



FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

***Competitiveness,
Sustainability and
Energy security;
FCH in the context of
EU energy policy***

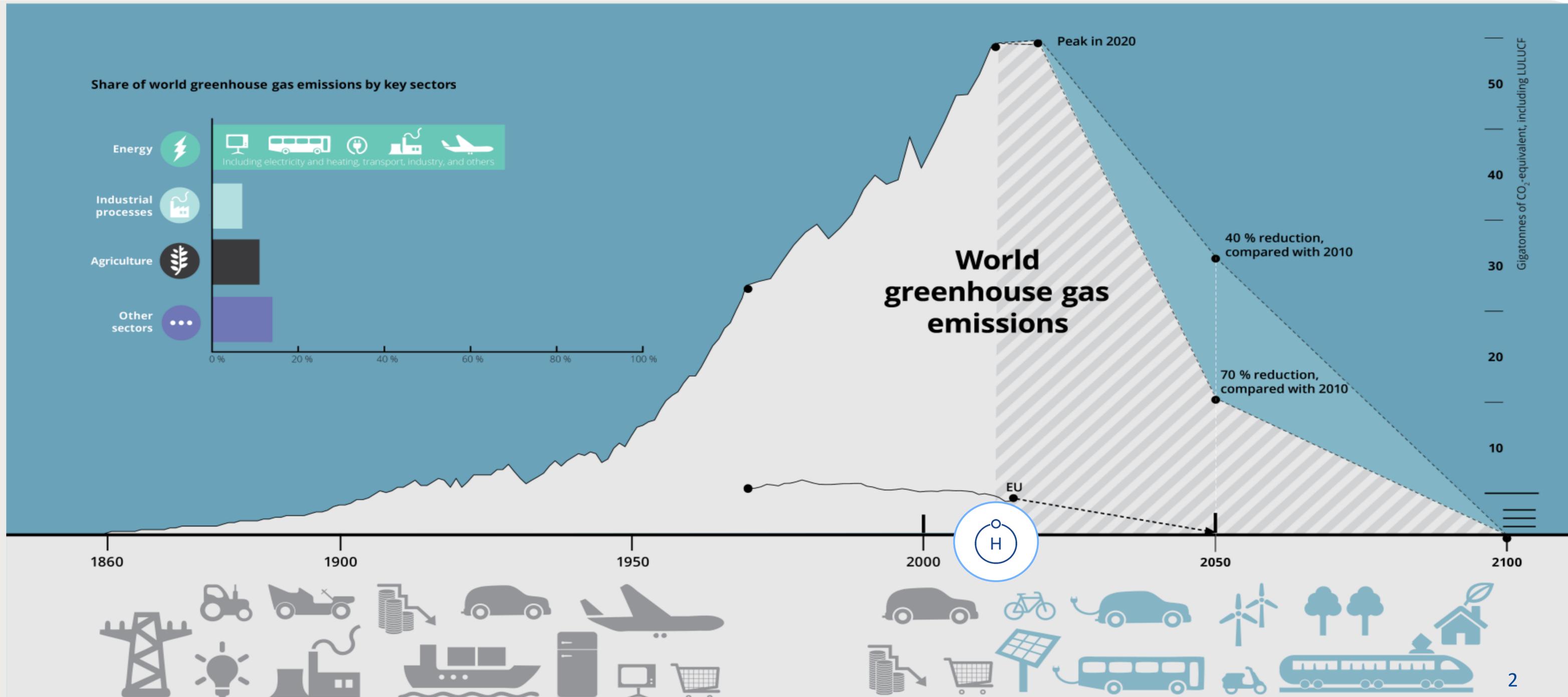
Bart Biebuyck
20th Nov. 2018

Hydrogen Sweden Conference
Stockholm



World Greenhouse gas emissions

Target is to stay below +2°C average global warming and to aim for +1.5°C (Paris Climate Agreement)



CO2 and Pollution are the problem

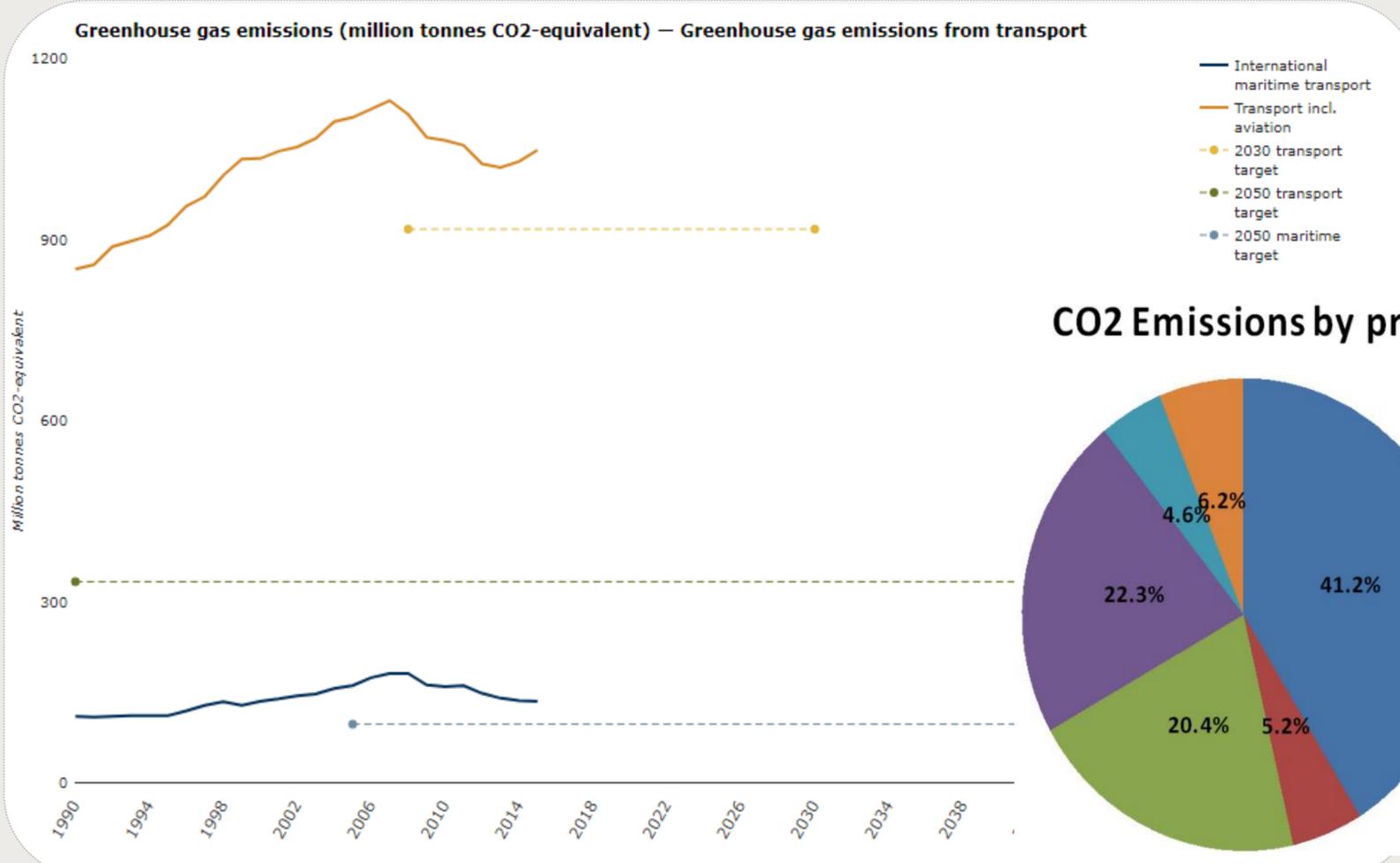
A) CO₂ problem:

- ✓ Transport CO₂ evolution on yearly basis vs 2030/2050 decarbonisation targets shows that the recent economical growth increases the CO₂ again.
- ✓ Transport counts for nearly a quarter of the CO₂.

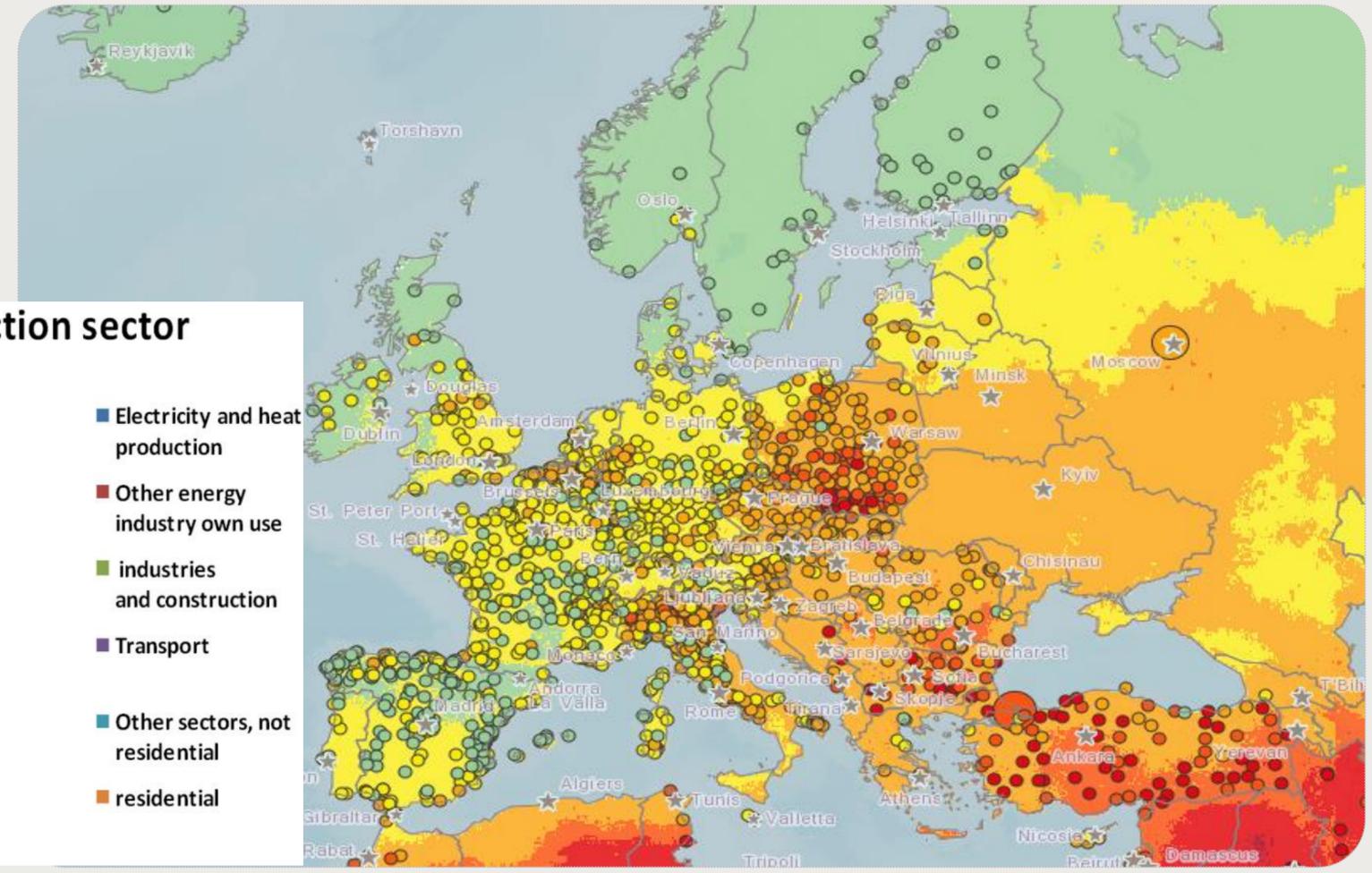
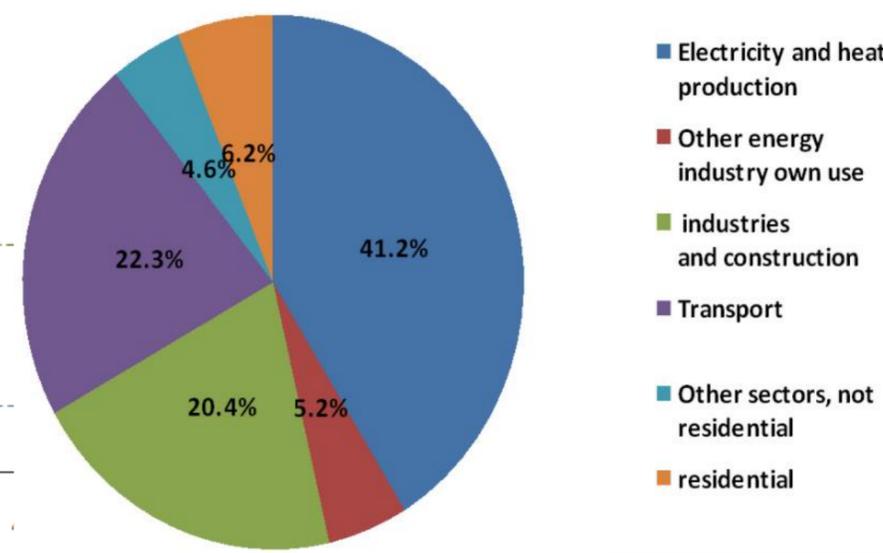


B) Pollution:

