FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

FCH JU supporting rail transport

European Green Deal

Improving the well-being of people by making Europe climate-neutral and protecting our natural habitat

"The European Green Deal is our new growth strategy.
It will help us cut emissions while creating jobs."

Ursula von der Leyen, President of the European Commission

"We propose a green and inclusive transition to help improve people's well-being and secure a healthy planet for generations to come."

Frans Timmermans, Executive Vice-President of the European Commission

European Green Deal

European Commission Communication and Roadmap (December 2019)

EU industry needs 'climate and resource frontrunners' *to develop the first commercial applications of breakthrough technologies in key industrial sectors by 2030. Priority areas include clean hydrogen, fuel cells and other alternative fuels, energy storage.*

Partnerships with industry & Member States will support research & innovation *on transport, including batteries,* ***clean hydrogen****, low-carbon steel making, circular bio-based sectors and the built environment.*

The regulatory framework for energy infrastructure should ***foster the deployment of innovative technologies and infrastructure****, such as smart grids,* ***hydrogen networks*** *or carbon capture, storage and utilisation, energy storage, also enabling* ***sectorial integration****.*

The role of hydrogen in our society & economy

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

STORAGE (seasonal)

SECTORAL INTEGRATION

Industry Feedstock

Electrolyser

Storage H_2

Transport

Heating & Cooling

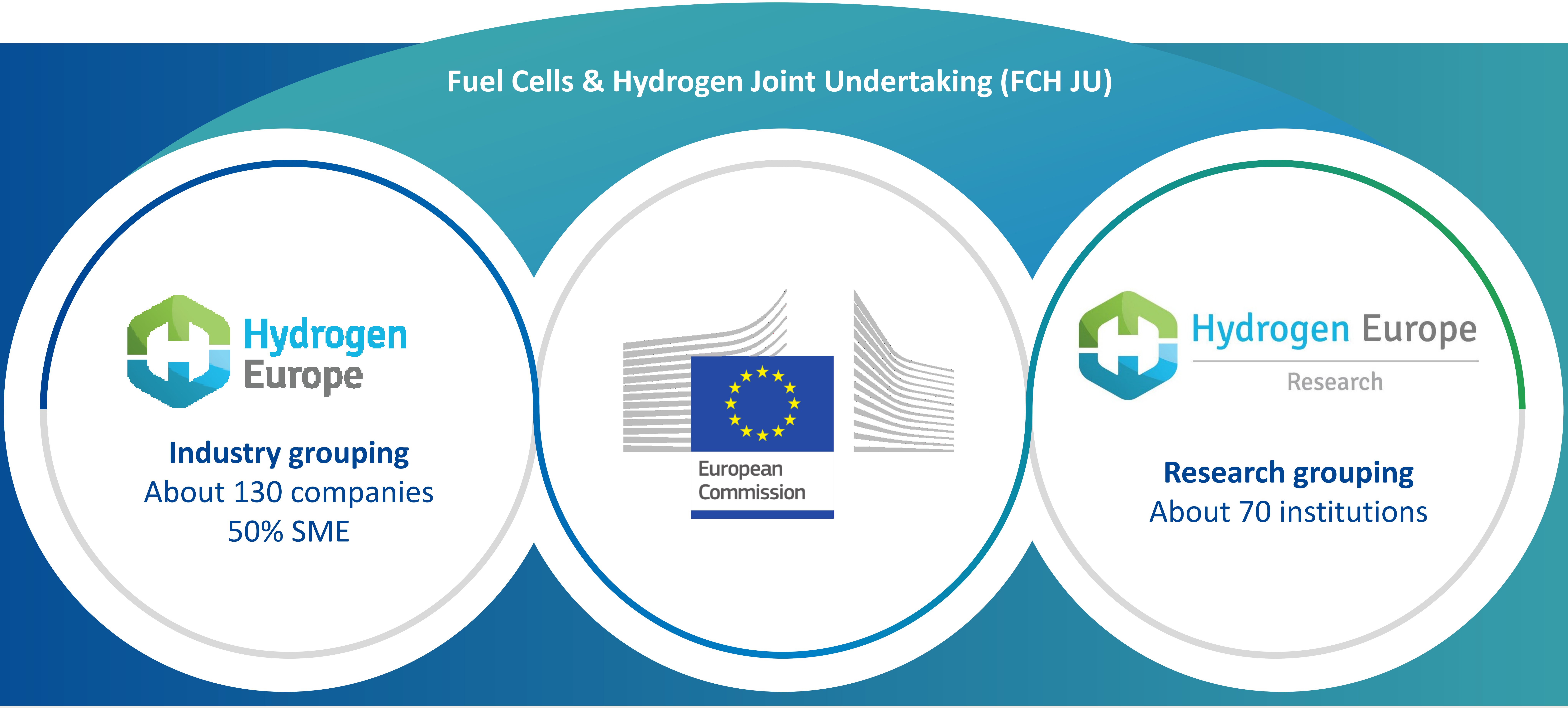
NG

H_2

⚡

Strong public-private partnership with a focused objective

EU Institutional Public-Private Partnership (IPPP)



Fuel Cells & Hydrogen Joint Undertaking (FCH JU)

Industry grouping
About 130 companies
50% SME

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)*

FCH JU programme implementation (2008-2019)

Energy

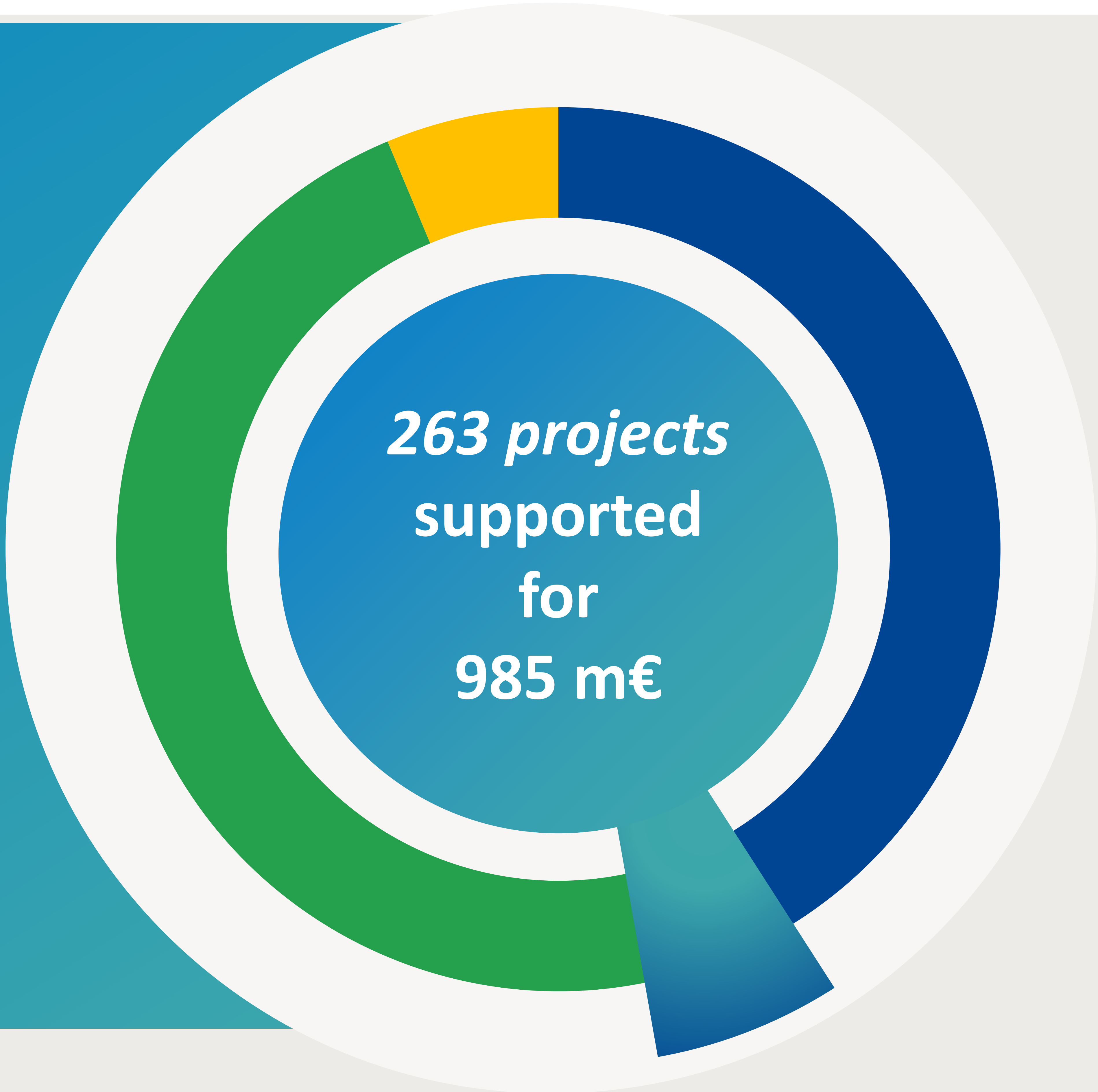
- Hydrogen production and distribution
- Hydrogen storage for renewable energy integration
- Fuel cells for power & combined heat & power generation

