FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

Trials and deployment of fuel cells applications - TRANSPORT

Lionel BOILLOT

PRD 2019

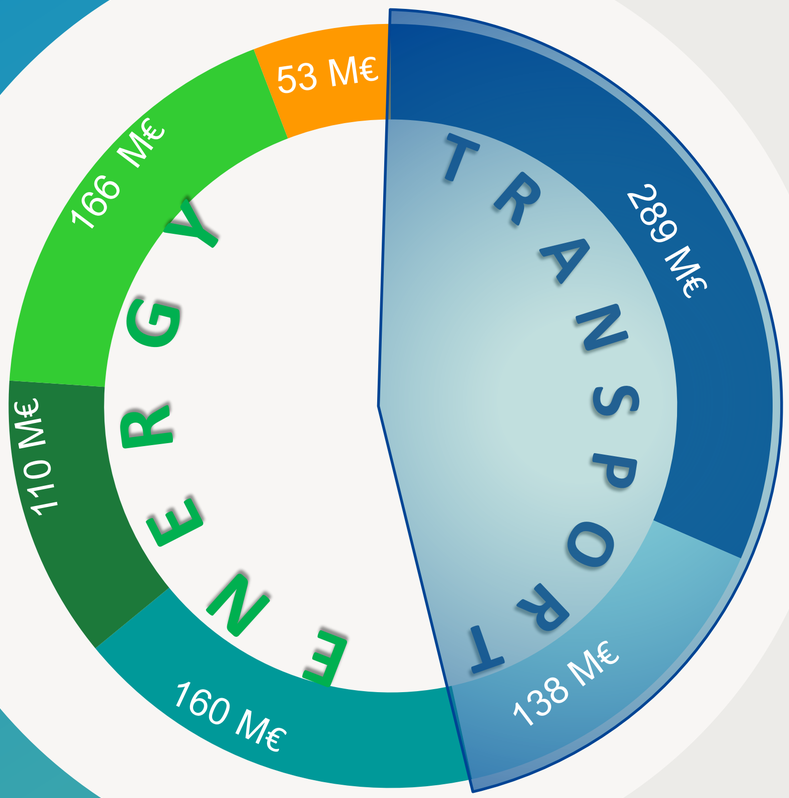
20 November 2019

Trials and Deployment of Fuel Cells Application-Transport

Related FCH JU objectives

Reduce fuel cell system costs for transport applications while increasing lifetime

