FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

Transport applications overview

Mirela Atanasiu
Head of Unit

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The role of hydrogen in our society & economy

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

Strong public-private partnership with a focused objective

EU Institutional Public-Private Partnership (IPPP)

Fuel Cells & Hydrogen Joint Undertaking (FCH JU)

Hydrogen Europe

Industry grouping
About 130 companies
50% SME

European Commission

Hydrogen Europe Research

Research grouping
About 70 institutions

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

FCH 2 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 2 JU*:

Total Budget: at least 1.3 bill.€

EU contribution: 665 mill.€

Continuation to previous 2007-2013 programme (at least 1 bill. € total budget)

Technology status in EU projects

FCH JU programme implementation (2008-2018)

Energy

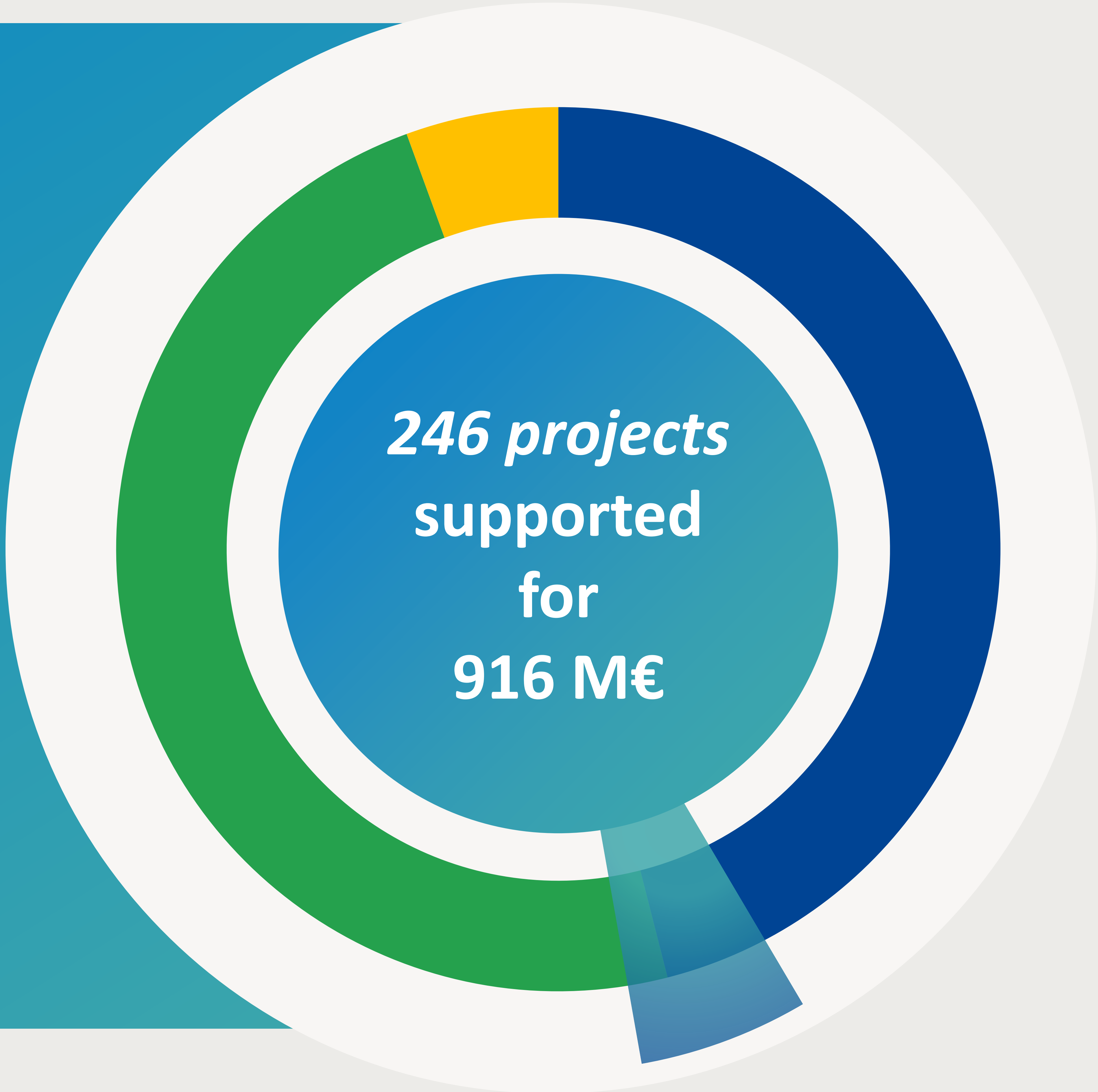
- Hydrogen production and distribution
- Hydrogen storage for renewable energy integration
- Fuel cells for power & combined heat & power generation

Transport

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

Cross-cutting

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



47 %

429 million euros
136 projects

42 %

387.5 million euros
66 projects

6 %

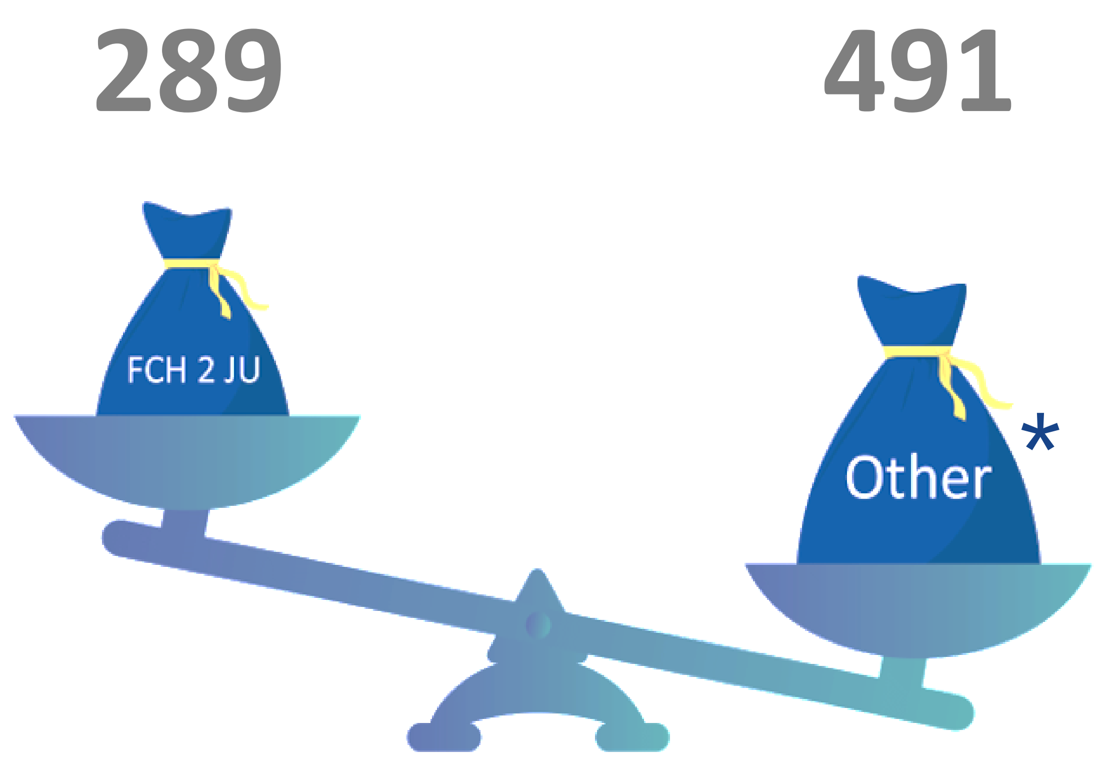
53 million euros
40 projects

5 %

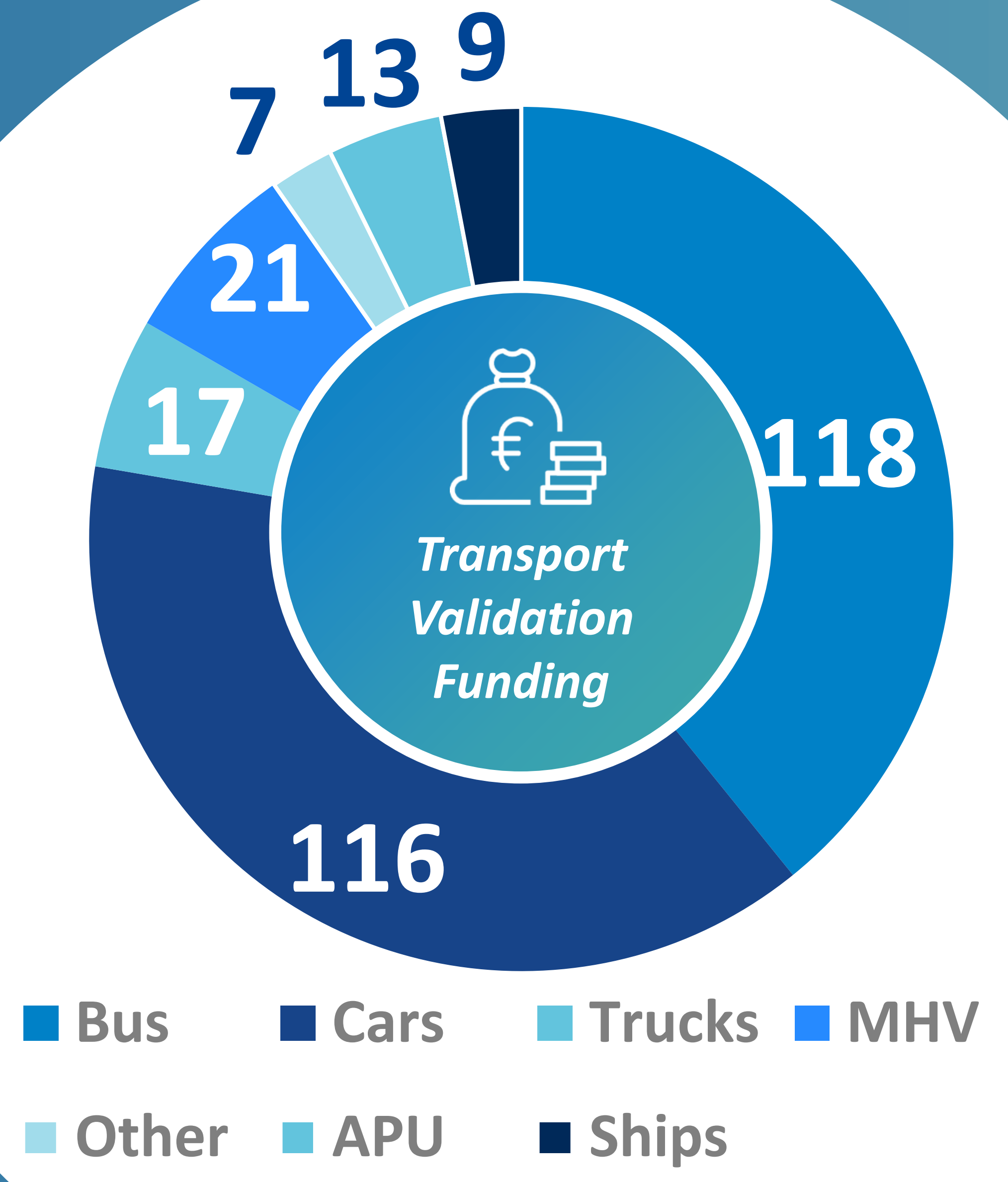
46 million euros
4 projects

Similar leverage of other sources of funding: more than 900 M€

On the road to widespread deployment



M€



M€

Extending the European network

Consolidating as market alternative

Exploring heavy-duty segments

DEPLOYING:

