FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

FCH JU:

Making hydrogen and fuel cells an everyday reality

CARLOS NAVAS

«Trasporti ad idrogeno per una migliore qualità dell'aria»
Spilamberto, 29 September 2018

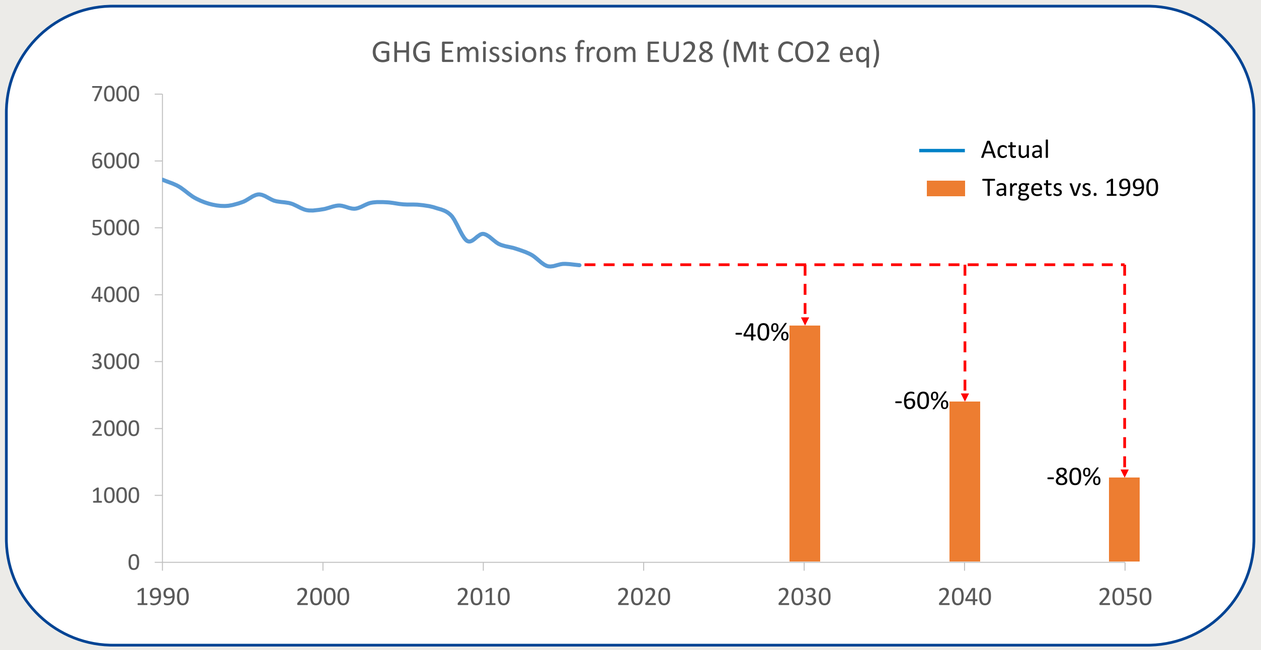
CO2 and Pollution are the problem

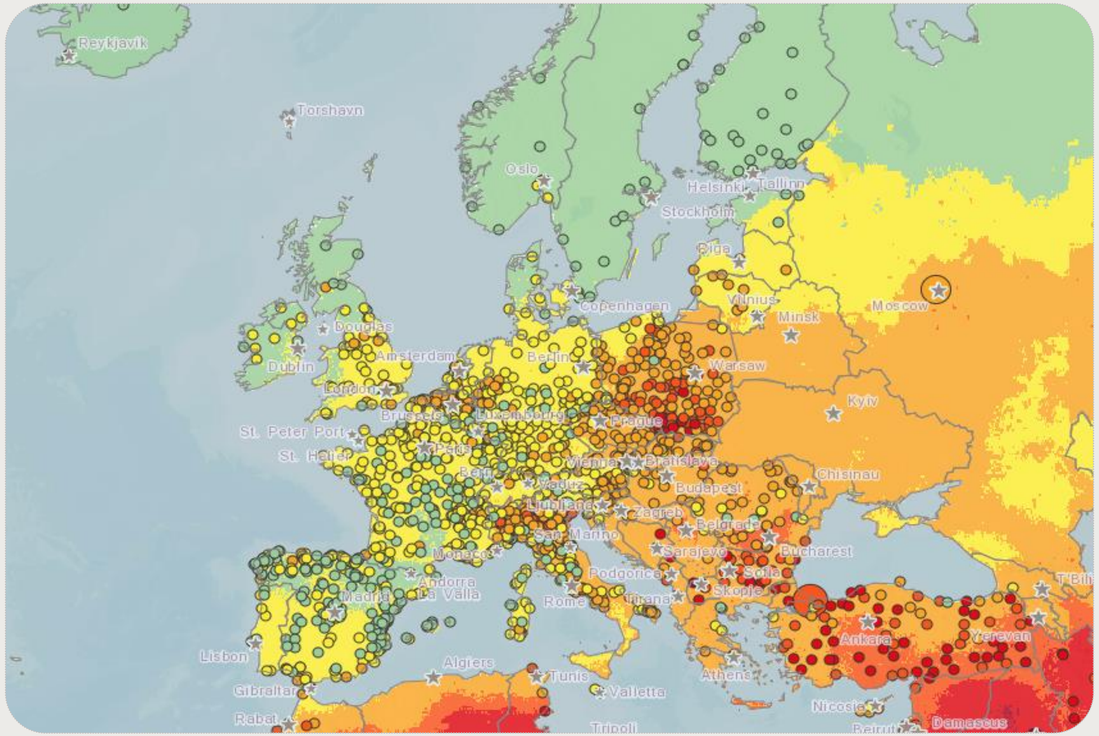
A) CO_2 problem:

- ✓ Ambitious targets for decarbonisation require a new energy system in the future
- ✓ Transport accounts for nearly a quarter of the CO_2 and is increasing