Reduce use of critical raw materials



Transport - Total

42 %

427 M€

68 Projects

Out of which

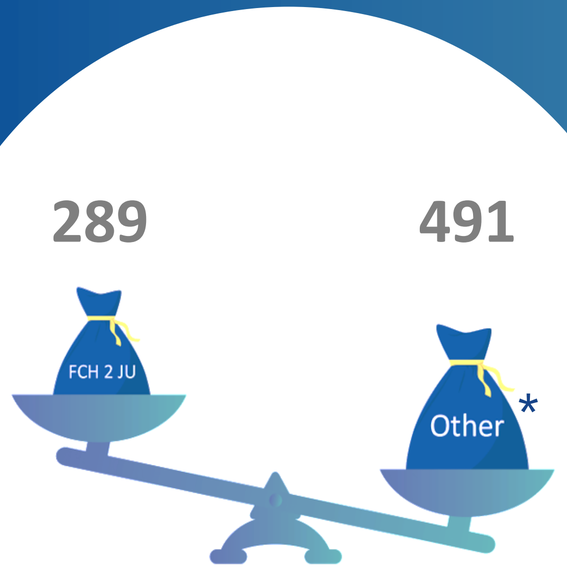
Transport Deployment

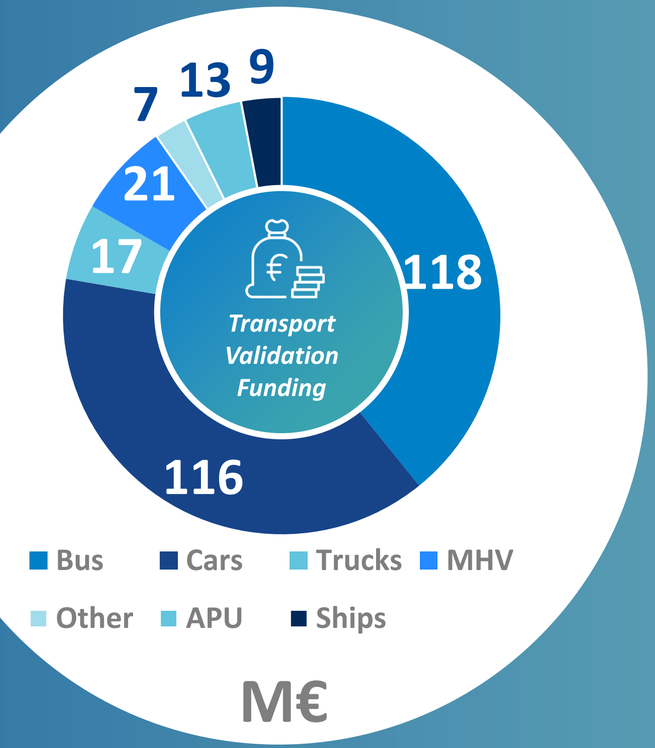
289 M€

26 Projects

On the road to widespread deployment

26 projects –780 M€





Extending the European network

Consolidating as market alternative

Exploring heavy-duty segments

DEPLOYING:

103 HRS

2000+ 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

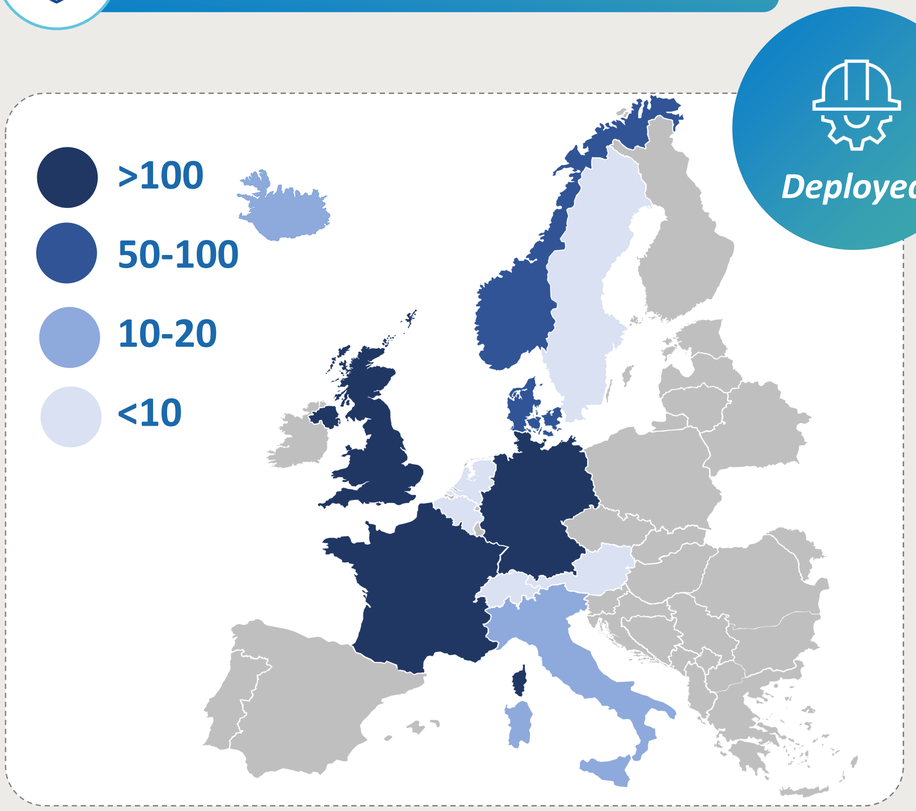
12 countries to deploy vehicles within our projects