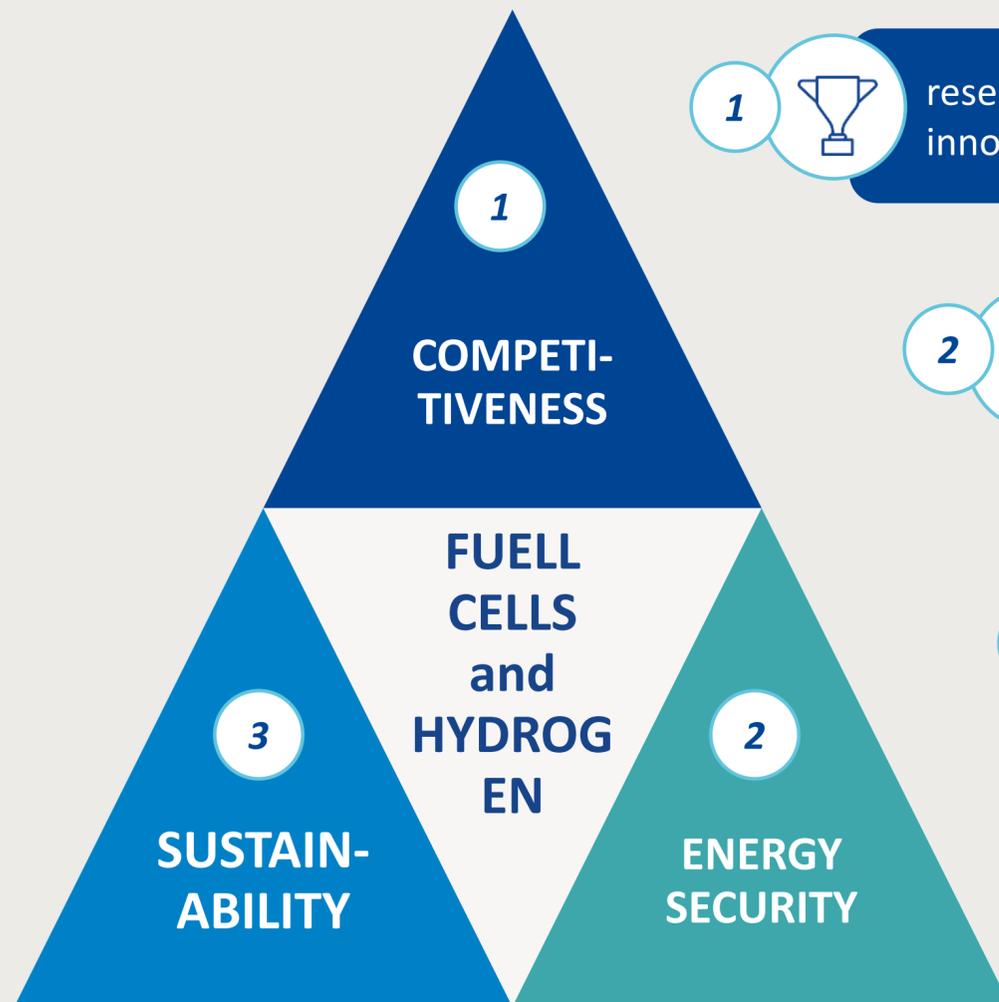
- ✓ Air pollution is a real problem for the health of EU citizens (467.000 premature deaths - EEA)
- ✓ EU cities forced to shut down due to high concentration of pollutants



CO2 Emissions by production sector



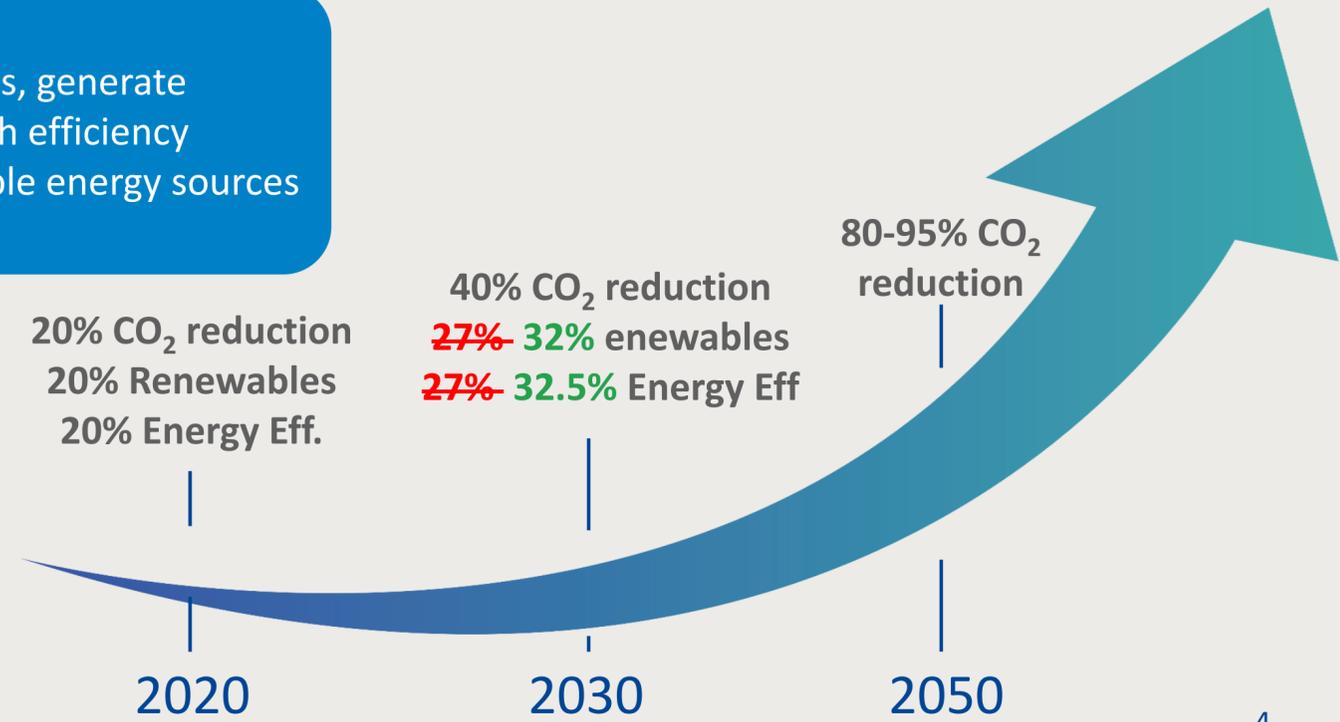
Fuel Cells & Hydrogen technologies in the context of the European Energy policy



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



Strong public-private partnership with a focused objective

A combined private-public of 1.73 billion Euro has been invested to bring products to market readiness by 2020



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING



Industry grouping
>130 members
50% SME



Research grouping
70 members



Energy

H₂ production and distribution
H₂ storage
F/C for CHP



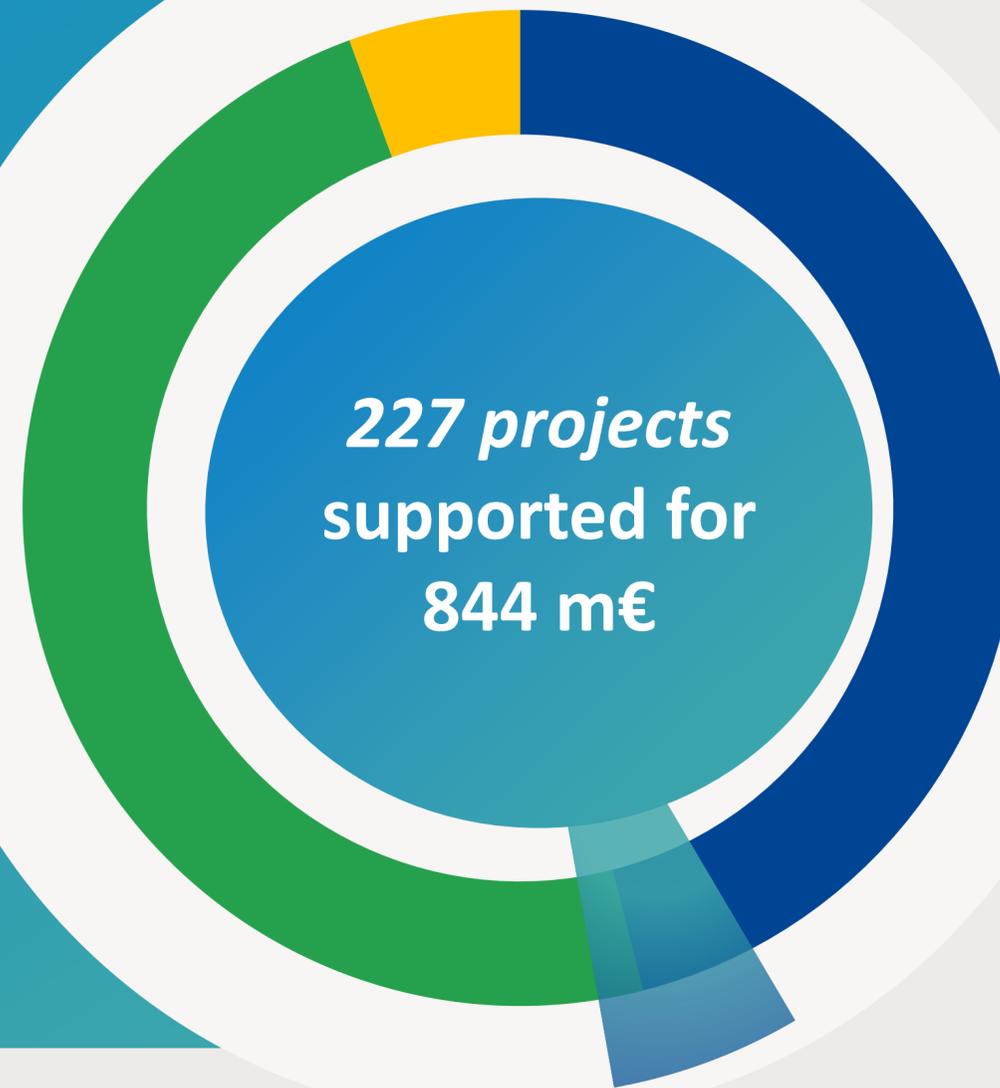
Transport

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



Cross-cutting

standards, safety, education, consumer awareness, ...



47.5%



401 million euros
128 projects

42%



353 million euros
59 projects

5.5%



47 million euros
37 projects

5%



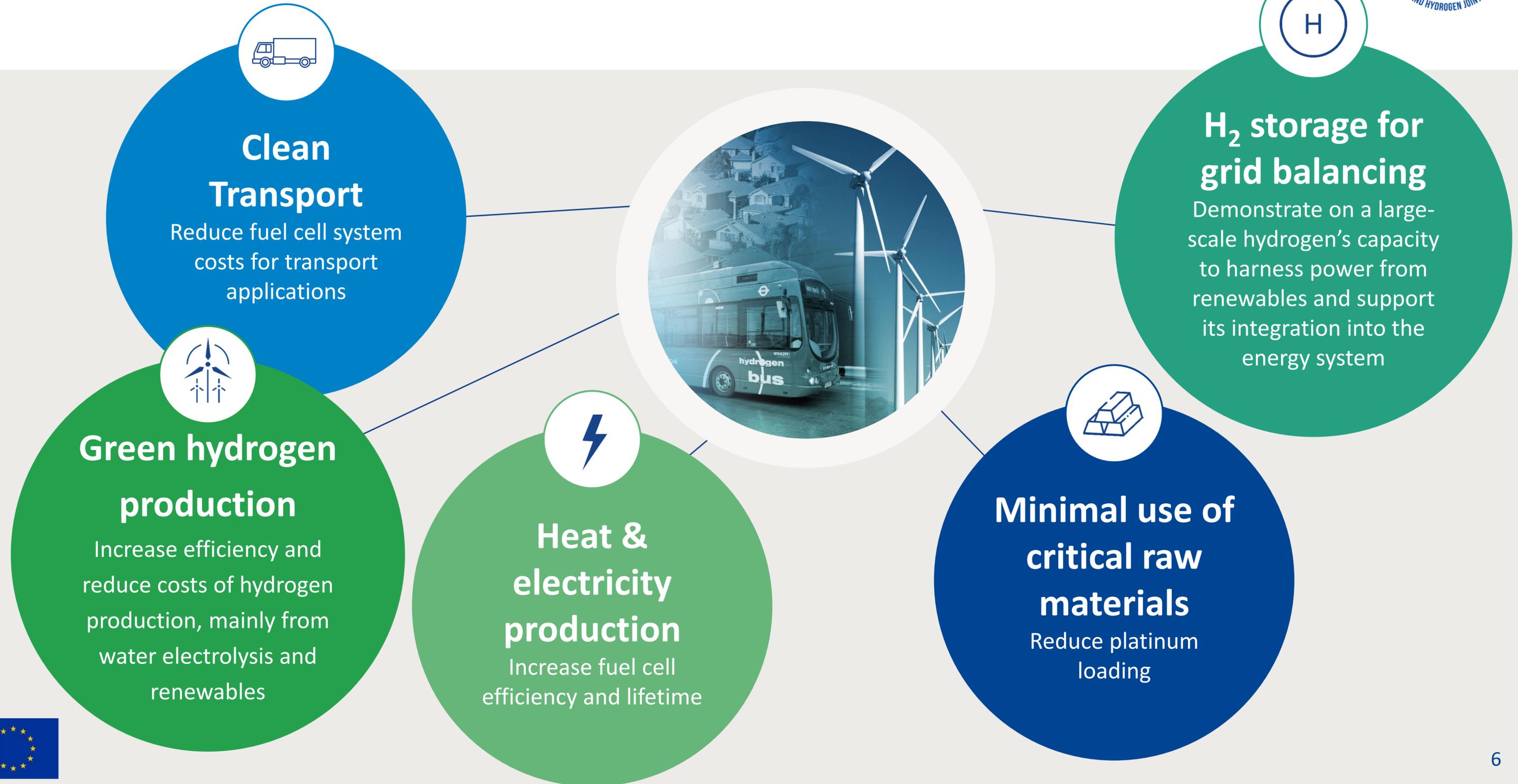
42 million euros
3 projects

Similar leverage of other sources of funding: 886 m€



FCH 2 JU Objectives

Market readiness of a portfolio of clean, efficient and affordable solutions for our energy and transport systems