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



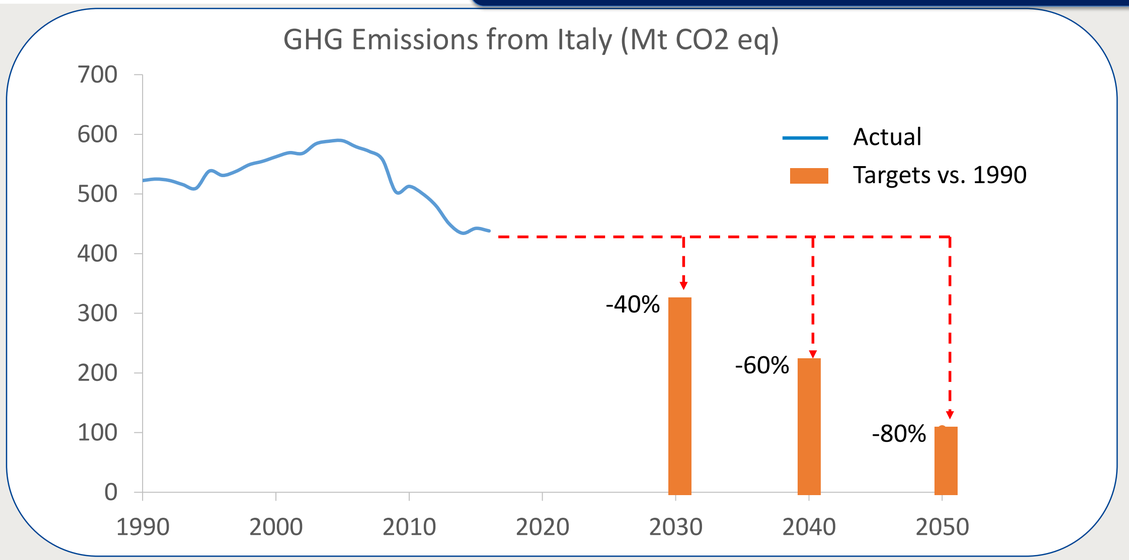


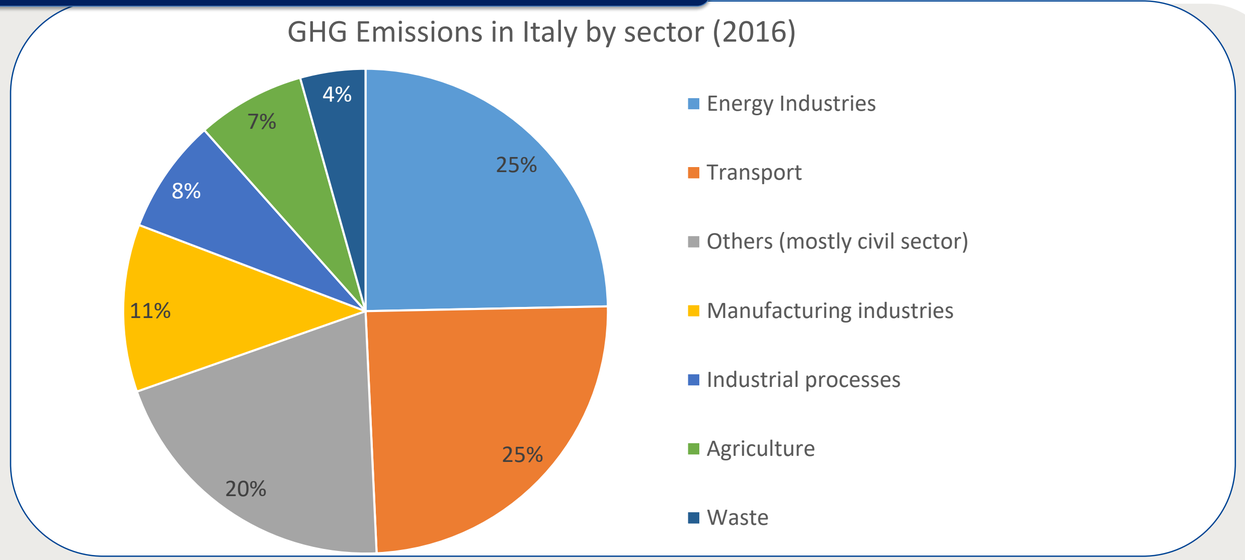
Source: European Environmental Agency

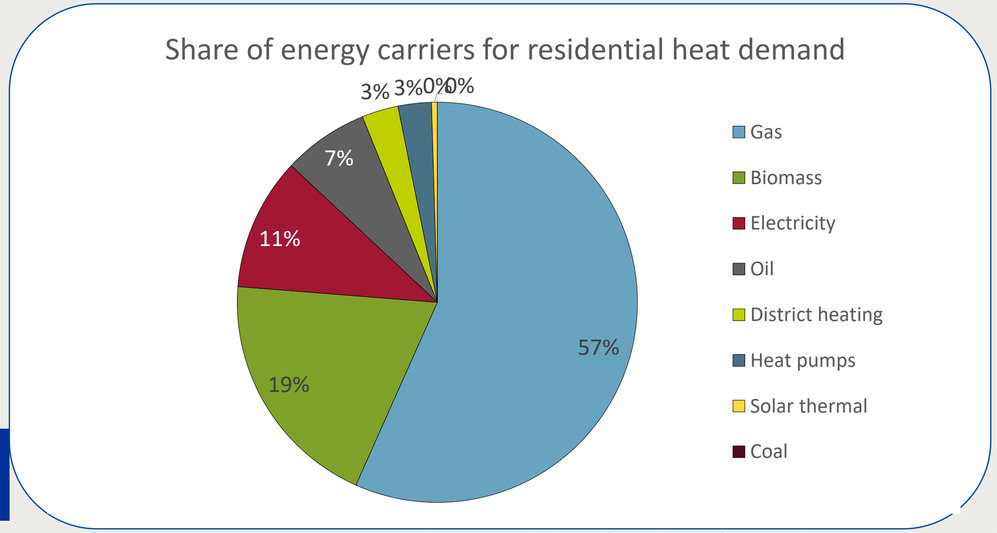
The Challenge in Italy: Reducing CO2 Emissions

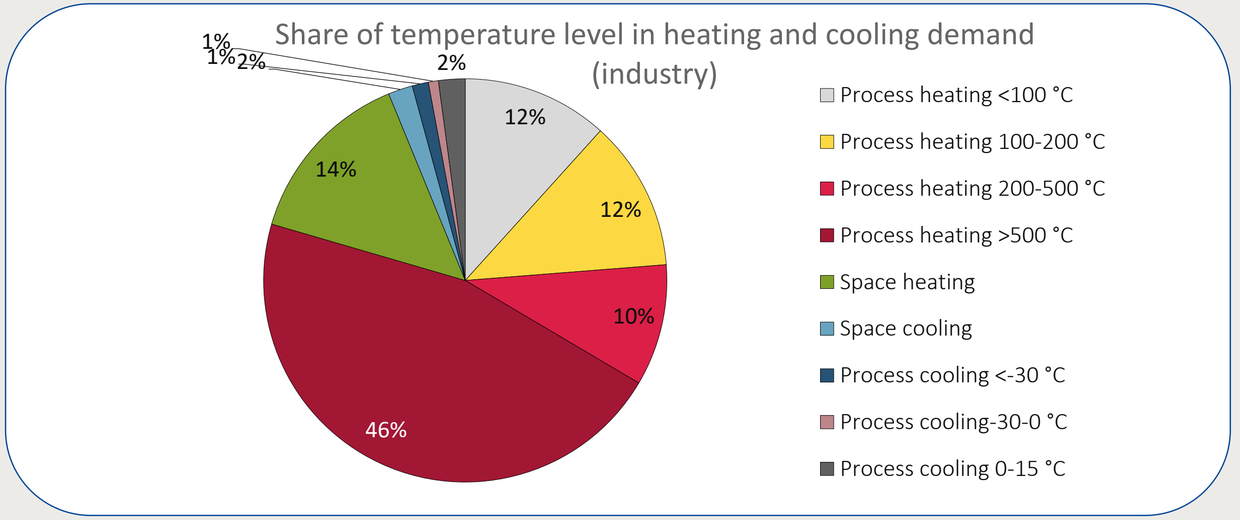
A transition to a new energy system is required

Strong reliance on natural gas and high share of industrial high grade heat





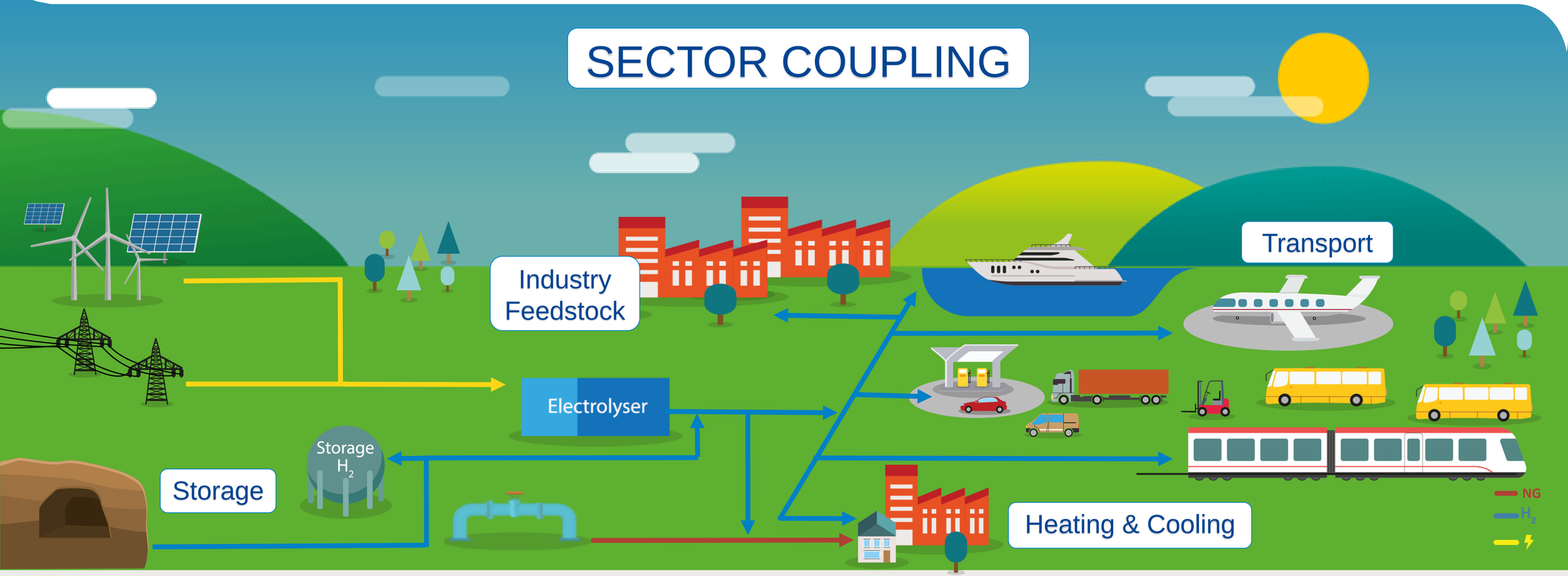




Sources: EEA; Italian Greenhouse Gas Inventory 1990-2016. National Inventory Report 2018. Ispra, Pub 283/2018; heatroadmap.eu