725 cars deployed

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

Availability close to 100%



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

Taxi / Car Sharing / Ridesharing, company lease and functional fleets

Uncompromised operations, creation of new mobility services

Fleet examples

Cities in DE, Sept. 2017

- 45 cars
- 2,2 millions km
- 567,000 passengers
- Hambourg, Munich and Stuttgart (DE)
- 12 H2 stations

CleverShuttle

London, April 2018

- 50 cars
- One million miles
- Saving 7.6 tonnes of CO2
- 80.000 passengers
- 5 H2 stations

greentomatocars

Paris, May 2018

- 50 vans HyKangoo
- Utility company
- Leased by Alphabet
- Loaded with tools and material
- 4 H2 stations

ENGIE Cofely

Cities in DE, July 2018

- 30 cars
- Use in fleet and as private cars
- Network of hydrogen stations in DE

Alphabet

Fleet operation – main contributor for H2 mobility experience

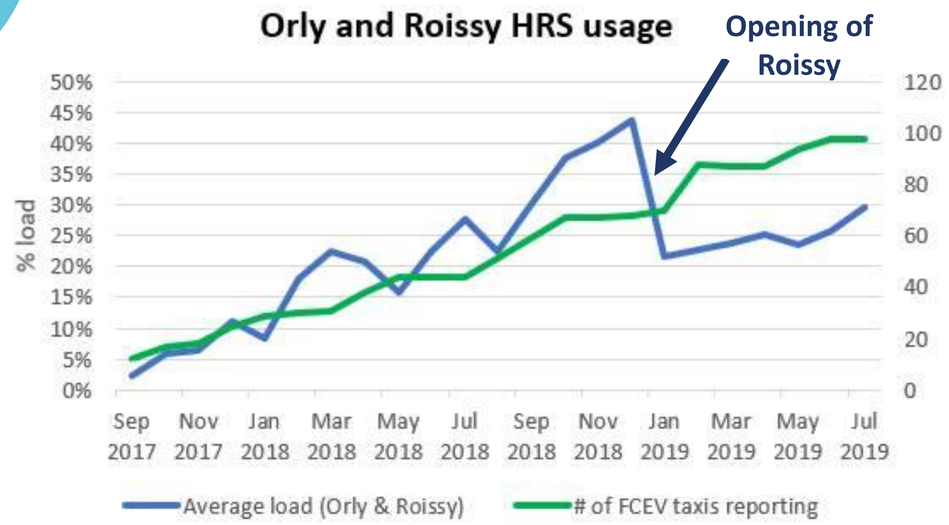
Demonstrating the efficiency of the technology – Vehicles and HRS pushed to intensive conditions

Taxi fleet (STEP) in Paris

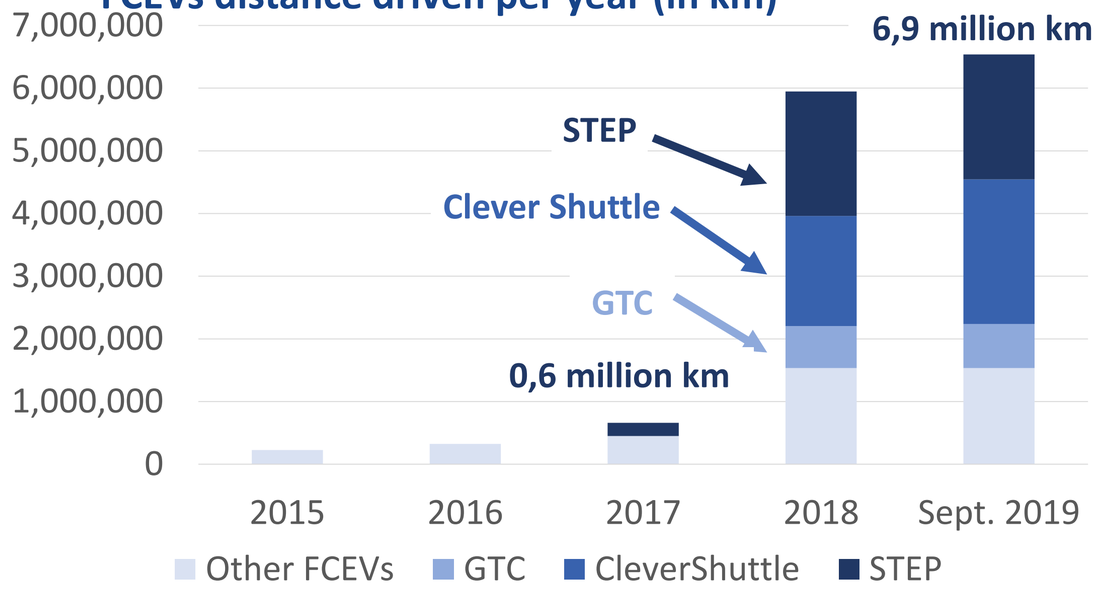
- July 2017 – Sept. 2019: 4,200,000 km driven
- ~ 40-60.000km/year/taxi in Paris
- Up to 24/7 operation