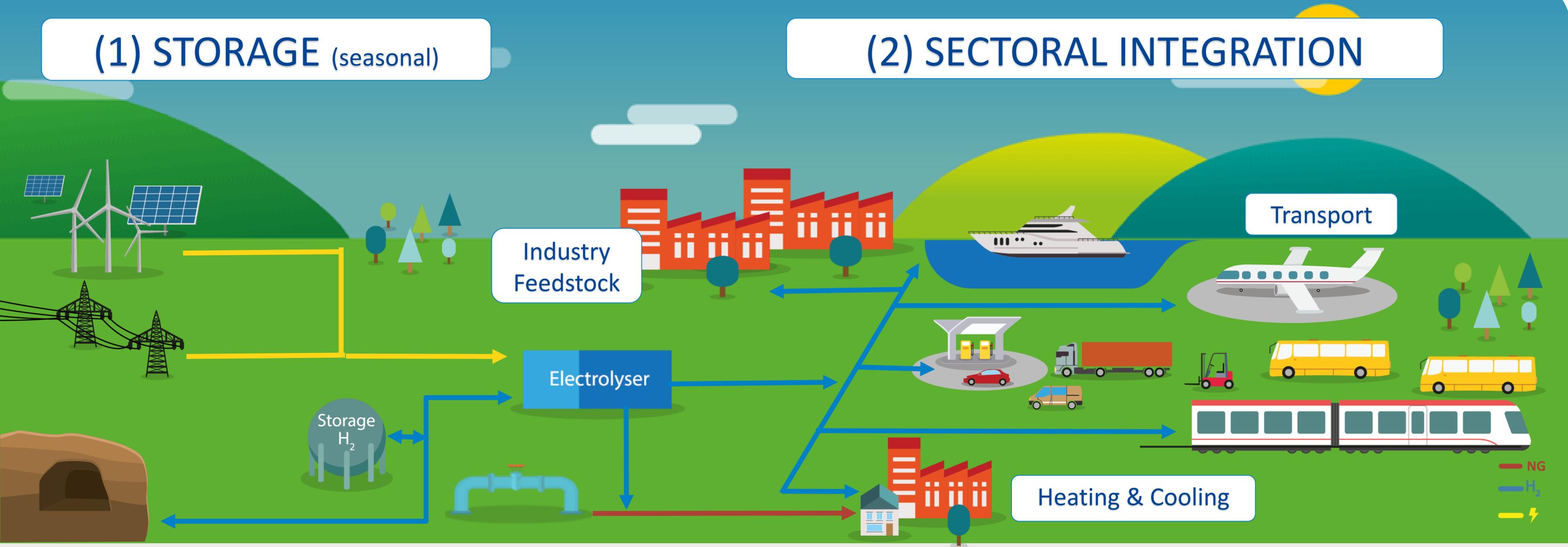
The role of hydrogen in our society & economy

Hydrogen allows more renewables in the energy system through storage and enables sectoral integration



(1) STORAGE (seasonal)

(2) SECTORAL INTEGRATION



Overview of FCH JU activities in Sweden

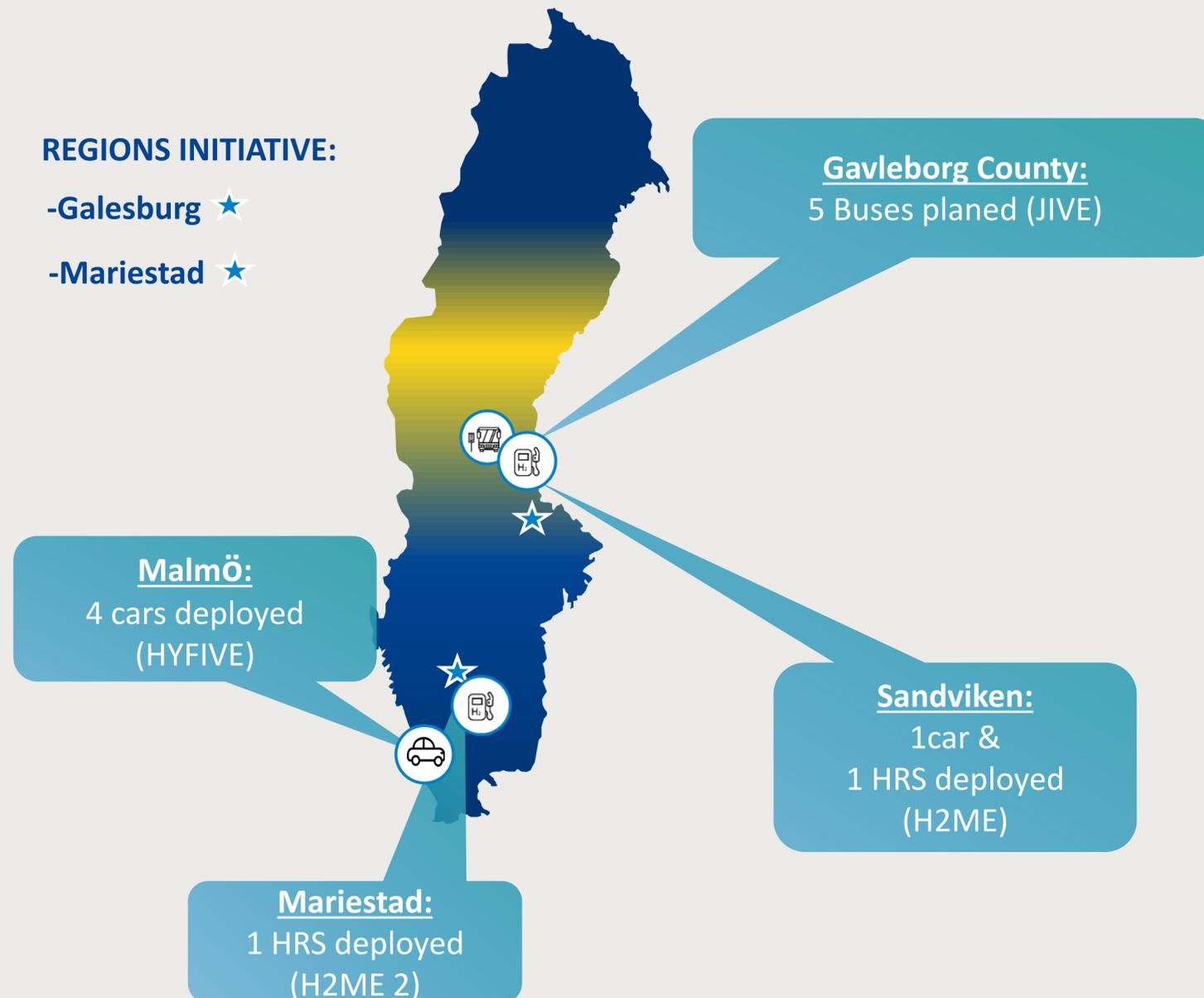


SWEDEN

- 24 Swedish beneficiaries
- Participating in 35* projects
- Total FCH JU contribution: 16.7 Mil €
- AFI shows 5 stations by 2025

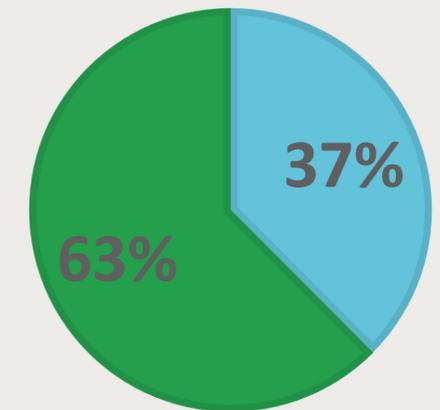
REGIONS INITIATIVE:

- Galesburg ★
- Mariestad ★



BUDGET ALLOCATION

■ Demonstration ■ Research



Plans:

- 5 planned FC cars –H2ME
- 1 planned H2 Refuelling Station in Stockholm – H2ME 2

In total 9 HRS* and more than 100 cars* are planned to be deployed in Sweden by 2020

Facts:

- More than 35 cars on the roads*
 - 7 deployed HRS*
- *Including non-FCH JU demonstrations

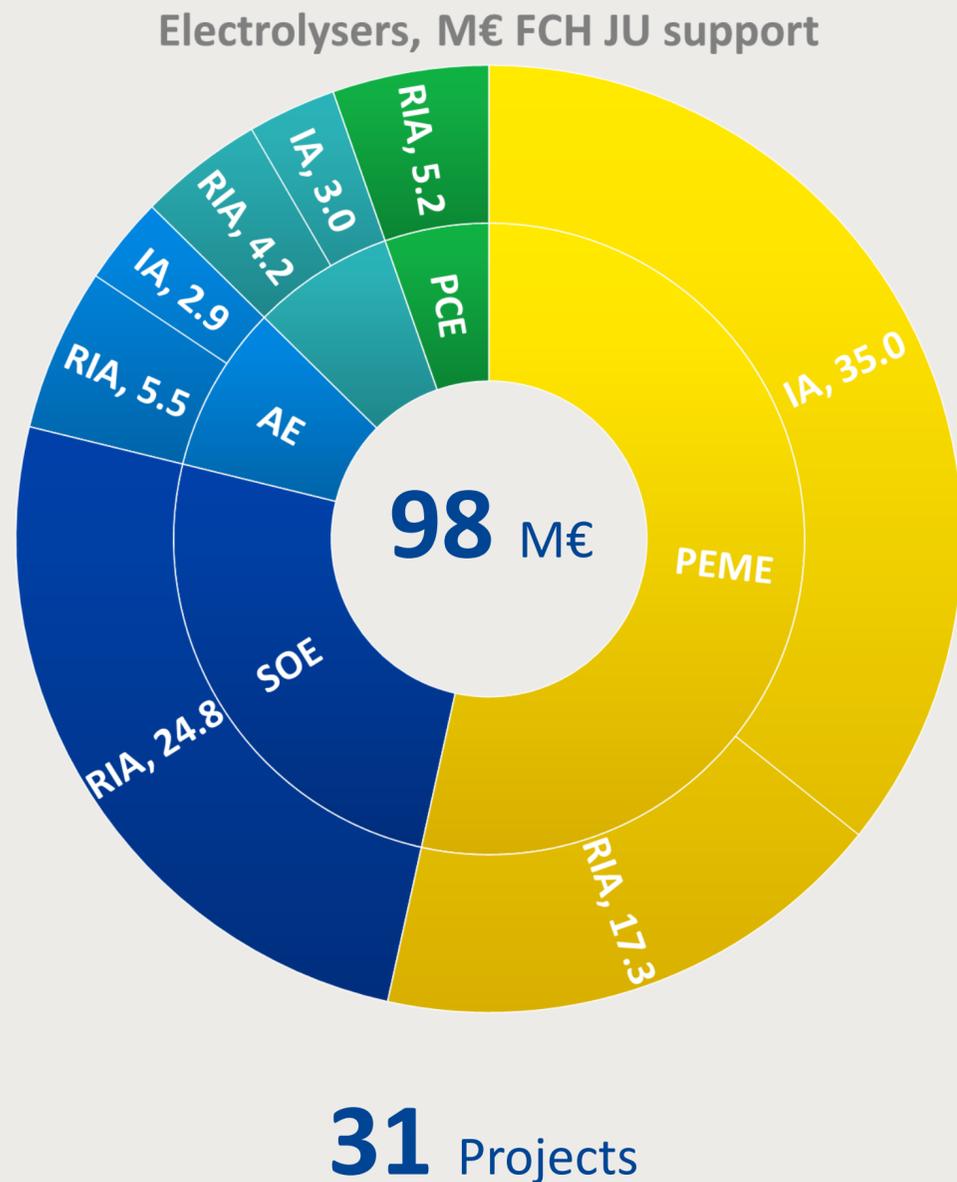


*Nordic Hydrogen Corridor & H2ME 2

Green H₂ production and industry

Electrolysis for energy storage and greening of Industry

Support to developing electrolysers; Increasing demonstrations with falling support



