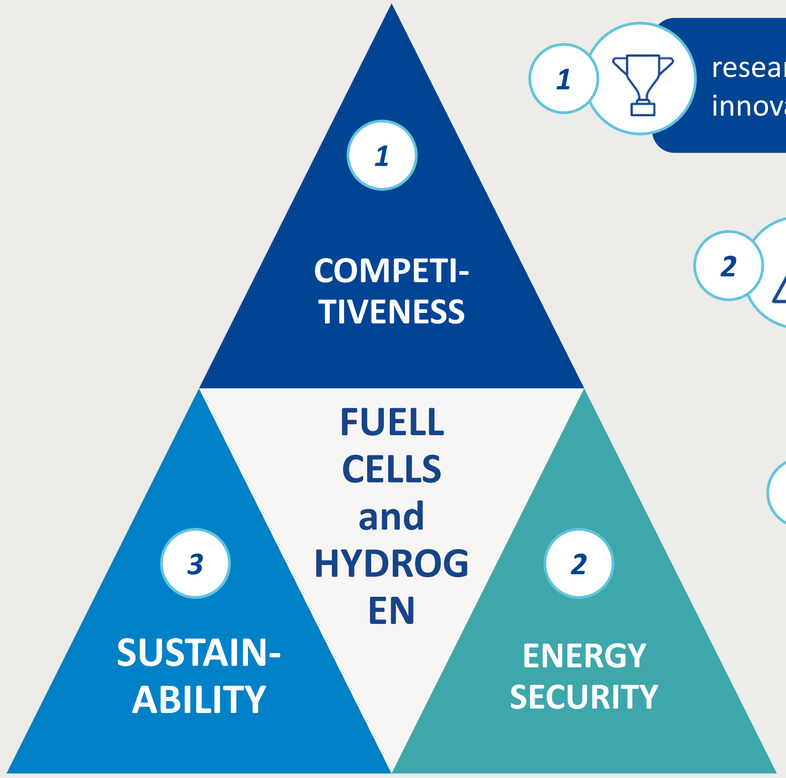
FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

FCH-JU: European Hydrogen ambitions

Bart Biebuyck

14 / 11 /2019 Den Bosch

Fuel Cells & Hydrogen technologies in the context of the European Energy policy

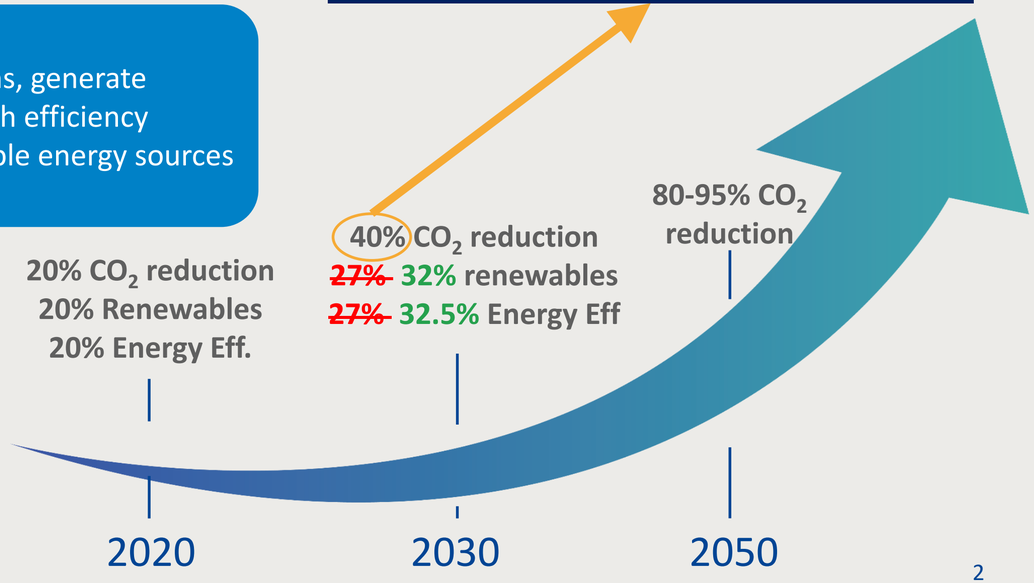


1 research excellence leading to industry innovation and growth

2 Increase independence from unstable outside regions

3
- H2 is a clean energy carrier
- Transport and Energy applications, generate electricity and heat with very high efficiency
- Possibility for storage of renewable energy sources
- Reduction of CO2 emissions

50-55% CO_2 reduction for discussion "The new green deal"



Strong public-private partnership with a focused objective

A combined private-public of 1.85 billion Euro has been invested to bring products to market readiness by 2020