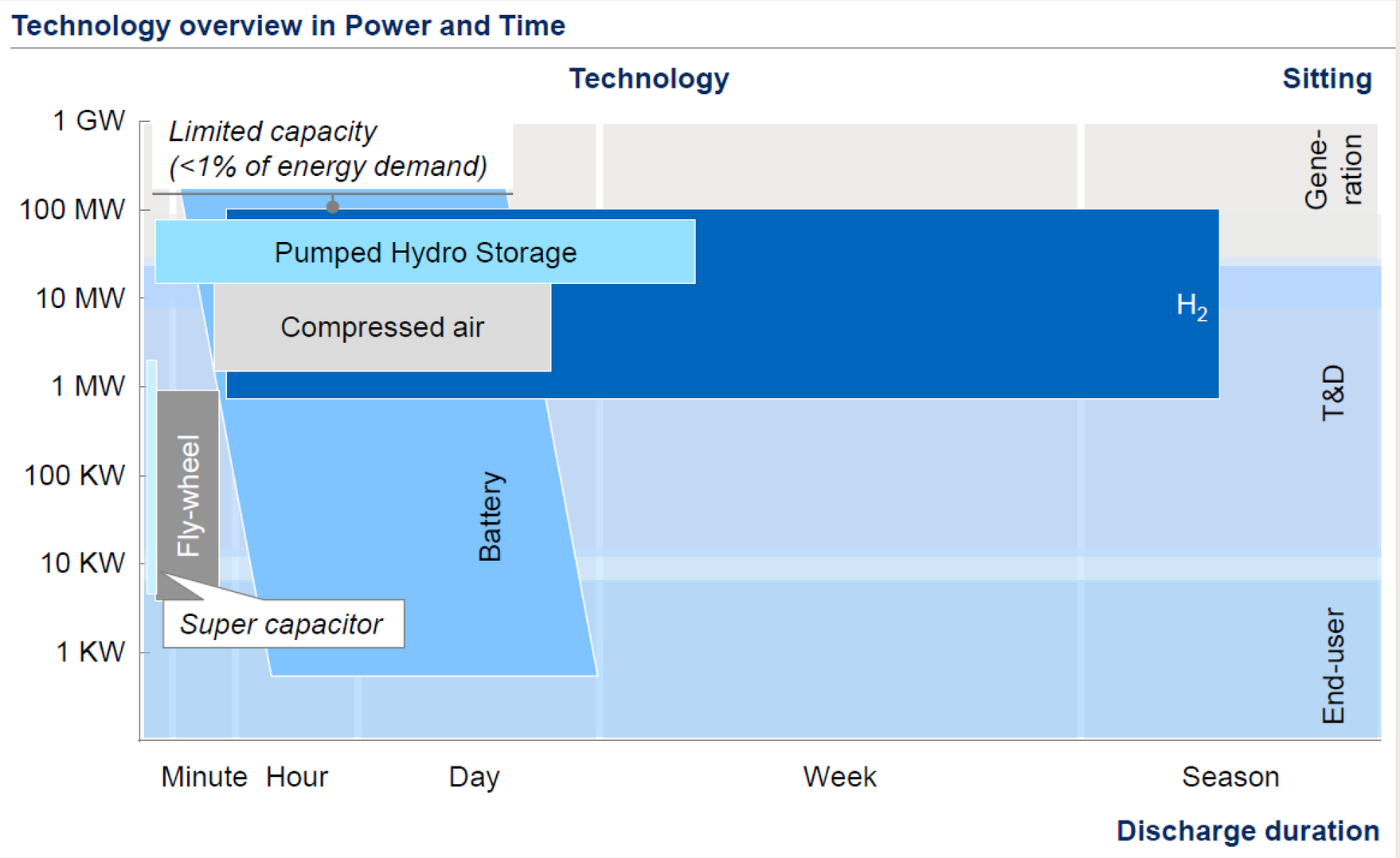
The hydrogen economy

Hydrogen allows more renewables in the energy system and enables sector-coupling



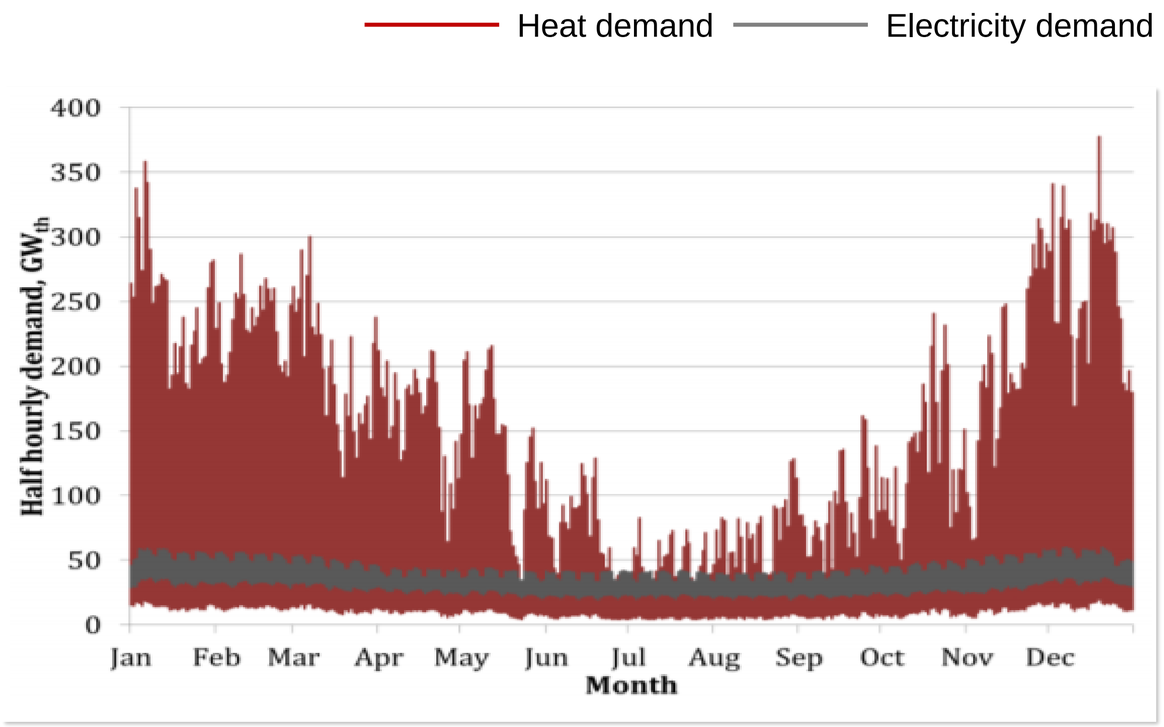
Hydrogen enables RE integration: answers demand imbalances, from short to long term

Long-term storage is particularly relevant in countries with large seasonal energy demand and high shares of renewables



In countries with high seasonal demand, full electrification would require massive new power generation to meet peak winter heat demand

Synthesized half-hourly heat and electricity demand, UK 2010



Implications

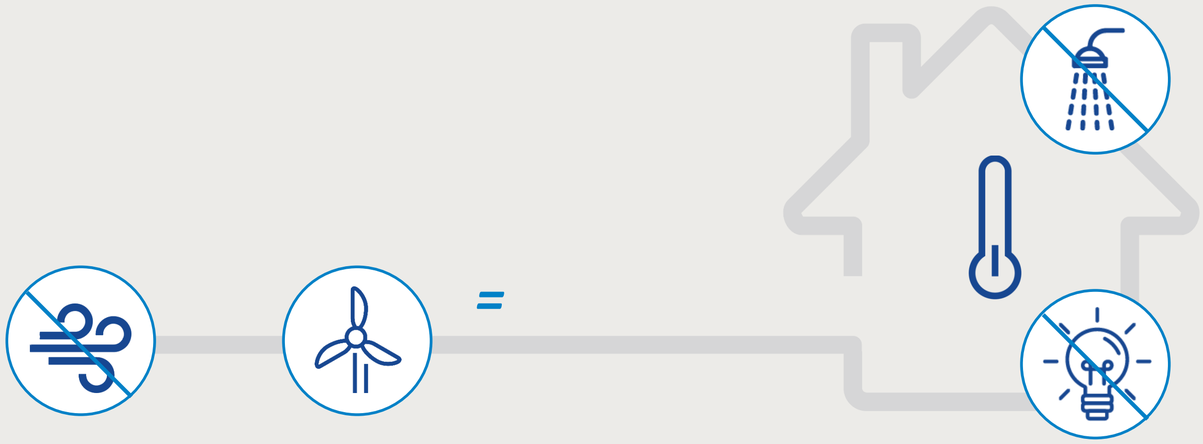
- Peak heating demand significantly higher than peak electricity demand (~360GW compared to ~60GW)
- Heating is primarily gas-based (>80%), since natural gas provides an implicit means of long-term energy storage
- Full electrification of building heating would require a massive increase in electricity generation or in seasonal energy storage (e.g., in pumped hydro)
- H2 provides alternative means of seasonal energy storage due to low discharge duration and high discharge capacity (e.g., underground storage in caverns)

SOURCE: Robert Sansom, Imperial College: Decarbonising Low Grade Heat For A Low Carbon Future, October 2014

Think of the customers: If heating depended on electricity from renewables...