103 HRS

2084 cars

360 buses

273 MHV

31 trucks

** Other resources including private and national/regional funding*

Putting the numbers in the streets

Several models on the road today

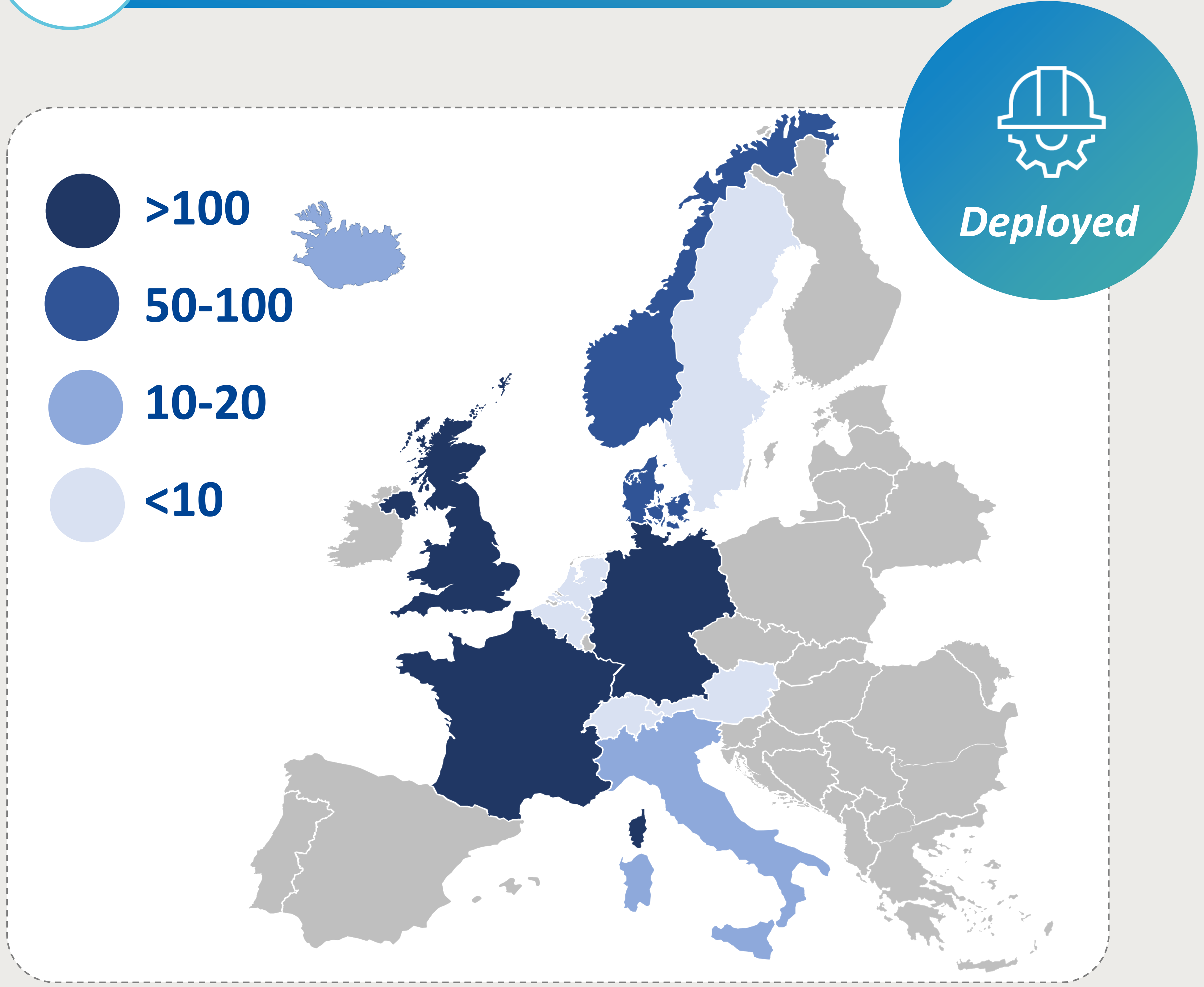
Deploying along the full European geography

12 countries to deploy vehicles within our projects

725 cars deployed

Availability close to 100%

Year (call)	*Projects*	*#FCEV*	*Already deployed*	*Countries*
2008	**H2MOVES**	19	19	2
2010	**Hytec**	24	24	3
2011	**SWARM**	35	13	3
2013	**Hyfive**	133	133	6
2014	**H2ME**	325	325	9
2015	**H2ME 2**	1109	186	10
2015	**BIGHIT**	5	5	1
2017	**ZEFER**	180	120	3



Finished projects are underlined

Cars and small vans are at commercial standards

New car models have been put on the roads, delivery/service fleets to emerge

Achieved since 2016
- > 13,700,000 km driven
- > 72 t of H_2 distributed

Product ready for commercialisation
- Up to 594 km of driving range
- 99.7 % availability
- 1.17 kg/100km average consumption
- > 152.000km travelled by one car

Challenges
- Still few choices in the market
- Cost
- Limited supply in EU

Fleet uses validated

New FCEV models deployed

HRS load reaching 45%

FCEV-RE

Renault is now proposing hydrogen version of its Kangoo and Master ZE

FCEV

The first **60 Daimler GLC FCell** and **30 Hyundai Nexo** deployed under H2ME

Reaching the market phase

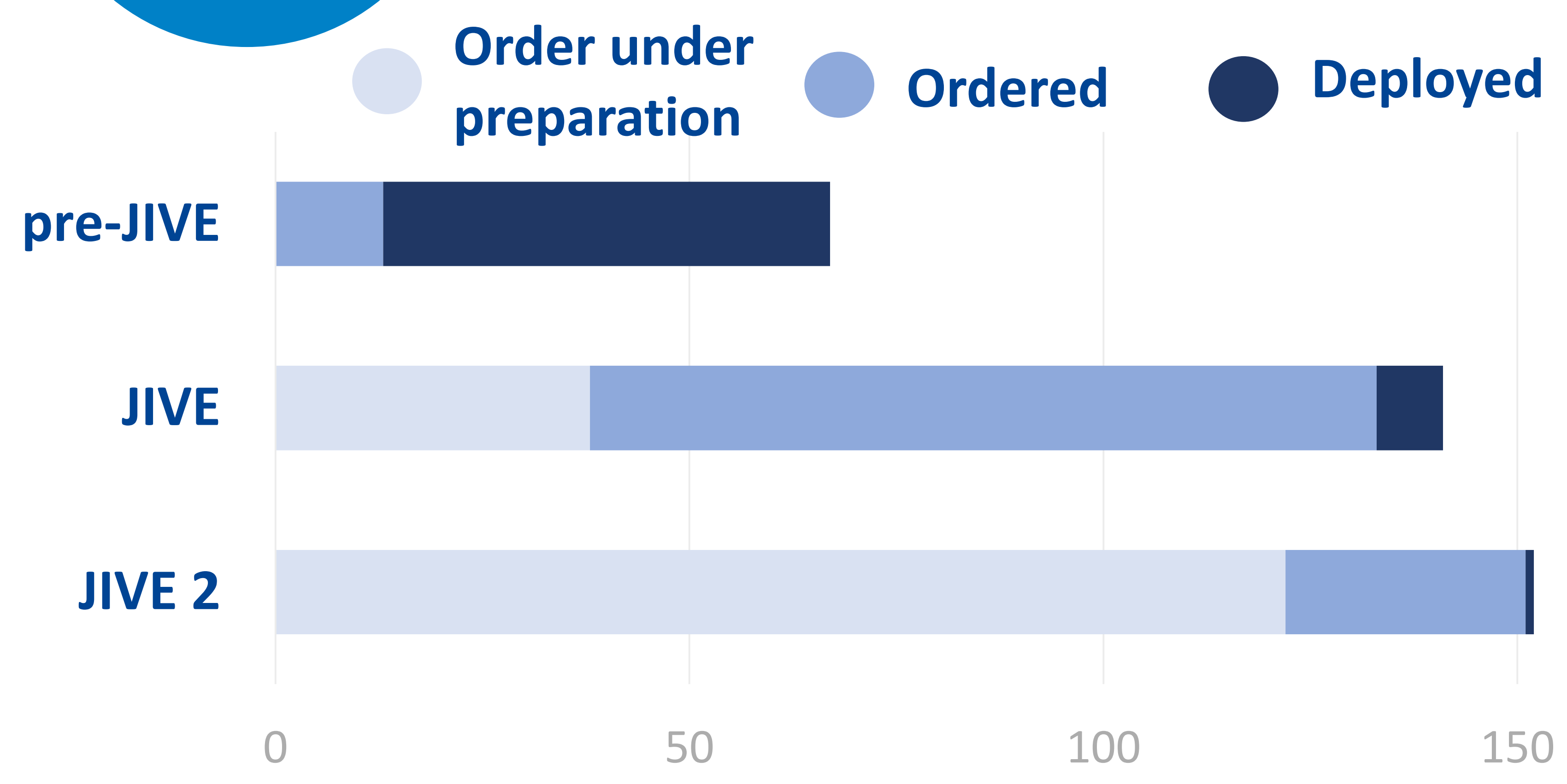
Offering a flexible clean competitive public transport solution