HRS



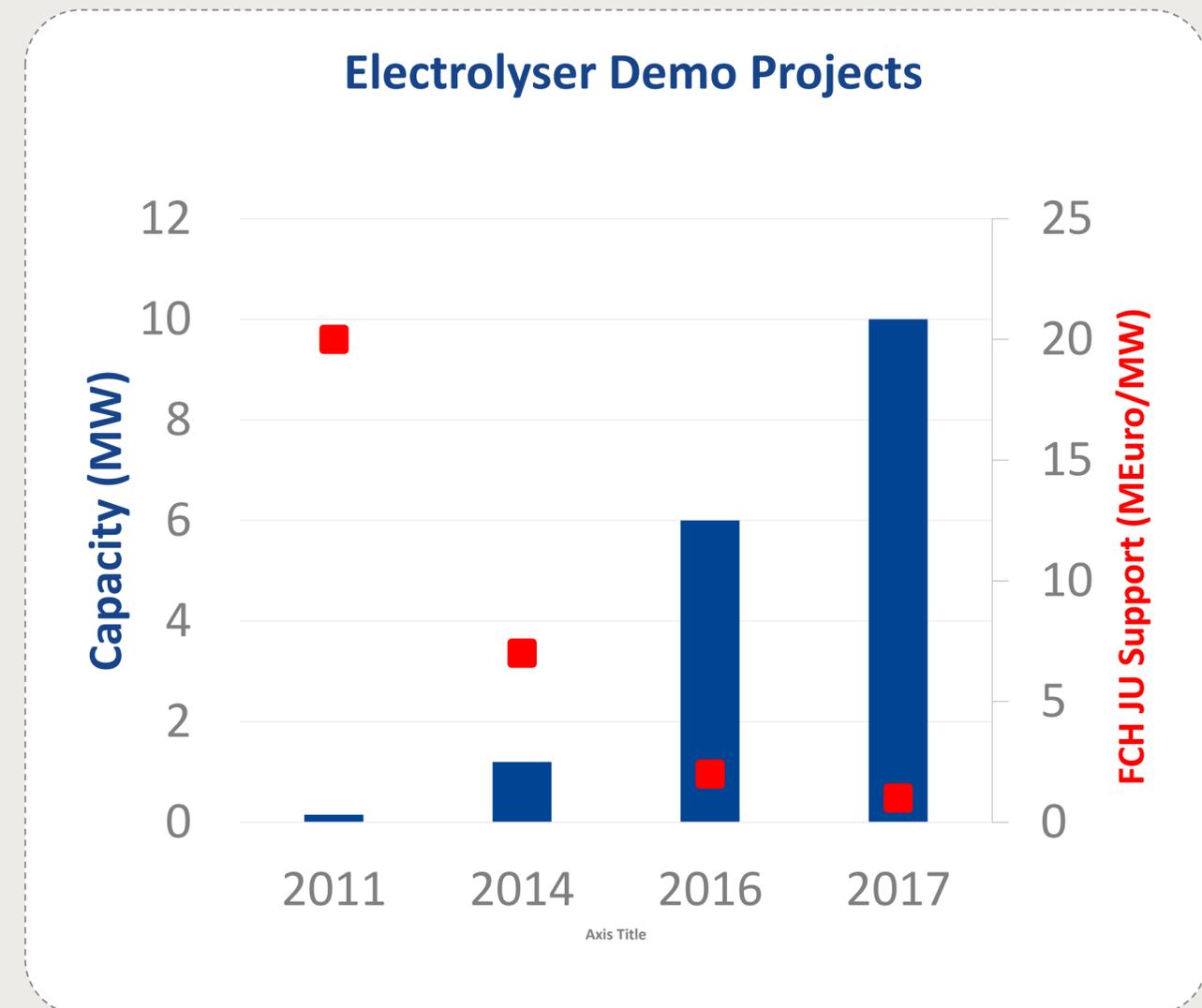
Steel industry



Refineries



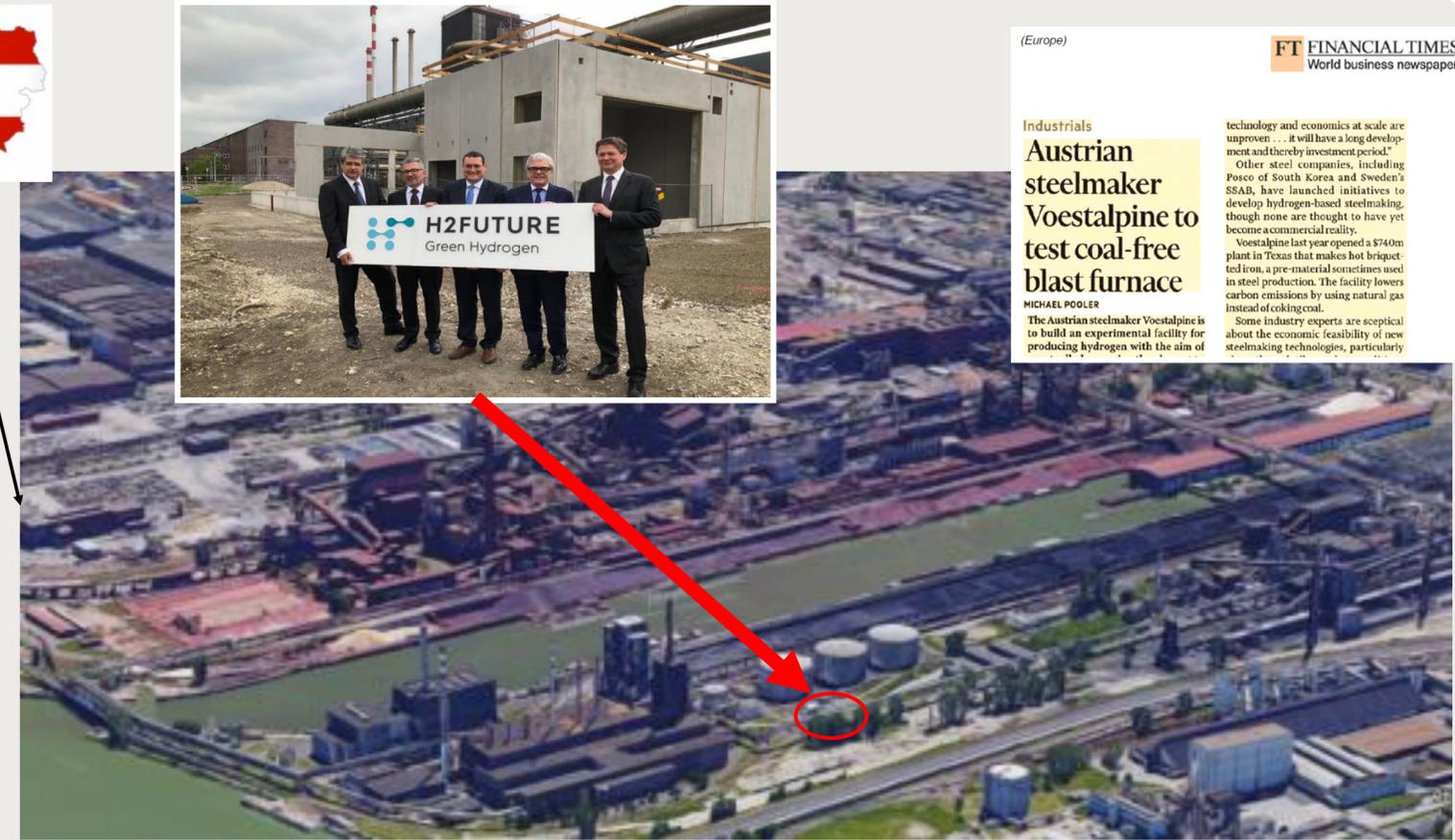
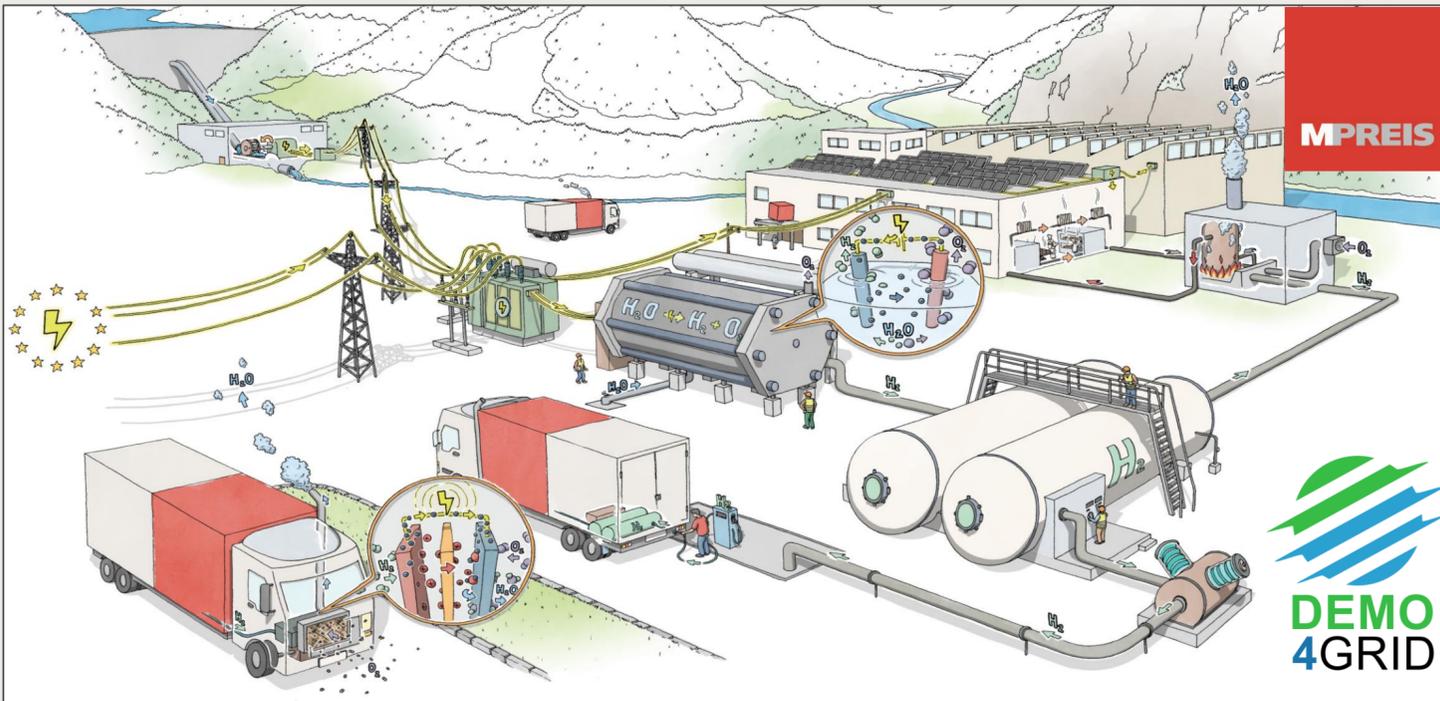
Food industry



Big industries are discovering the potential of Hydrogen (1/2)



Thanks to FCH-JU research projects the costs of electrolysers decreased and became interesting for big industries to invest



FT FINANCIAL TIMES
World business newspaper

Austrian steelmaker Voestalpine to test coal-free blast furnace

technology and economics at scale are unproven... it will have a long development and thereby investment period.

Other steel companies, including Posco of South Korea and Sweden's SSAB, have launched initiatives to develop hydrogen-based steelmaking, though none are thought to have yet become a commercial reality.

Voestalpine last year opened a \$740m plant in Texas that makes hot briquetted iron, a pre-material sometimes used in steel production. The facility lowers carbon emissions by using natural gas instead of coking coal.

Some industry experts are sceptical about the economic feasibility of new steelmaking technologies, particularly

3.4 MW electrolyser at MPREIS (bakery plant) in Völs

- The green H₂ is produced from hydro-electricity (from Alps)
- 1st phase: it is used to heat the ovens to bake the bread
- 2nd phase: distribution by using H₂ trucks

DURATION: 2017-2022; project 7.74 M€ (2.93 M€ by FCH-JU)

6 MW electrolyser at VOESTALPINE (steel plant) in Linz

- The green H₂ is produced from hydro-electricity (from Alps)
- It is used to produce steel in this way the industry can make a first step towards CLEAN STEEL

DURATION: 2017-2021; project 18 M€ (12 M€ by FCH-JU)



<https://www.demo4grid.eu/>

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

Big industries are discovering the potential of Hydrogen (2/2)

Thanks to FCH-JU research projects the costs of electrolysers decreased and became interesting for big industries to invest



10 MW electrolyser at SHELL in Köln

- The green H₂ is produced from curtailed wind energy due to a full electricity grid.
- The produced H₂ will be injected in the natural gas grid (part of it can be used for Shell internal processes)

DURATION: 2018-2022; project 16 M€ (10 M€ by FCH-JU)

150/30kW Reversible electrolyser, Salzgitter

- To operate a high-temperature Electrolyser as reversible generator (rSOC, reversible Solid Oxide Cell) in the industrial environment of an integrated iron and steel work.
- The system is flexible to produce either H₂ or electricity.