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Hydrogen Europe

Industry grouping
>150 members
50% SME

European Commission

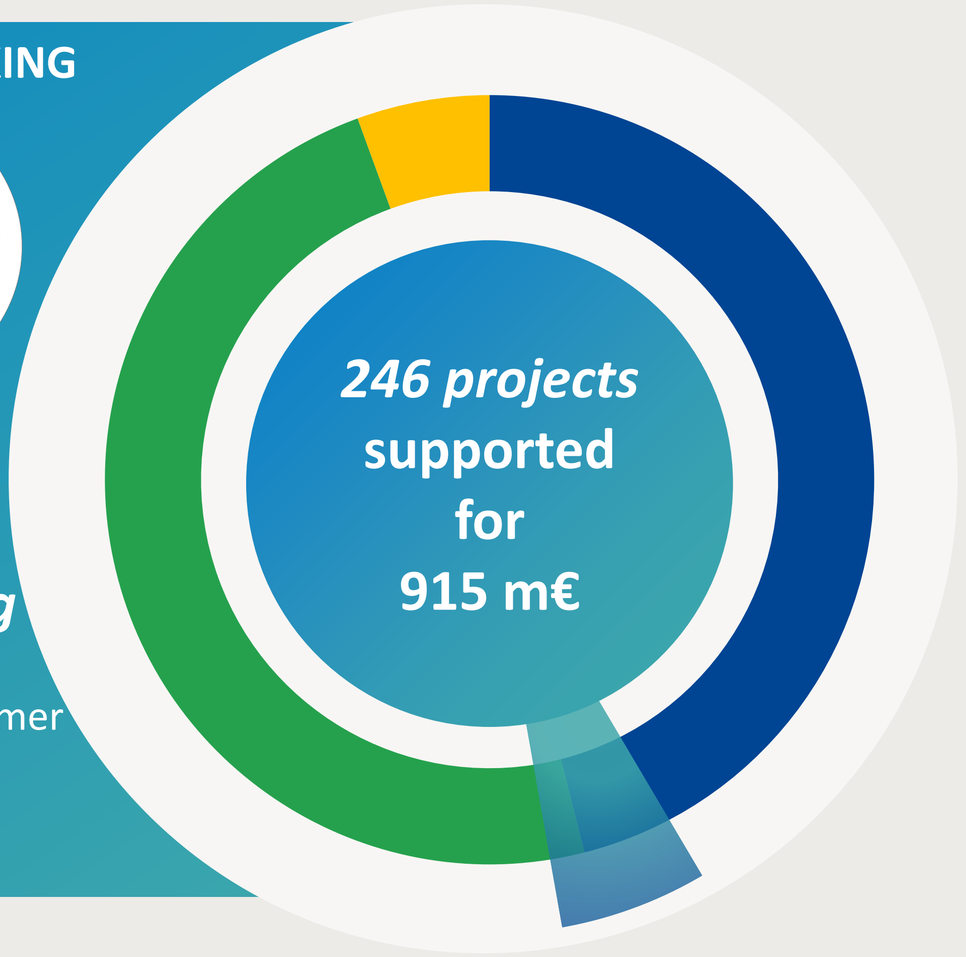
Hydrogen Europe Research

Research grouping
73 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, …



47 %

428 million euros
136 projects

42 %

388 million euros
66 projects

6 %

53 million euros
40 projects

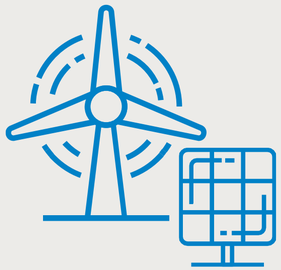
5 %

46 million euros
4 projects

Similar leverage of other sources of funding: 935 m€

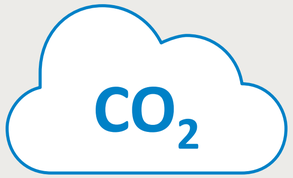
Besides CO_2 abatement, deployment of the hydrogen roadmap also cuts local emissions, creates new markets and secures sustainable employment in EU

2050 hydrogen vision



~24%

of final energy demand[1]



~560 Mt

annual CO_2 abatement[2]

~EUR 820bn

annual revenue (hydrogen and equipment)

~15%

reduction of local emissions (NO_x) relative to road transport

~5.4m

jobs (hydrogen, equipment, supplier industries)[3]

1 Including feedstock 2 Compared to the reference technology scenario 3 Excluding indirect effects

SOURCE: Hydrogen Roadmap Europe team

Strong EU presence in international cooperation's around Hydrogen

In the past year many high level international cooperation agreements have been signed where the EU is part of

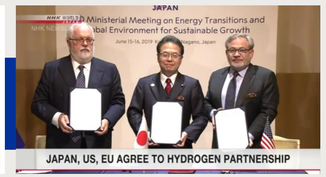
IPHE – International Partnership for Hydrogen and Fuel Cells in the economy
19 member countries; meeting 2 times / year
Objective: to facilitate and accelerate the transition to clean and efficient energy and mobility systems using Hydrogen and fuel cell technologies across applications and sectors

MISSION - INNOVATION – Innovative Challenges 8 « Renewable and Clean Hydrogen Challenge"
May 23-24, 2018, Malmö, Sweden
Objective: To accelerate the development of a global hydrogen market by identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale

Informal EU energy ministerial – The Hydrogen Initiative (signed by 28 countries)
Sept. 17-18, 2018, Linz, Austria
Objective: the signatory states commit themselves to continue research and investment in the production and use of hydrogen as a future-oriented technology

HEM - Hydrogen Energy Ministerial Meeting 2019
1st one held Oct. 23, 2018; 2nd one on Sept. 25, 2019, Tokyo, Japan
Objective: Follow up "Tokyo Statement" to realize it and set "Global Hydrogen Target" to share global goal.

CEM -New Hydrogen Initiative
May 27-29, 2019, Vancouver, Canada
Objective: Advance policies, programs and projects to accelerate commercial scale deployment of hydrogen and fuel cell technologies across all sectors of the economy



G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth
June 15-16, 2019, Karuizawa, Japan
The importance of hydrogen mentioned for 1st time in the G20 Ministerial Communique and IEA released their H2 report.
=> Japan, US and EU agree to a hydrogen partnership

BENELUX-On the road to deployment

BELGIUM

40 Belgian beneficiaries Participating in **56** projects FCH JU contribution
35 Mil € (3.8% of total FCH JU funding)

National Policy Framework:
Target to reach **22** Public H2 refuelling stations by 2020

NEW:
Flemish Government expressed the ambition to have European leadership in hydrogen technology.

Planned
- **60** planned FC cars
- 2 planned HRS
- 2 planned FC garbage trucks
- 4 planned m-CHP

Petten:
24 kW UPS system (FITUP)

Antwerp:
- 5 deployed buses
- 1 deployed HRS (High V.LO.City)

Brussels:
- 2 deployed cars (SWARM)
- 1 deployed HRS

Halle:
- 2 deployed MHVs (Hylift-DEMO)
- 1 deployed HRS
- 2 deployed Electrolysers (Don Quichote)

Rotterdam:
- 2 buses active (3EMOTION)

Groningen:
- 2 buses active (High V.LO.city)
- 1 HRS active (High V.LO.city)

Various locations:
501 m-CHP installations (ene.field & PACE)

LUXEMBOURG

1 beneficiary Participating in **1** project FCH JU contribution
0.5 Mil €

- *1 planned HRS**

THE NETHERLANDS

52 beneficiaries Participating in **74** projects FCH JU contribution
55 Mil € (**6** % of total FCH JU funding)

National Policy Framework:
Target to reach **20** Public H2 refuelling stations by 2020

Planned
- **3** planned HRS (H2ME 2, JIVE 2)
- **2** planned buses (3EMOTION)
- **19** FC cars
- **50** FC buses (JIVE2)
- 11 FC garbage trucks
- **1** planned Electrolyser

** Not directly related to FCH JU activities*

Towards a H_2 Valley

Orkney Islands: Europe's first Hydrogen territory

Blueprint for other territories which consider hydrogen to decarbonise

BIG HIT

A hydrogen territory in Scotland: hydrogen production, storage, transportation and utilization for heat, power and mobility.

2016-2021

FCH Funding: ~5M€

HySeas III: the world's first zero emission, sea-going ferry. Demonstrate a circular economy model for the local production of H2 fuel

2017-2021

H2020 Funding: ~9.3M€

FINANCIAL TIMES

US COMPANIES MARKETS OPINION WORK & CAREERS LIFE & ARTS

Ideas to Change the World

Renewable Energy + Add to myFT

Orkney project shows potential of hydrogen as a fuel source

The gas may be best option for heavy transport such as trucks, ships and trains

Scotrenewables' prototype tidal energy converter - the SR2000 was used for the conversion of tidal energy to hydrogen gas © Scotrenewables

H_2 Valley Support for 20 Million Euro (Call Jan. 2019)

6 proposals received and 1 selected to start the grant preparation

HEAVENN KEY FACTS:

- North Netherlands (Gronningen / Delfzijl / Emmen)
- Total project circa 90 million Euro
- 31 partners (public + private)
- Project supported by 65 parties (Nat. + Int.)
- 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)

https://www.youtube.com/watch?v=L27dkYyg04g

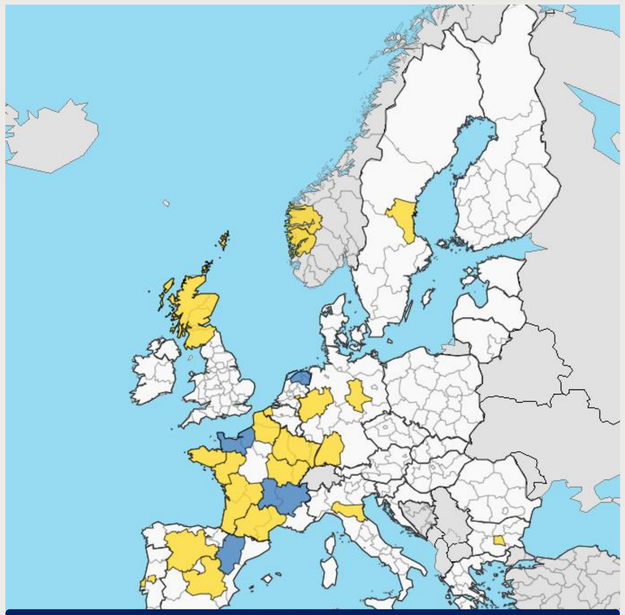
Hydrogen Valleys Partnership (European + Worldwide)