More cities, larger fleets, more suppliers: approaching market stage

80 buses ordered in 2018-19, most of them for operation imminently

50 FCB on the road

Buses deployment status



Next generation products

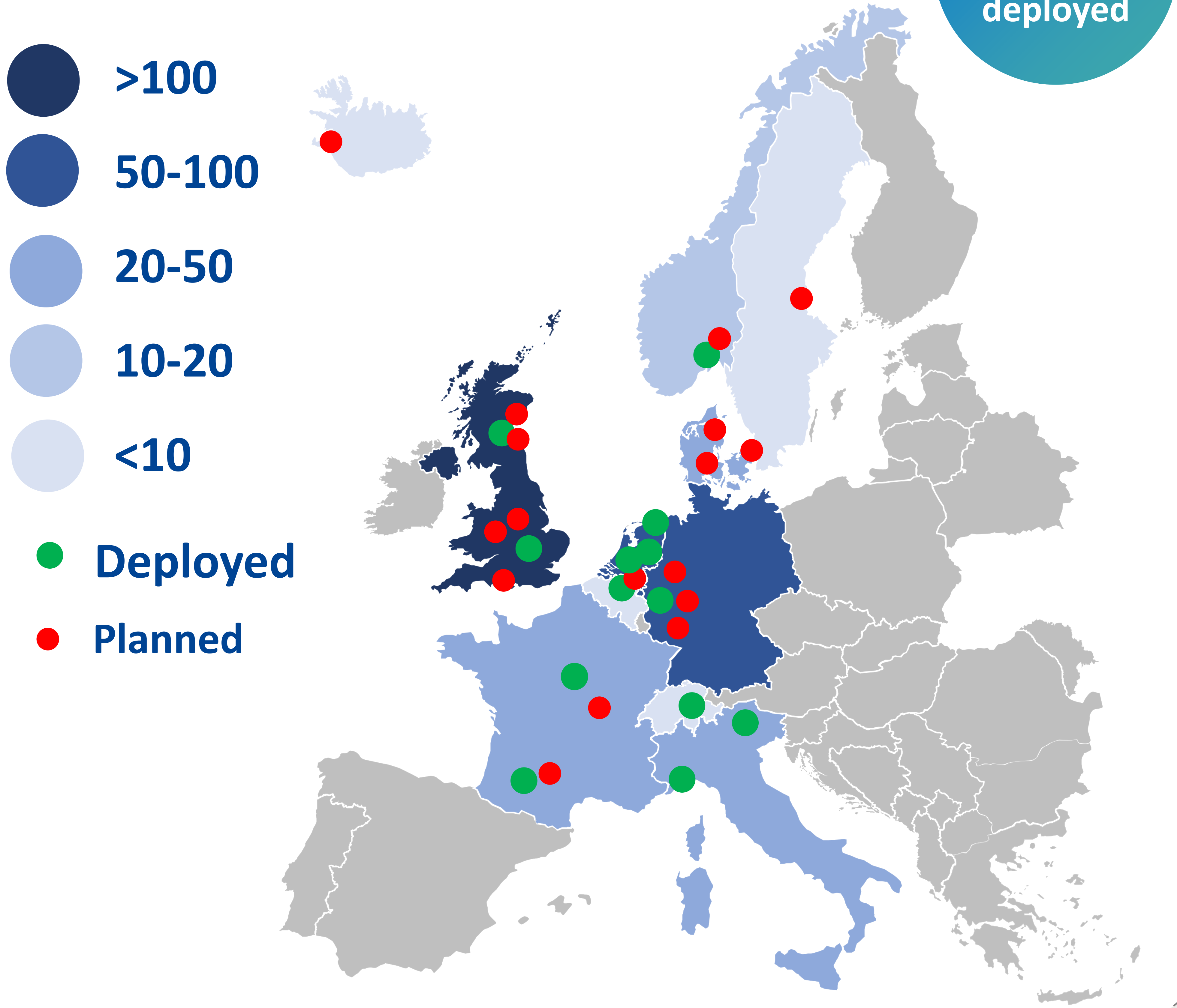
Flexible bus design and lenghts

CEF and EIB support FCB deployment

Bus of the Year 2019

Buses deployment geography

Planned and deployed



A flexible competitive clean solution

Europe is world leader

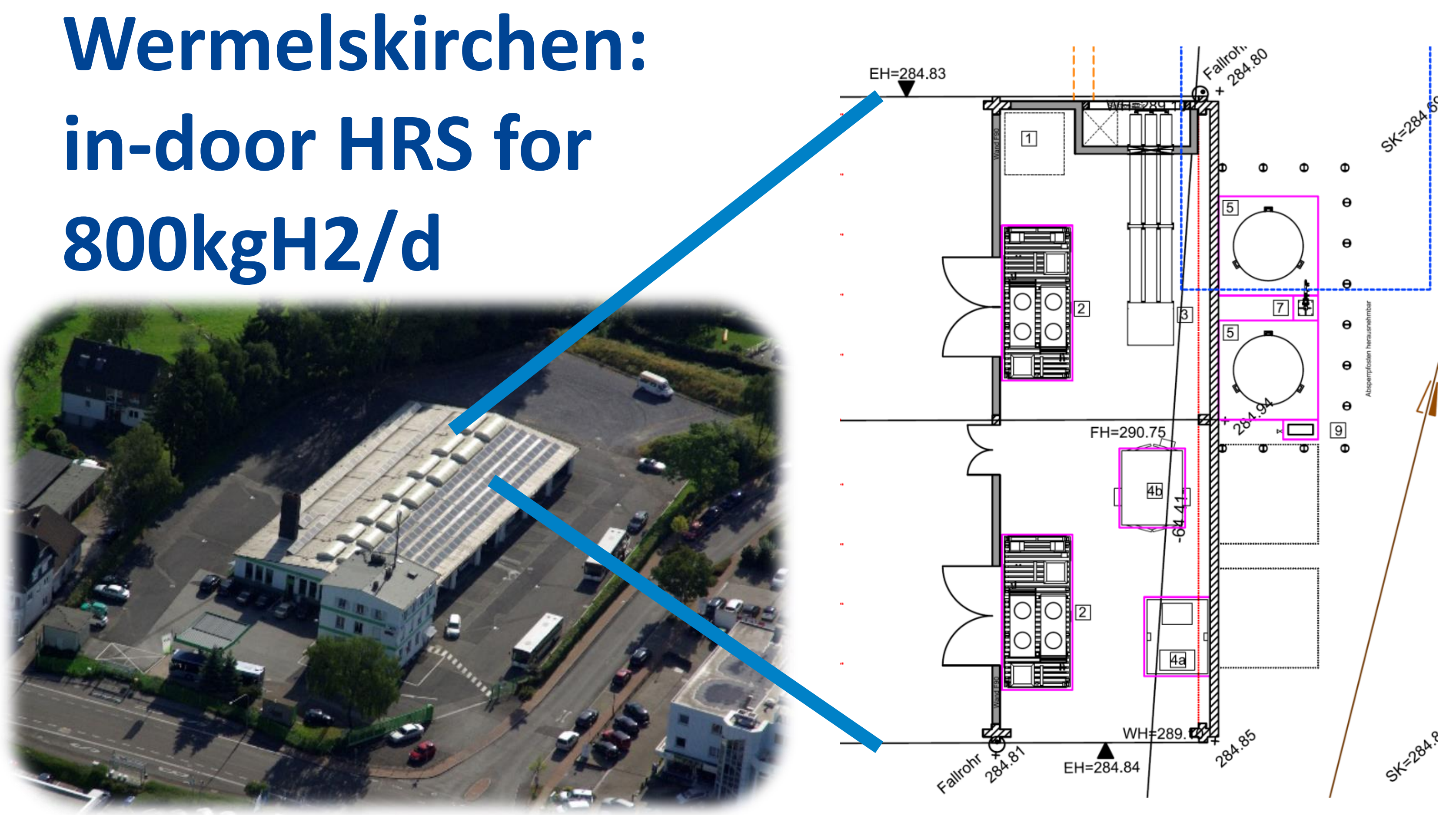
Achieved
- \> 10,000,000 km since projects started
- \> 35,000 h lifetime reached
- 625,000 €/bus offered
- 40.000km/y per bus on average

87%
low carbon hydrogen

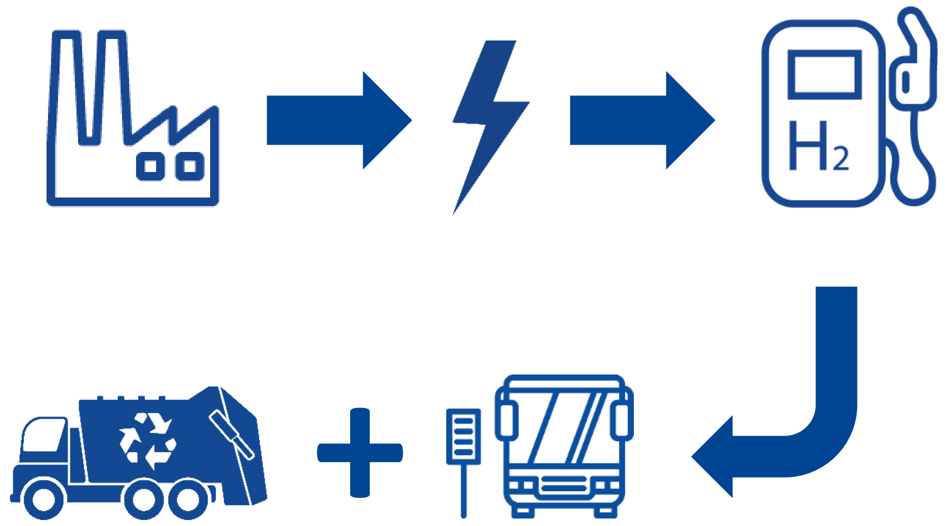
Trends
- Cities order **fleet of 10-40 buses**
- **Zero-emission tenders**
- **Novel HRS designs** (in-door, scalable)
- Zero-emission transport integrated in larger **hydrogen ecosystems**:
  - Waste to wheel
  - Hydrogen valleys

Preparation for deployment:
- Upgrade of depot sites
- Creation of maintenance pits
- Placing H2 supply contracts
- Training of staff, technicians, drivers
- Defining routes and operations

Wermelskirchen: in-door HRS for 800kgH2/d



"Waste to wheel", from waste incineration to hydrogen for mobility



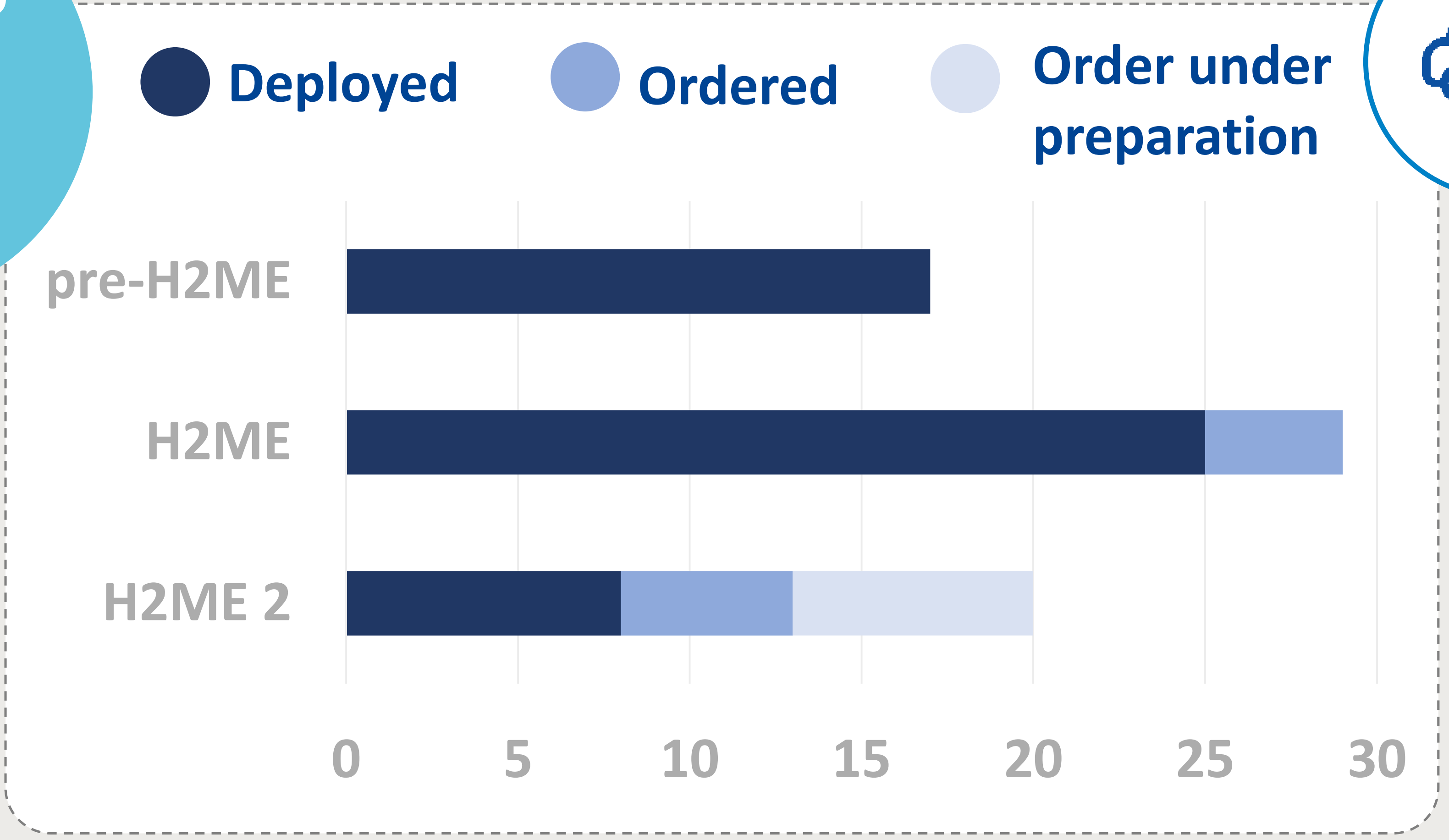
Paving the way for FCEV deployment in Europe

