovation in integrating several technology elements together to improve overall synergies, facilitate sector coupling and improve energy and economic efficiency of the whole system;
2. Improved security and resilience of the energy systems;
3. Demonstration of new markets for hydrogen;
4. Complementarity of the development of hydrogen with RES, integration with other technologies, existing infrastructure, etc;
5. Assessment of the availability and affordability of clean energy provision for industry and city uses.

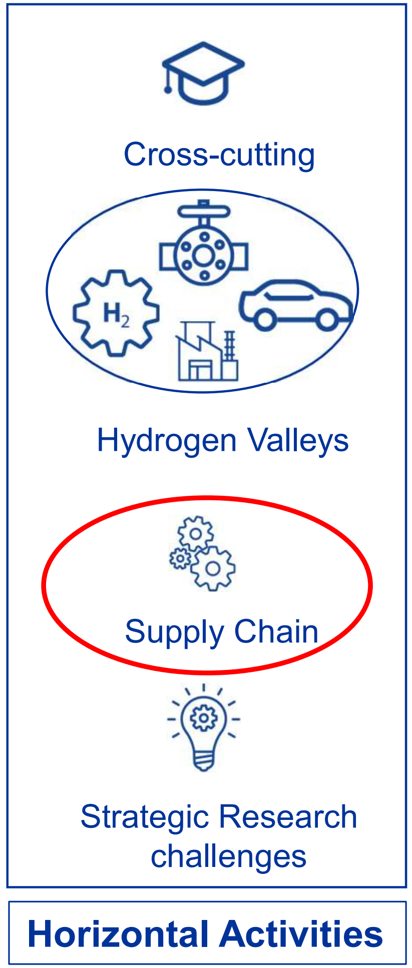


Horizontal Activities (3)

3. Hydrogen Supply Chains

OBJECTIVES

1. Identification of potential vulnerabilities in EUs hydrogen supply chain;
2. Development of new and improved manufacturing technologies and production processes that facilitate the safe and sustainable use of non-critical (raw) materials, as well as the adoption of the circular economy principles;
3. Reducing the use of critical (raw) materials with sustainability or environmental concerns, such as for instance those deriving from poly/perfluoroalkyls.



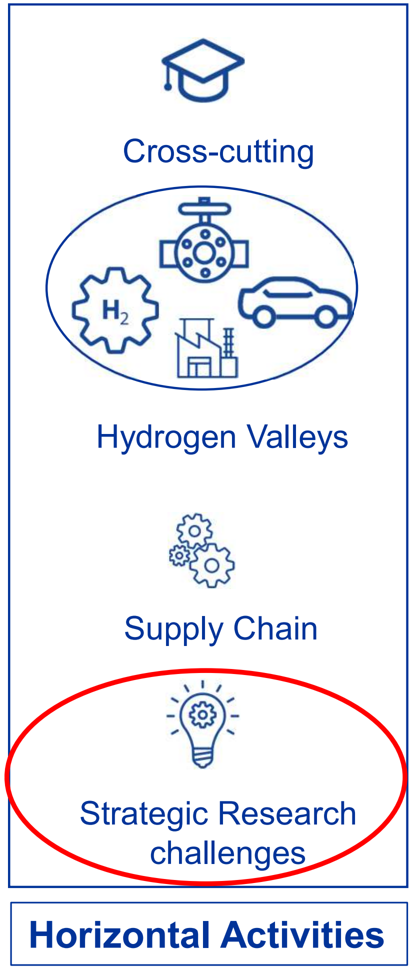
Clean Hydrogen Partnership

Horizontal Activities (4)

4. Strategic Research Challenges

OBJECTIVES

- To ensure a continuous generation of early-stage research knowledge, the above actions will be supplemented by multidisciplinary investigations, gathering expertise at different technology scale (materials, component, cell, stack and system).
- The considered approach will gather the required expertise from European Research and Technology Organisations (RTO).
- The result will lead to a comprehensive strategy investigating new design, characterisation and testing, accelerating the developments in basic low-TRL research and innovation actions.