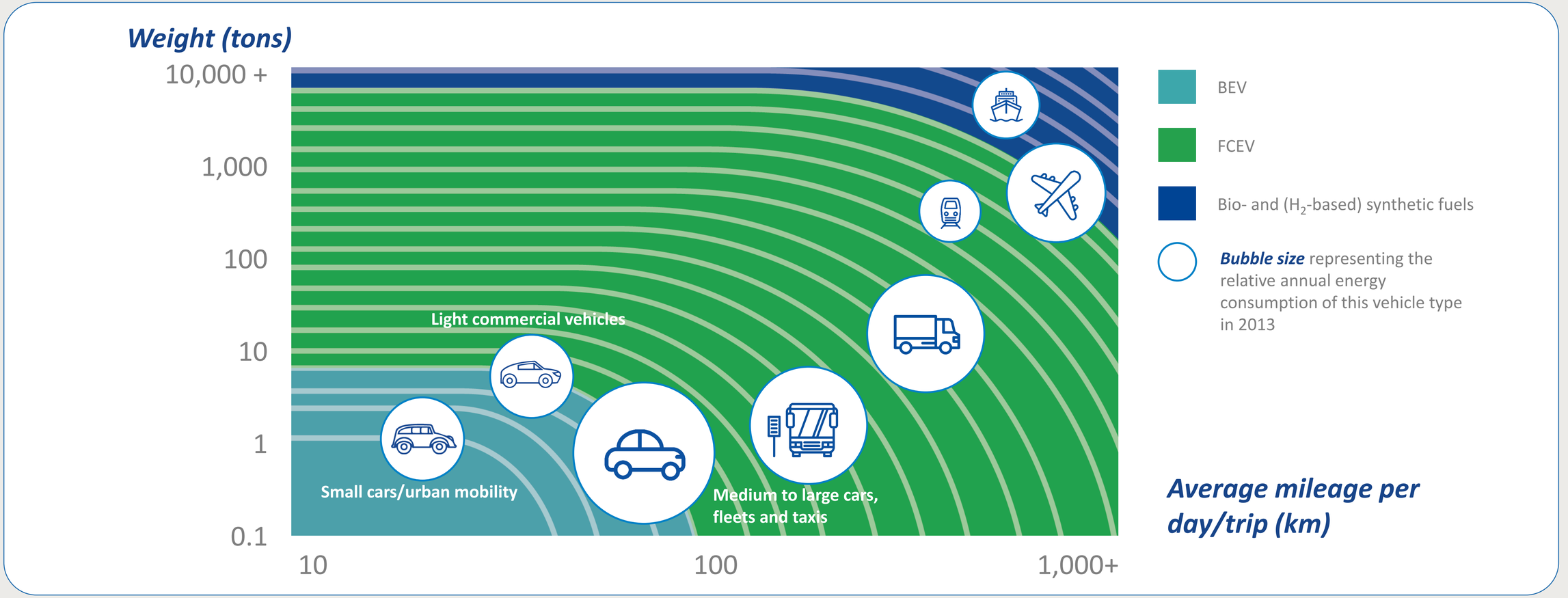
Wind

After no wind for several days…



FCEVs best decarbonisation level for long distances and heavy payloads

Spain’s large surface area makes hydrogen fuel cell vehicles a good fit



Source: “Hydrogen: Scaling Up”, Hydrogen Council, November 2017

Transport: think of the customers

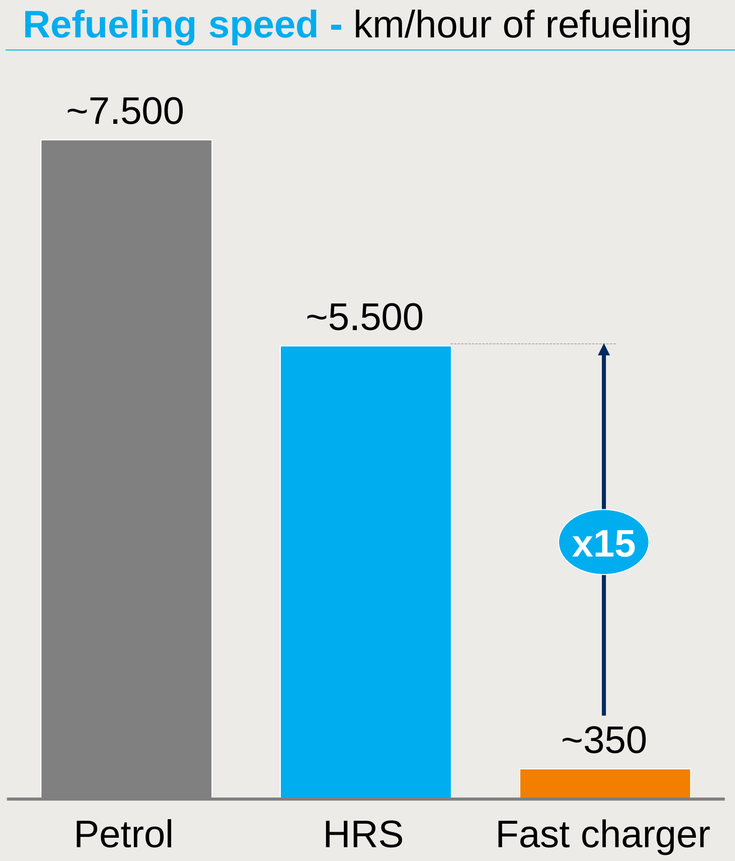
What happens if recharging/refilling each vehicle takes...

How long does this car wait?

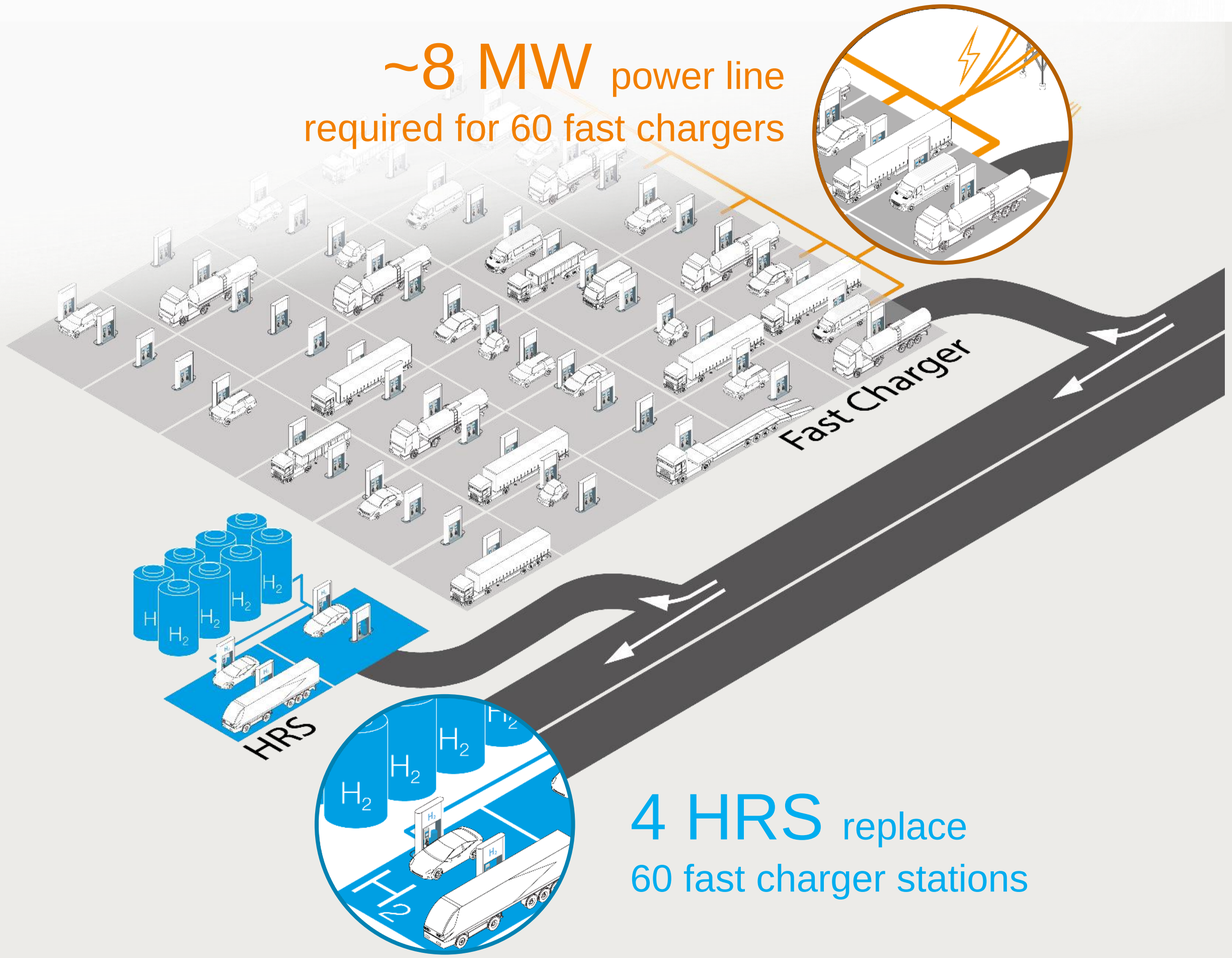
How long does this car wait?

At scale electromobility cannot be done only with batteries

A Hydrogen station is able to refuel ~15 times more vehicles than a fast charging station, leading to significantly less space requirements



Hydrogen refueling is **15x faster** than fast charging

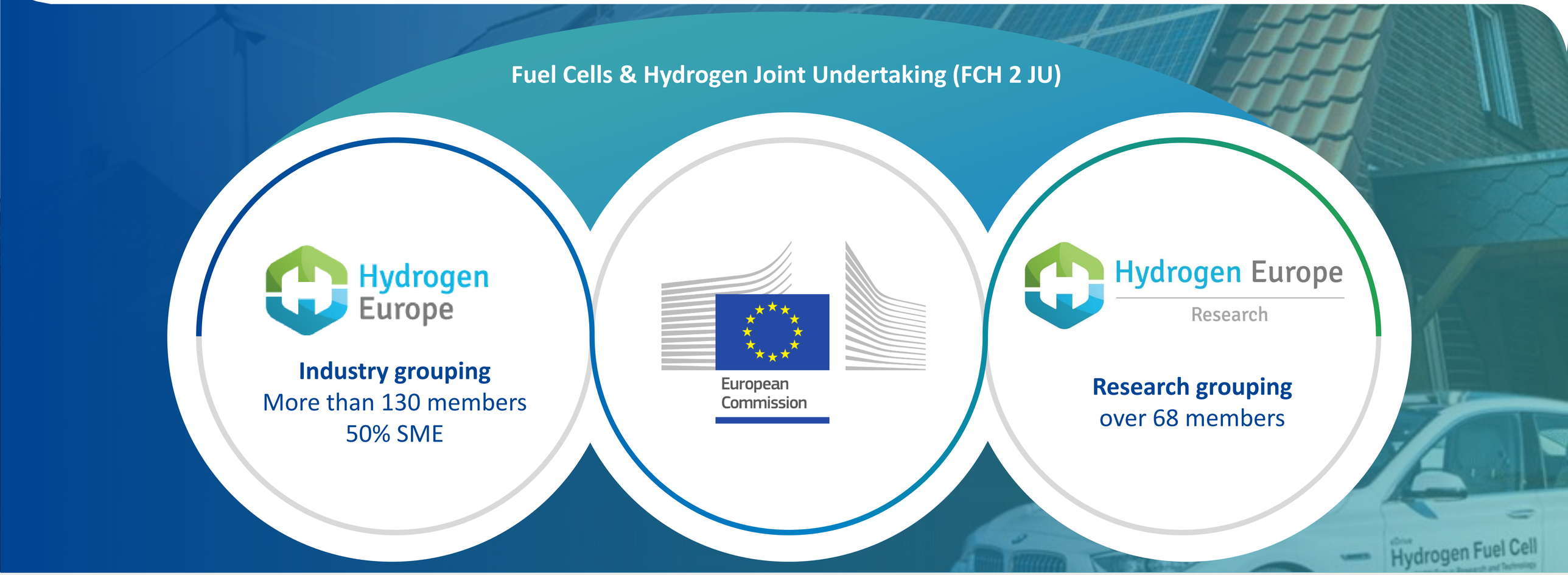


Assumptions: Average mileage of passenger car = 24,000 km; Number of PCs in EU in 2050: ~180 million; ICE: Range = 750 km/refueling, Refueling time = 3 minutes; FCEV: Range: 600 km/refueling, Refueling time = 4, Fast charger = 1,080 km^2; BEV: Range = 470 km/refueling, Refueling time = 75 min, Petrol station = 1,080 m^2

SOURCE: Nationale Plattform Elektromobilität (NPE)