Transport

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

Cross-cutting

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



***263 projects* supported for 985 m€**

46 %

457 million euros
145 projects

41 %

404 million euros
70 projects

6 %

58 million euros
43 projects

7 %

66 million euros
5 projects

Similar leverage of other sources of funding: 1 b€

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

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Hydrogen Europe · ENGIE · ITM POWER · TOYOTA · gasunie · HYDROGENICS · SALZGITTER AG Stahl und Technologie · nel · equinor

PLASTIC OMNIUM · SolidPower · MICHELIN · Air Liquide · BMW Group · TOTAL · enagas · Verbund · DWV Deutscher Wasserstoff- und Brennstoffzellen-Verband

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]

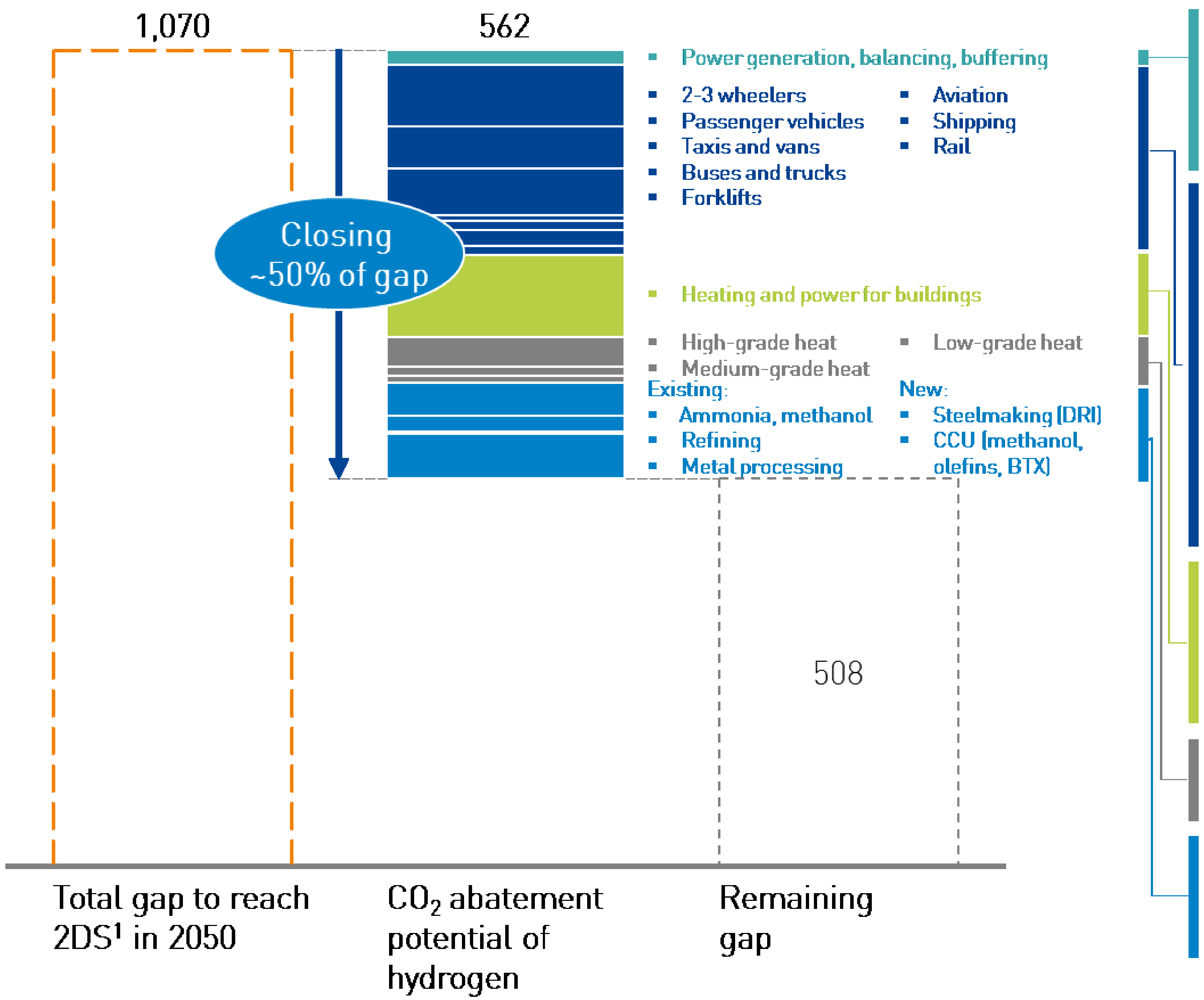
[1] Including feedstock [2] Compared to the reference technology scenario [3] Excluding indirect effects

SOURCE: Hydrogen Roadmap Europe team

WHY HYDROGEN?