Clean Hydrogen Partnership

Next steps

Launch of the call + info days

- March 1st 2022: Launch of the call for proposals (indicative)
  - ➢ Around 300m EUR call and 41 topics:
    - ✓ Hydrogen production
    - ✓ Hydrogen distribution
    - ✓ Transport
    - ✓ Heat and Power
    - ✓ Cross-cutting
    - ✓ Overarching
  - ➢ Two cut-off dates: 31st May and 20th September (each half of the topics)
  - ➢ Open to all, some topics will require a member of Hydrogen Europe in the consortium

- March 15th 2022: Info day

Co-funded by the European Union

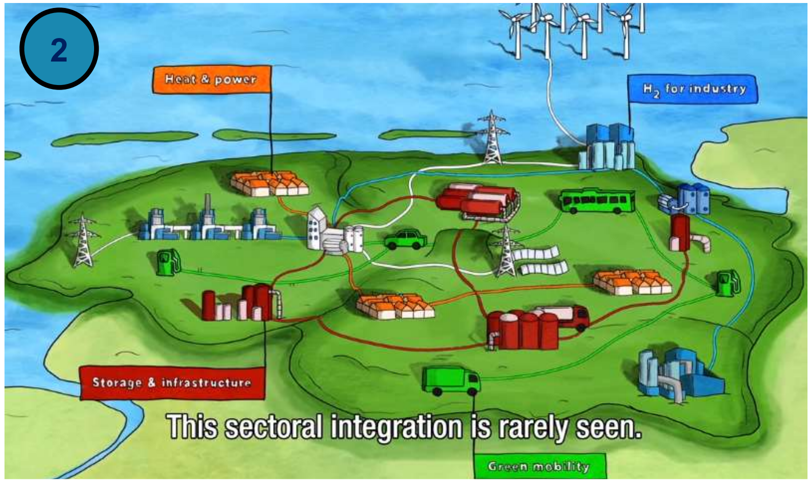
Clean Hydrogen Partnership

Clean Hydrogen Partnership funded Hydrogen Valleys

Three different projects were supported

2015: Orkney's Island (Scotland):

- H2 production by wind on Islands
- Storage & transportation by truck
- Use: heat (school), power (ferries) & mobility (municipality cars)



2019: North Netherlands (Groningen):

HYDROGEN VALLEY

- 31 partners (public + private)
- Electrolysis for green H2 production,
- H2 Mobility: buses, passenger cars and trucks
- H2 Refueling stations
- E-Kerosene for aviation
- H2 for an inland water transport barge
- Domestic Heat applications
- Underground H2 storage (Hystock)

2020: Hydrogen Island (Spain)

- H2 production from solar
- H2 injection in gas-grid
- Use: heat (hotel, municipality buildings), power (port of Palma), mobility (buses)

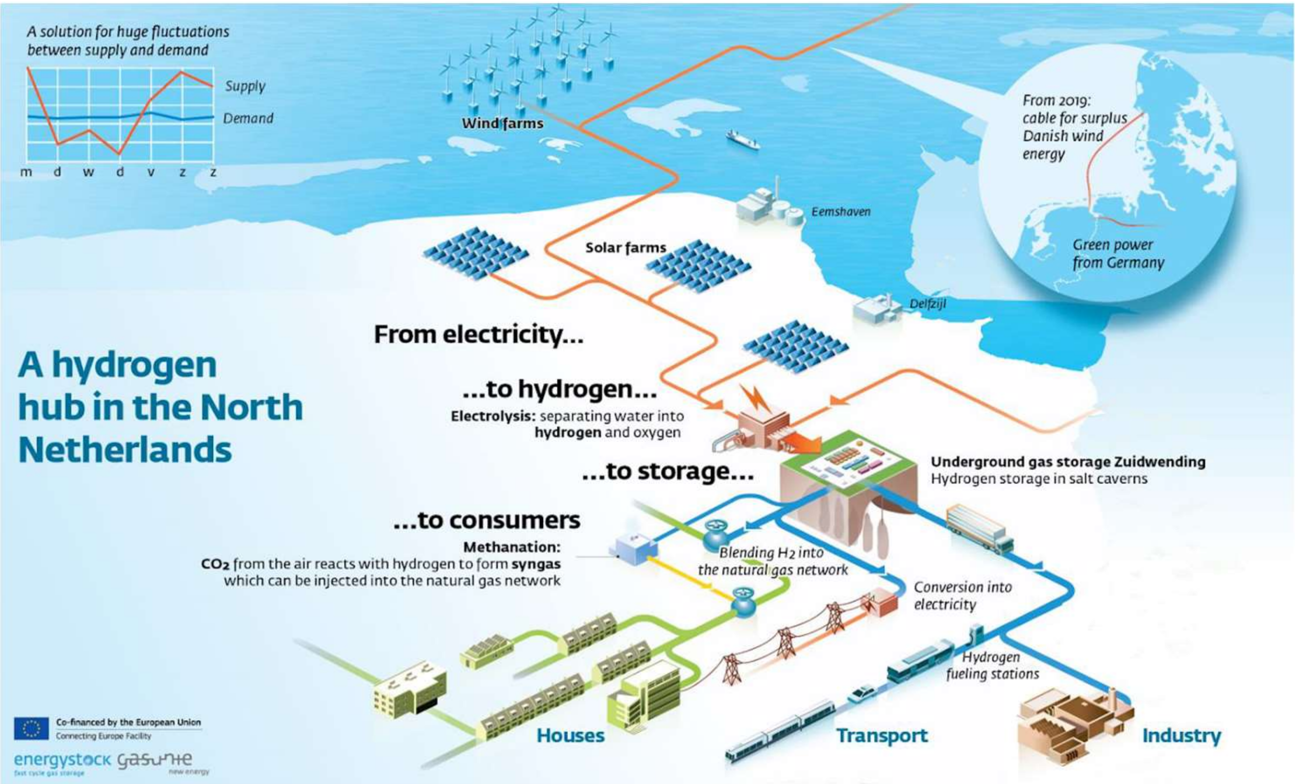
Future Possible (cross-border) H_2 valleys: Ports, Airports, Industrial hubs, Logistical hubs, A H2 city (or area)