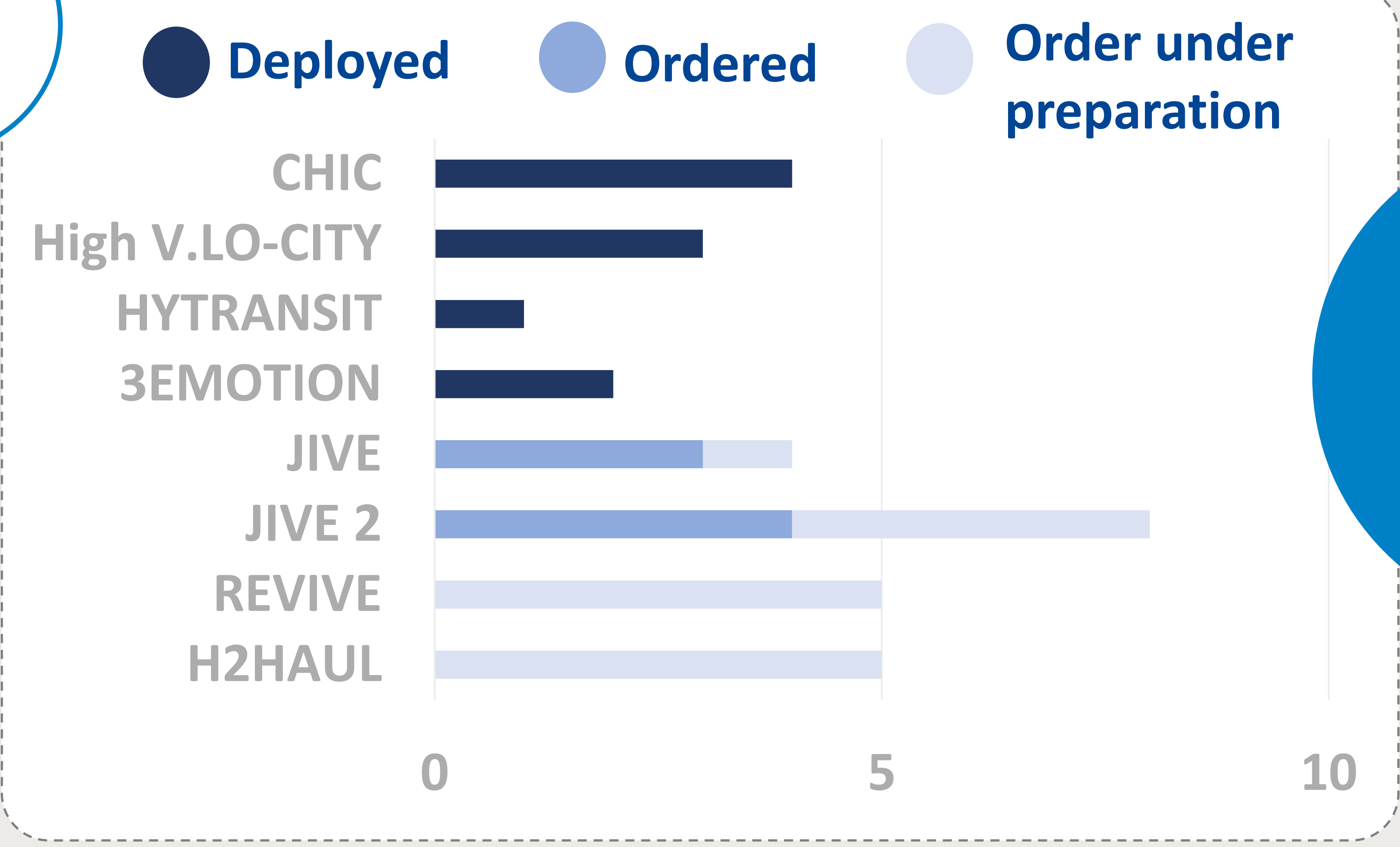
Exporting technology

Making FCEV deployment possible

13 countries involved in HRS deployment, now putting the first HRS for heavy-duty