Across applications hydrogen can close half of the gap towards the 2DS (two degrees scenario)

Carbon emissions gap to reach 2DS[1] in 2050, Mt



Hydrogen decarbonization levers

Power generation	Integration of renewables into the power sector[2] Power generation from renewable resources
Transportation	Replacement of combustion engines with FCEVs, in particular in buses and trucks, taxis and vans as well as larger passenger vehicles Decarbonization of aviation fuel through synthetic fuels based on hydrogen Replacement of diesel-powered trains and oil-powered ships with hydrogen fuel-cell-powered units
Heating and power for buildings	Decarbonization of natural gas grid through blending Upgrade of natural gas to pure hydrogen grid
Industry heat	Replacement of natural gas for process heat
Industry feedstock	Switch from blast furnace to DRI steel Replacement of natural gas as feedstock in combination with CCU

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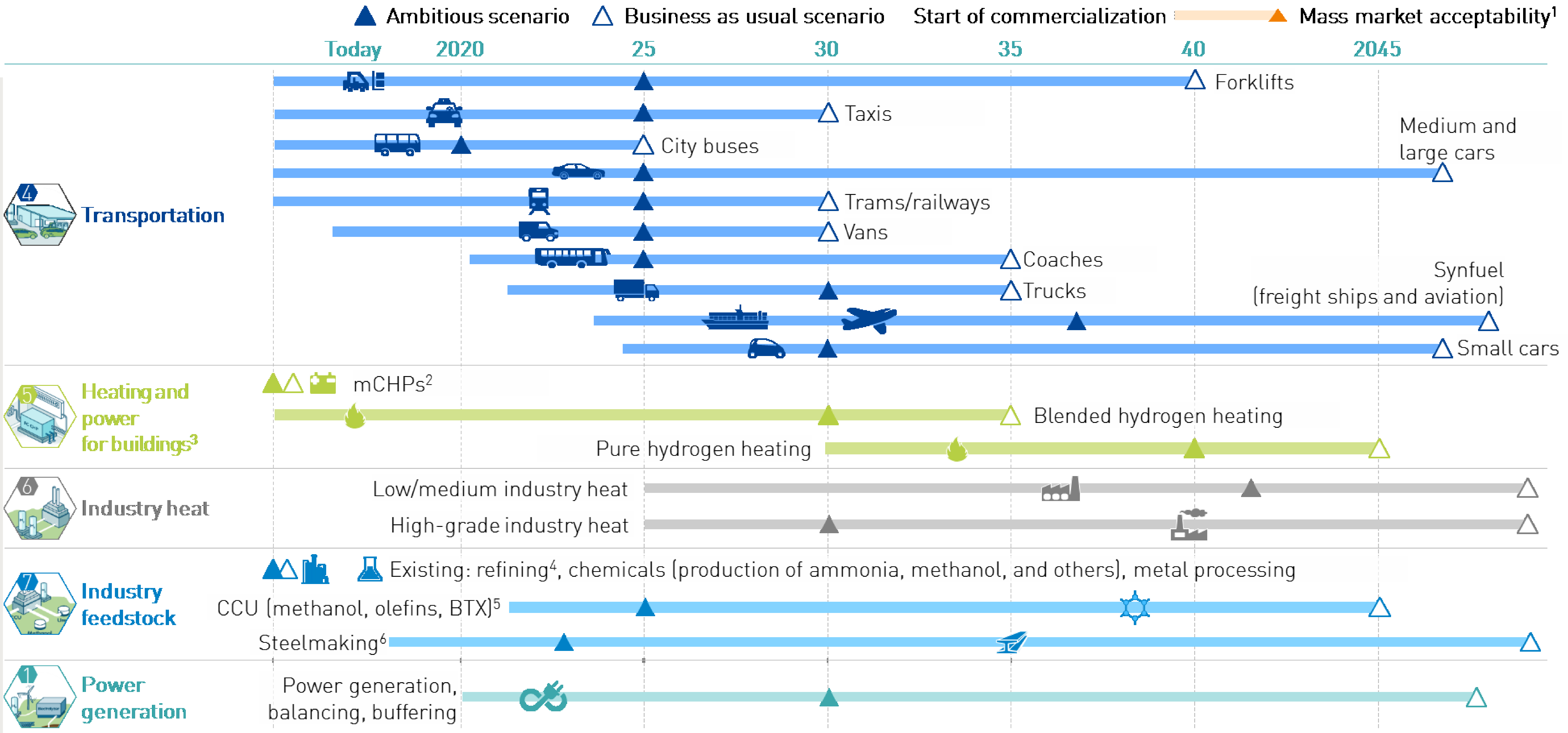
[1] 2-degree scenario [2] Please see the chapter on renewables and power for information on the role of hydrogen as enabler of a renewable power system. The "enabled" carbon abatement from renewables is not included here and is an additional benefit of hydrogen for decarbonization

SOURCE: IEA Energy Technology Perspectives 2017; Hydrogen Roadmap Europe team

Hydrogen technology exists and is ready to be deployed



1 Defined as sales >1% within segment; 2 mCHPs sales in EU independent of fuel type (NG or H_2); 3 Pure and blended H_2 refer to shares in total heating demand; 4 Refining includes hydro-cracking, hydro-treating, bio-refinery; 5 Market share refers to the amount of production that uses hydrogen and captured carbon to replace feedstock; 6 CDA process and DRI with green H_2, iron reduction in blast furnaces, and other low-carbon steel making processes using H_2

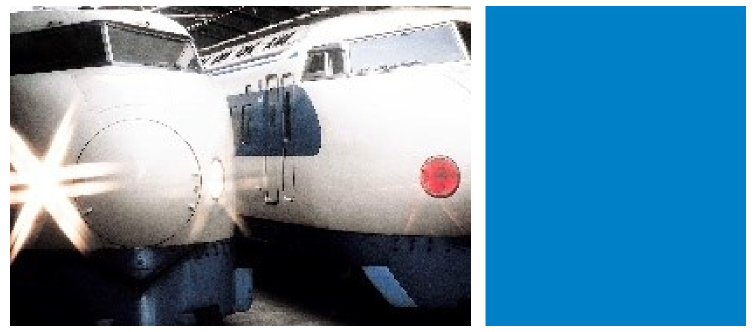
SOURCE: Hydrogen Roadmap Europe team

Hydrogen for rail applications is becoming more and more visible publicly – First FCH regional train demonstrated in Germany

Recent developments ...

News

"Germany launches world's first hydrogen-powered train"
The Guardian,
17 September 2018