Strong public-private partnership with a focused objective

EU Institutional Public-Private Partnership (IPPP)



To implement an *optimal research and innovation programme* to bring FCH technologies to the point of market readiness by 2020

FCH JU Programme structure

ENERGY

- Hydrogen production and distribution
- Hydrogen storage for renewable energy integration
- Fuel cells for power & combined heat & power generation

TRANSPORT

- Road vehicles
- Non-road vehicles and machinery
- Refuelling infrastructure
- Maritime, rail and aviation applications

CROSS-CUTTING

(e.g. standards, safety, education, consumer awareness, …)

FCH JU (2008-2013):
Total Budget: 940 mill €
EC contribution: 467 mill €

FCH 2 JU (2014-2020):
Total Budget: at least 1.3 bill €
EC contribution: 665 mill €

FCH JU programme implementation

Energy

- Hydrogen production and distribution
- Hydrogen storage for renewable energy integration
- Fuel cells for power & combined heat & power generation

Transport

- Road vehicles
- Non-road vehicles and machinery
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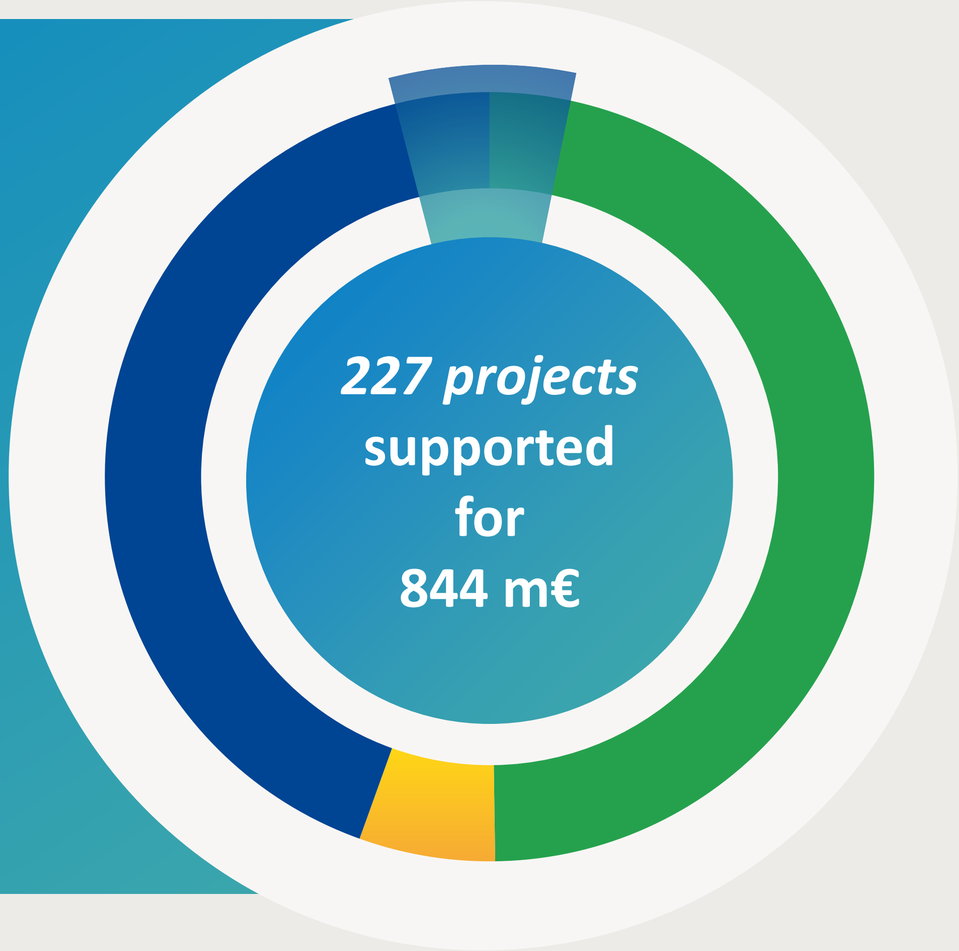
Cross-cutting

- E.g. standards, safety, education, consumer awareness …



48%

401 million euros

128 projects

41%

354 million euros

59 projects

6%

47 million euros

37 projects

5%

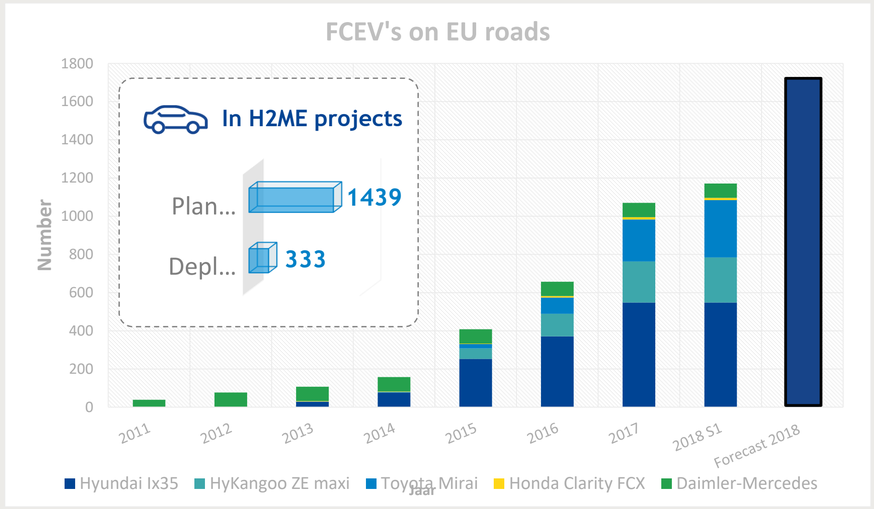
42 million euros

3 projects

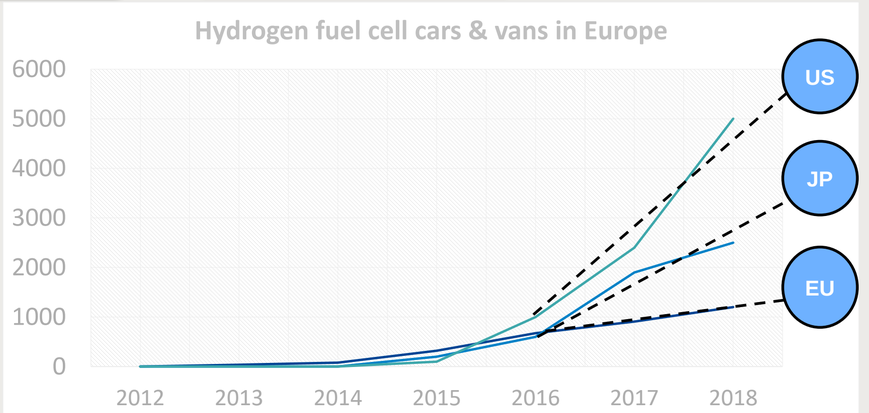
Similar leverage of other sources of funding: 886 m€

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 H_2 competition in '24
- California & Japan sales are going fast due to strong policy support
  EU mobility package is good chance to catch up



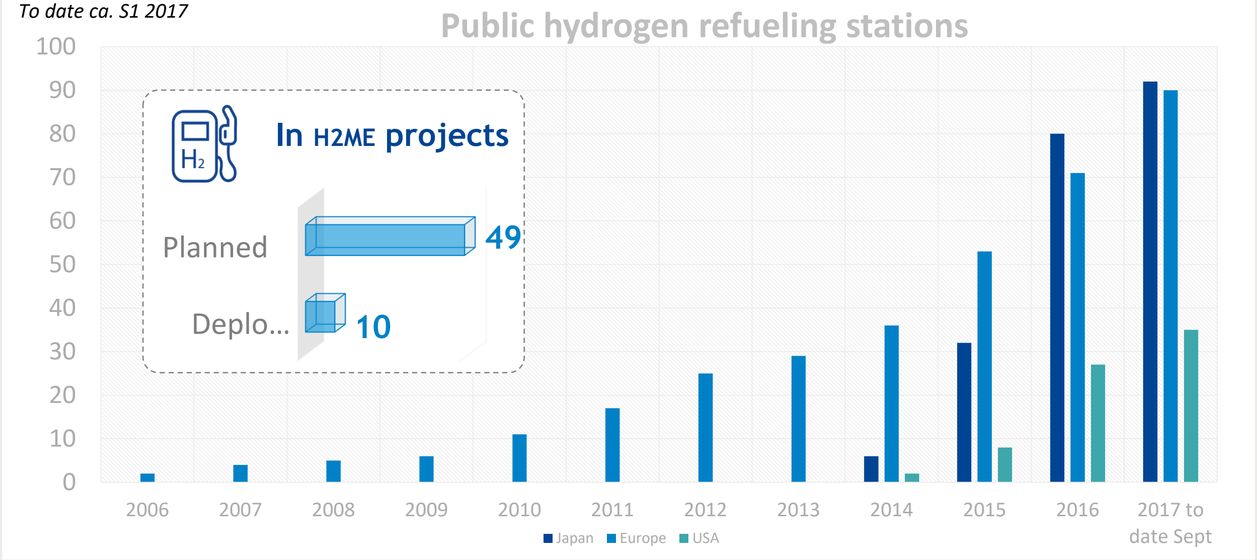
	2018	2020	2022	2025	2030
Europe	1200	-	-	(0.9 -1 mill)*	Tbc **
China	150	5000	-	50.000	1 million
Japan	2500	40.000	-	200.000	800.000
USA	5000	-	-	-	-
S-Korea	0	-	16.000	-	-

* According to the action plan of Alternative Fuel Directive
** FCH JU 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