Established under the EC smart specialization platform for Industrial Modernization

European Hydrogen Valleys Partnership launched May ‘19 at EVS 32 in Lyon

EUROPEAN HYDROGEN VALLEYS PARTNERSHIP

http://s3platform.jrc.ec.europa.eu/hydrogen-valleys



Partnership led by:

- North of Netherlands (NL)
- Auvergne-Rhône Alpes (FR)
- Le Normandy (FR)
- Aragon (ES)

Around 40 regions joined and more will follow.

Tender: Platform for Exchanges Between Worldwide Initiatives on Hydrogen Valleys:

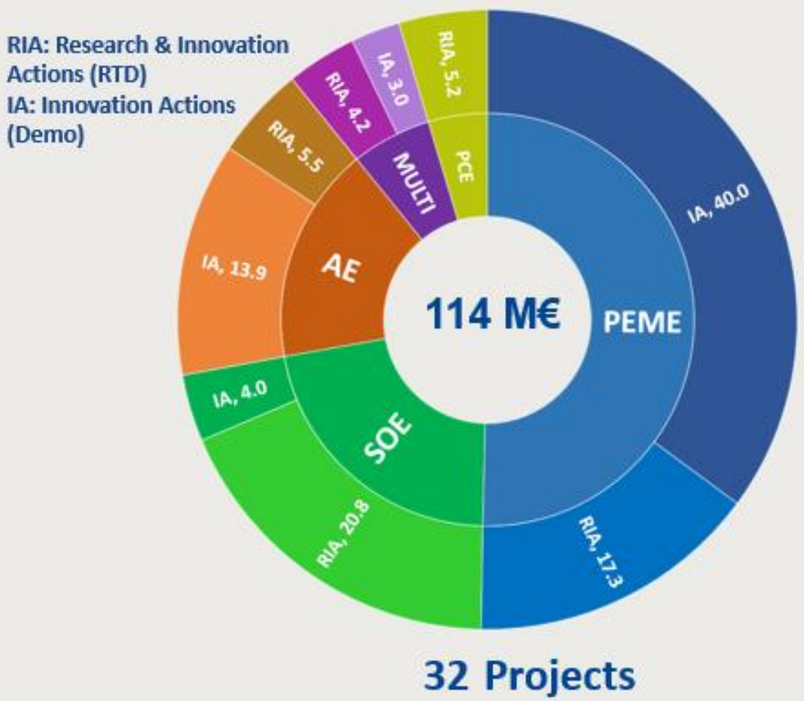
To set-up a global Information Sharing Platform within MI-IC8, to facilitate the emergence and implementation of large-scale hydrogen projects and leveraging the knowledge where IPR issues are less sensitive.

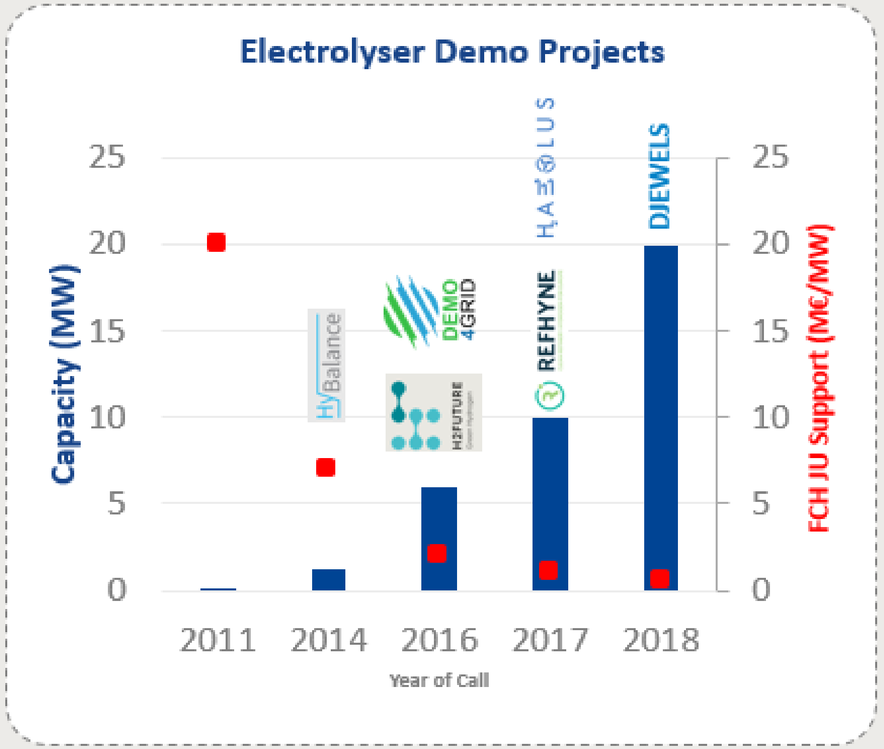
STATUS: Consultant is selected and informed

Green H_2 production and industry

Electrolysis demonstrations for energy storage and greening of Industry

Continues support to develop higher capacity electrolysers led to cost reduction and increased interest by industry





https://www.h2future-project.eu/

https://www.refhyne.eu/

HRS

Steel industry

Refineries

Food industry

Developing an EU wide Guarantees of Origin Scheme for Hydrogen

Two definitions: one for Green and one for Low-Carbon Hydrogen – more than 70,000 GOs issued already

Four production plants included in the pilot scheme which have been already audited

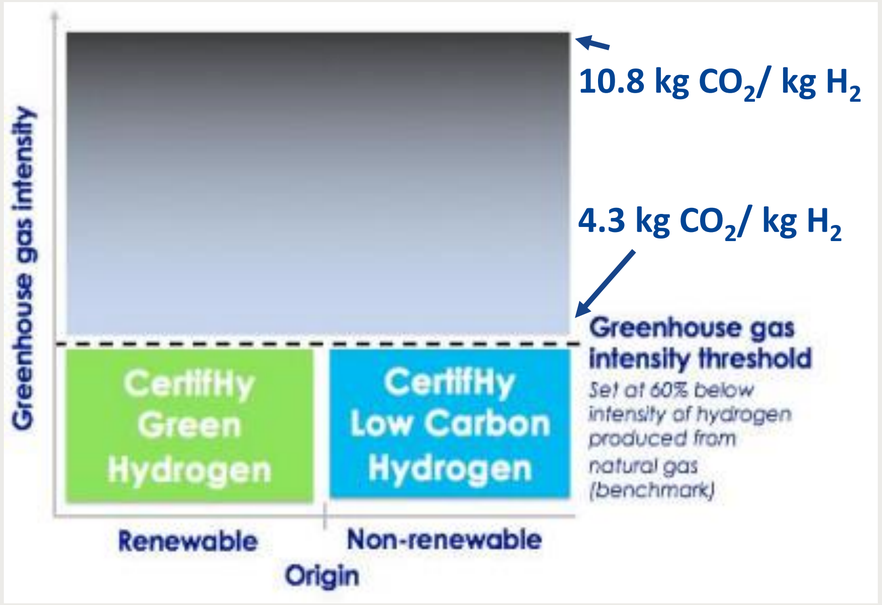
Air Liquide, Port Jerome (SMR +CCS)