"Hydrogen fuel cell trains herald new steam age"
The Times, 13 May 2018

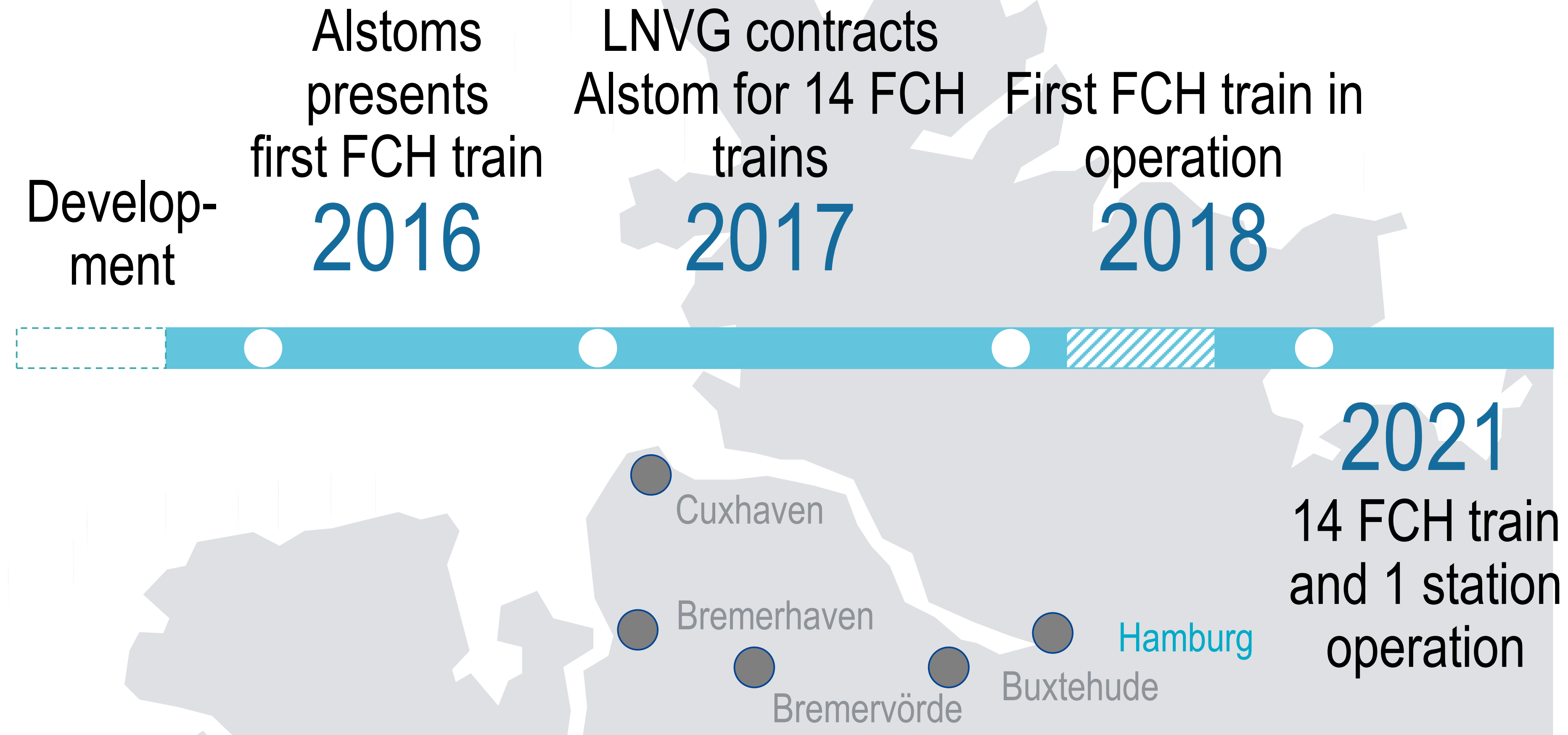
"French train giant Alstom set to make UK's first hydrogen fleet at British site"
The Telegraph,
14 May 2018

Benefits of FCH rail applications

- > Zero emission
- > Route flexibility
- > Reduced noise
- > Higher range compared to battery solutions
- > Avoidance of electrification cost

Project example:

FCH trains in North-West Germany



- > FCH train "Coradia iLint" development by Alstom (with support from German government)
- > Northern German regional rail operator LNVG commissioned Alstom for 14 FCH trains incl. a 30 year maintenance contract
- > Hydrogen is provided by a refuelling station built and operated by Linde (30 year contract)
- > State government of Lower-Saxony is supporting the project

Source: Alstom; Roland Berger

FCH technology can become a viable alternative to replace diesel engines – First products for passenger service enter market

Shift2Rail and FCH JU study focus applications

- We analysed the potential of fuel cell and hydrogen technology for rail transport for three application areas
- Most activity visible in multiple unit application area (products already being launched)
- First insights suggest attractive use cases and good market potential

	Multiple units 🟦	🛠	Passenger operation in regional transport
		◢	First FCH trains in operations since September
		📍	up to 1,000 km1)
		⏲	up to 140 km/h
		📅	30 years
	Shunters	🛠	Shunting and short distance operation
		◢	?
		📍	200-1,000 km1)
		⏲	up to 50 km/h
		📅	35 years
	Mainline Locomotives	🛠	Med. + long distance freight + passenger service
		◢	?
		📍	500-1,100 km1)
		⏲	up to 120 km/h
		📅	30 years

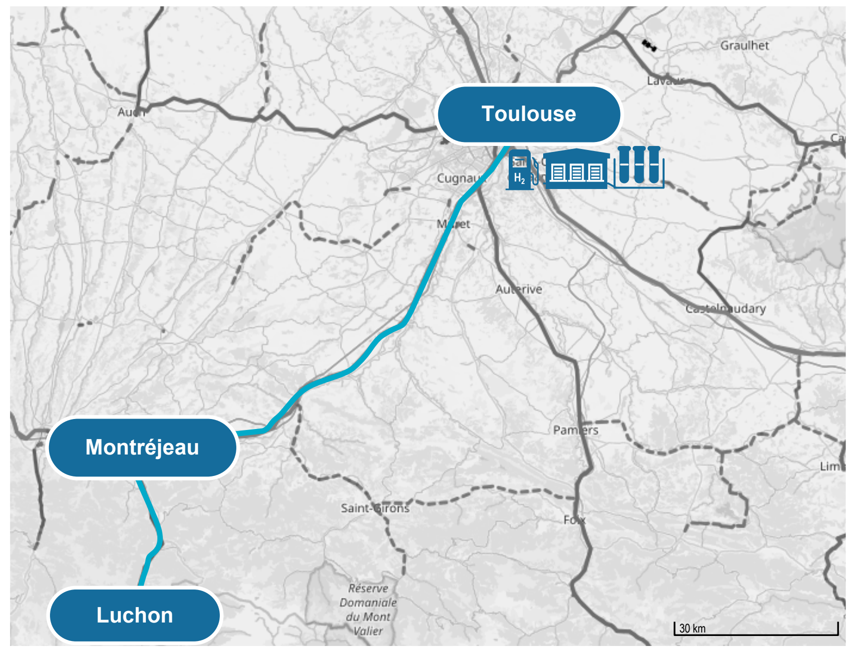
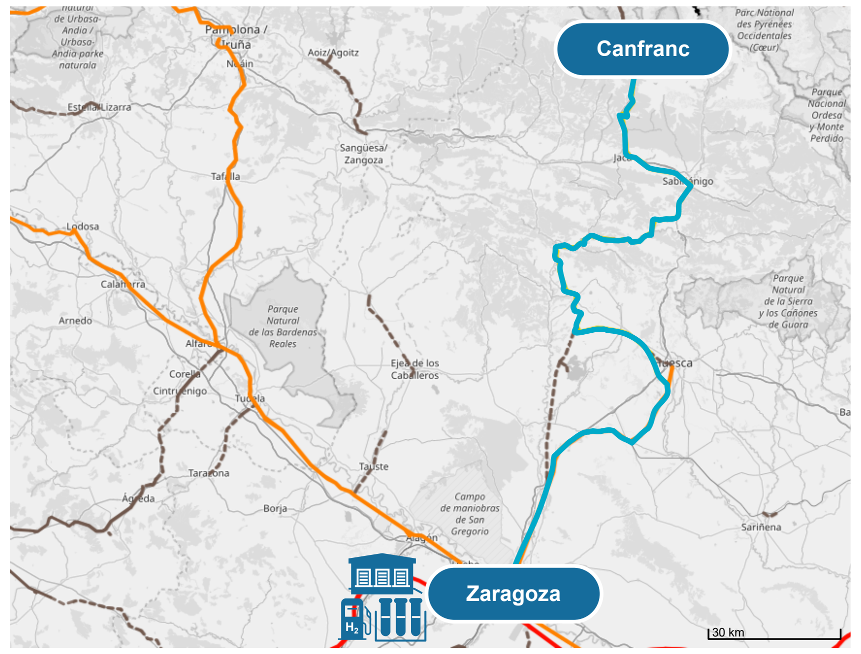
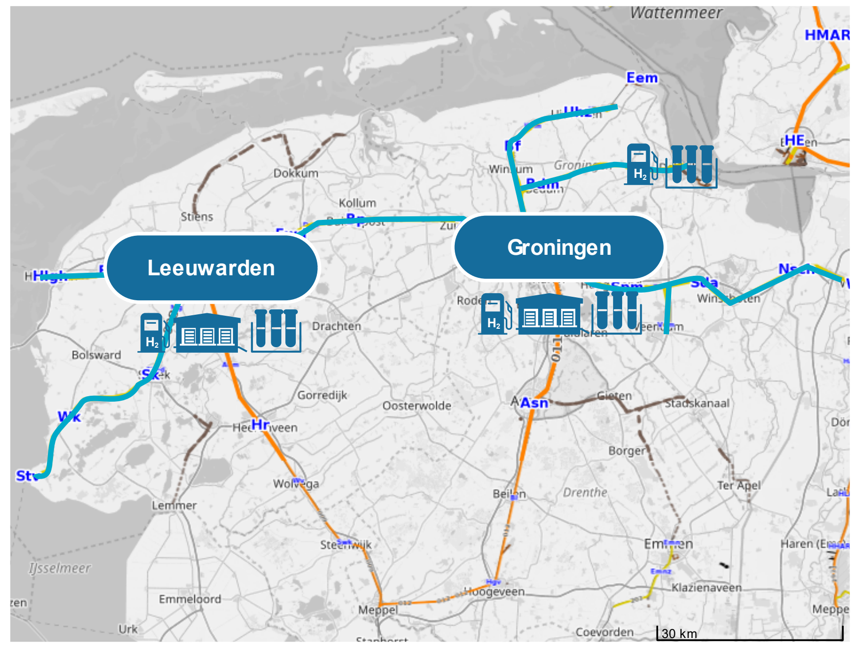
1) Depending e.g. on # cargo/passengers, stops and topography