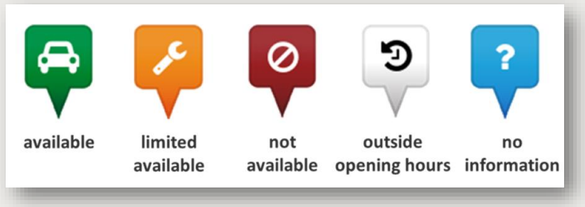
Source: FCH JU KM data collection file, 20/09/2017, public stations
USA-DoE & CaFCP, Japan-HySUT
To date ca. S1 2017

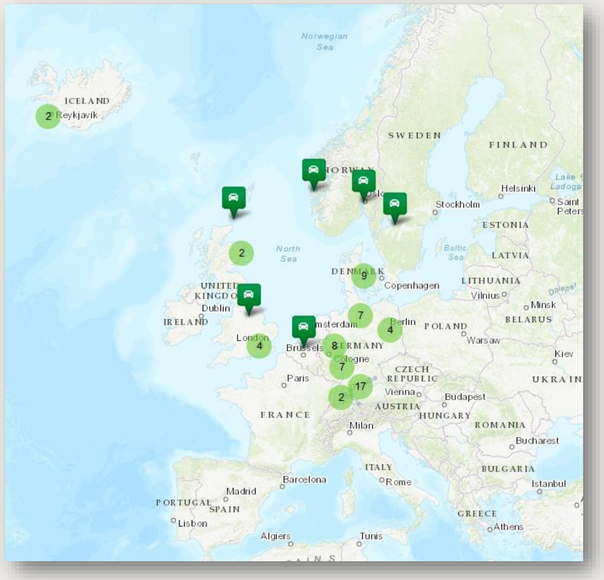


	2018	2020	2022	2025	2030
Europe	100	-	-	(820~842)*	Tbc **
China	12	100	-	350	1000
Japan	100	160	-	320	(900)
USA	35	100	-	200~225	-
S-Korea	0	-	310	-	-

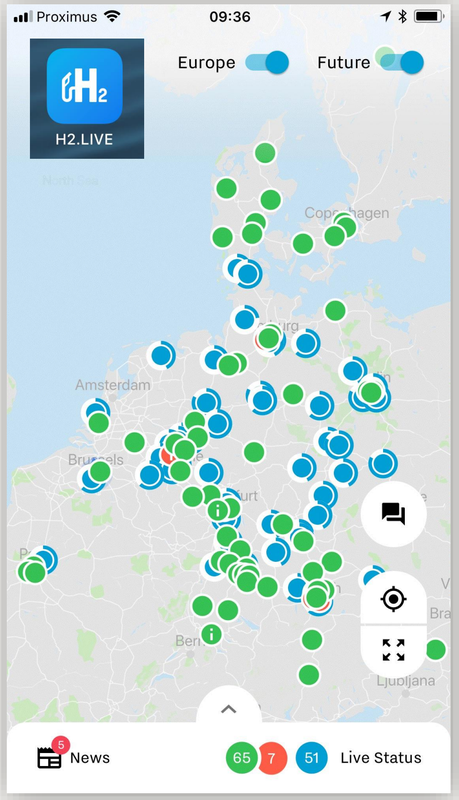
* According to the action plan of Alternative Fuel Directive
** McKinsey study H2: Europe roadmap to be released Oct '18.

Development of a system for HRS availability in the EU





https://h2-map.eu/



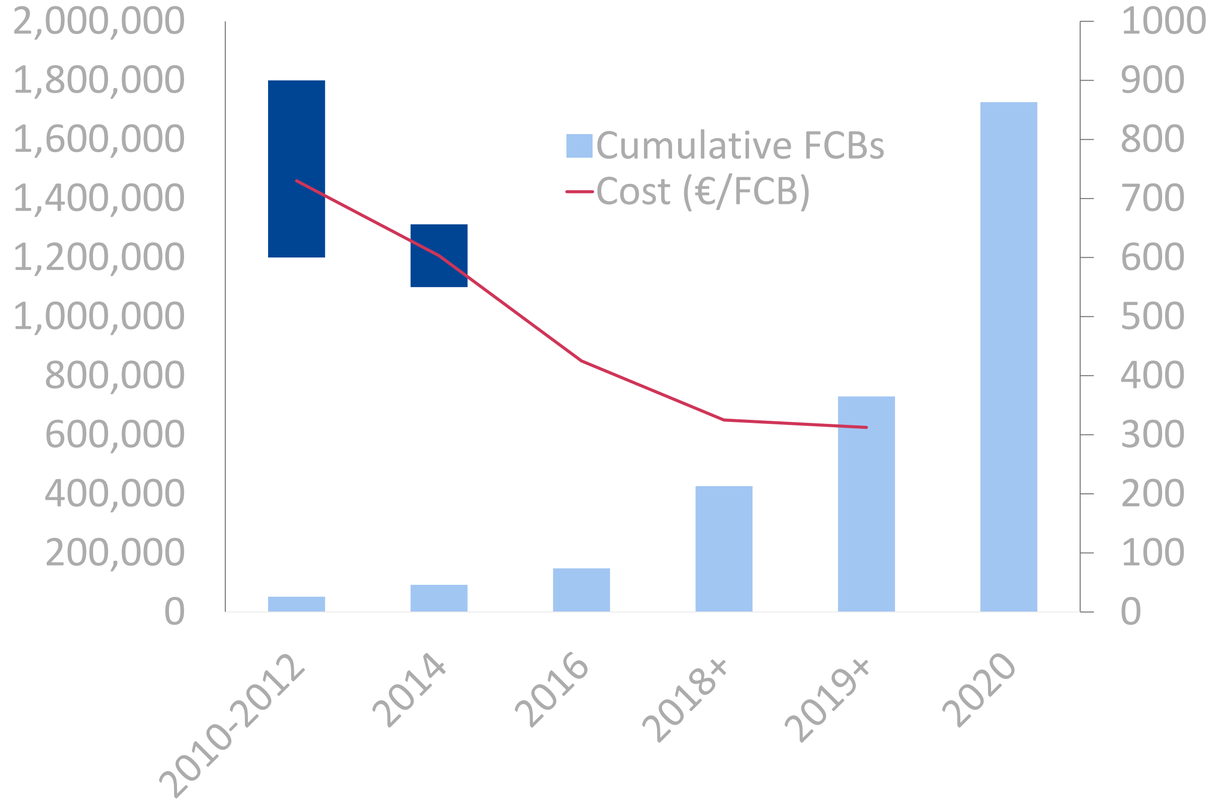
"H2 live" App

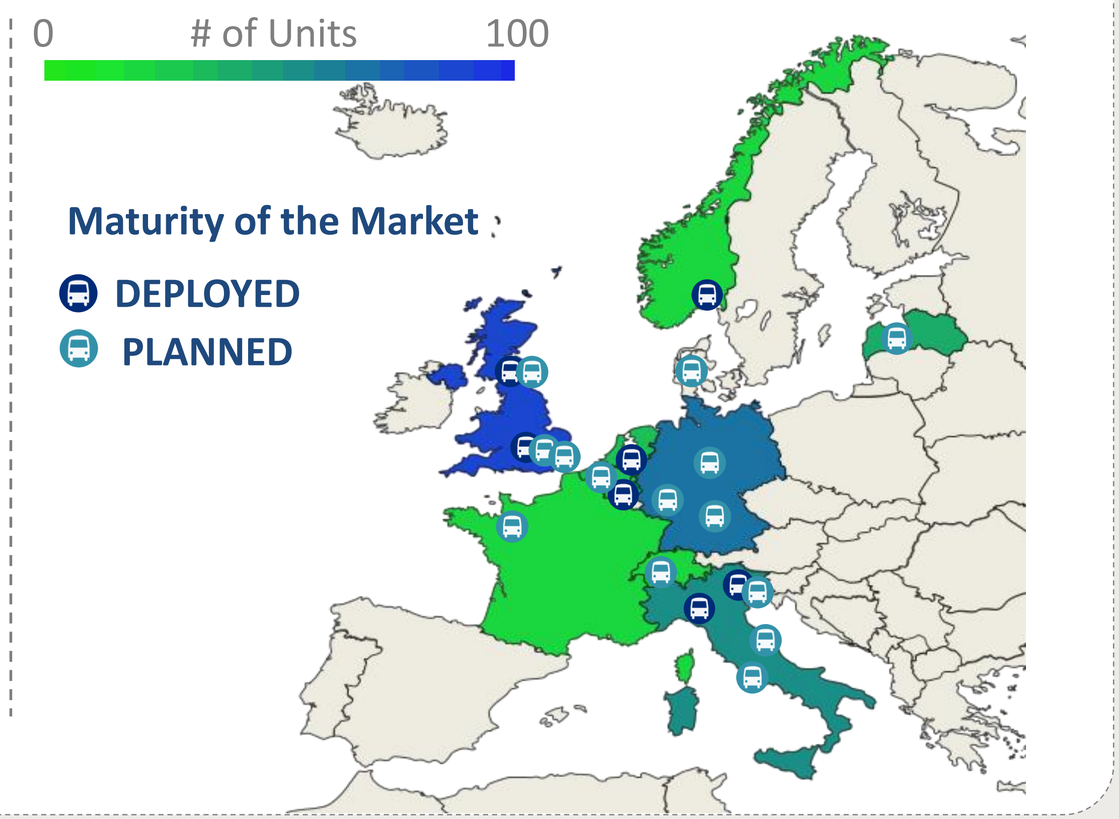
H2 mobility Deutschland

The roll out of hydrogen buses in Europe

Europe is supporting a total of 360 Hydrogen buses, leading 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 OEMs 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

ESORO COOP

ASKO-SCANIA

VDL - COLRUYT

Nicola Truck

Toyota Truck @LA port

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 APUs but was found to 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

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Norway aims for 1000 hydrogen trucks by 2023

September 19, 2018

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
- H_2 train requires up to 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