DURATION: 2016-2019; project 4.5 M€ (100% by FCH-JU)



(Website under preparation)

(<http://www.green-industrial-hydrogen.com/home/>)

Next steps

Scaling-up from MW to GW-scale through further research and an EU wide electrolyser initiative



(1) Continue RESEARCH (low TRL) to bring costs further down & performances up

May '18: Research Ministers worldwide agreed on a new H₂ Mission Innovation challenge

*“Accelerating development of a global hydrogen market by identifying and overcoming key barriers to the production, distribution, storage and use of hydrogen at **gigawatt** scale”*

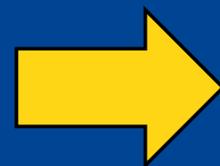
Led by: Australia, European Commission and Germany

(others: Austria, Canada, China, France, India, Italy, Japan, Norway, Saudi Arabia, UK, USA)



(2) Market ACCELERATION to keep EU leadership, creating jobs and growth in EU

Thanks to FCH-JU,
EU has a 3 year technological lead
vs others and can be the supplier
of the world



To boost investments and create the
supply chain an initiative is needed e.g.
40GW electrolyser initiative



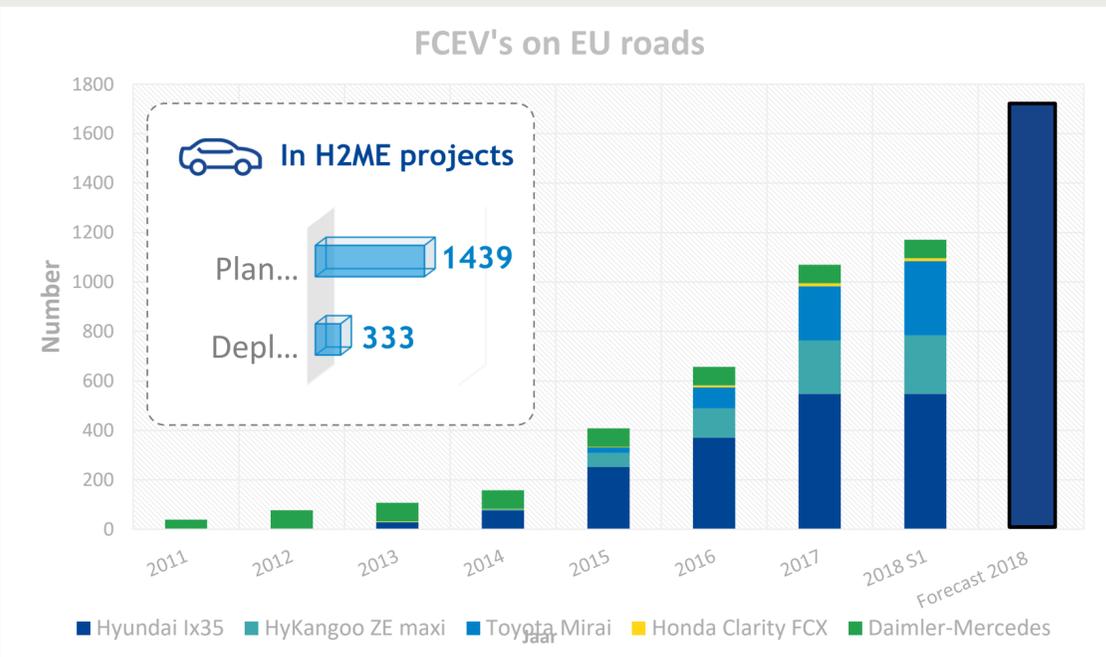


TRANSPORT

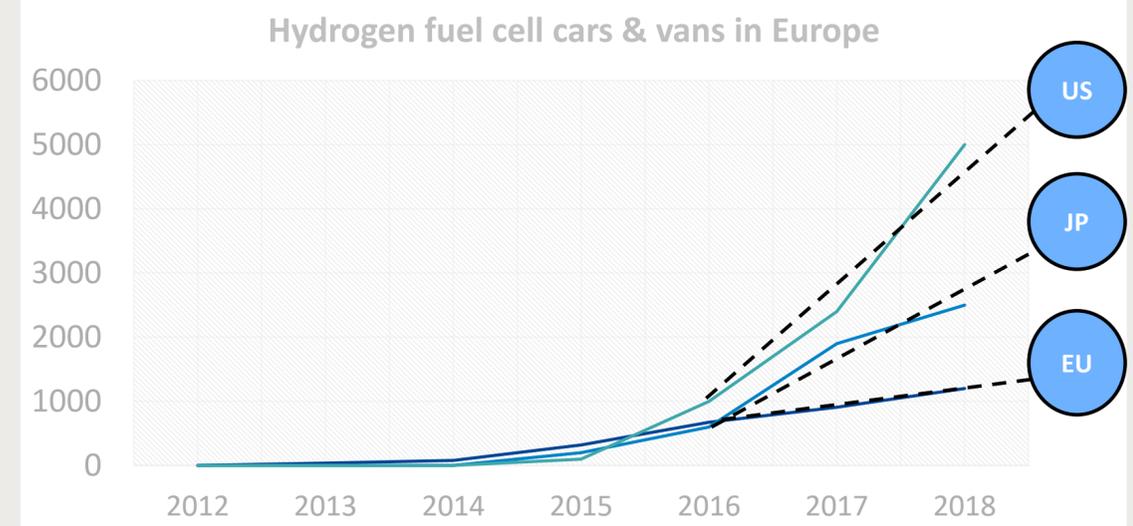
Roll out of cars by FCH-JU Hydrogen Mobility Europe (H2ME)



All FCH-JU projects together will put 1600 vehicles on the EU market to gain experience with the technology



- About 1200 FCEV's on EU roads
- EU OEM's: small demo's ~2025, mass production 2025~ (EU OEM's part of FCH-JU)
- PSA: start FCV development
- FIA: Start H₂ competition in '24
- California & Japan sales are going fast due to strong policy support
- EU mobility package is good chance to catch up



	2018	2020	2022	2025	2030
Europe	1200	-	-	(0.9 -1 mill)*	Tbc **
China	150	5000	-	50.000	1 million
Japan	2500	40.000	-	200.000	800.000
USA	5000	-	-	-	-
S-Korea	0	-	16.000	-	-

* According to the action plan of Alternative Fuel Directive
 ** McKinsey study Hydrogen: Europe roadmap to be released Oct 2018.



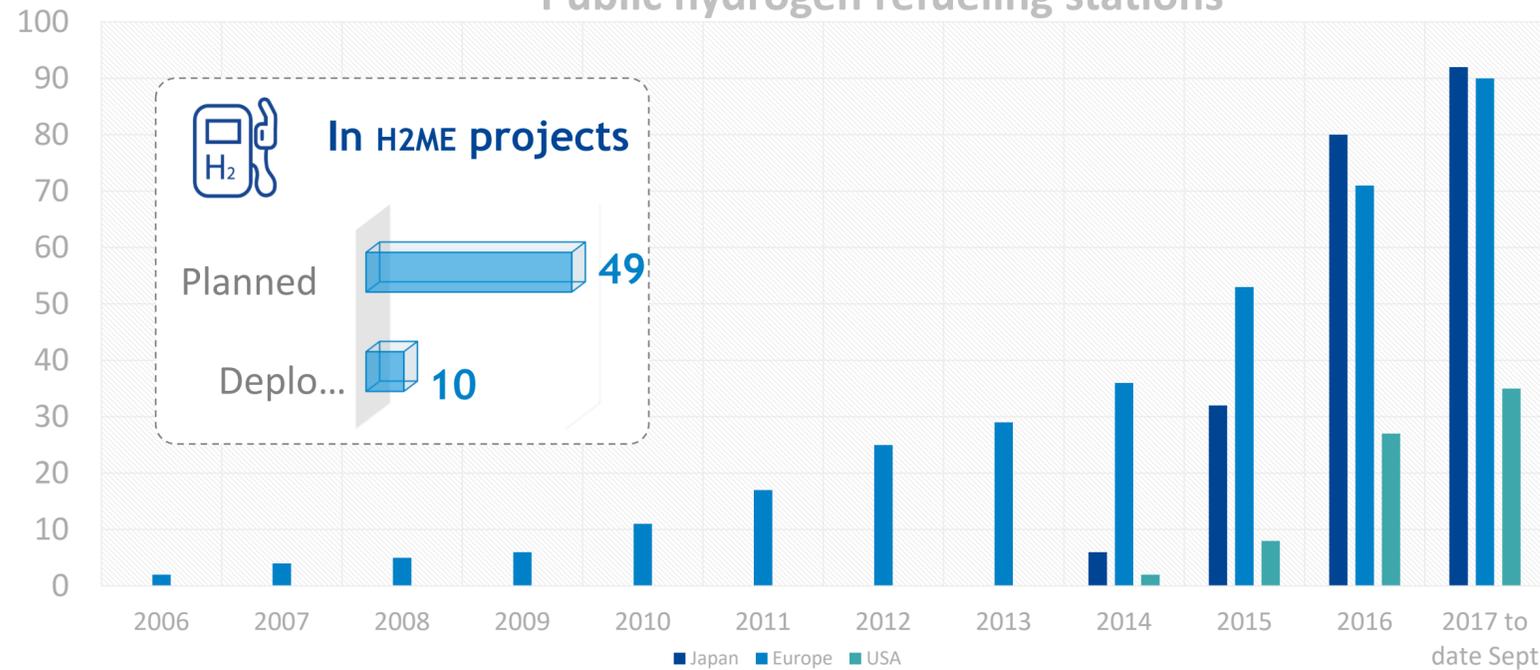
Roll-out of the required infrastructure in Europe



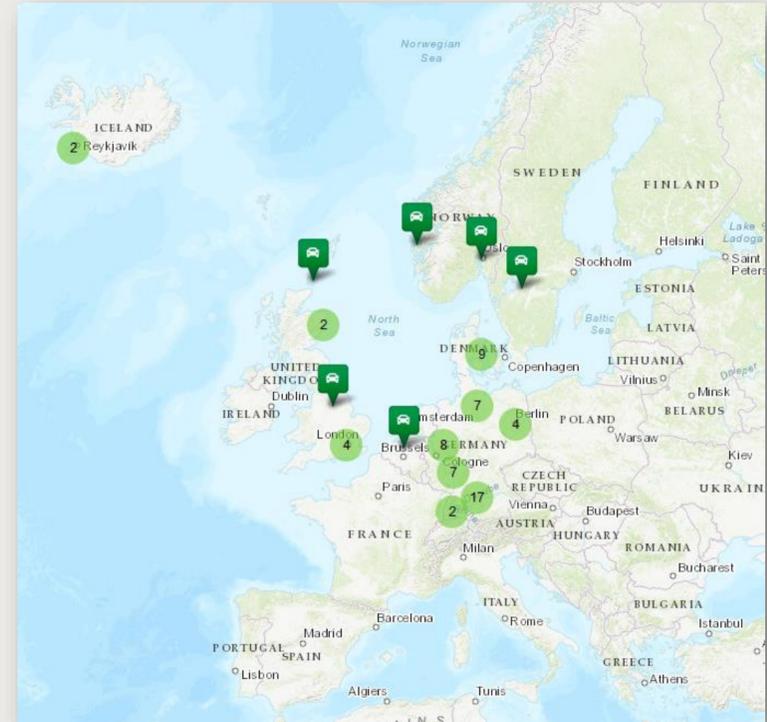
Europe installs Hydrogen Refuelling Stations thanks to European programs (FCH-JU & CEF) & national programs.

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

Public hydrogen refueling stations



Development of a system for HRS availability in the EU



<https://h2-map.eu/>

“H2 live” App

H2 mobility Deutschland

	2018	2020	2022	2025	2030
Europe	100	-	-	(820~842)*	Tbc **
China	12	100	-	350	1000
Japan	100	160	-	320	(900)
USA	35	100	-	200~225	-
S-Korea	0	-	310	-	-

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



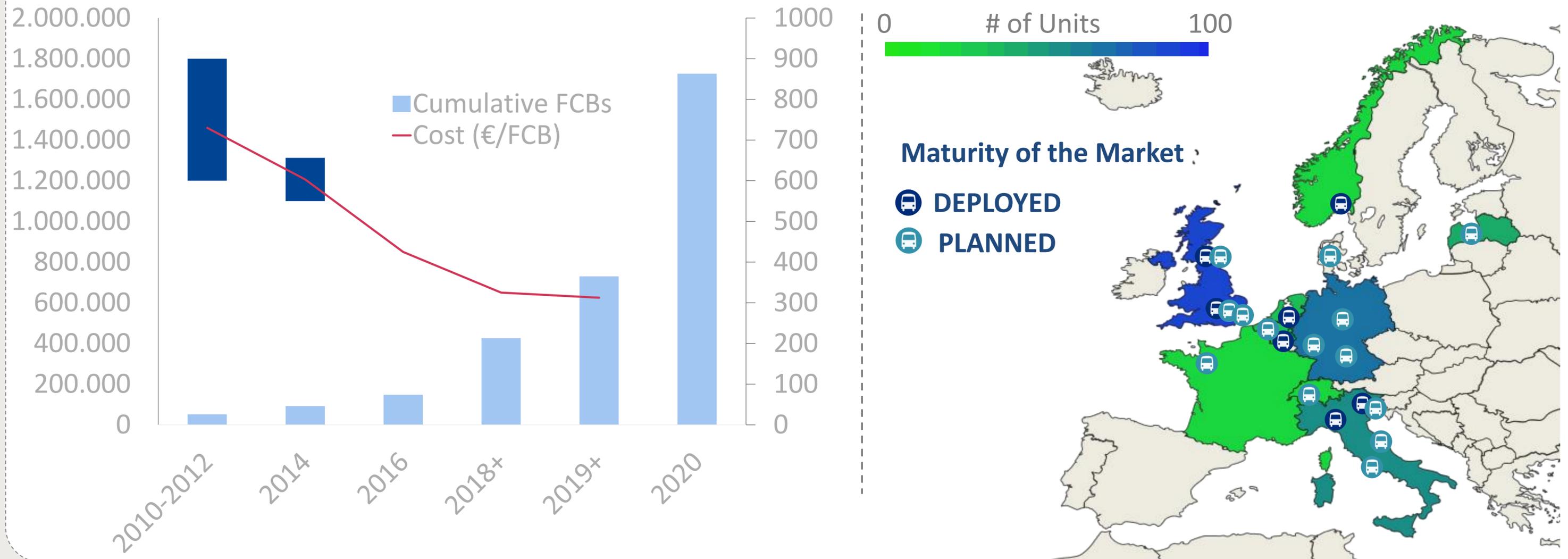
* According to the action plan of Alternative Fuel Directive
** McKinsey study H2: Europe roadmap to be released Oct '18.

The roll-out of hydrogen buses in Europe

Europe is supporting totally 360 Hydrogen buses deployment that lead to a price reduction of 66% vs 2010.