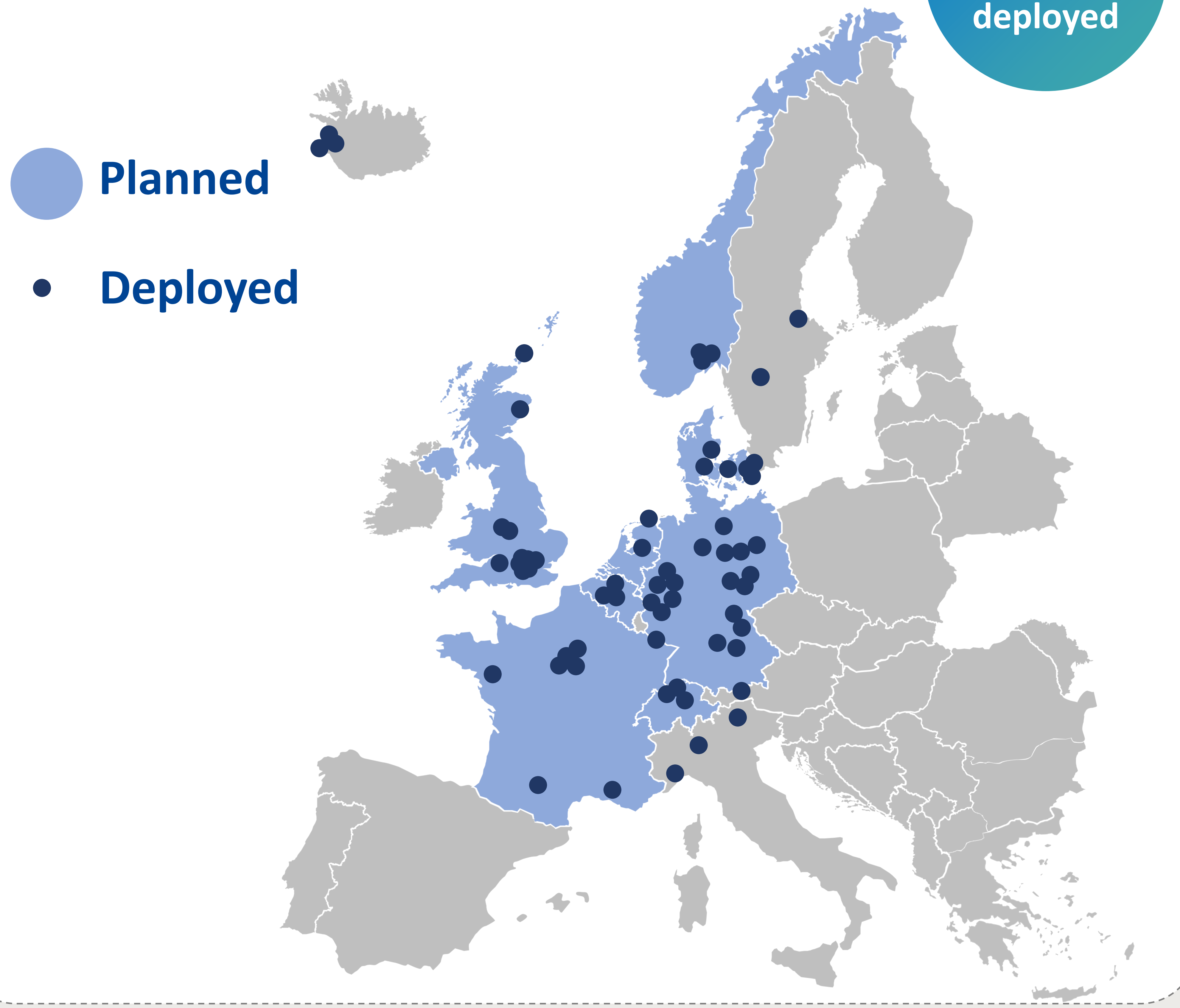
66 HRS for cars





32 HRS for buses / trucks

Planned and deployed

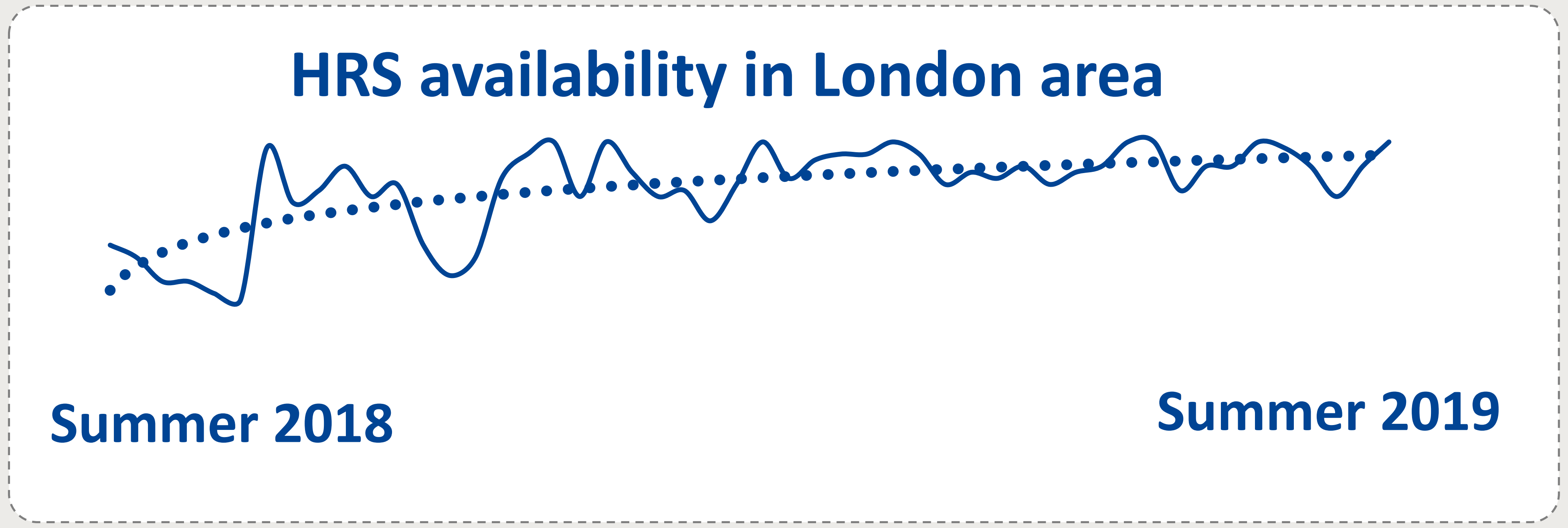


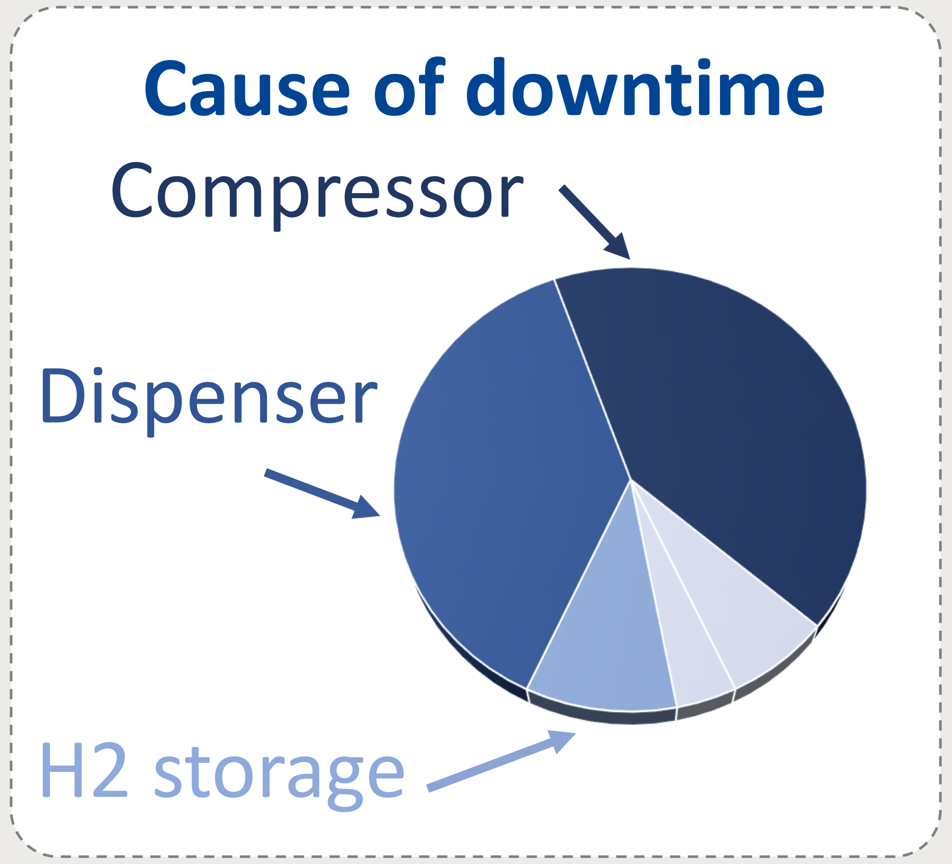
CEF supports HRS deployment as well

Developing technology for everyday customer

Managing a network of HRS for demanding customers

HRS tuned for demanding customer experiences
- Higher usage is resulting in more station damage
- Frequent driver changes means training
- Communication sources are vital to ensure drivers are redirected to available HRS
- Users need real time support to assist 24/7/365



Achieved from 2016 (1 HRS) to Sept. 2019 (25 HRS reporting)
- Availability > 96%
- >35,000 refuelling operations
- > 72 t H_2 dispensed

Safety
- HRS comply with safety codes and standards
- Third parties certify HRS safety compliance
- Annual incident rate:
  - US gas station* = 4.3%
  - Worldwide HRS = 1.3%

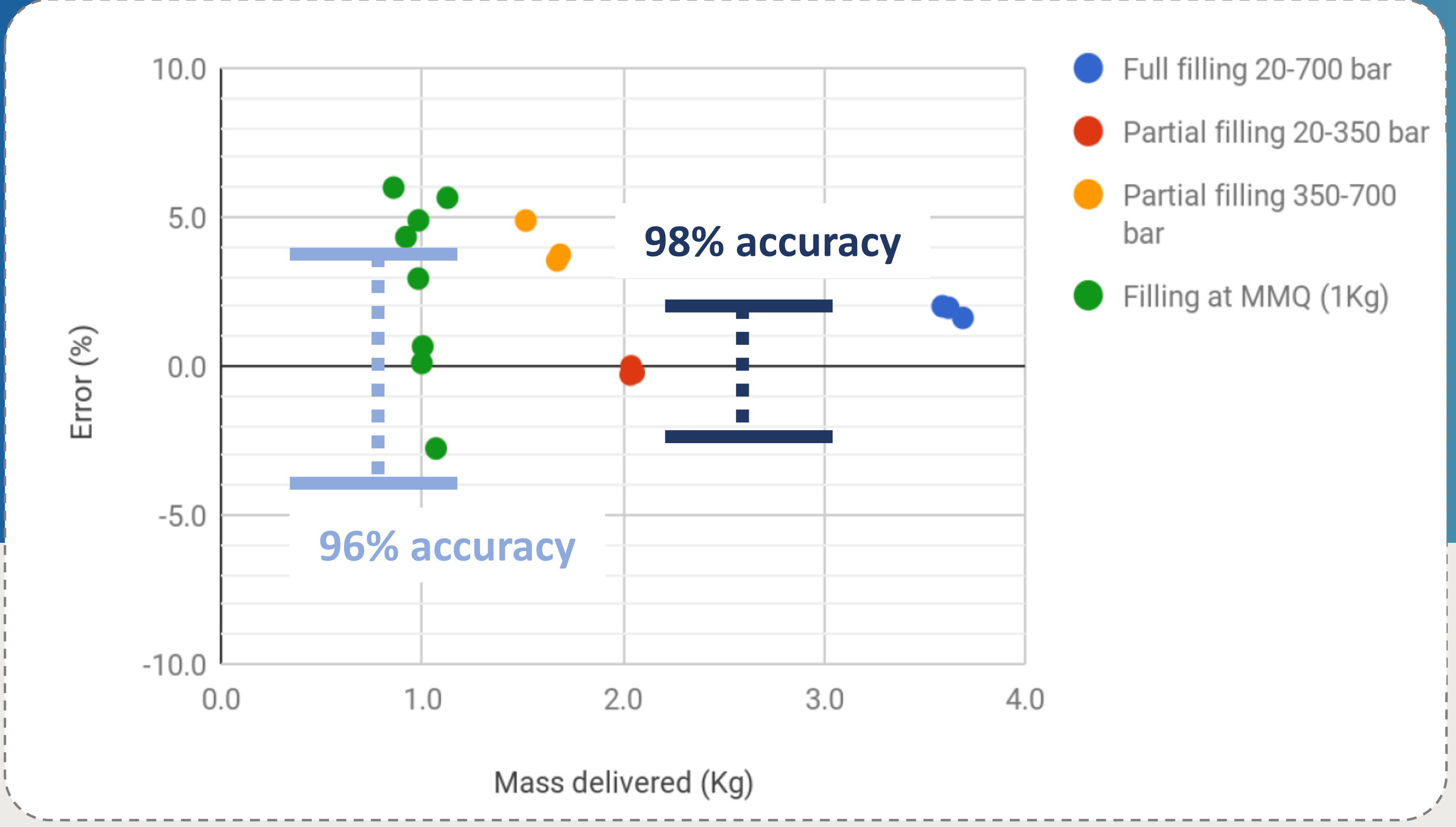
*National Fire Protection Association

HRS service is getting closer to commercial operations

Metering accuracy and open source for public HRS online monitoring in all EU countries

Expectation for commercial operations = ability to **measure accurately** the amount of hydrogen dispensed

Field tests and measured accuracies

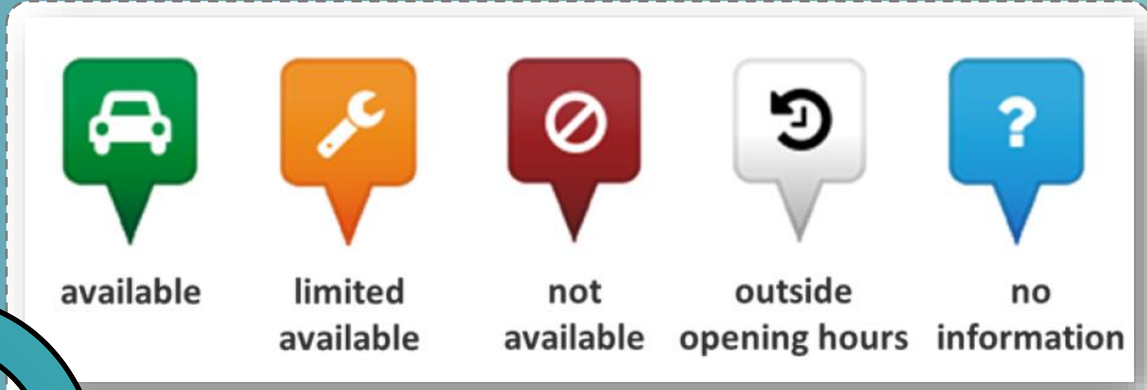


Development of a system for HRS availability in the EU

139 HRS connected sending live data

https://h2-map.eu/

Status definition



Possible end users

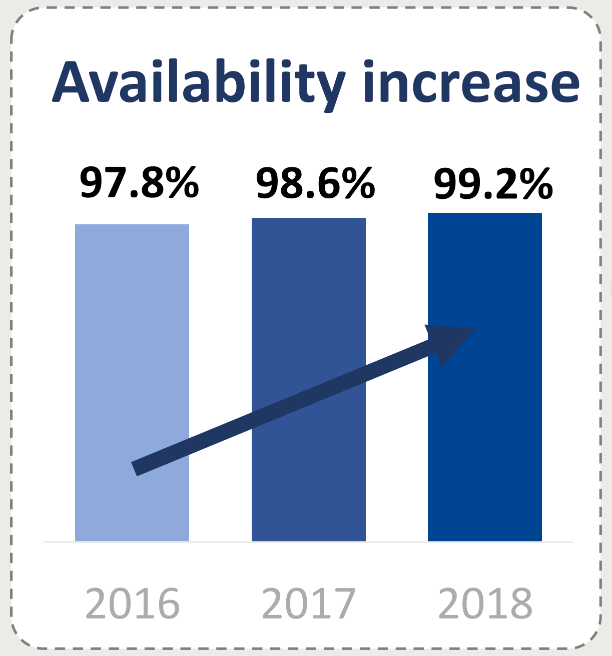
First steps into the business case

Expanding the fleets giving answers to the market

First steps to develop a European business case for forklifts

Looking into market diversification and new segments

First greenfield warehouse and the two largest fleet in Europe



Large fleet

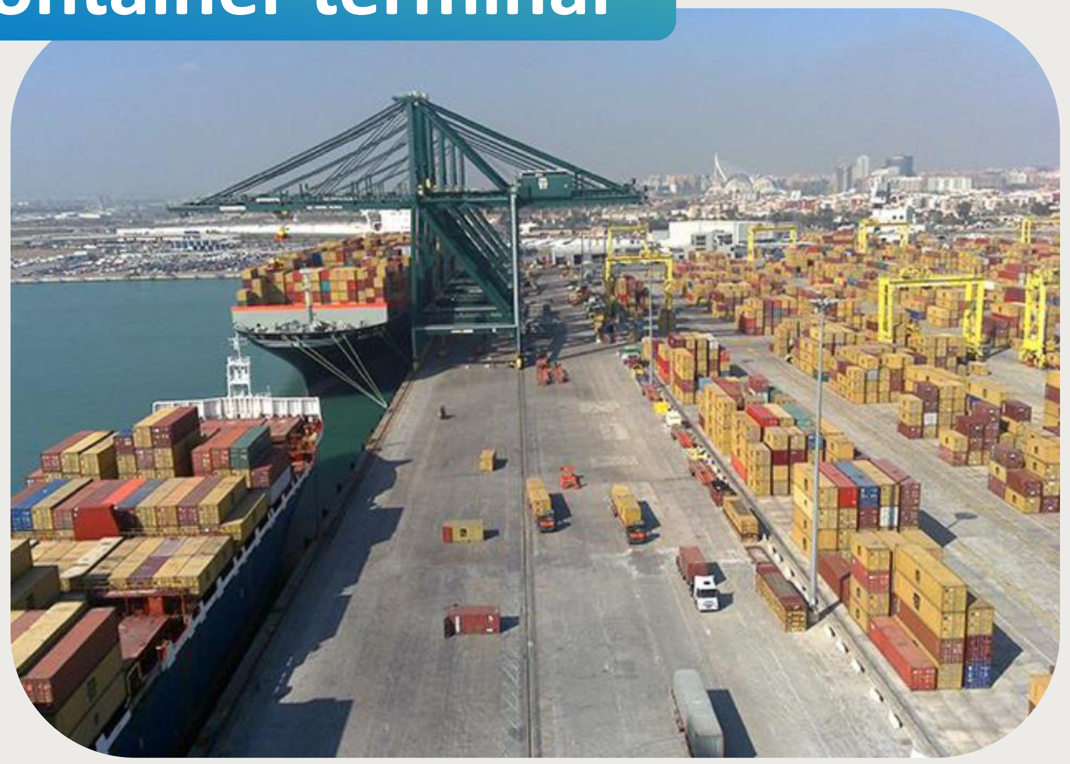
Diversity of vehicle types

Delivery as a service

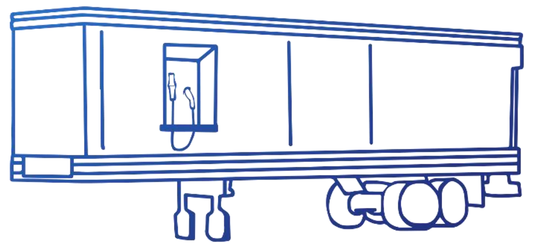
Achievements since 2016

- 273 MHVs in 3 warehouses
- Availability > 99%
- > 152.000 refuelings
- > 1.000.000 hours of operation
- Publication of regulation for warehouse H2 operations: ease replication (FR)