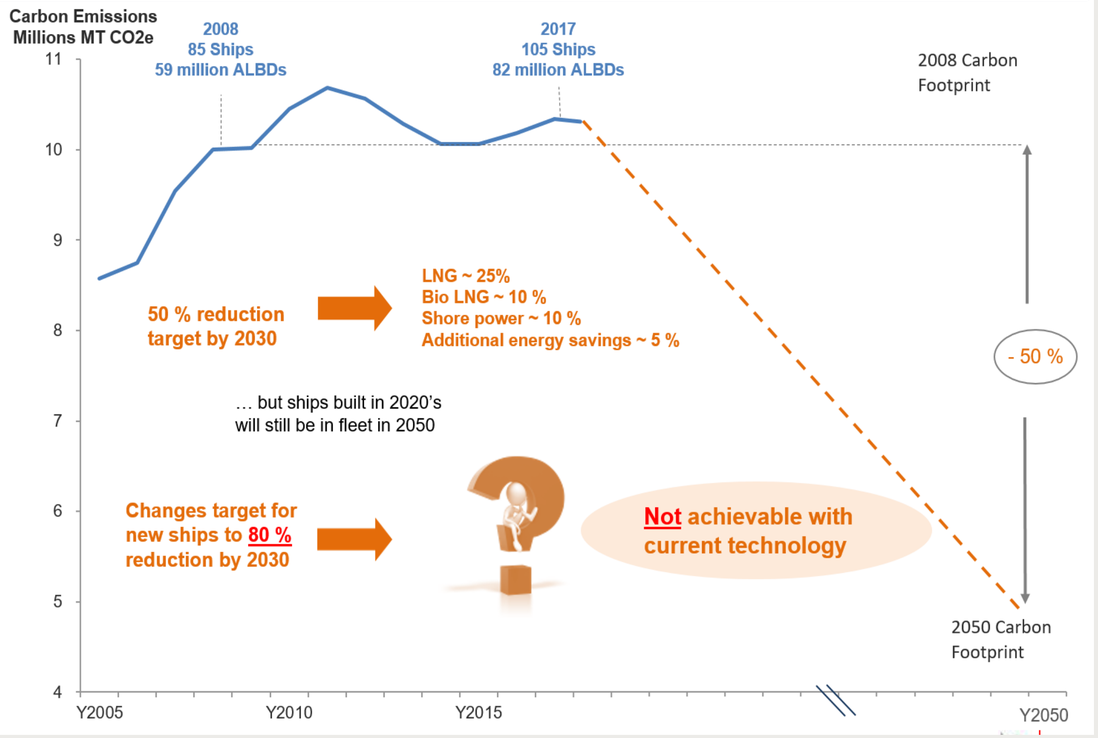
International Maritime Regulations

Class Rules

International Standards

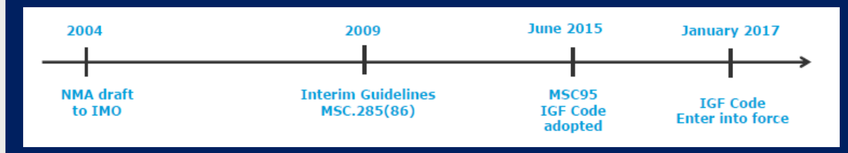
National Regulations

- IMO April 2018: “at least 50% of 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€

Call 2018: 2 successful proposals under GAP

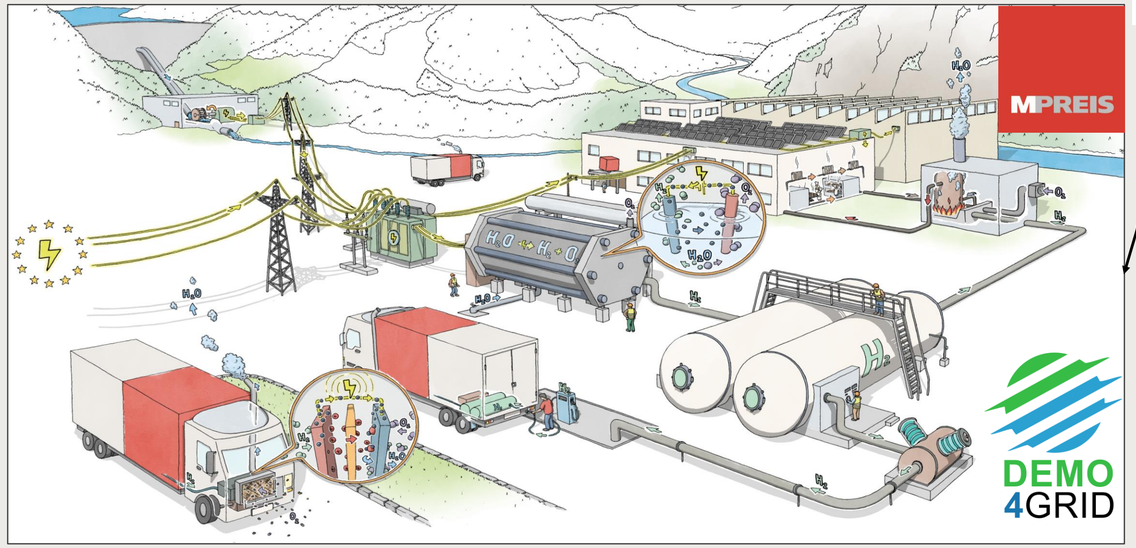
Mid-size passenger ships of inland freight
FC for port/harbor ecosystems

around 9M€

Further R&D needed e.g. LH_2 storage, MW scale Fuel Cells,…

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



(Europe)

FT FINANCIAL TIMES
World business newspaper

Industrials

Austrian steelmaker Voestalpine to test coal-free blast furnace

MICHAEL POOLER

The Austrian steelmaker Voestalpine is to build an experimental facility for producing hydrogen with the aim of

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 Austria. The green hydrogen is produced from hydro-electricity (from the Alps) which is being used to heat the ovens to bake the bread. In a 2nd phase the distribution will be done by H2 trucks

6 MW electrolyser at VOESTALPINE (steel plant) in Linz Austria. The green hydrogen is produced from hydro-electricity (from the Alps) which is being used to produce steel in this way the industry can make a first step towards CLEAN STEEL

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, Germany

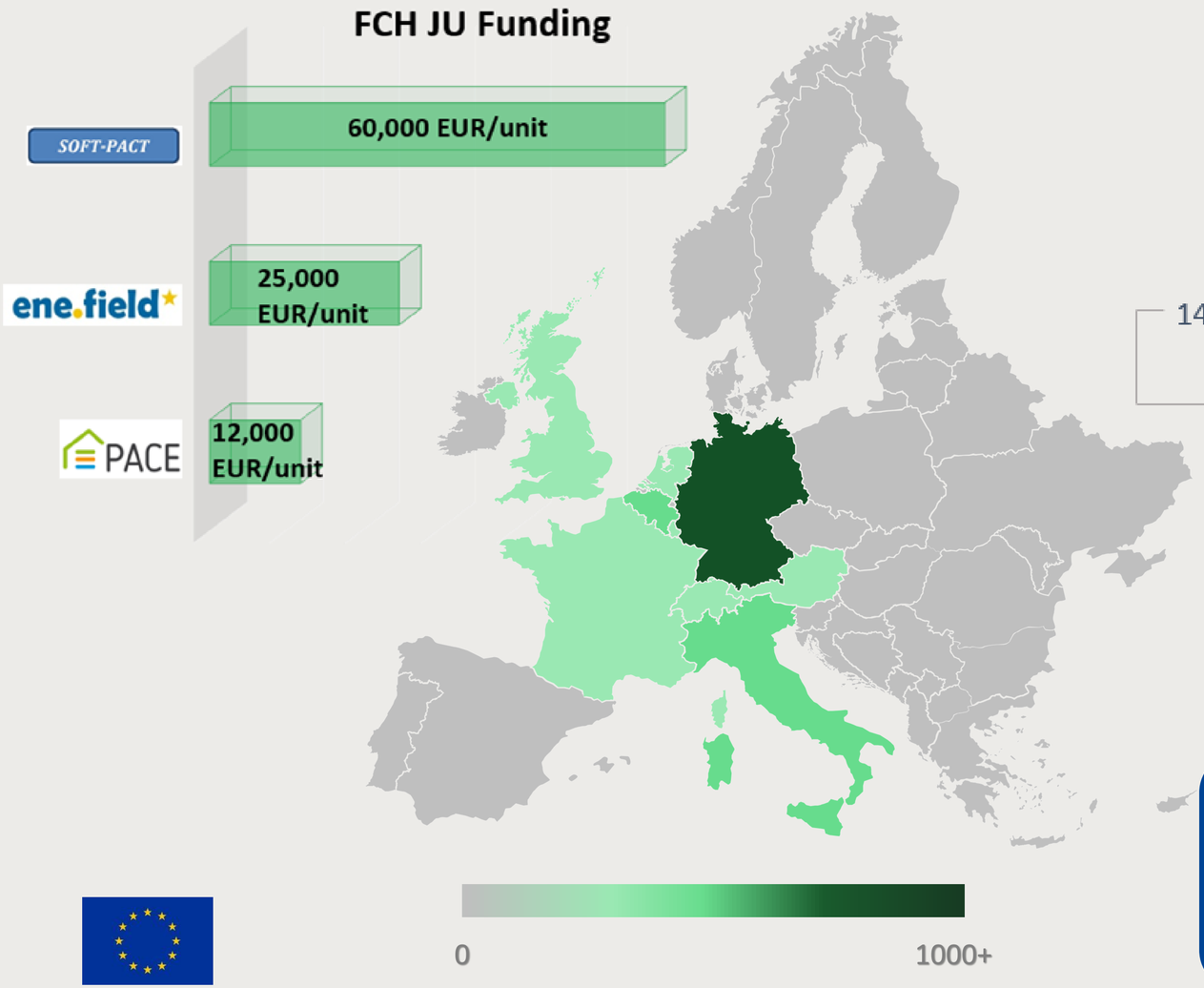
The green Hydrogen is produced from curtailed wind energy which can not be put on the electricity net as it is already full and so the produced hydrogen will be injected in the natural gas grid (part of it can be used for Shell internal processes)