94%
low carbon hydrogen

HRS response to fleet operation (2018)



FCEVs distance driven per year (in km)



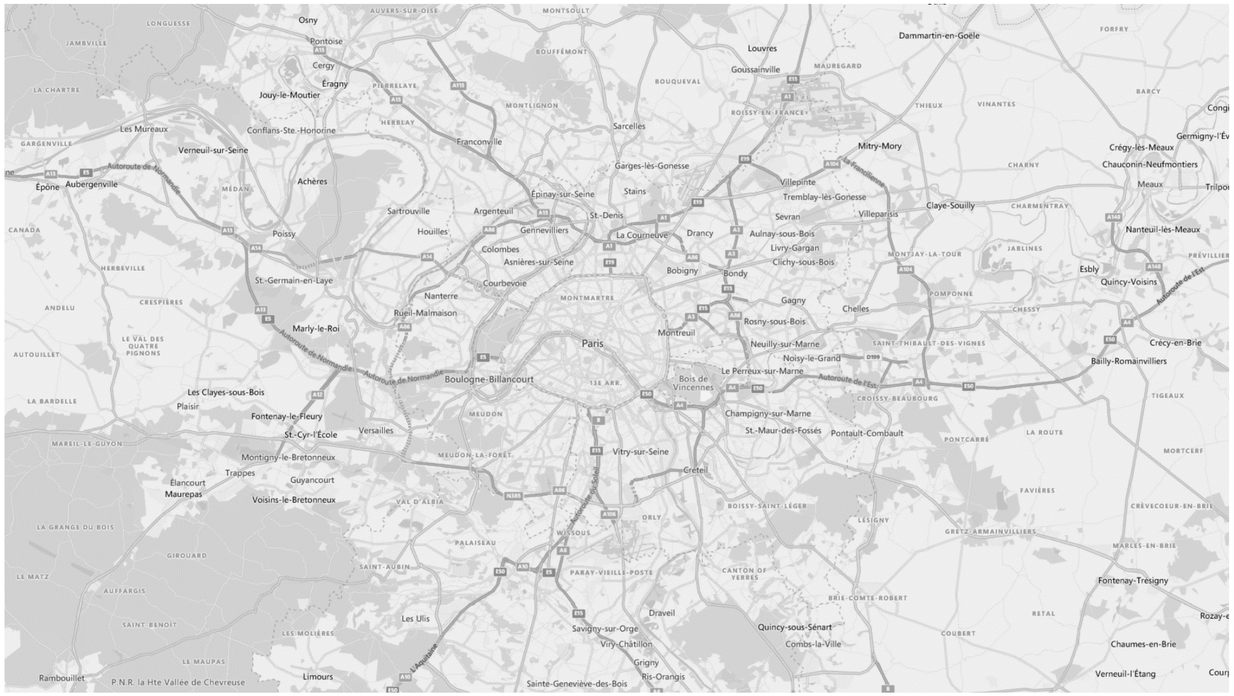
HRS high quality service required

- Upgrade of HRS
- Constant use over the day – like gasoline station
- Capacity for back-to-back refill
- Proprietary « App » for HRS status