There is an appetite to roll-out more than 1600 buses by 2020 by cities and regions



10 European OEM's are developing Hydrogen buses: <https://www.fuelcellbuses.eu/>

In 2017 first trucks appeared 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**



 **2018: Heavy Duty truck call for proposal**

Call 2018: 1 successful proposal under signature

  **Nicola Truck**  **Toyota Truck @LA port**

 **ESORO COOP**



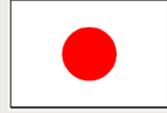
 **ASKO-SCANIA**



 **VDL - COLRUYT**



  **Partners planning 2,000 commercial trucks on the road by 2020**

  **Toyota and 7-eleven collaboration**

  **Hyundai truck**

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

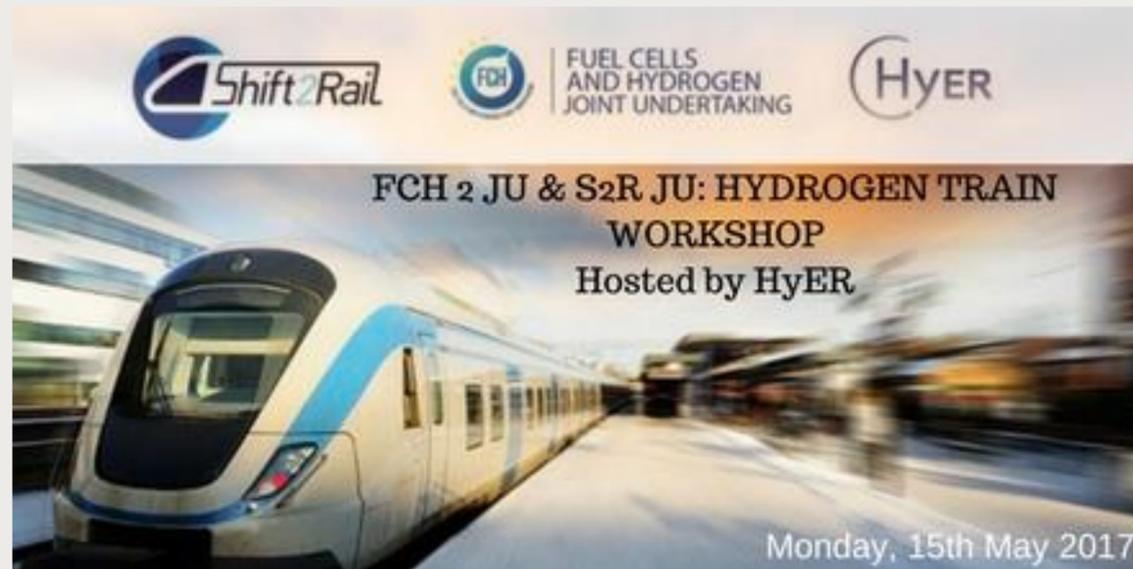
Hyundai signs deal to sell 1,000 hydrogen-powered trucks in Switzerland

Hyunjoo Jin



Rail discovered Hydrogen and Fuel Cells

The first business models are appearing



On-going cooperation
“Study on use of fuel cell hydrogen in railway environment”

- 42% of EU railway not electrified
- H₂ train requires half the investment vs full electric train (catenary 1 million € / km)

- 17 Sept. '18 commercial operation starts in Germany. Other EU countries are on the way

- FCH-JU + S2R JU cooperating in a joined study to look at business cases beyond Regional trains



Maritime discovering Hydrogen and Fuel Cells

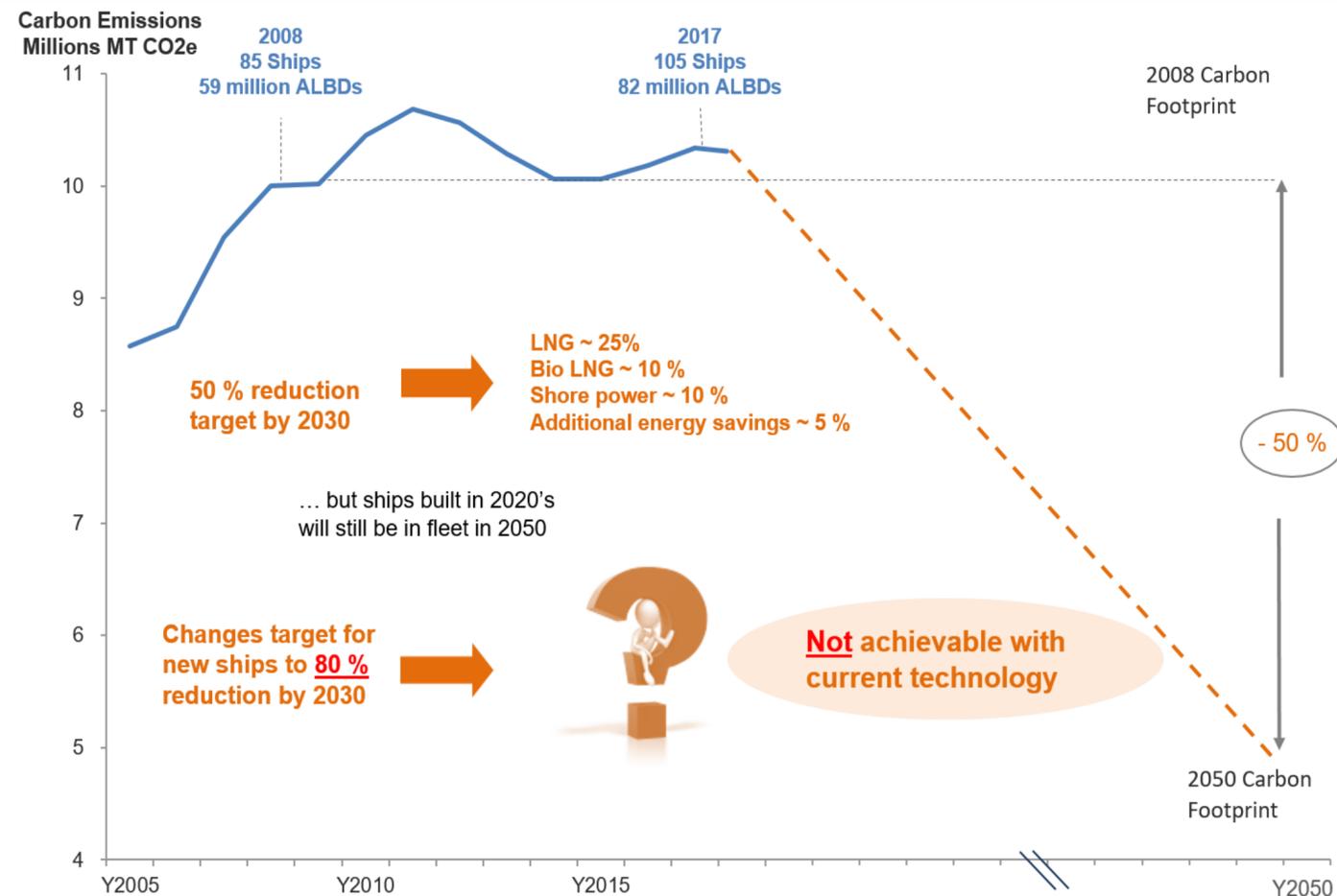
To accelerate the decarbonisation of Maritime, regulation for hydrogen need to be prepared



International Maritime Regulations
Class Rules
International Standards
National Regulations

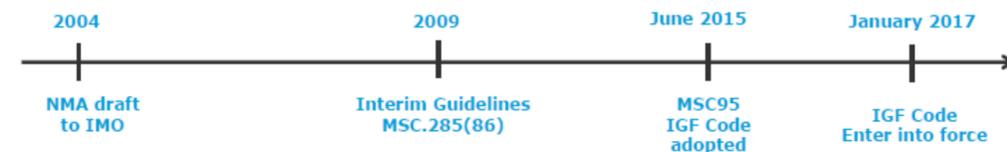


- IMO April 2018: “at least 50% of CO₂ reduction by 2050”



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€

Call 2018: 2 successful proposals under GAP

Mid-size passenger ships of inland freight
FC for port/harbor ecosystems

around 9M€



- Further R&D needed e.g. L H₂ storage, MW scale Fuel Cells,...

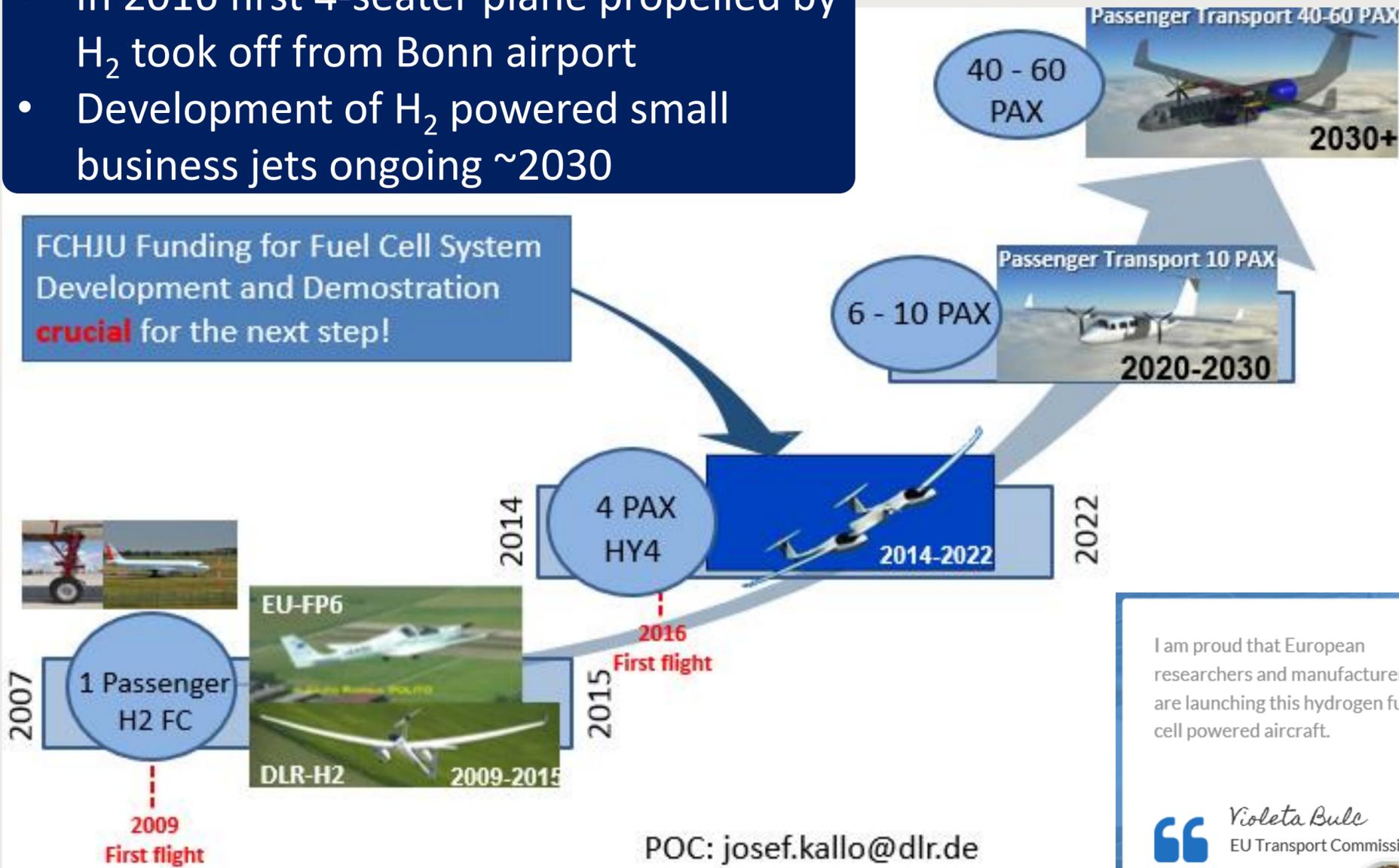
Aviation sees a future in Hydrogen for small planes

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



- In 2016 first 4-seater plane propelled by H₂ took off from Bonn airport
- Development of H₂ powered small business jets ongoing ~2030

FCHJU Funding for Fuel Cell System Development and Demonstration **crucial** for the next step!



- HYCARUS is a FCH JU project where the kitchenette runs entirely on Hydrogen and Fuel Cells

Maiden flight: by the end of 2018



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

Violeta Bulc
EU Transport Commissioner

Call 2018: 1 successful proposal under GAP

FC system for propulsion of regional passenger aircraft 4M€



FCH-JU Research boosts EU supply chain!



Europe is leading in several parts of the Hydrogen and Fuel Cells technologies sector

EU H2 TANK DEVELOPMENT

- Reduced cost by 5 to 3000€
- 20% reduced mass by design
- Use of robots to produce



FCH-JU conducts a study

Europe leads in several parts of the Hydrogen and Fuel Cells sector such as:

- Electrolysers
- Solid oxide Fuel Cells
- Hydrogen Refuelling Stations
- Hydrogen buses
- ...

“Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies”
(Due by end 2018)

EU FUEL CELL STACK DEVELOPMENT

- Established a EU supply chain for a fuel cell stack.
- Standardisation based on OEM requirements

June '17: **4 German OEM's will industrialise this stack**

Nov. '17: Nikola US truck OEM buy stacks in Sweden



REDUCTION OF CRITICAL RAW MATERIAL (PLATINUM)

- 70% reduction between 1st & 2nd generation
- Fuel cell platinum amount about equal to diesel catalyst
- 2 projects aiming for zero-platinum



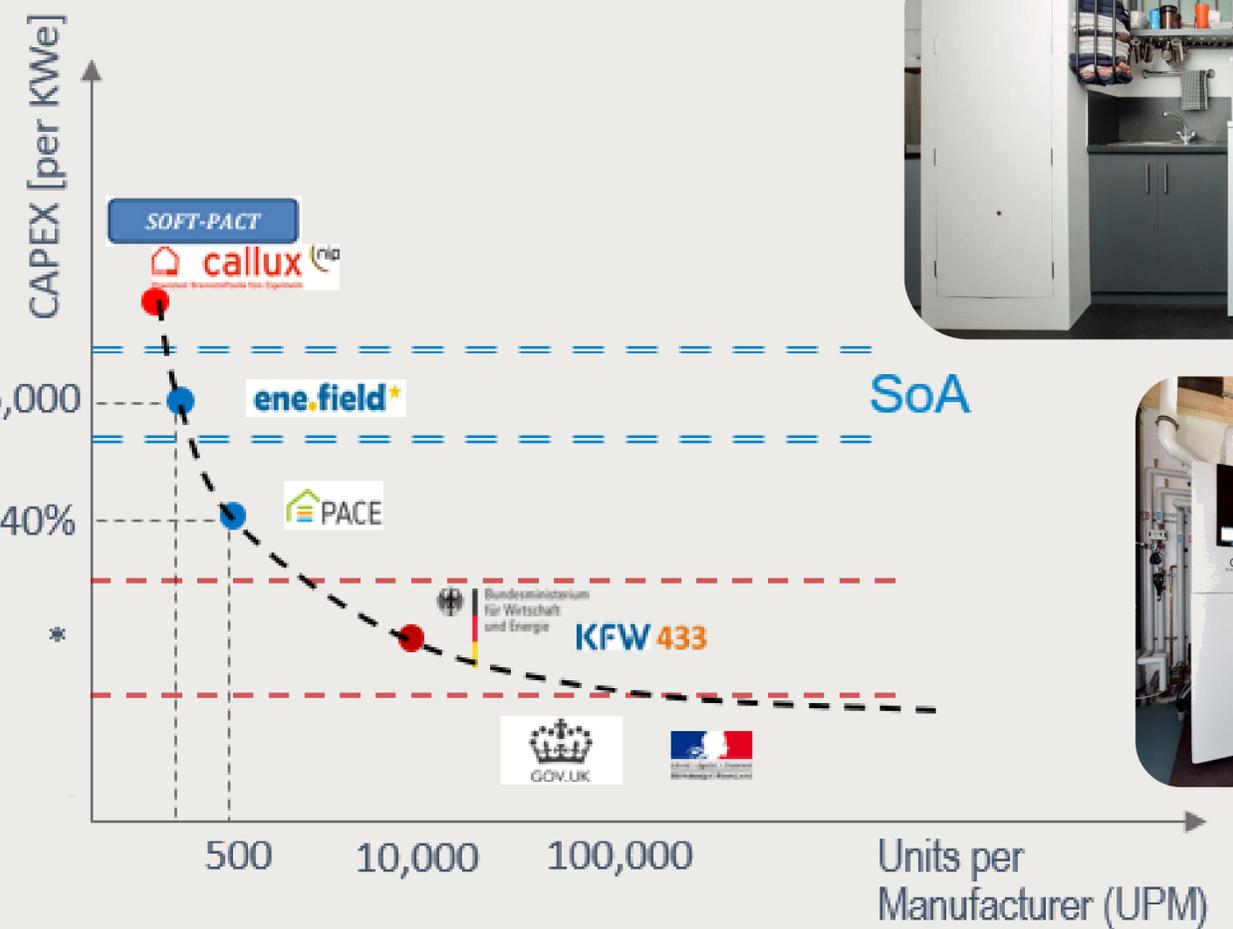
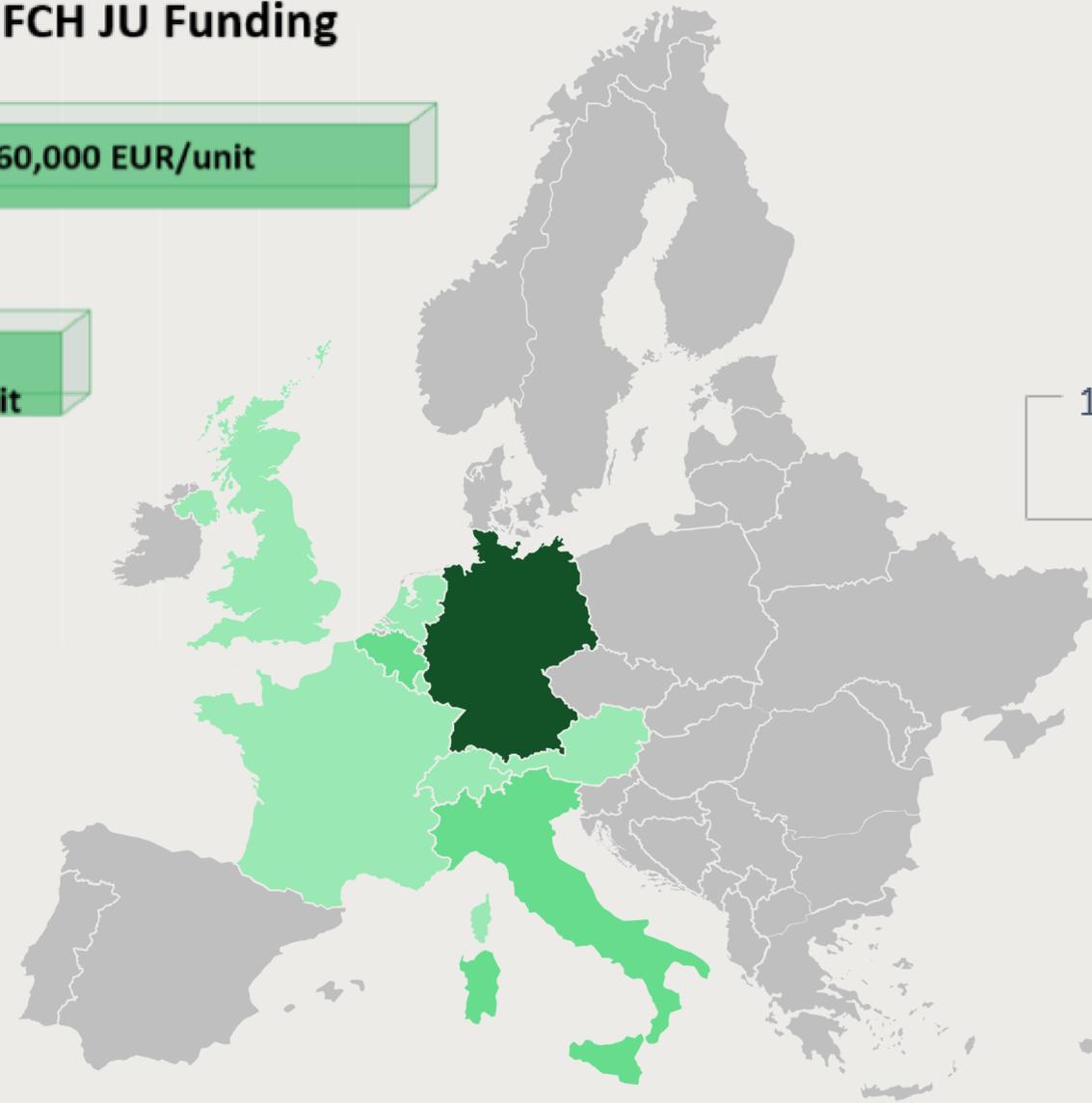
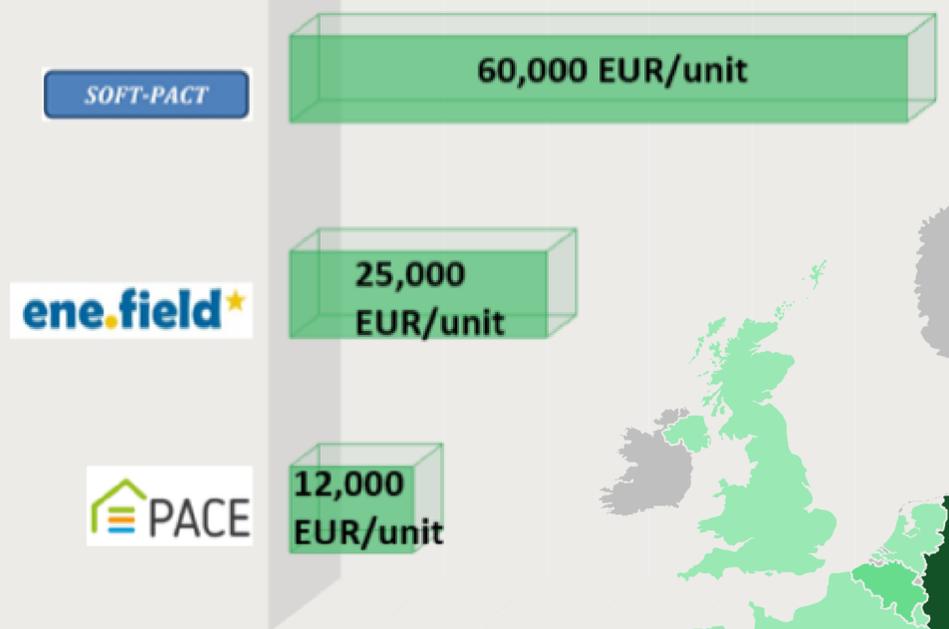
Heating and Cooling

Over 1000 fuel cell μ CHP systems installed across EU

Track record of domestic heat and power systems created



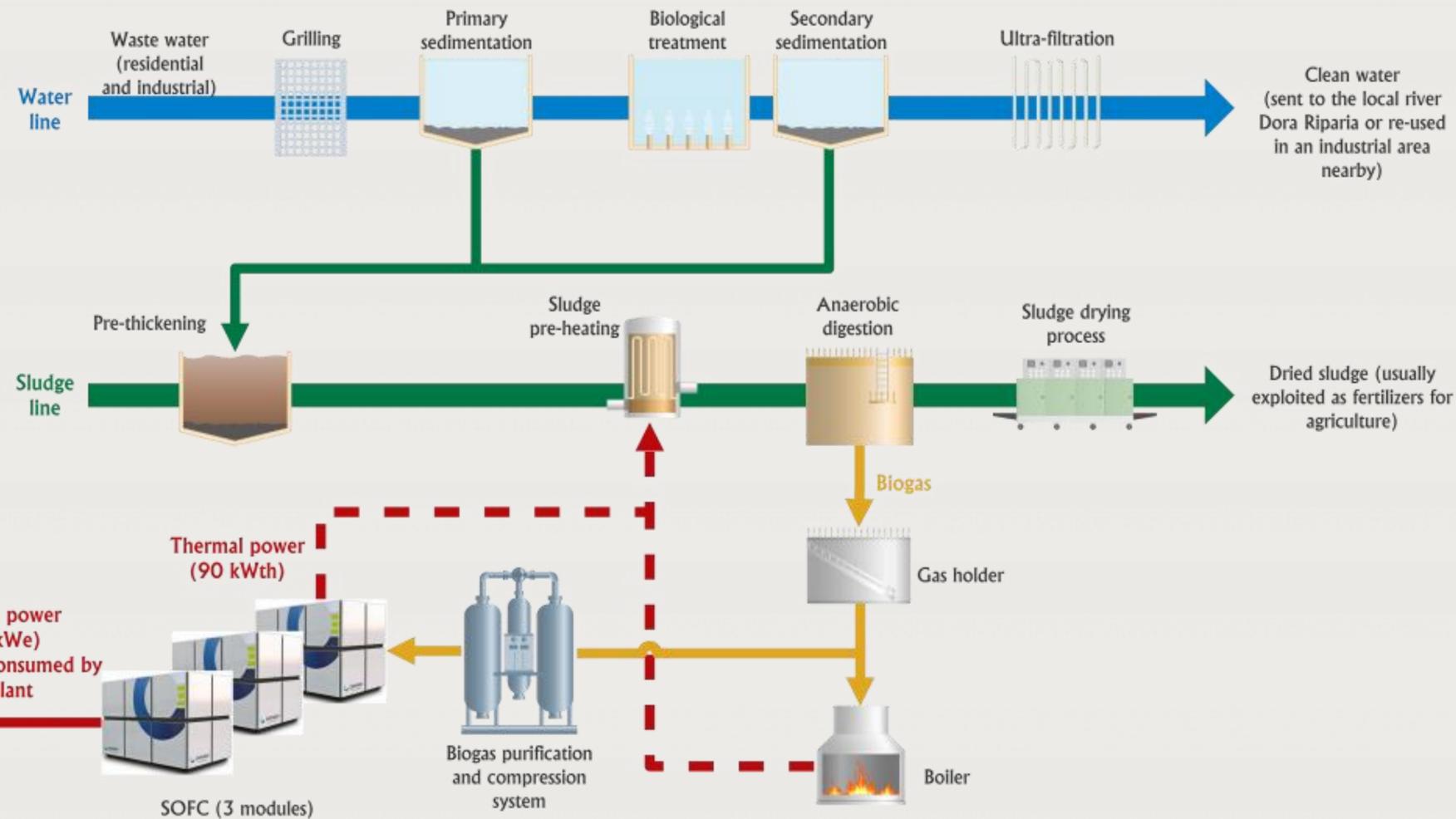
FCH JU Funding



1046 units deployed under ene.field project
 Over 1 MWe capacity installed
 >5 million operating hours
 Additional >1,000 units deployed under German scheme