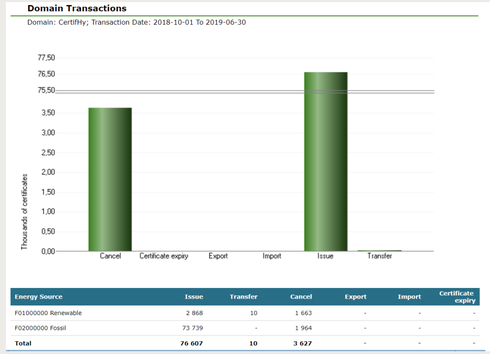
Colruyt Group, Halle (Electrolysis +RE)

Air Products, Rotterdam (by product H2 from Chlor-alkali process)

Uniper, Flakenhagen (Electrolysis + RE and methanation

Two labels are defined for hydrogen





Energy Source	Issue	Transfer	Cancel	Export	Import	Certificate expiry
F01000000 Renewable	2 868	10	1 663	-	-	-
F02000000 Fossil	73 739	-	1 964	-	-	-
Total	**76 607**	**10**	**3 627**	-	-	-

Name	GSRN	Installed Capacity (MW) (MW)	Commissioning Date	Domain	Fuel	Technology
Eoly H2 Production Plant	643002406971000037	8,50	2017-10-23	CertifHy	F01000000 - Renewable	W010101 - Hydrogen/Water electrolysis/Low temperature/Main-product
MEB Rotterdam	643002406971000068	2 000,00	1983-01-01	CertifHy	F01000000 - Renewable	W020001 - Hydrogen/Chlor-alkali electrolysis/By-product
Port Jerome	643002406971000051	4 200,00	2007-07-01	CertifHy	F02000000 - Fossil, F01000000 - Renewable	W030201 - Hydrogen/Steam methane reforming/With CCS or CCU/Main-product
WindGas Falkenhagen	643002406971000044	32,13	2013-08-01	CertifHy	F01000000 - Renewable	W010101 - Hydrogen/Water electrolysis/Low temperature/Main-product

https://cmo.grexel.com/Lists/PublicPages/Statistics.aspx

Next:

Expanding the GO scheme to all Member States and establish one central GO scheme.

It would be important for many countries to join this platform

TRANSPORT

Simultaneously roll-out of vehicles and infrastructure in Europe

Europe supports FC vehicles and Hydrogen Refuelling Stations thanks to EU programs (FCH-JU & CEF) & national programs.

Fuel Cell vehicles

~2020

- ’13 Hyundai IX35
- ’15 Renault Hykangoo
- ’15 Toyota Mirai
- ’16 Honda Clarity
- ’18 Mercedes GLC
- ’18 Hyundai NEXO

~2025

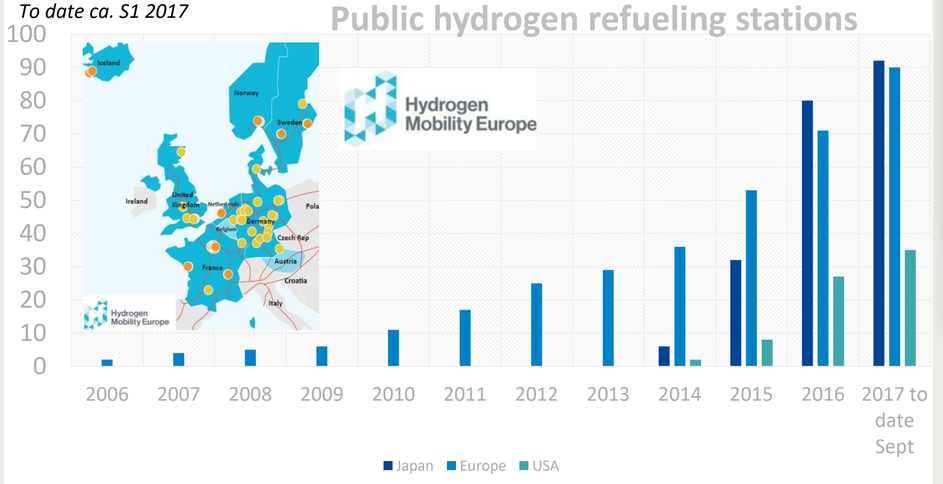
- AUDI model
- BMW X5 Small series
- PSA Expert & Jumpy
- Opel Zafira Life
- New Toyota Mirai
- Lexus model
- New Honda Clarity

	S1 ‘19	2020	2022	2025	2030
Europe	1731	-	-	(0.9 -1 mill)*	1.2 million **
China	112	5000	-	50.000	1 million
Japan	3219	40.000	-	200.000	800.000
USA	7450	-	-	-	-
S-Korea	2353	-	67.000	-	-

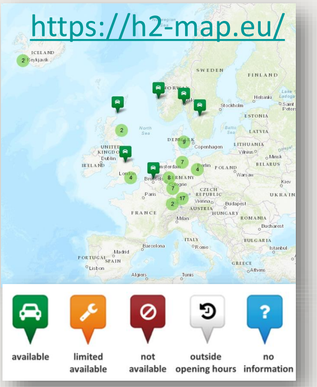
- <u>EU OEM’s:</u> small demo’s ~2025, mass production 2025~
- FIA: In 2024 a H_2 class @ Le Mans
- California & Japan sales higher due to strong policy support

Hydrogen Refuelling Stations

Source: FCH JU KM data collection file, 20/09/2017, public stations
USA-DoE & CaFCP, Japan-HySUT
To date ca. S1 2017



https://h2-map.eu/



“H2 live” App

H2 mobility Deutschland

	S1 ‘19	2020	2022	2025	2030
Europe	134	-	-	(820~842)*	3750 **
China	12	100	-	350	1000
Japan	108	160	-	320	(900)
USA	41	100	-	200~225	-
S-Korea	27	-	310	-	-

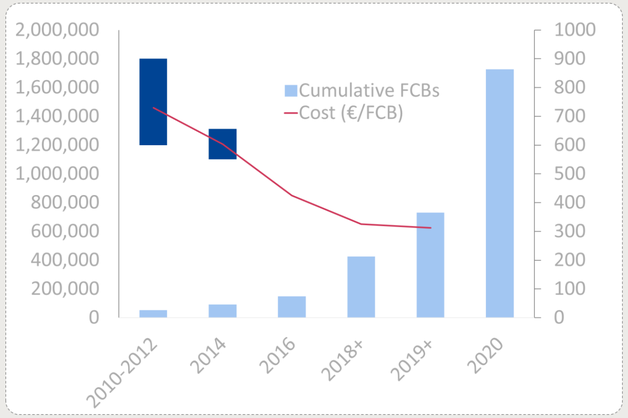
* According to the action plan of Alternative Fuel Directive
** McKinsey study H2: Europe roadmap (ambitious scenario).