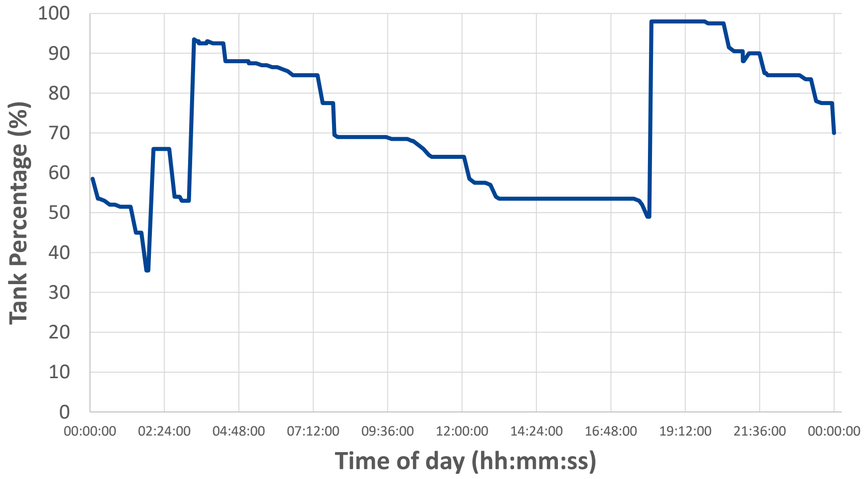
Typical day in a hydrogen taxi in Paris

28/07/19: Distance: 500km, Refuels: 3, Amount refuelled: 6kg H2

Geographical coverage of a taxi in Paris



Vehicle refueling gauge level



Fleet needs

- High availability and HRS networks covering operating areas
- Two or more HRS close to each other helps for redundancy.
- Need for higher redundancy in future individual HRS - especially dispensers

Reaching the market phase

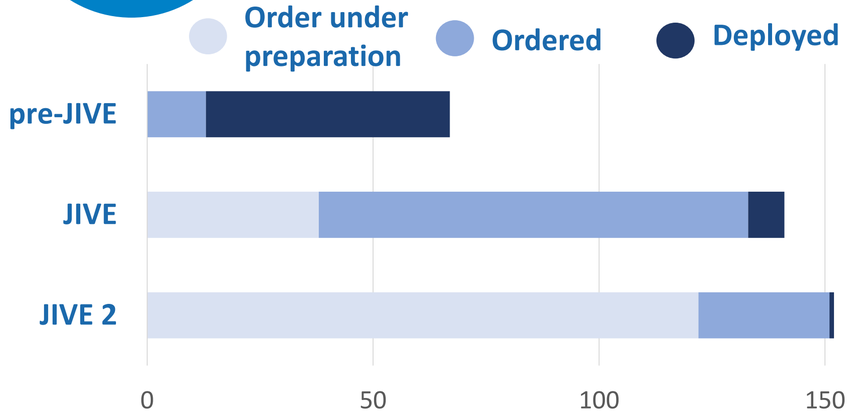
Offering a flexible clean competitive public transport solution