🛠 Application ◢ Maturity of technology 📍 Range ⏲ Speed 📅 Lifetime 🟦 Market entry

Source: Alstom, ÖBB, Roland Berger

FCH MUs present a clean, economically sensible alternative to existing technology in dense networks with many unelectrified lines

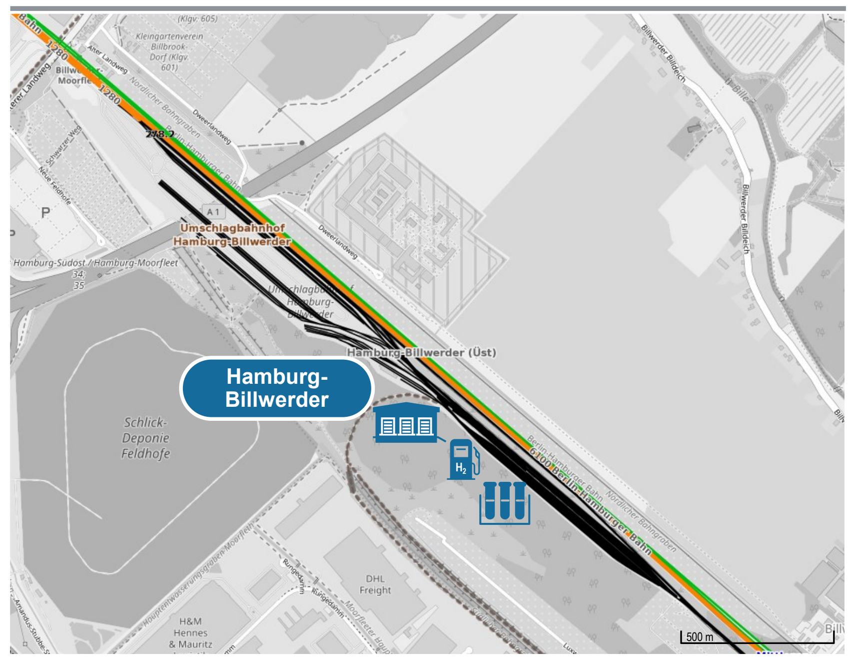
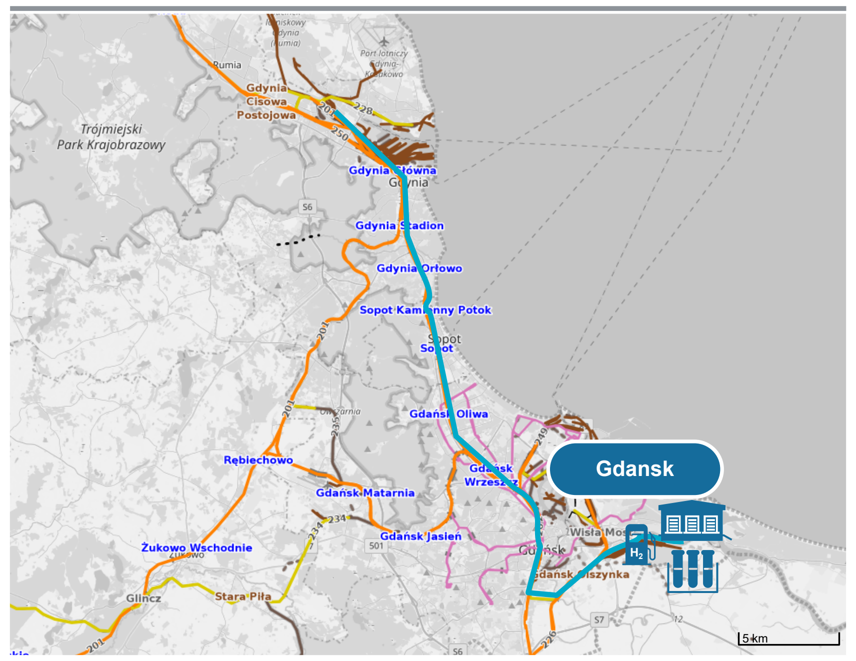
Multiple Unit case study results [EUR/km_{train}]

	Montréjeau – Luchon, France	**Aragon, Spain**	**Groningen & Friesland, Netherlands**
Overview			
Track length	140 km	165 km	300 km
Rolling stock	3x 4 car trains (bi-mode)	2x 4 car trains (bi-mode)	70x 3 car trains
H_2 consumption	0.36 kg/km	0.31 kg/km	0.22 kg/km
Characteristics	Partly electrified route with a low utilisation on 36 km	Cross border connectivity and long rout without electrification	Fast trains for intercity connections
Diesel	18.5	9.3	4.8
FCH	**21.2**	**12.4**	**4.9**
Catenary	27.5	22.5	4.4
Battery	19.9	13.7	5.2
CO_2 saving potential in one year	**1,334 t**	**767 t**	**56,389 t**

Source: Expert interviews, Roland Berger

FCH technology is more competitive in use cases where Shunters have larger loads, idle less and travel longer distances