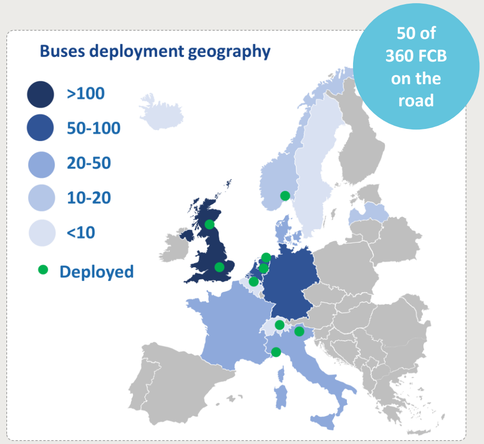
Japan: Air Liquide opens a hydrogen station in Shichinomiya, Kobe

Nel ASA: Awarded frame contract for multiple hydrogen fueling stations in California by Royal Dutch Shell Plc

Roll-out of FC buses accelerates and become commercial

EU is supporting totally 360 Hydrogen buses deployment that lead to a price reduction of 66% vs 2010 and a new initiative of 1000 buses in EU create scale and get cheaper than other zero-emission buses.





Van Hool hydrogen bus for PAU crowned as best bus of the world 2019!

10 European OEM's are developing H_2 buses: www.fuelcellbuses.eu

Single Deck - 12 m
Price < €375k
Range >450 km* Extended >675 km*
*Dependent on duty cycle calculated at 10°C

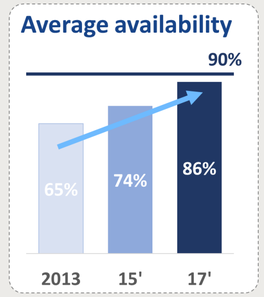
Double Deck - 10.9 m
Price < €410k
Range >310 km* Extended >420 km*
*Dependent on duty cycle calculated at 10°C

Articulated - 18 m
Price < €465k
Range >520 km* Extended >750 km*
*Dependent on duty cycle calculated at 10°C

Everfuel, Wrightbus, Ballard Power Systems, Hexagon Composites, Nel Hydrogen and Ryse Hydrogen, leading players in the hydrogen fuel cell electric value chain, are joining forces to form the H2Bus Consortium. The members are committed to deploying 1,000 hydrogen fuel cell electric buses, along with supporting infrastructure, in European cities at commercially competitive rates.

88%
green hydrogen

Achieved
- **> 6,000,000 km driven since projects started**
- **> 92 t of H_2 consumed only in 2017**
- **> 25,000 h lifetime reached**
- **625,000 €/bus offered**
- From order to operation, 18m delivery time



First H2 trucks appearing on the EU roads and more are to come

Worldwide there is a clear traction towards Hydrogen for trucks due to the limited range of batteries.

FCH-JU H2ME project Batt+RE

REVIVE: H2 Garbage Trucks in 8 EU cities

H2HAUL: 15 Heavy Duty trucks in 4 countries

CNH Industrial takes $250 million lead in Nikola's Series D round

Fuel cell startup gets access to Iveco European network and purchasing might

Alan Adler · 2 days ago · 0 · 325 · 2 minutes read

ESORO COOP

ASKO-SCANIA

VDL - COLRUYT

FCH-JU started with Fuel Cells in trucks for APU's but was found to expensive, therefor focus shifted to developing and testing trucks with range-extenders or fuel cell only e.g.: garbage trucks in mayor cities.

Hyundai signs deal to sell ~~1,000~~ 1600 hydrogen-powered trucks in Switzerland

Hyunjoo Jin — 3 MIN READ

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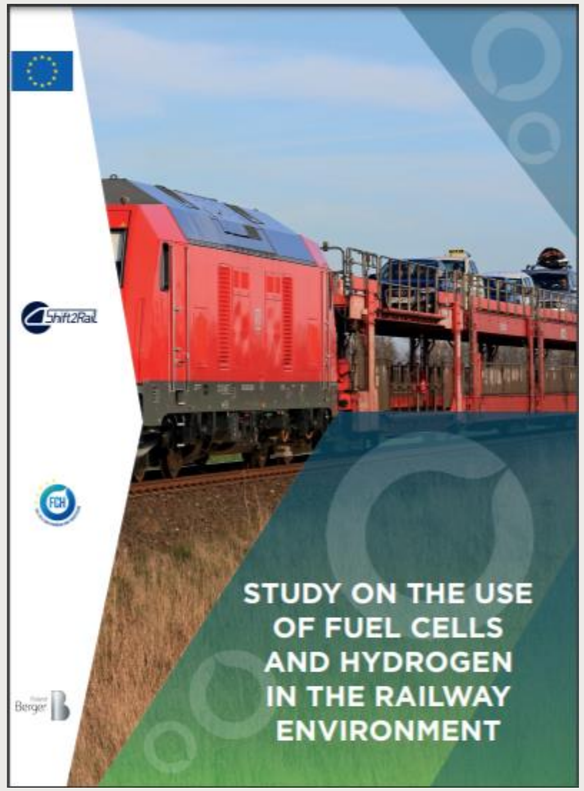
Norway aims for 1000 hydrogen trucks by 2023

September 19, 2018

Rail accelerates Hydrogen and Fuel Cells technology

The first business models are appearing

- 42% of EU railway not electrified
- 17 Sept. ’18 commercial operation starts in Germany. Other EU countries are on the way. Recently a big order of 27 H_2 trains placed in Germany.



- FCH trains make economic sense above all on longer non-electrified routes >100 km
- FCH trains esp. for last mile delivery & main routes with very low utilisation (<10 trains/day)
- Low electricity costs (<EUR 50 /MWh) & high infra utilisation (HRS…) favour FCH technology;
- FCH trains has downtimes <20 minutes (due to fast refuelling) and withstand long operating hours >18 hours w/o refuelling;
- FCH trains are economically feasible clean alternative to diesel trains in many cases;
- In some cases, battery trains may appear as more cost-effective option but come with operational constraints resulting from highly route-specific tailored battery configurations.

https://fch.europa.eu/publications/use-fuel-cells-and-hydrogen-railway-environment

Maritime discovering Hydrogen and Fuel Cells

To accelerate the decarbonisation of Maritime, regulation for hydrogen need to be prepared