Container terminal



Mobile HRS



Reach stacker

~ 35 kgH2/d

~ 20 kgH2/d

Yard tractor

Opportunities

- Logistics beyond the warehouse
- Decarbonise container operation in urban ports
- Ports as hydrogen « coastal hubs »

Reaching out to cover all transport applications

Testing the technology, broadening its application

Supporting the growing sectors of heavy duty vehicles (HDV)

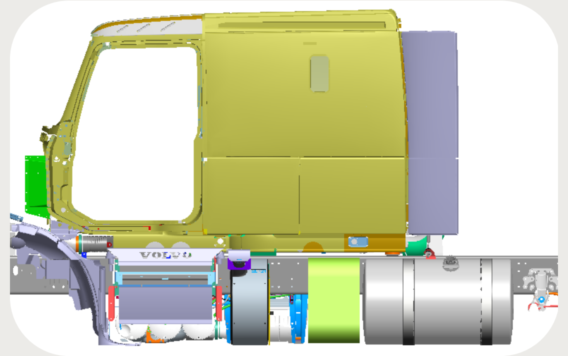
Penetrating municipal garbage collection, logistics operations for industry and supermarkets chains

From APU to truck fleets

2018 – 15 HD trucks

2017 – 15 garbage trucks

2013 - APU for diesel truck

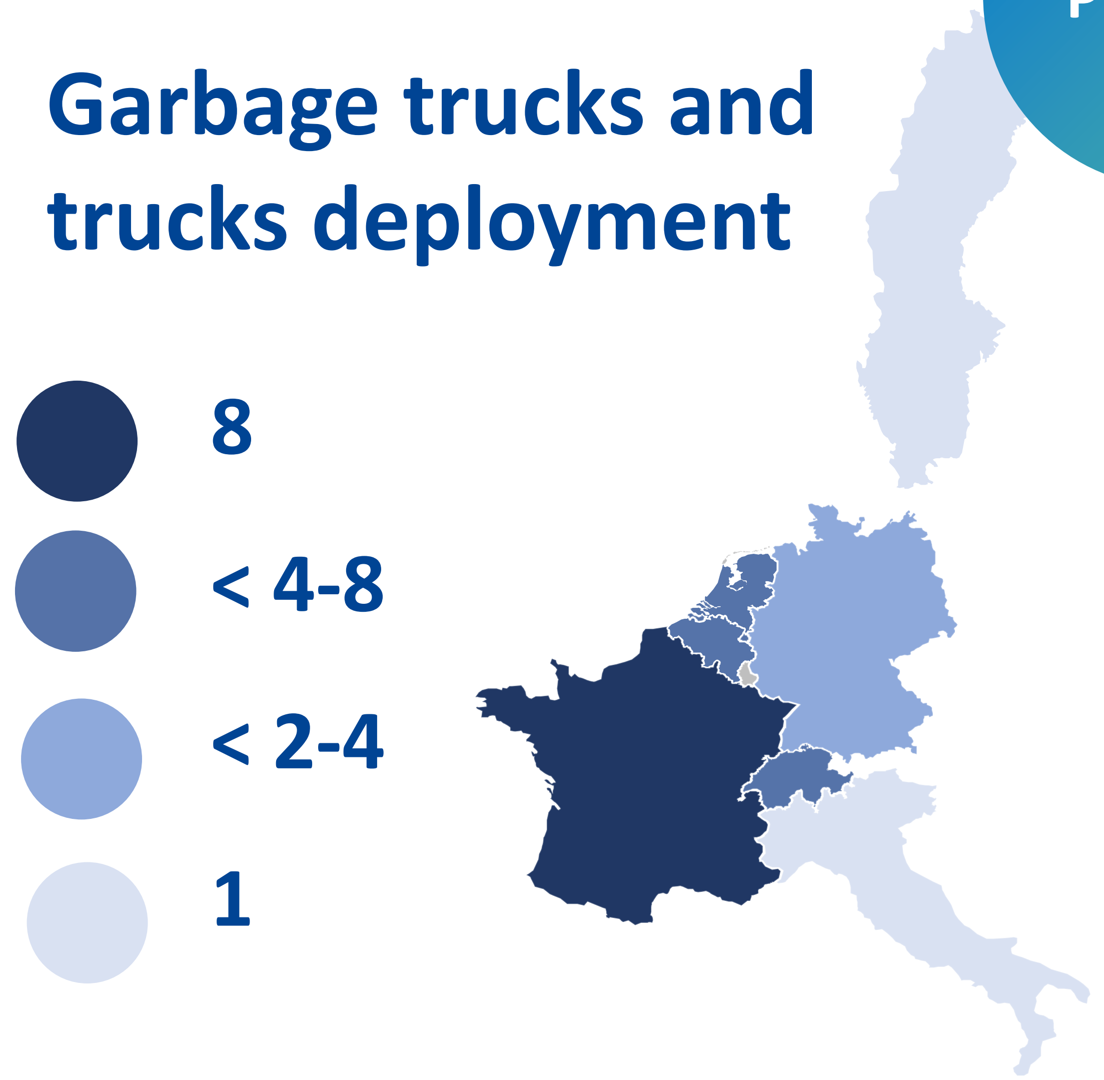


April 2019: New EU legislation for HDVs CO2 emissions

Year	2025	2030
CO2 reduction	15%	30%

Planned

Garbage trucks and trucks deployment



Next steps:

- FCH2 JU study on H2 HDV business cases
- Project on H2 fueling protocols for HDV

Key considerations

- Non-European OEM pressure
- Building up the first small fleets (4 trucks/site)
- Diverse operations (last mile, long haul, urban or interurban)
- Support to EU value chain (EU FC system suppliers)

Supporting the growing sectors of maritime

Continuum of funding in the best fit for business case

2019 – sea-going vessel

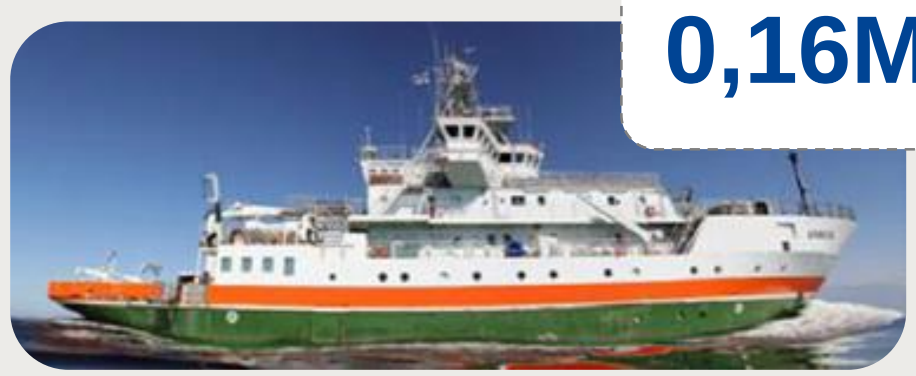
2MW

2017 – ferry + barge pusher

1MW

2017 – research vessel

0,16MW



2013 - APU for yachts

0,05MW

No « one size fits all »

- Different vessels segments
- Different power and autonomy
- Various fuels (H2, NH3, LOHC)
- FC technologies (PEM, SOFC)

U.S. DEPARTMENT OF ENERGY

"H2@Ports workshop" Sept. 2019

Key considerations

- Crucial need for international cooperation
- Importance of regulatory aspects (IMO and CESNI)
- Ports as hydrogen « coastal hubs »
- FC for hotel load at port or propulsion at sea

Challenges: R&D in the area's of LH_2 storage (bunkering), MW scale Fuel Cells, carriers,…

Identifying and supporting the uptake of H2 for aircrafts

Continuum of funding in the best fit for business case

From APU to aircraft propulsion

2018 – Aircraft propulsion

2017 – FC for emergency operation

2012 - APU for secondary electrical system

Towards aircraft propulsion

Decarbonising aeronautics

- Review and state of the art
- Concept studies for regional, commuter, LR, MR, SMR aircrafts
- Impact at air transport system level
- Recommendations on future R&I

FCH · Clean Sky

"Study on use of on use of hydrogen and fuel cells for aircraft propulsion"

Challenges

- Specifics safety measures
- Aircraft specific duty cycles and form/fit/function requirements
- Weight, sound and pressure for demanding application

For each railway application, FCH can present a clean, economically sensible alternative to existing technology

Continuum of funding in the best fit for business case

Multiple units

- Passenger in regional transport
- Up to 1,000 km
- 30 years

Shunters

- Shunting and short distance
- 200-1,000 km
- 35 years

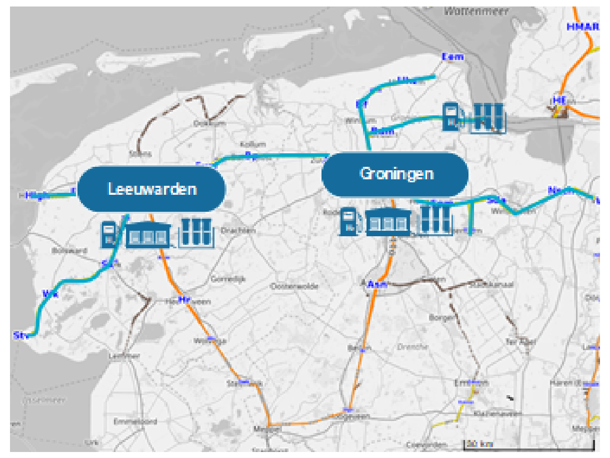
Mainline locomotives

- Med. distance freight + passenger
- 500-1,100 km
- 30 years

Identify best scenario

« Study on the use of fuel cell hydrogen in railway environment »

Shift2Rail

	Mult. units	Shunter	Main. loco
	Groningen & Friesland, Netherlands	Riga Node, Latvia	Kalmar – Linköping, Sweden
Overview			
Track length	300 km	100 km	230 km
Rolling stock	70x 3 car trains	15 Shunters	5 Locomotives
H_2 consumption	0.22 kg/km	0.49 kg/km	0.48 kg/km
Characteristics	Fast trains for intercity connections	Shunting operation between several port terminals	Passenger and freight transport between two cities
Results in EUR/km_{train}			
Diesel	4.8	20.9	5.7
FCH	**4.9**	**20.4**	**6.7**
Catenary	4.4		22.0
Battery	5.2	21.8	
CO_2 saving potential in one year	56,389 t	3,350 t	4,980 t