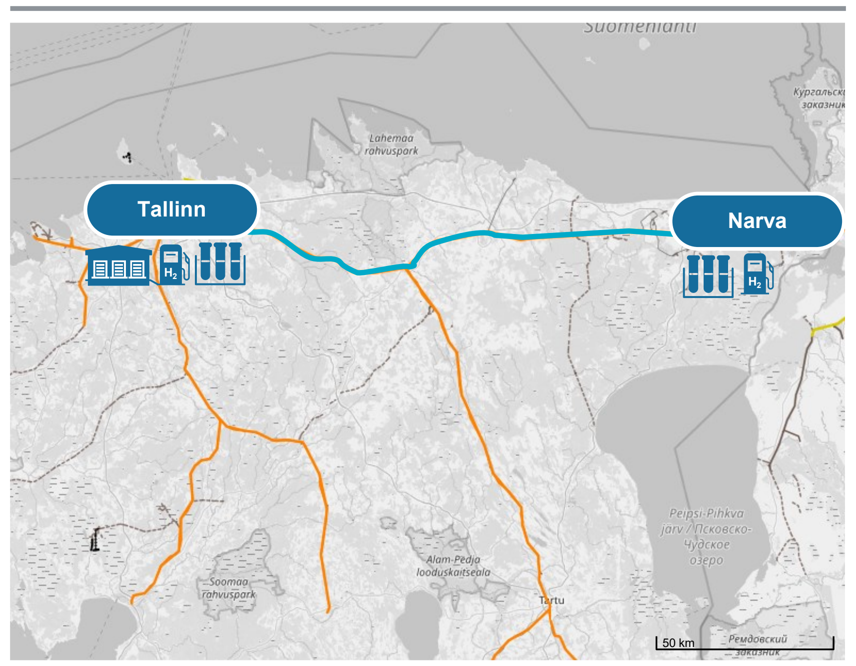
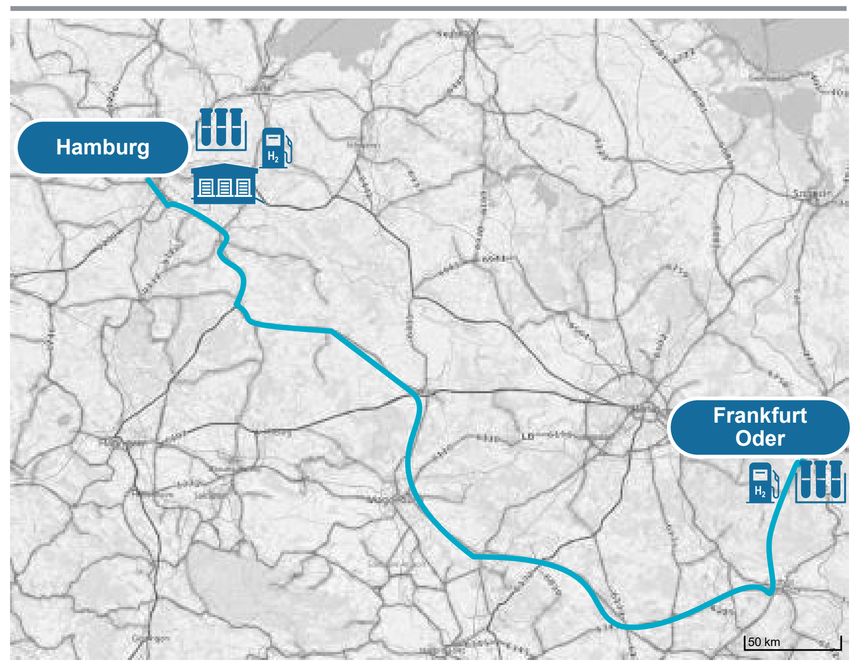
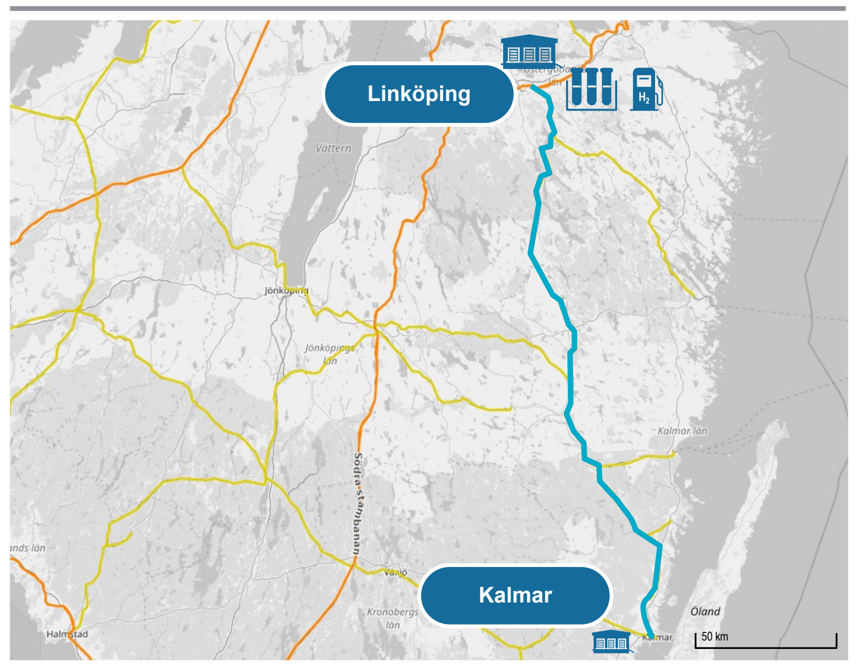
Shunter case study results [EUR/km$_{train}$]

	Hamburg-Billwerder, Germany	**Riga Node, Latvia**	**Gdansk, Poland**
Overview			
Track length	10 km	100 km	35 km
Rolling stock	15 Shunters	15 Shunters	10 Shunters
H_2 consumption	0.39 kg/km	0.49 kg/km	0.72 kg/km
Characteristics	Shunting yard in a large urban area and next to Hamburg port	Shunting operation between several port terminals	Marshalling yard in collocation of the refinery supplying hydrogen
Diesel	10.1	20.9	32.1
FCH	**12.7**	**20.4**	**36.7**
Catenary			
Battery	11.6	21.8	36.9
CO_2 saving potential in one year	**1,969 t**	**3,350 t**	**339 t**

Source: Expert interviews, Roland Berger

FCH Mainline Locomotives could be competitive in cases where route interoperability is limited, but still face barriers to market entry

Mainline Locomotive case study results [EUR/km$_{train}$]

	Tallinn – Narva, Estonia	**Frankfurt (Oder) – Hamburg, Germany**	**Kalmar – Linköping, Sweden**
Overview			
Track length	210 km	720 km	230 km
Rolling stock	2 Locomotives	5 Locomotives	5 Locomotives
H_2 consumption	0.67 kg/km	0.82 kg/km	0.48 kg/km
Characteristics	Cross-border operation between Russia and Estonia	Shunting operation between several port terminals	Passenger and freight transport between two cities
Diesel	22.6	9.2	5.7
FCH	**22.8**	**11.9**	**6.7**
Catenary	24.4	6.4*	22.0
Battery			
CO_2 saving potential in one year	**2,556 t**	**12,874 t**	**4,980 t**

*Only 20% of catenary costs assigned to this case due to increase line usage

Source: Expert interviews, Roland Berger

A Market potential in the base scenario is driven by FCH Multiple Units in the Frontrunner markets; by Shunters – in other markets

Overview of FCH train markets outlook for 2030 [standard units$^{1)}$]