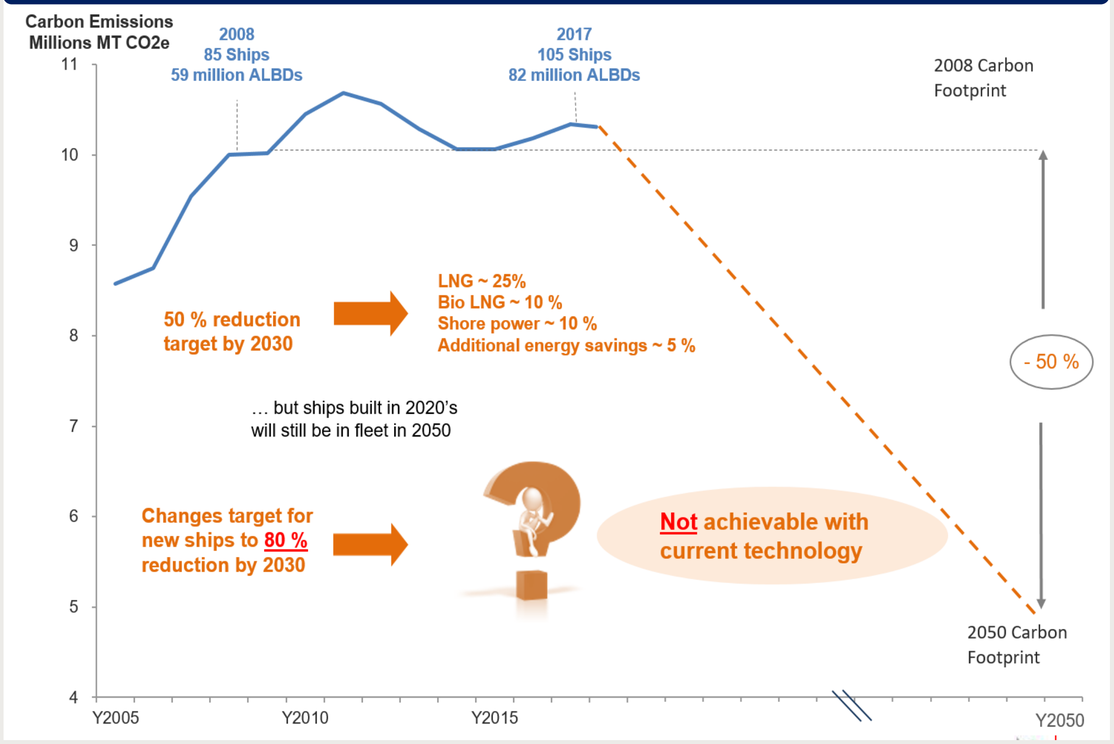
International Maritime Regulations

Class Rules

International Standards

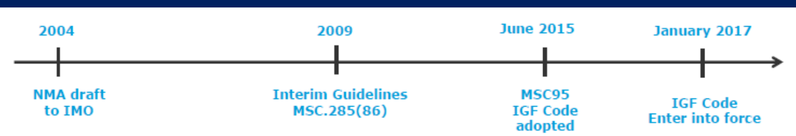
National Regulations

- IMO April 2018: “at least 50% of CO_2 reduction by 2050”



Reduction in emissions by fuel conversion (Petroleum oils → Natural gases)

NOx	SOx, PM	GHG
80%～90% reduction	Zero emission	20%～25% reduction



IMO targets are not achievable with current technologies, converting the entire fleet to LNG will not be sufficient. Urgent need to regulate H2 for ships

PURE aims at developing auxiliary power units (APUs) for recreational yachts

DURATION: 2013-2016
FCH JU Funding: ~1.6M€

MARANDA: H2 PEMFC based hybrid powertrain for marine applications, validated on board the research vessel Aranda

DURATION: 2017-2021
FCH JU Funding: ~3M€

Passenger & car ferry
- Stavanger area Norway
- 600 kW FC power

Pusher
- Lyon, France
- 400 kW FC power

FLAGSHIPS:
will deploy 2 commercially operated 0-emission hydrogen vessels in France and Norway

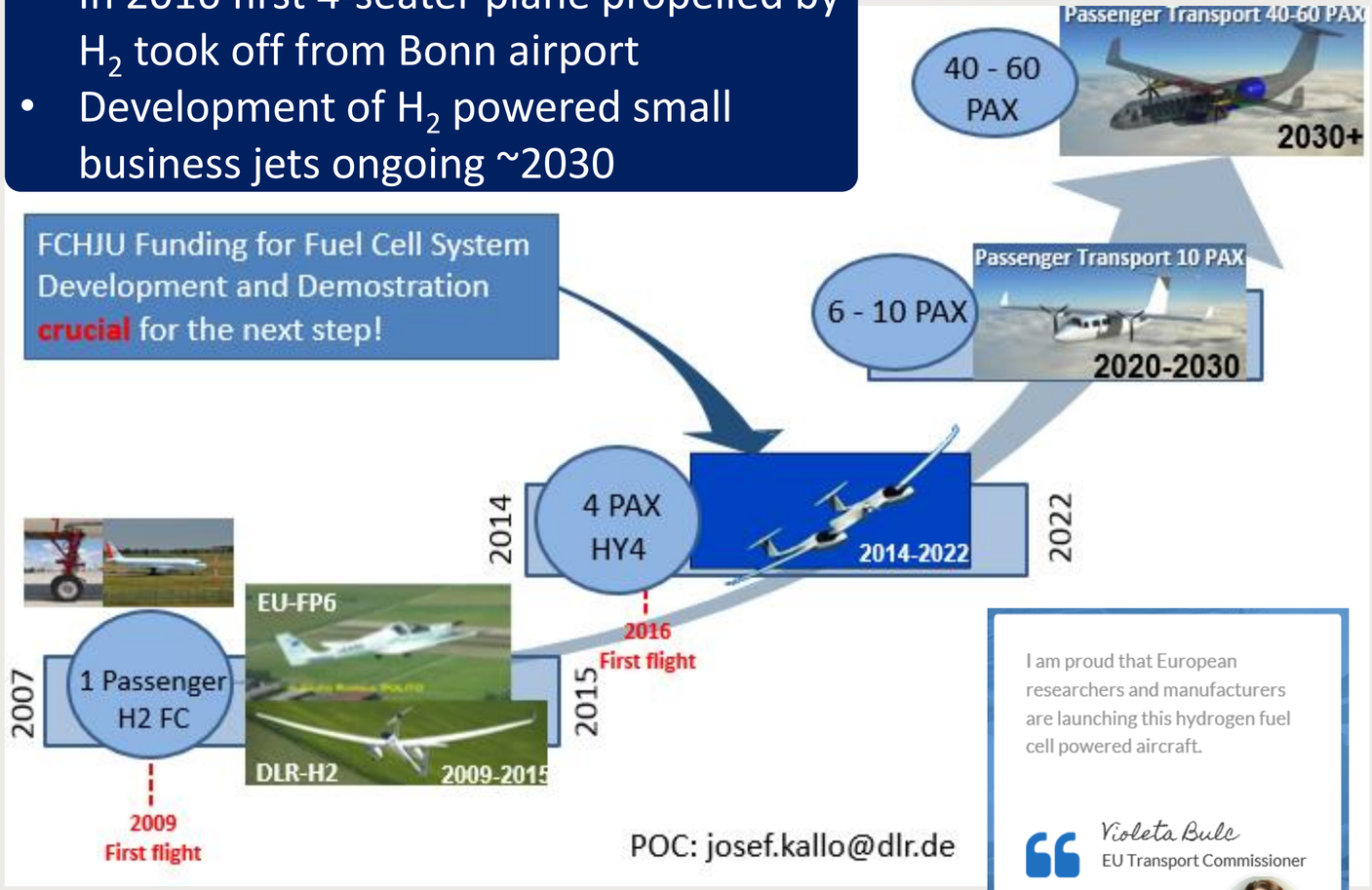
DURATION: 2019-2022
FCH JU Funding: ~5M€

- Joined R&D in the area’s of LH_2 storage (bunkering), MW scale Fuel Cells, carriers,…

Aviation sees a future in Hydrogen for small planes

Hydrogen in the aviation sector causes much less noise and no pollution.