Co-funded by the European Union

Clean Hydrogen Partnership

Hydrogen Valleys

HEAVENN project - Hydrogen Energy to decarbonize an entire region in Northern Netherlands

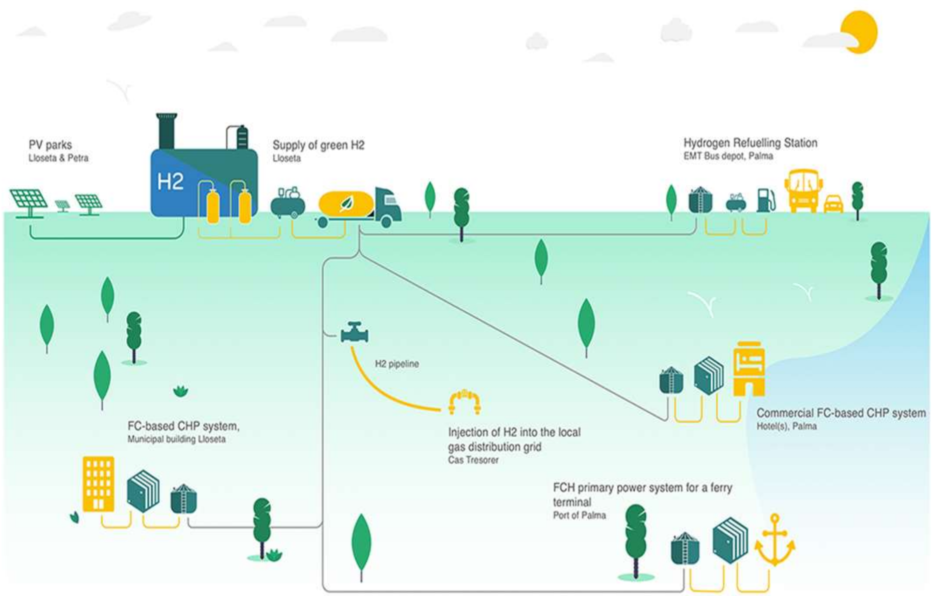


- **Integration of existing & planned project clusters across 6 locations**
- **Integration of RES (onshore and offshore)**
- **Deployment of key transport & distribution gas infrastructure**
- **Deployment of 11 HFC end-user applications across the project**
- **Part of the H2 to be injected up to 3% in NG prior to firing in Gas Turbine**

Clean Hydrogen Partnership

Hydrogen Valleys

GreenHysland H_2 Valley: deployment of a H_2 Ecosystem on the Island of Mallorca



Green Hydrogen production using RES (PV) , 300 tonnesH_2/year

Injection of H2 into the local NG distribution grid

HRS at bus depot in Palma
H2 buses, Light vehicles

Fuel Cells-based (CHP) (municipal building, hotels, port)

2050 roadmap for long-term vision for the development of a H2 economy in Mallorca and the Balearic Region

Replication experiences and business models are foreseen in five other EU island

Clean Hydrogen Partnership

Hydrogen valleys have become a global theme

Integrated projects are emerging all around the world and sharing lessons learned to accelerate the energy transition

A fast-growing landscape of globally leading projects …

Netherlands
- > HEAVENN
- > Hydrogen Delta
- > H2 proposition Zuid-Holland/Rotterdam
- > Port of Amsterdam region

EU IPCEI
- > Blue Danube
- > Black Horse
- > Green Octopus
- > Green Crane
- > New Green Flamingo