Frontrunner	Low	Base	High
	150	273	569
	12	25	50
	10	20	40
	951	805	465

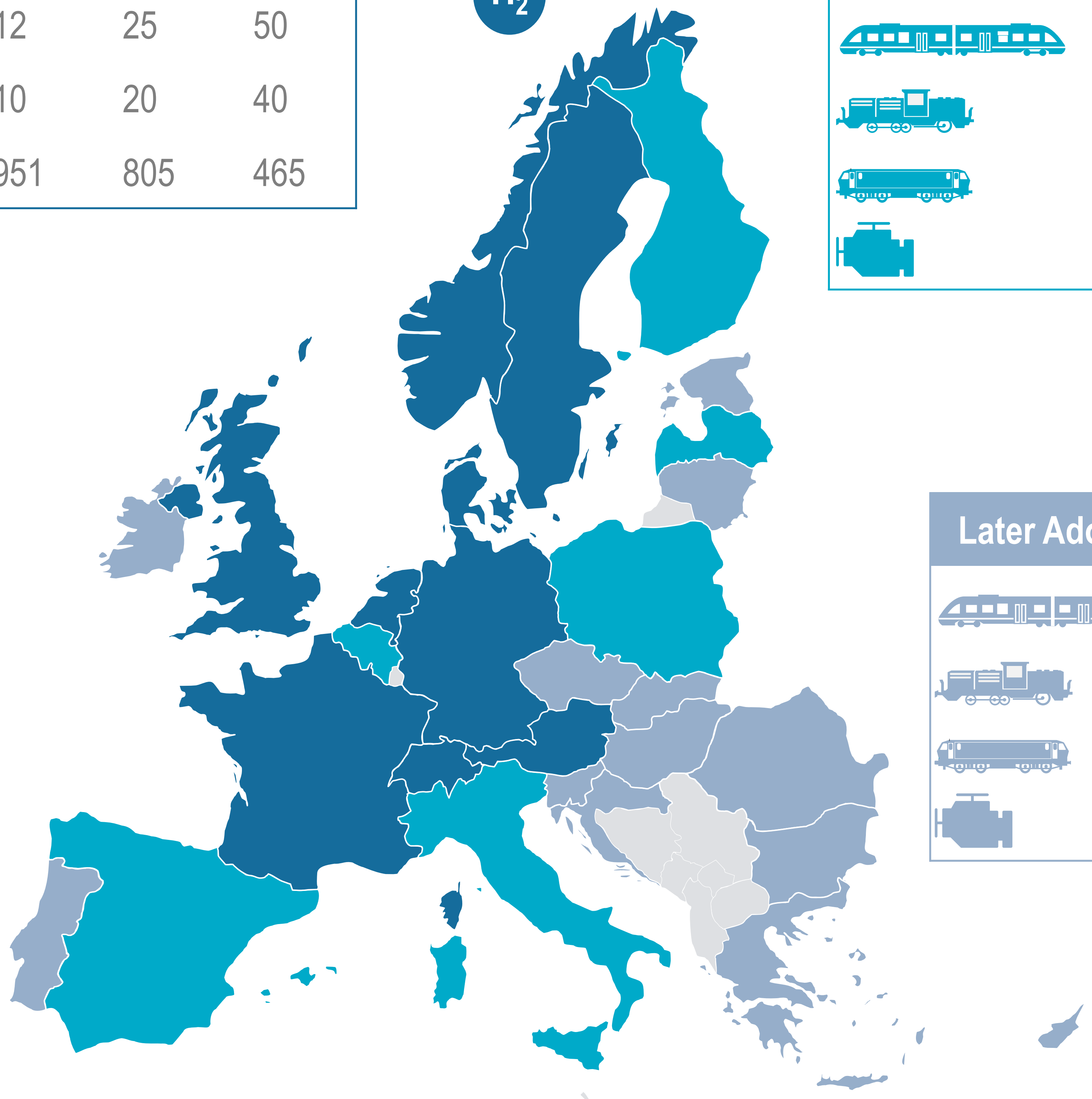
Base 2030 28% H_2

Newcomer	Low	Base	High
	10	21	41
	15	29	58
	4	8	17
	497	467	409

Base 2030 11% H_2

Later Adopter	Low	Base	High
	7	15	30
	9	19	37
	4	8	15
	419	398	357

Base 2030 9% H_2



X% H_2 Market share of FCH in 2030

Comments

> The Market potential will depend on the projected diesel purchasing volumes

> Substitution of diesel trains is driven by the Multiple Units in the Frontrunner markets

> On the other hand, Shunters drive the substitution in the Newcomer and Later Adopter markets

1) According to definition of UNIFE World Rail Market Report

Source: Market research, Expert interviews, Roland Berger

No barriers are show-stoppers for FCH rail technology, but R&I projects are required to realise a broader commercial potential

Conclusions

Barriers for FCH trains

> **No** principle **show-stoppers** to the deployment of FCH technology in the rail environment exist

> **High priority barriers** are related to **financing** FCH train deployment, **lack of standard scalable design** and **H_2 storage optimisation**

Suggested Research and Innovation (R&I)

> **R&I projects** can bring FCH technology significantly closer to commercialisation by **addressing high priority barriers**

> Three key project topics
  - **Large-scale demonstration** of Multiple Units fleets
  - **Prototype devel.** and testing of Shunters or Mainline Locomotives
  - Research and **tech. dev.** of **optimised H_2 storage** system

> **Medium**, **low** priority **barriers can integrated** in the same R&I project

Source: Expert interviews, Roland Berger

Study is published and available

FINAL REPORT: Study on the use of fuel cells and hydrogen in the railway environment