- In 2016 first 4-seater plane propelled by H_2 took off from Bonn airport
- Development of H_2 powered small business jets ongoing ~2030



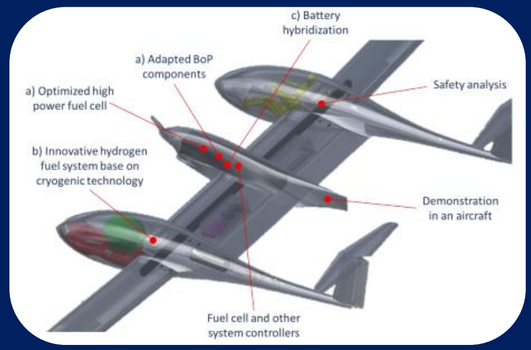
I am proud that European researchers and manufacturers are launching this hydrogen fuel cell powered aircraft.

Violeta Bulc
EU Transport Commissioner

- HYCARUS (5.2 **M€)** where the kitchenette runs entirely on Hydrogen and Fuel Cells

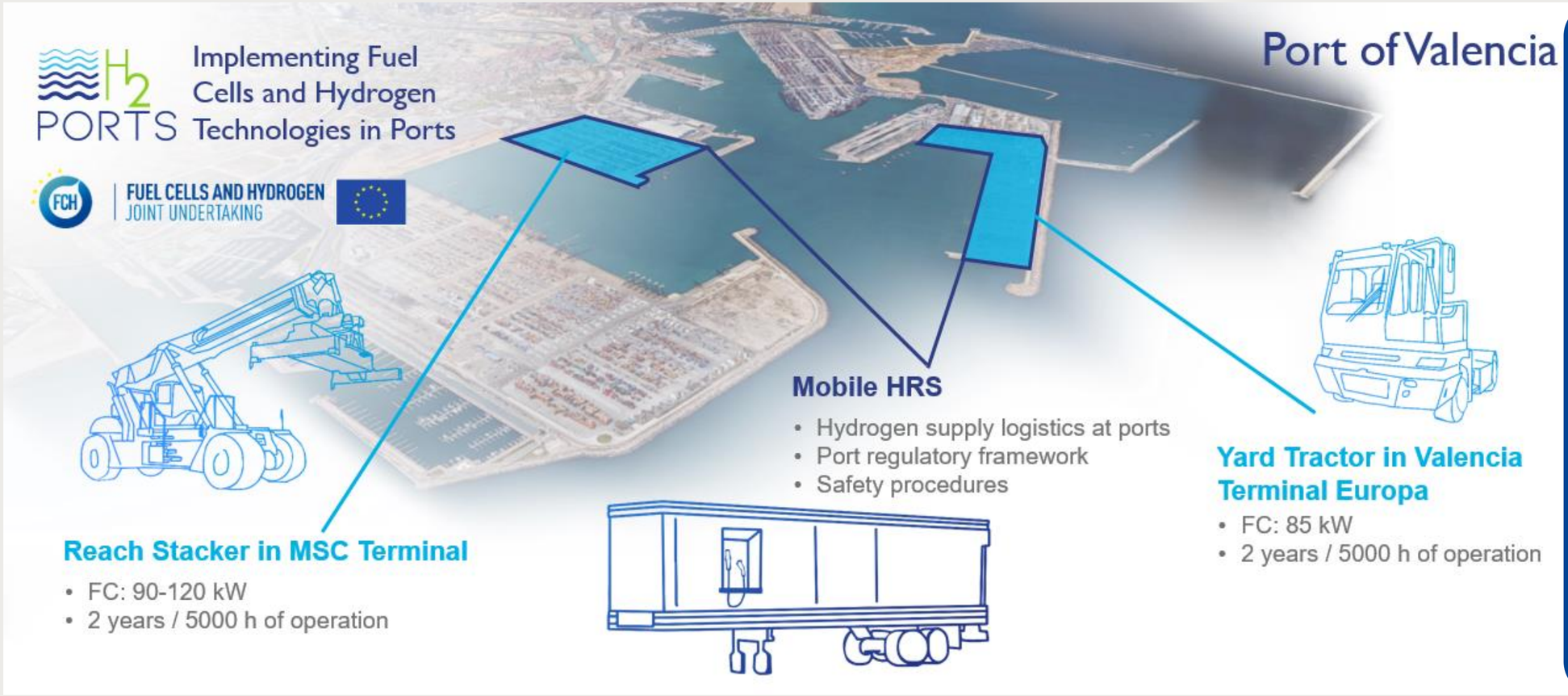
HEAVEN (4 **M€)**
- Modular architecture of a 90 kW fuel cell based on two 45 kW FC stacks fit for aeronautic use

- Cryogenic H_2 storage with 10% weight efficiency



H2Ports project aims to implement Fuel Cells and Hydrogen in Ports

First application of hydrogen technologies in port handling equipment in Europe



H2PORTS project in the port of Valencia

- Reach stackers and yard tractors will be demonstrated in the port
- A mobile hydrogen refueling station will be operated inside the port

DURATION:
2019-2022; project 4.1 M€ (4 M€ by FCH-JU)

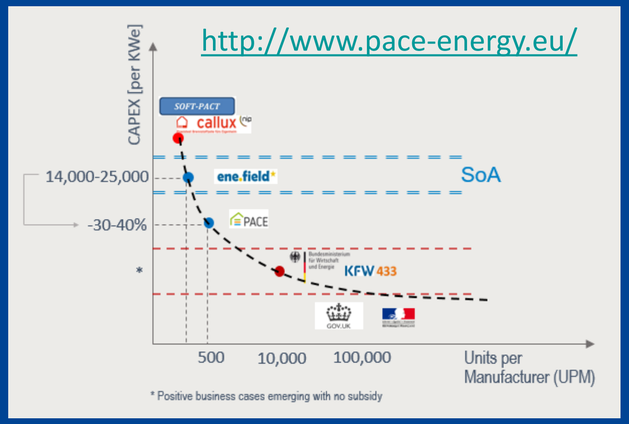
Next: to build a worldwide hydrogen ports coalition

Heating and Cooling

Over 1000 fuel cell µCHP systems installed across EU

Track record of domestic heat and power systems created

0.5~1.5 kW



1046 units deployed in various European countries

- >1 MWe capacity installed; >5 million operating hrs.
- Cost reduced drastically through various projects
- National authorities start own subsidy scheme (e.g. >1,000 units deployed by a German scheme)

DURATION: 2016-2021 with FCH JU Funding: ~34M€

50~200 kW

175kW SOFC in waste water treatment plant, Turin Italy

Area will guarantee the supply of around 30% of the site electrical consumption, and almost 100% of the thermal requirement.