Germany
- > H2Rivers/ H2Rhein-Neckar
- > HyBayern
- > Norddeutsches Reallabor
- > eFarm
- > Hyways4 future

China
- > Pearl River Delta (Foshan)
- > Beijing-Zhangjiakou
- > Rugao

Japan
- > FH2R Fukushima

United Kingdom
- > HyNet North West England
- > BIG HIT Orkney Island

Chile
- > Hydrogen Facility Initiative

USA
- > ACES, Utah
- > Port of LA, Shore to Store Project, California

France
- > Zero emission valley Auvergne-Rhône-Alpes
- > Normandy Hydrogen Deployment Plan
- > Hydrogen Territory Bourgogne Franche Comté
- > CEOG, French Guiana

Spain
- > Green Hysland Mallorca
- > Basque Hydrogen Corridor

Denmark
- > HyBalance

Thailand
- > Phi Suea House

Italy
- > South Tyrolean hydrogen valley

Austria
- > WIVA P&G

Australia
- > Neoen Crystal Brook Energy Park
- > Eyre Peninsula Gateway

Oman
- > Green Hydrogen and Chemicals Oman

Countries with hydrogen valleys on the initial platform

Additional countries with major hydrogen valley activity where outreach is ongoing

… featured on the new platform

> 34 valleys from 19 countries

> 3,500 data points

10 in-depth best-practice profiles

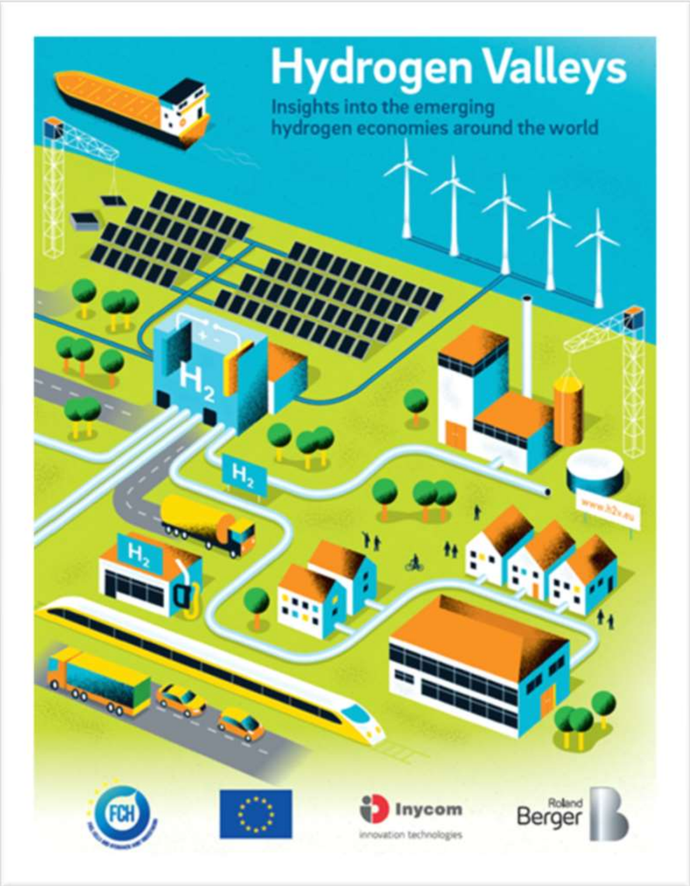
Hydrogen Valleys in Europe

24 Hydrogen valley's identified in 11 European countries

Clean Hydrogen Partnership

Hydrogen Valleys continue under Mission Innovation 2.0

Final report identified key barriers to be tackled under the next Hydrogen Mission



MI 1.0 identified Key Remaining Barriers:

- Obtaining **public funding support** to close funding gaps
- Finding green hydrogen off-takers and signing long-term contracts
- Ensuring FCH applications **Technology readiness**
- Ensuring adequate **legal regulatory support** (carbon pricing, standardization, fast permitting…)

Next steps under MI 2.0:

Further development and enhancement of the MI Hydrogen Valley Platform. Target for 100 Hydrogen Valleys and minimum three in each member country.

Co-funded by the European Union

Clean Hydrogen Partnership

Bart Biebuyck
Executive Director
Bart.Biebuyck@clean-hydrogen.europa.eu
@bart.biebuyck
in Bart Biebuyck

For further information

www.clean-hydrogen.europa.eu
www.hydrogeneurope.eu
www.hydrogeneurope.eu/research

in Clean Hydrogen Partnership @CleanHydrogenEU

Co-funded by the European Union