Medium size Fuel Cells first deployments

FCH-JU research projects demonstrates medium size Fuel cells potential in waste water treatment plants



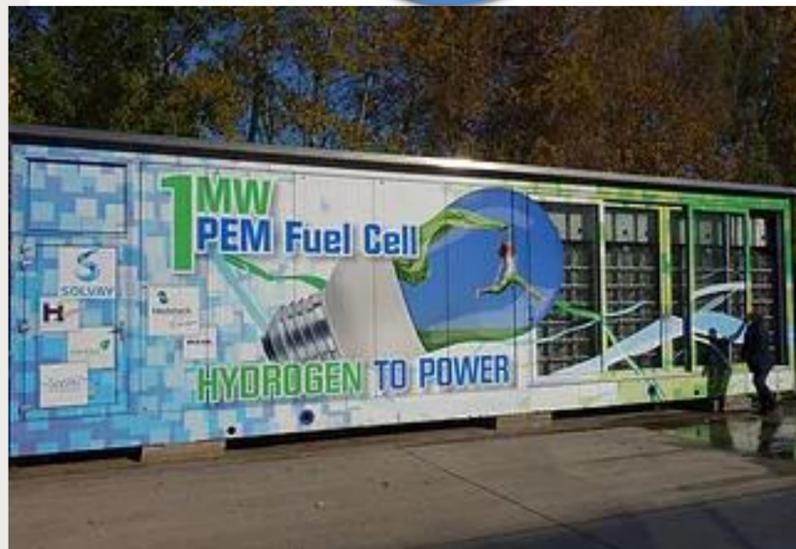
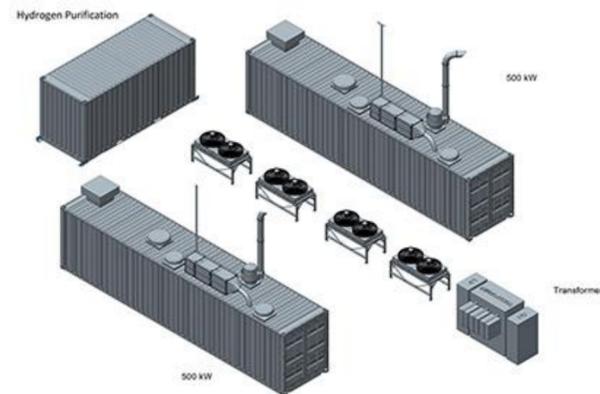
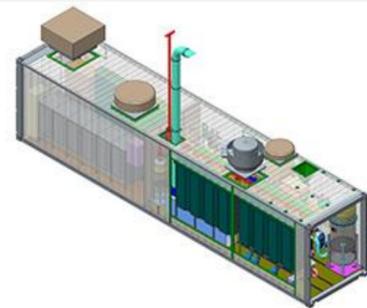
175 kW SOFC in Collegno Waste Water Treatment Plant, Turin Itay area will guarantee the supply of around 30% of the site electrical consumption, and almost 100% of the thermal requirement.
DURATION: 2015-2020 with FCH JU Funding: ~4.5M€

MW fuel cells greening big industry by using waste hydrogen

FCH-JU research projects shows Fuel Cells can help to decarbonise industry like the Chlor-Alkali industry



CG Démo



DEMCOPEM 2MW



1MW plant at Martinique, oversea territory of France
 Demonstrate the deployment of a 1MW PEM Fuel Cell, developed and purpose-built for the EU market, running on waste hydrogen from a refinery plant (246 t/year flared)
DURATION: 2012-2020 with FCH JU Funding: ~4.6M€

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

SAFETY, STANDARDS, EDUCATION....

At a glance

Cross-cutting activities comprise projects and complementary actions



Preparing the European workforce

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




HyResponse
Training for first responders



KnowHy
Courses for professionals/ general public



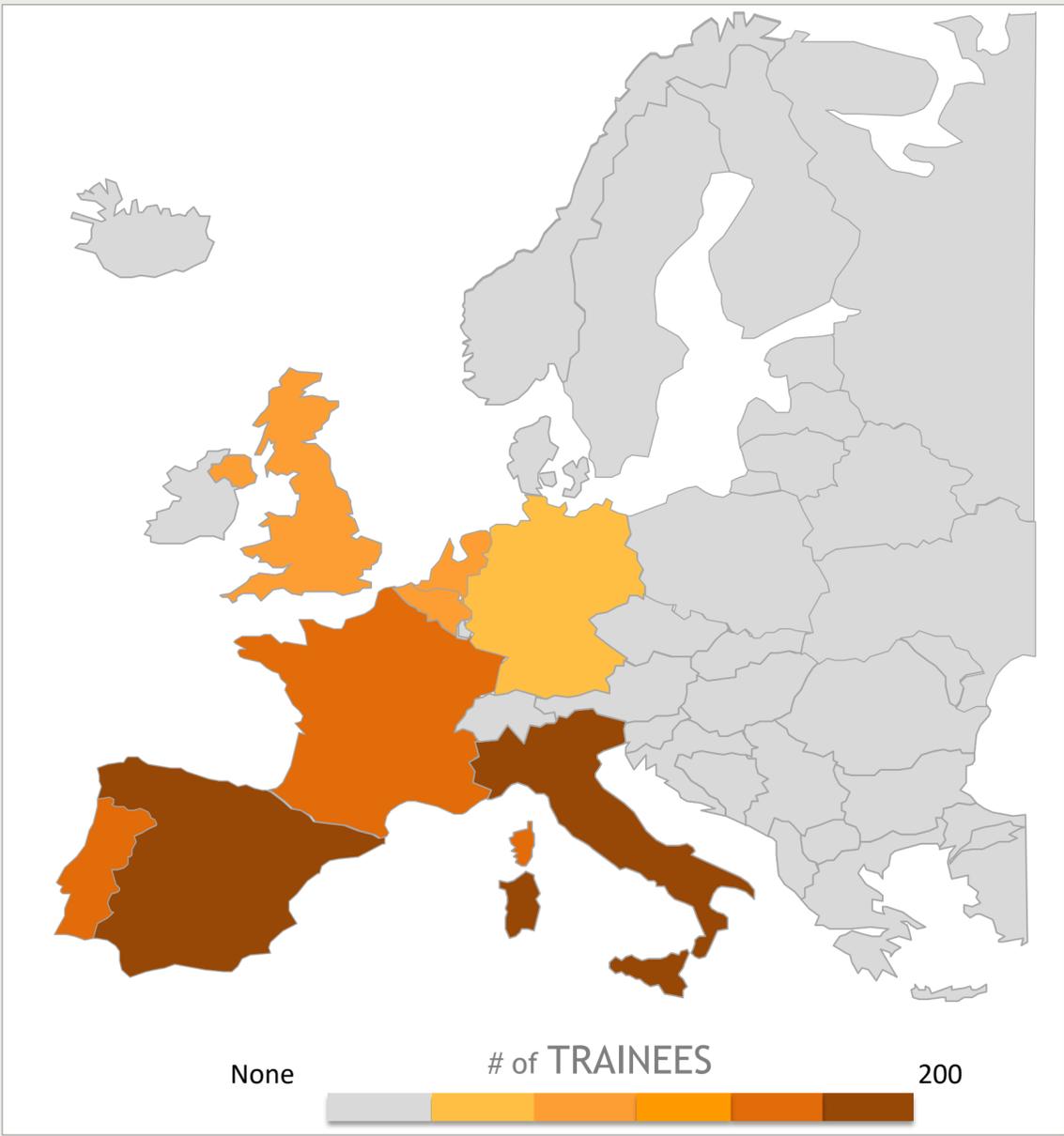
TeachHy
*undergraduate & graduate education PhD
 BEng/BSc
 MEng/MSc*

Country	Total
BE	33
DE	8
ES	170
FR	71
IT	188
NL	35
PT	80
UK	21

2016
>600 trainees
8 countries
7 languages



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



1st guarantees of origin for green hydrogen about to hit the market

Important for member states to implement these Guarantees of Origin in their national legislation



<http://www.certifhy.eu/>

Main objectives:

- To define a widely acceptable definition of green H₂
- Design a robust GoO scheme for green hydrogen
- Propose roadmap to implement the initiative in EU
- Establish a stakeholder platform
- Real trial in 4 pilot operations for a guarantee of origin scheme for green and low carbon H₂

NEXT: FAST IMPLEMENTATION IN NATIONAL LEGISLATION

The 1st Green Hydrogen Guarantee of Origins are available soon by CertifHy Pioneers:

Become an Early Adopter

Logos of participating companies: AIR LIQUIDE, AIR PRODUCTS, AkzoNobel, COLRUYTGROUP, uni per

Financed by: FCH | FUEL CELLS AND HYDROGEN JOINT UNDERTAKING, European Union

Project Coordinator: Hincio

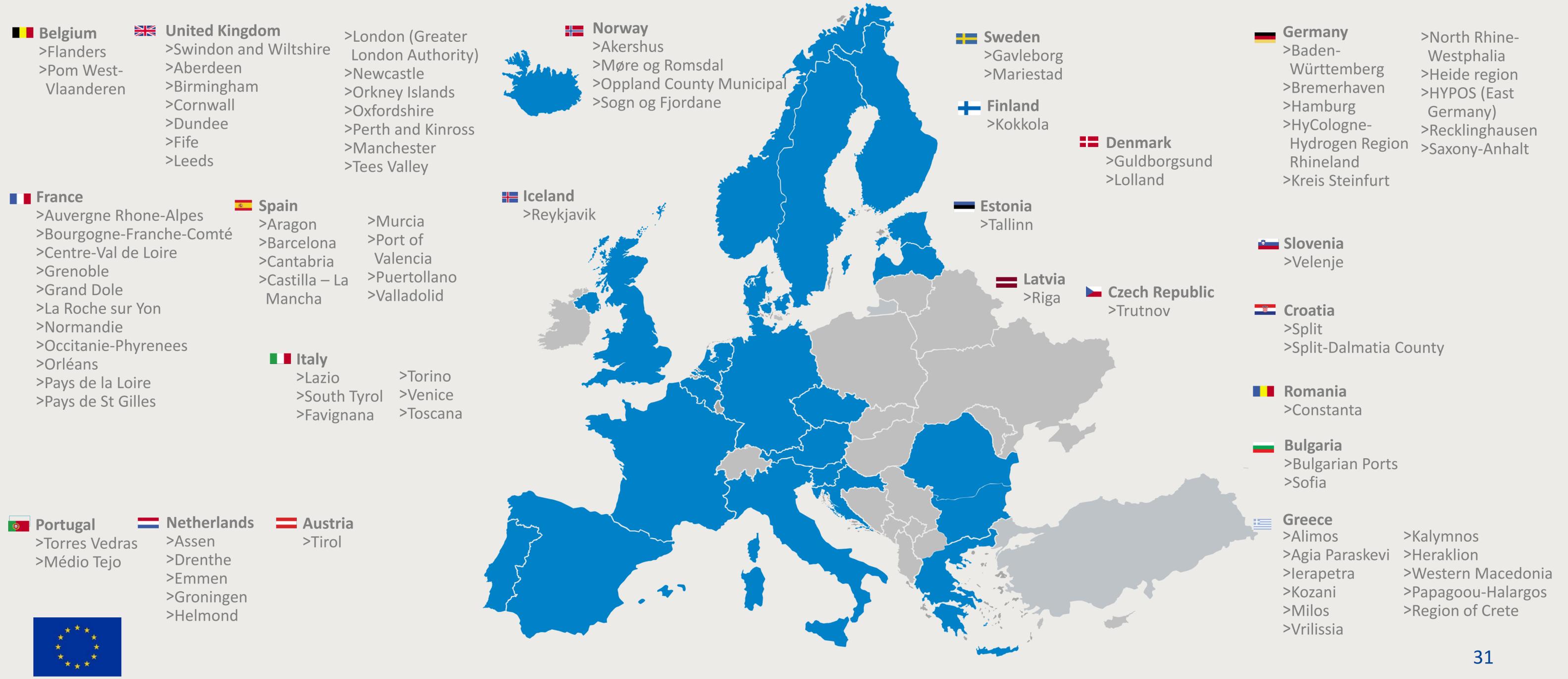
Consortium Partners: ECN, grexel, TUM



FCH-JU initiative: 91 Regions/Cities from 22 countries (about 25% of EU) study to:



- (1) assess FCH applications,
- (2) identifying financing/funding options
- (3) develop roadmaps,
- (4) engage their stakeholders



Looking to the future

Energy ministers of 25 European countries signed the “Hydrogen initiative” launched by the Austrian presidency in Linz.



Last week Slovenia, Ireland and Slovakia has signed too, Only UK and **Sweden** have not signed as EU M/S

<https://www.eu2018.at/latest-news/news/09-18-Informal-meeting-of-energy-ministers.html>

H₂ Ministerial in Tokyo, 23 Oct. '18



- Horizon Europe mentions H₂ and Fuel Cells.
- Oct. '18: EC proposes partnership for Fuel Cells and H₂
- EC Seek to agree by Jan. '19

EU new gas directive is in preparation

EU Mid-century (2050) strategy is being prepared and Hydrogen will play a role



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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FCH JU

Public-private-partnerships play a significant role in Hydrogen & Fuel cell technologies commercialization



Technology explanation

Fuel Cell

A fuel cell is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen-containing fuel with oxygen or another oxidizing agent