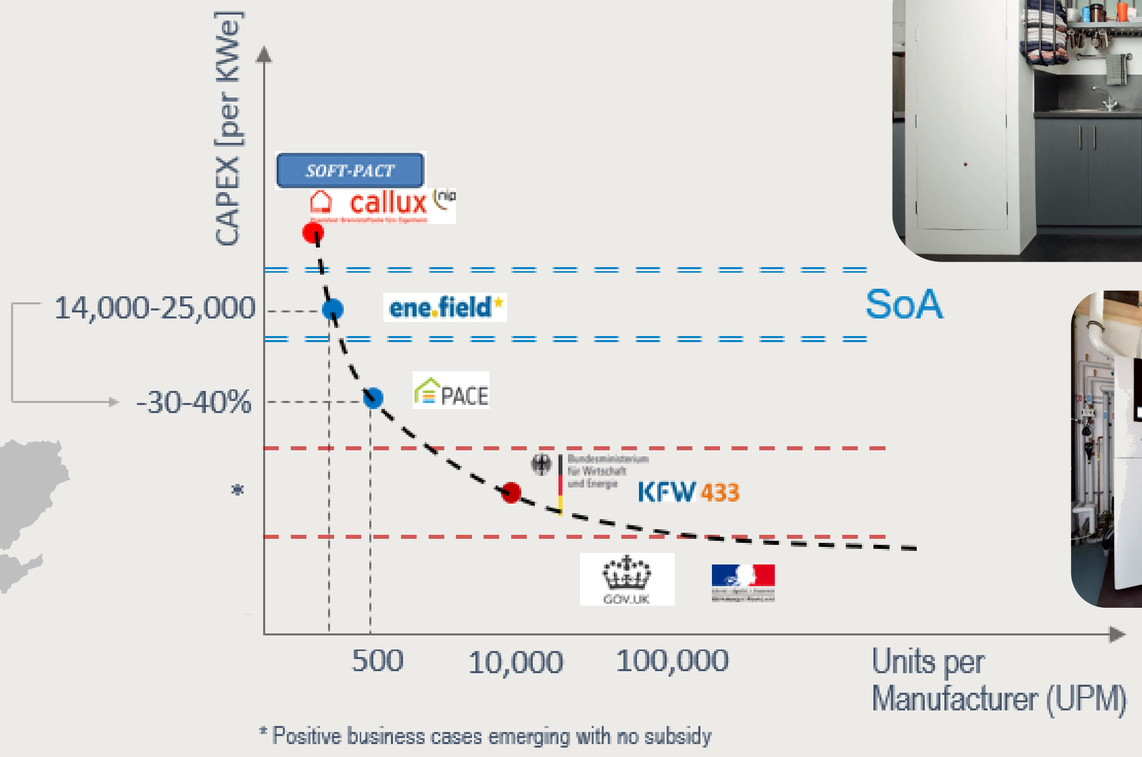
150/30kW Reversible electrolyser, Salzgitter, Germany

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 hydrogen or electricity.

Over 1000 fuel cell µCHP systems installed across EU

Track record of domestic heat and power systems created





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

91 Regions/Cities from 22 countries representing ca. one quarter of Europe participate

Belgium
>Flanders
>Pom West-Vlaanderen

United Kingdom
>Swindon and Wiltshire
>Aberdeen
>Birmingham
>Cornwall
>Dundee
>Fife
>Leeds
>London (Greater London Authority)
>Newcastle
>Orkney Islands
>Oxfordshire
>Perth and Kinross
>Manchester
>Tees Valley

Norway
>Akershus
>Møre og Romsdal
>Oppland County Municipal
>Sogn og Fjordane

Sweden
>Gavleborg
>Mariestad

Finland
>Kokkola

Denmark
>Guldborgsund
>Lolland

Germany
>Baden-Württemberg
>Bremerhaven
>Hamburg
>HyCologne-Hydrogen Region Rhineland
>Kreis Steinfurt
>North Rhine-Westphalia
>Heide region
>HYPOS (East Germany)
>Recklinghausen
>Saxony-Anhalt

France
>Auvergne Rhone-Alpes
>Bourgogne-Franche-Comté
>Centre-Val de Loire
>Grenoble
>Grand Dole
>La Roche sur Yon
>Normandie
>Occitanie-Phyrenees
>Orléans
>Pays de la Loire
>Pays de St Gilles

Spain
>Aragón
>Barcelona
>Cantabria
>Castilla – La Mancha
>Murcia
>País Vasco
>Port of Valencia
>Puertollano
>Valladolid

Iceland
>Reykjavik

Estonia
>Tallinn

Latvia
>Riga

Czech Republic
>Trutnov

Slovenia
>Velenje

Croatia
>Split
>Split-Dalmatia County

Italy
>Lazio
>South Tyrol
>Favignana
>Torino
>Venice
>Toscana
>Emilia-Romagna

Romania
>Constanta

Bulgaria
>Bulgarian Ports
>Sofia

Portugal
>Torres Vedras
>Médio Tejo

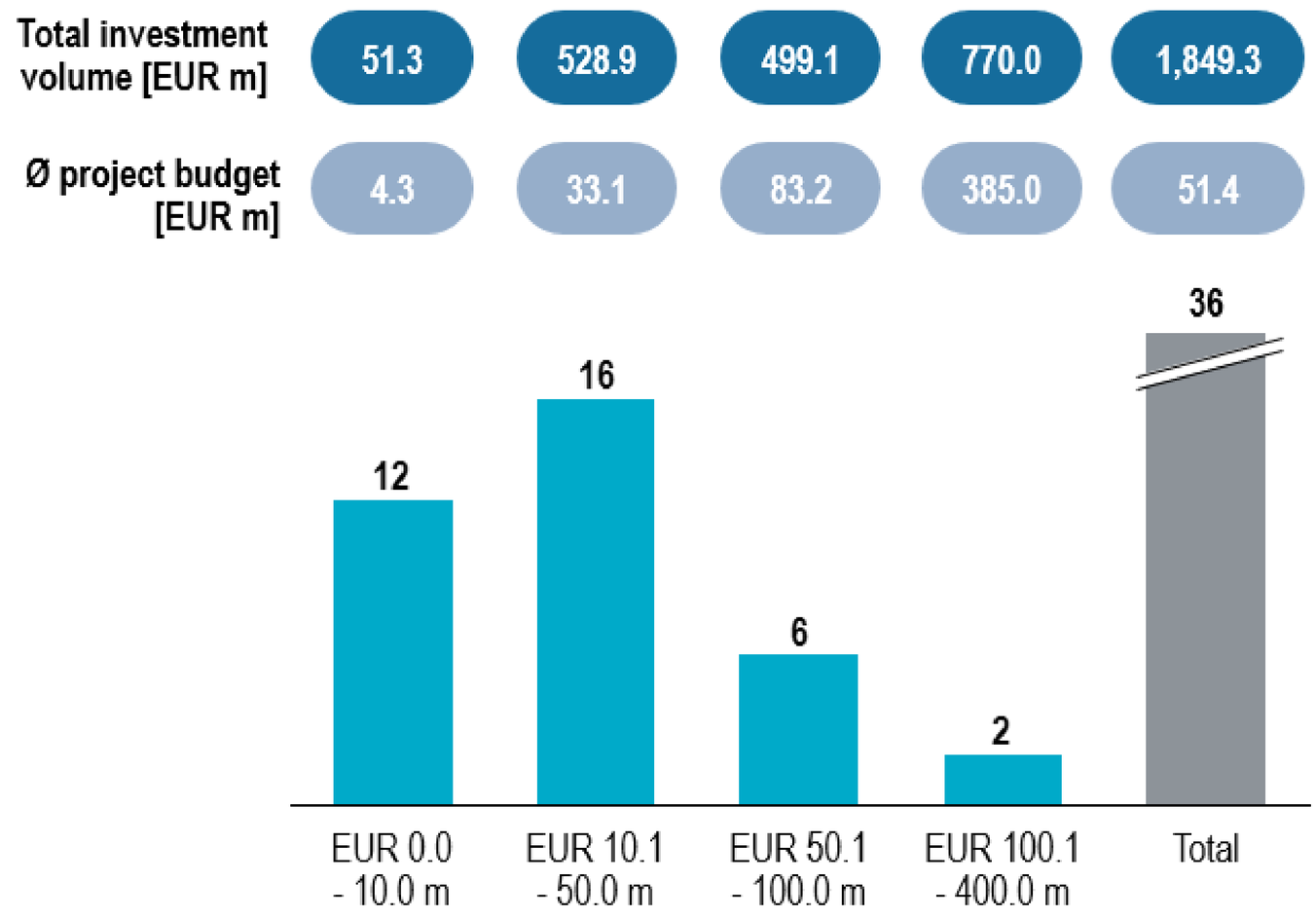
Netherlands
>Assen
>Drenthe
>Emmen
>Groningen
>Helmond

Austria
>Tirol

Greece
>Alimos
>Agia Paraskevi
>Ierapetra
>Kozani
>Milos
>Vrilissia
>Kalymnos
>Heraklion
>Western Macedonia
>Papagoou-Halargos
>Region of Crete

Planned deployments result in total investments of >EUR 1.8bn in the next 5 years – Majority small to medium sized projects

Envisaged investment volumes for next implementation projects



High future FCH investment volumes

> Participants indicate significant investments in FCH projects in the next 5 years and beyond

> Typically, regions with no FCH experience so far start with smaller projects and investments

> Nevertheless, some newcomer regions intend to make significant investments of up to EUR 50 m as well

> Overall investment volume is driven by a few very large projects which aim at realising very ambitious investment plans

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