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

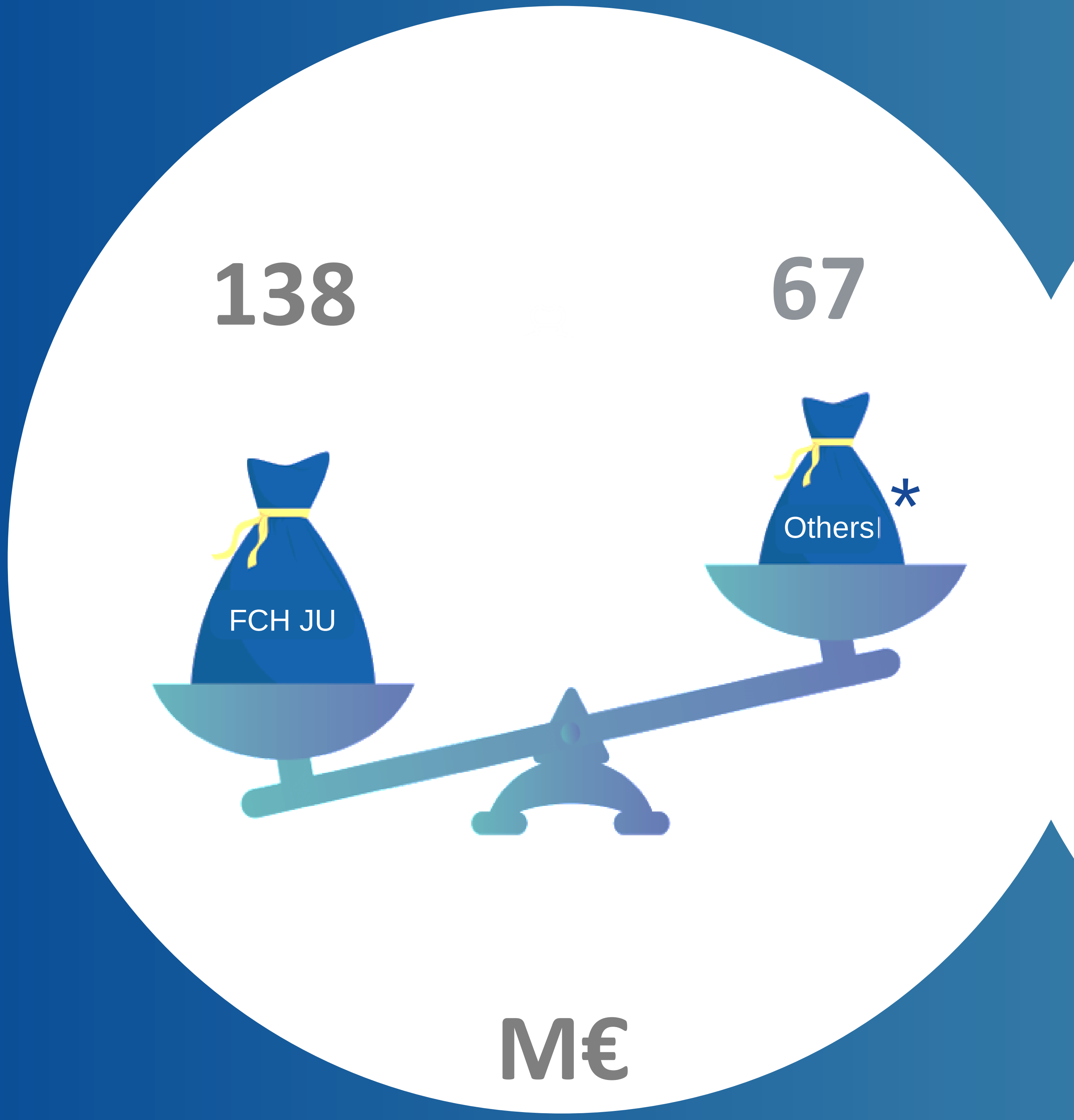
Renewable Energy + Add to myFT

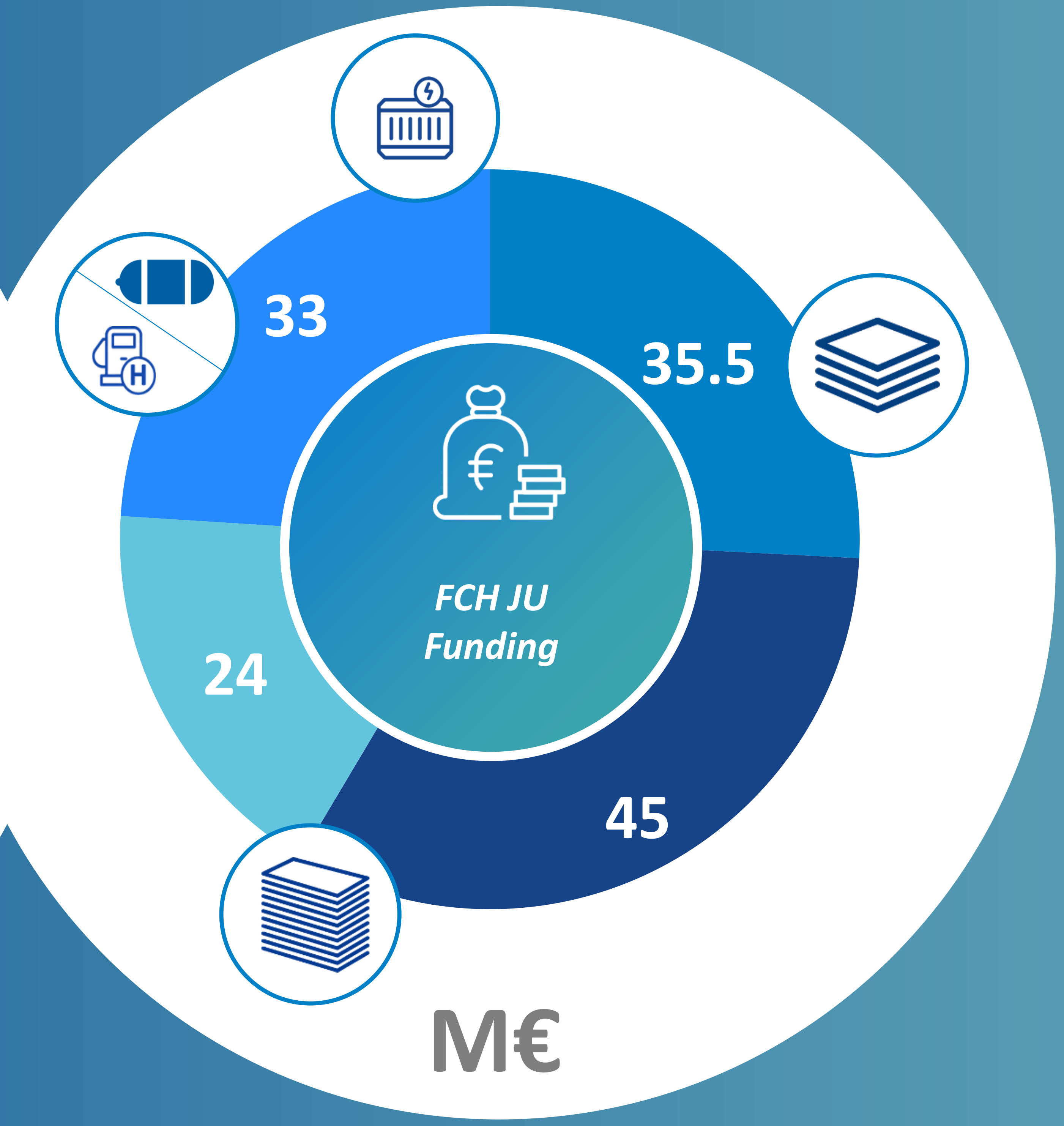
Orkney project shows potential of hydrogen as a fuel source

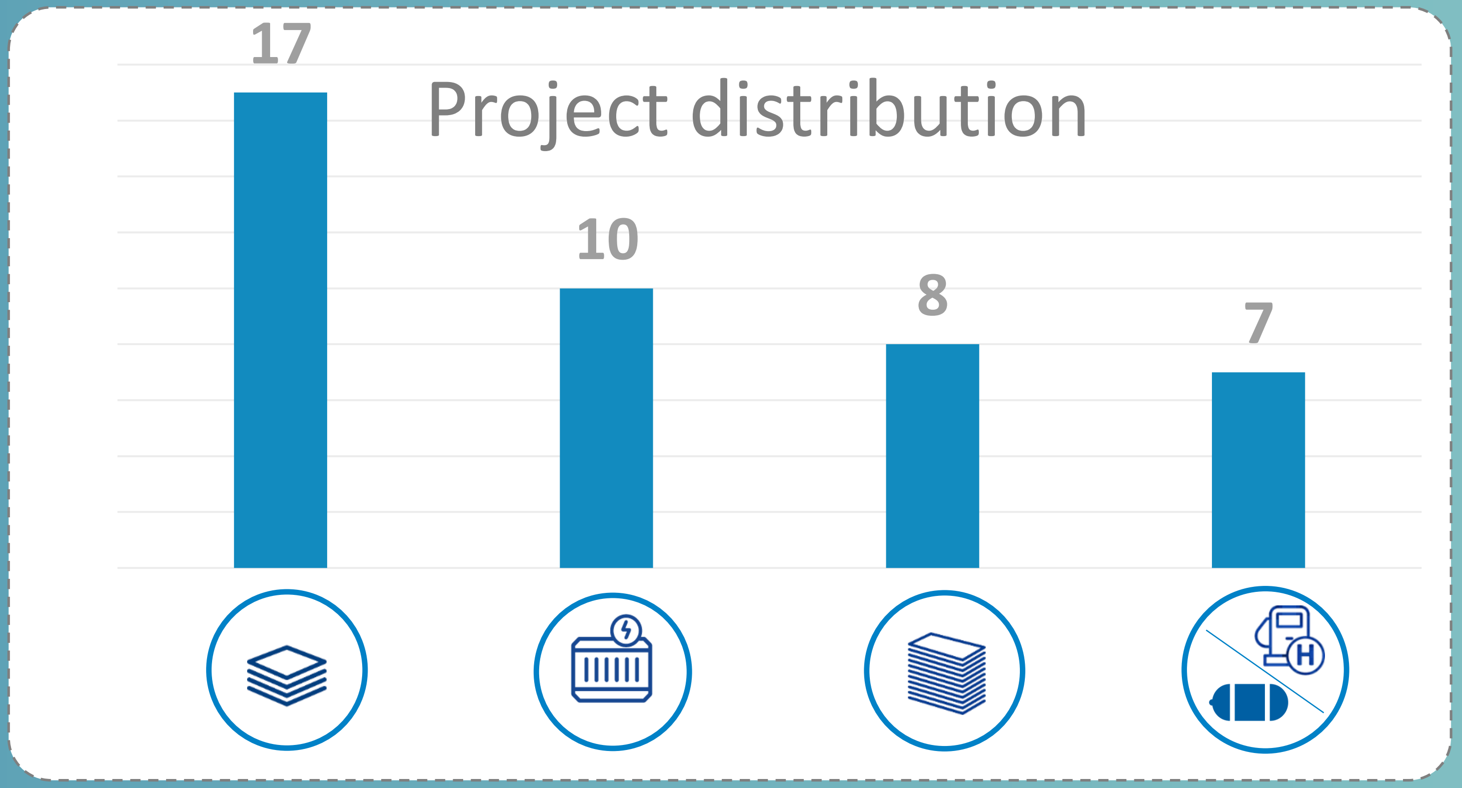
The gas may be best option for heavy transport such as trucks, ships and trains