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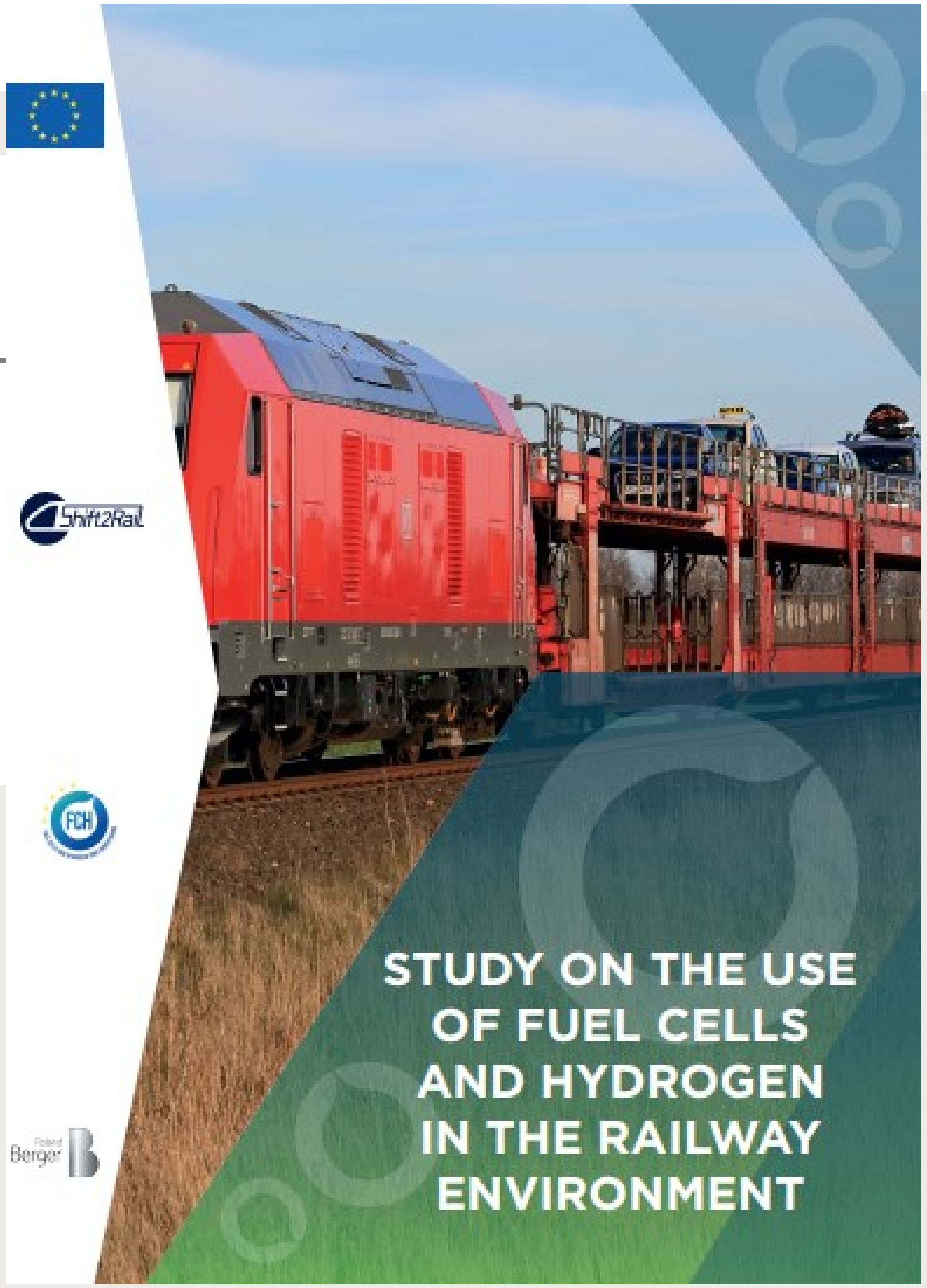
REPORT 1: State of the art & business case and market potential

REPORT 2: Analysis of boundary conditions for potential hydrogen rail applications of selected case studies in Europe

REPORT 3: Overcoming technological and non-technological barriers to widespread use of FCH in rail applications, and recommendations on future R&I



STUDY ON THE USE OF FUEL CELLS AND HYDROGEN IN THE RAILWAY ENVIRONMENT

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

FCH 2 JU: Call for proposals 2020

10 million EUR for trains

Topic	*Type of Action*	*Ind. Budget (M€)*
FCH-1-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework	***IA***	***10*,*****

**** Eligibility criterion: maximum funding; ** Included under leftover budget flexibility***

FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework

Develop new FC-powered train designs

- Innovative prototype design to be tested (demonstrate TRL 7)
- Can address: regional trains, shunting or main line locomotives
- Propose a normative framework for the placement on the market of trains using FCH propulsion

Proposed objectives for Clean Hydrogen Partnership

3 main pillars: H_2 production, distribution and end-uses next to supply chain, ecosystems and cross-cutting.

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

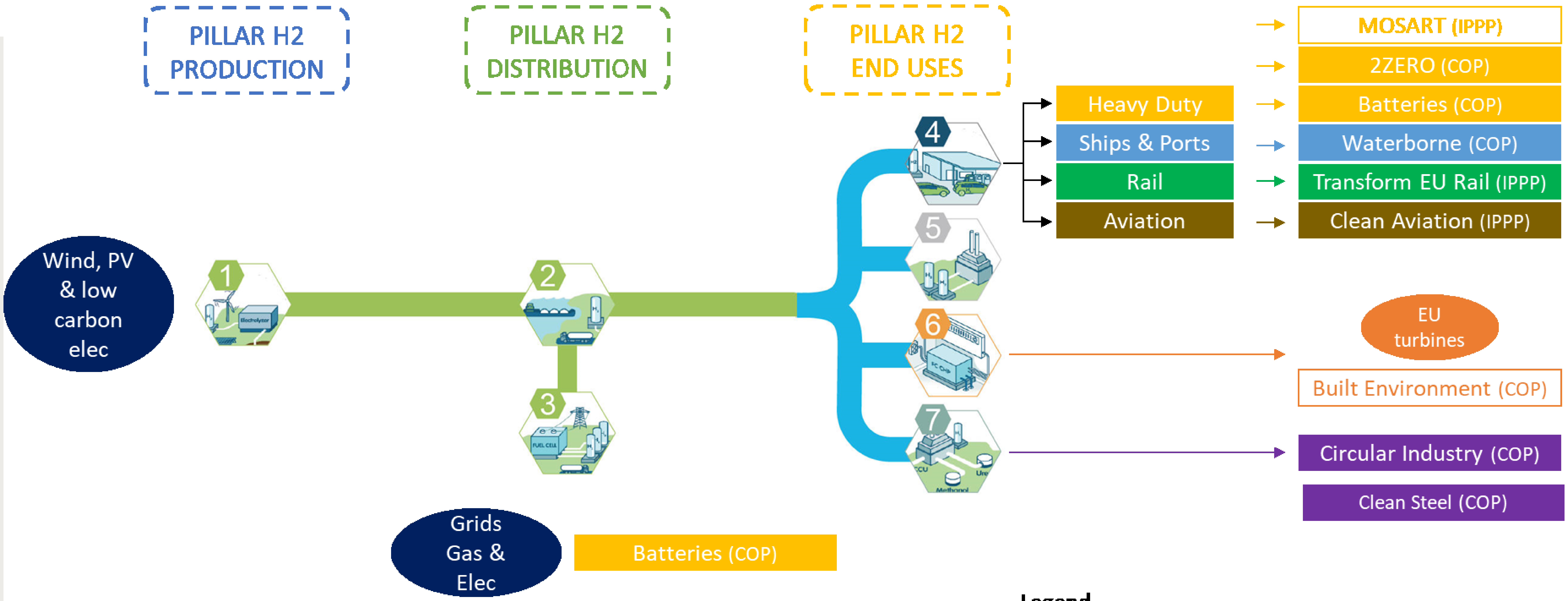
Integrated H2 ecosystems combining multiple applications (ports, industrial hubs, cities, etc.)

S10 Cross-Cutting

Regulations, Codes, Standards, Training, Safety, social, etc.

Consultation with other sectors

Looking to complementarities and cooperation with other partnerships



PILLAR H2 PRODUCTION

PILLAR H2 DISTRIBUTION

PILLAR H2 END USES

Wind, PV & low carbon elec

Grids Gas & Elec

Batteries (COP)

Heavy Duty

Ships & Ports

Rail

Aviation

MOSART (IPPP)

2ZERO (COP)

Batteries (COP)

Waterborne (COP)

Transform EU Rail (IPPP)

Clean Aviation (IPPP)

EU turbines

Built Environment (COP)

Circular Industry (COP)

Clean Steel (COP)

Clean Energy Transition (COF)

EIT Climate

EIT Raw material

Legend

■ Complementarity + wish of active coordination

☐ Complementarity + exchange of information

● No PPP but wish of active coordination

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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

FCH JU