DURATION: 2015-2020 with FCH JU Funding: ~4.5M€

1 ~ 2 MW

2MW plant at Ynnovate, Yingkou (province Liaoning), China

Design, build and operate a 2 MW power generator, with full integration of heat and power with an existing chlorine production plant. Fully automated way of operation + remote control

DURATION: 2015-2018 with FCH JU Funding: ~5.5M€

SAFETY, STANDARDS, EDUCATION…

Preparing the European workforce

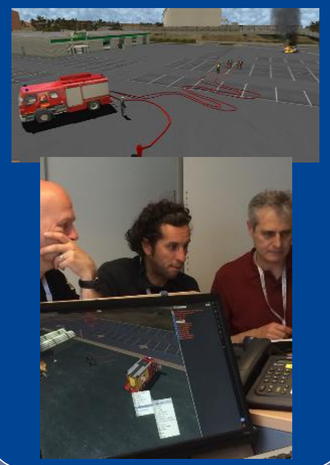
Projects running include training packs in different languages, formats, means, etc.

European hydrogen emergency response training program for first responders
Follow-up project to start in Jan ’20

HyResponse A comprehensive training program

Educational

Virtual reality



Operational

in person training, e-learning, blended learning…virtual reality, serious games…
…mock-up installations…

TeacHy

undergraduate & graduate education PhD BEng/BSc MEng/MSc

KnowHy

Courses for professionals/ general public

FCHgo!

https://fchgo.eu/

European Hydrogen Safety Panel (EHSP) initiative

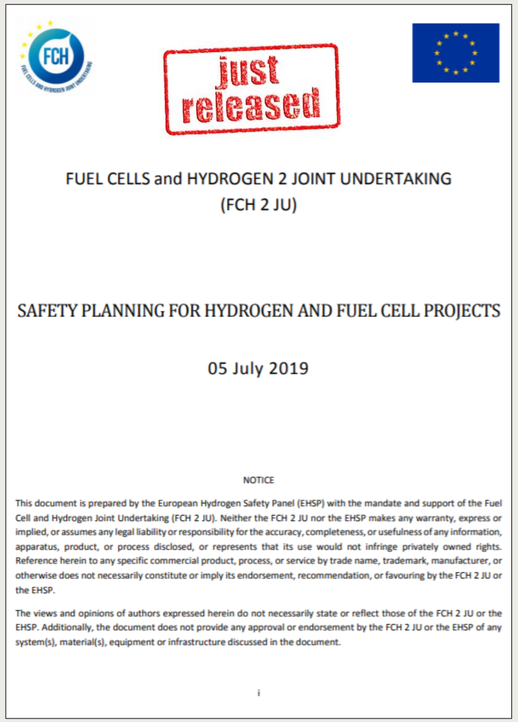
Expert group on hydrogen safety assisting the FCH 2 JU at project and programme level

EHSP Launched and running!

17 experts from industry & research

Assuring that H2 safety is adequately handled
Promoting and disseminating H2 safety culture

The EHSP released the first 2 reports on:
- Safety planning in FCH projects
- Lessons learnt from HIAD


just released

FUEL CELLS and HYDROGEN 2 JOINT UNDERTAKING
(FCH 2 JU)

SAFETY PLANNING FOR HYDROGEN AND FUEL CELL PROJECTS

05 July 2019

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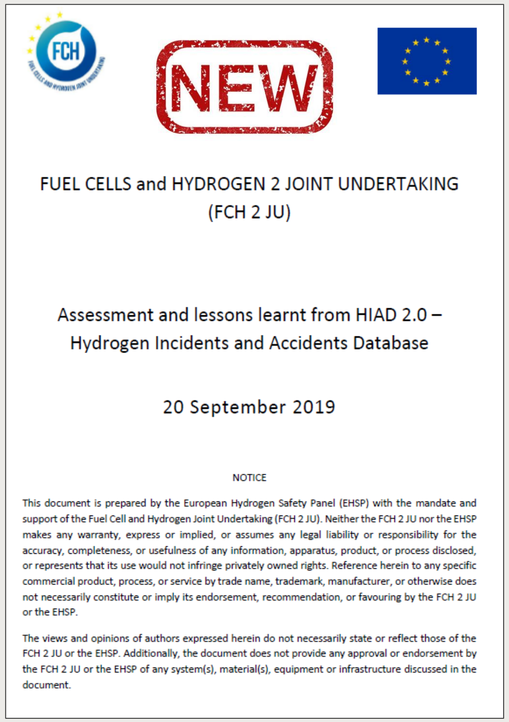
NEW

FUEL CELLS and HYDROGEN 2 JOINT UNDERTAKING
(FCH 2 JU)

Assessment and lessons learnt from HIAD 2.0 –
Hydrogen Incidents and Accidents Database

20 September 2019

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Everyone is welcome to cooperate with the European Hydrogen Safety Panel !!!

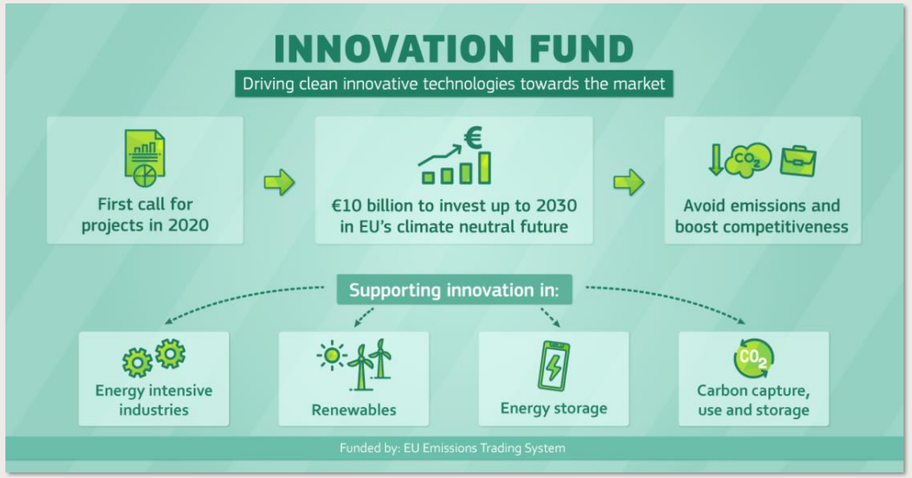
Future European Funding opportunities for hydrogen

Depending on the project seize and goal, the right funding instrument should be chosen, FCH can help you

New partnership: CLEAN HYDROGEN EUROPE

- **Channel cross-sectoral collaboration**
- **Involve more energy companies**
- **Include waterborne and rail transport industry**
- **The industrial sectors** (chemical, steel, refineries, etc.)
- **Include civil society and NGOs.**

Start in Jan 2021 with industry request a doubling of the budget



Industry expressed huge interest for an IPCEI on hydrogen

Including companies from the Benelux had proposed a common project called “Green Octopus”

Very Significant KPIs

11 projects presented

- 65 billion € total investment
- 35 Mio tons of CO_2 savings per year
- 30 GW of Renewable Energy capacity
- 120.000 Hydrogen powered vehicles
- 1300 Hydrogen refueling stations
- 22 Member states covered

Next: April 2020: Official request

Oct. 2020: IPCEI approval

NEXT

Yearly program review days and stakeholder forum

Program Review days
19 & 20 Nov. 2019

Stakeholder Forum
21 Nov 2019

Charlemagne building Brussels, Belgium

Registrations are open

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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