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

Towards competitiveness – next generation of products





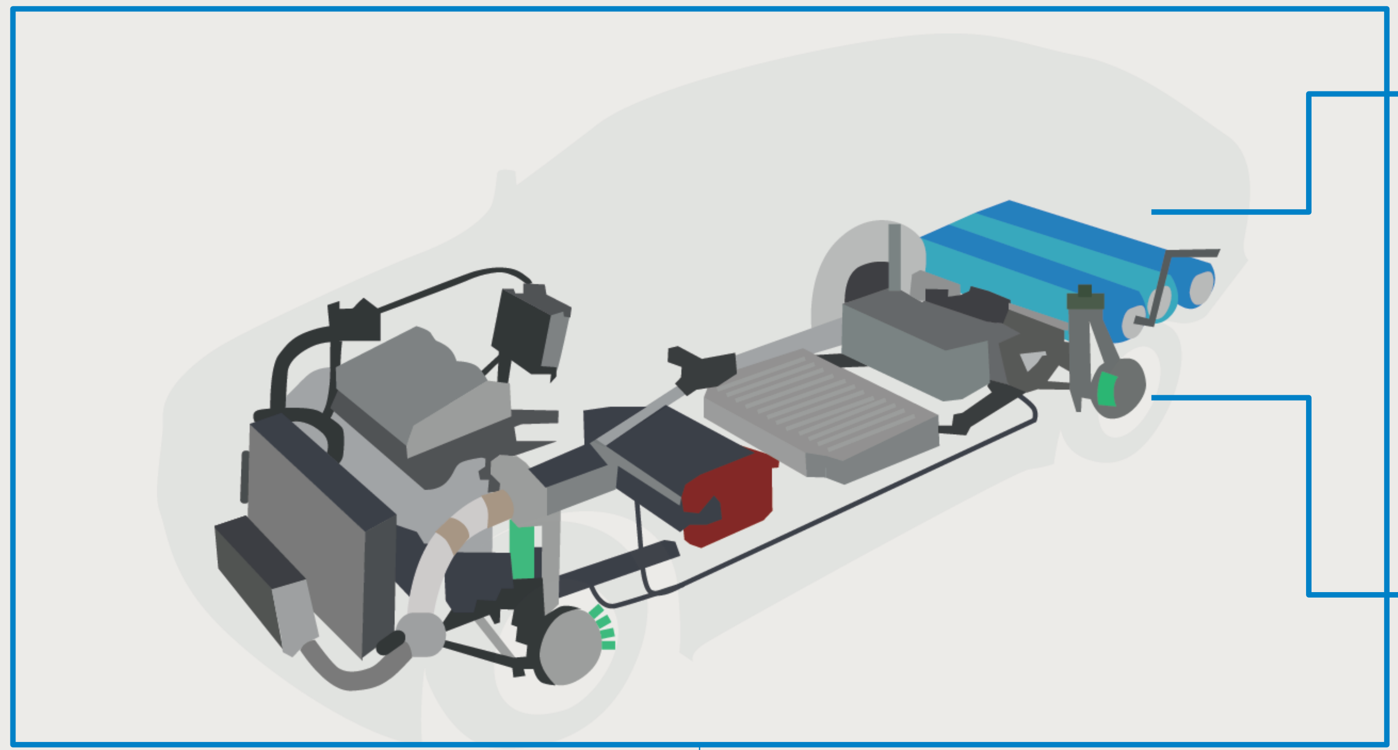


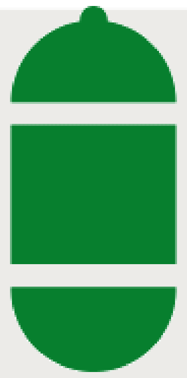
- MEA, catalysts, GDL, materials
- Auxiliary power units
- Stack modelling, development, BPP, manufacturing, next generation
- Hydrogen refueling station, On-board H2 storage

** Other resources including private and national/regional funding*

FCH JU support to all FCEV research aspects

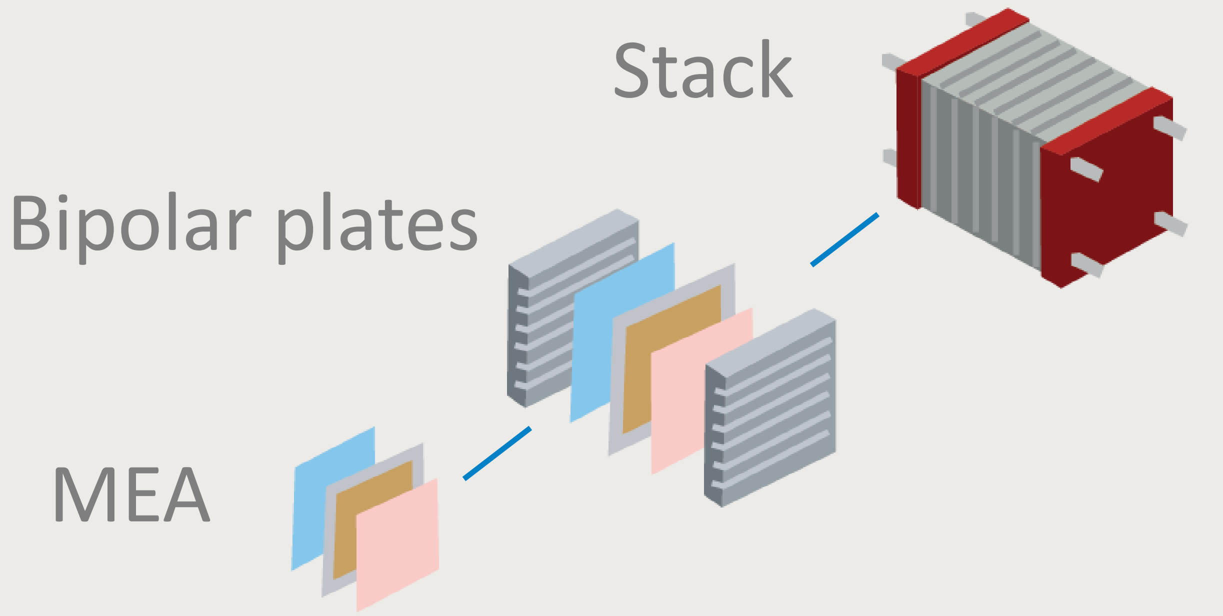
Supporting the competitiveness of the technology and the EU supply chain



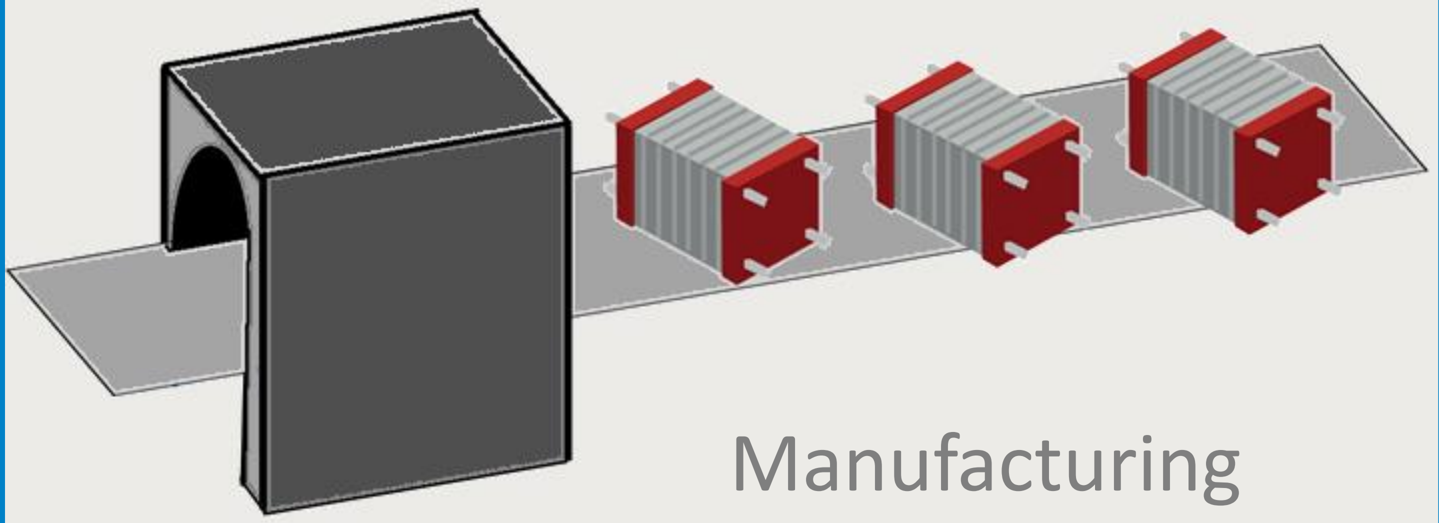


Tanks design optimisation and development of components

Optimised H_2 compression and storage systems



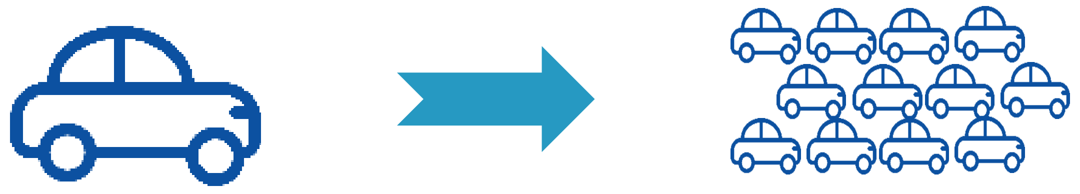
Low-costs and high-performance FC systems

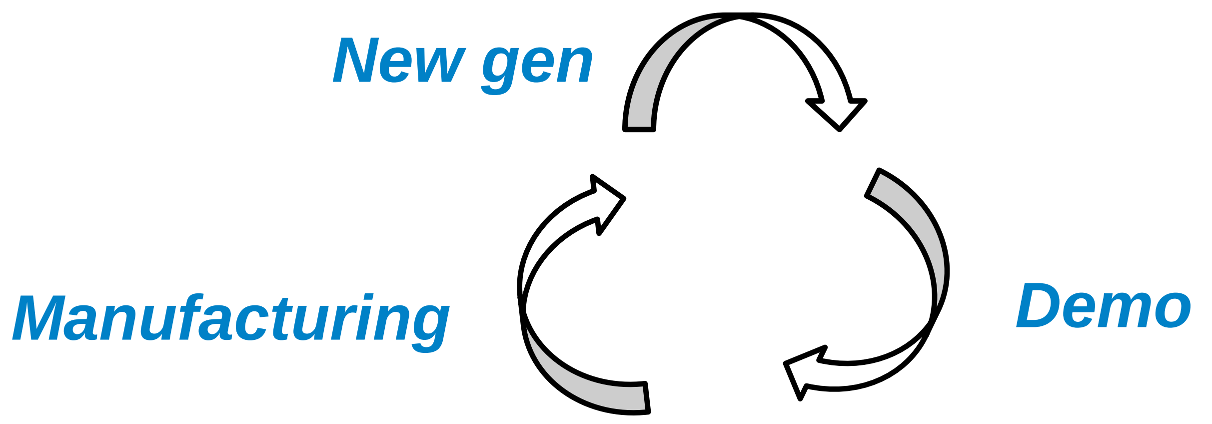


Lean and quality manufacturing at volume

Heavy-duty applications

kg → ***Ton***





Mirela Atanasiu

HoU Operations and Communication
Mirela.Atanasiu@fch.europa.eu

For further information

www.fch.europa.eu
www.hydrogeneurope.eu
www.hydrogeneurope.eu/research

@fch_ju

Fch-ju@fch.europa.eu

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