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

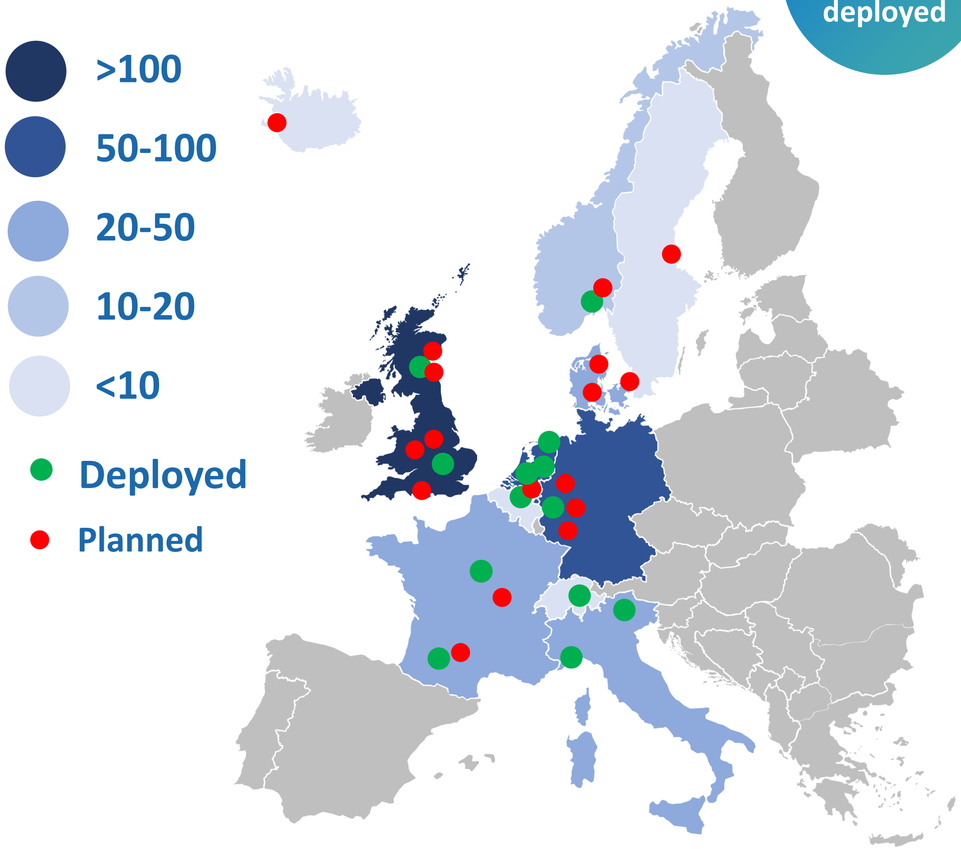
Flexible bus design and lenghts

CEF and EIB support FCB deployment

Bus of the Year 2019

Buses deployment geography

Planned and deployed



OEMs in Europe are responding to the growing demand for FC buses and preparing to offer new solutions

Yet Non European OEMs are also active in the sector

European bus OEMs with fuel cell buses demonstrators / offering fuel cell buses for sale

ALEXANDER DENNIS

CAETANOBUS

ebe EUROPA

DAIMLER EvoBus

rampini

Safra

ŠKODA

SOLARIS

URSUS BUS

VANHOOL

VDL BUS & COACH

WRIGHTBUS

A flexible competitive clean solution

Europe is world leader

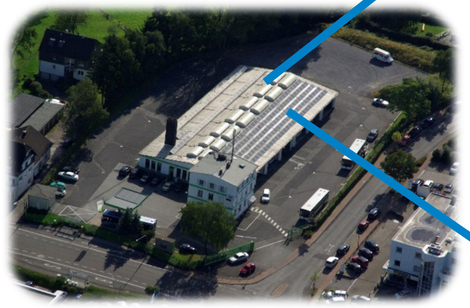
Achieved
- > 10,000,000 km since projects started
- > 35,000 h lifetime reached
- 625,000 €/bus offered
- 40.000km/y per bus on average

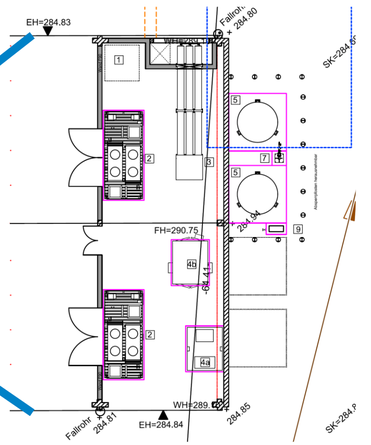
87%
low carbon hydrogen

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

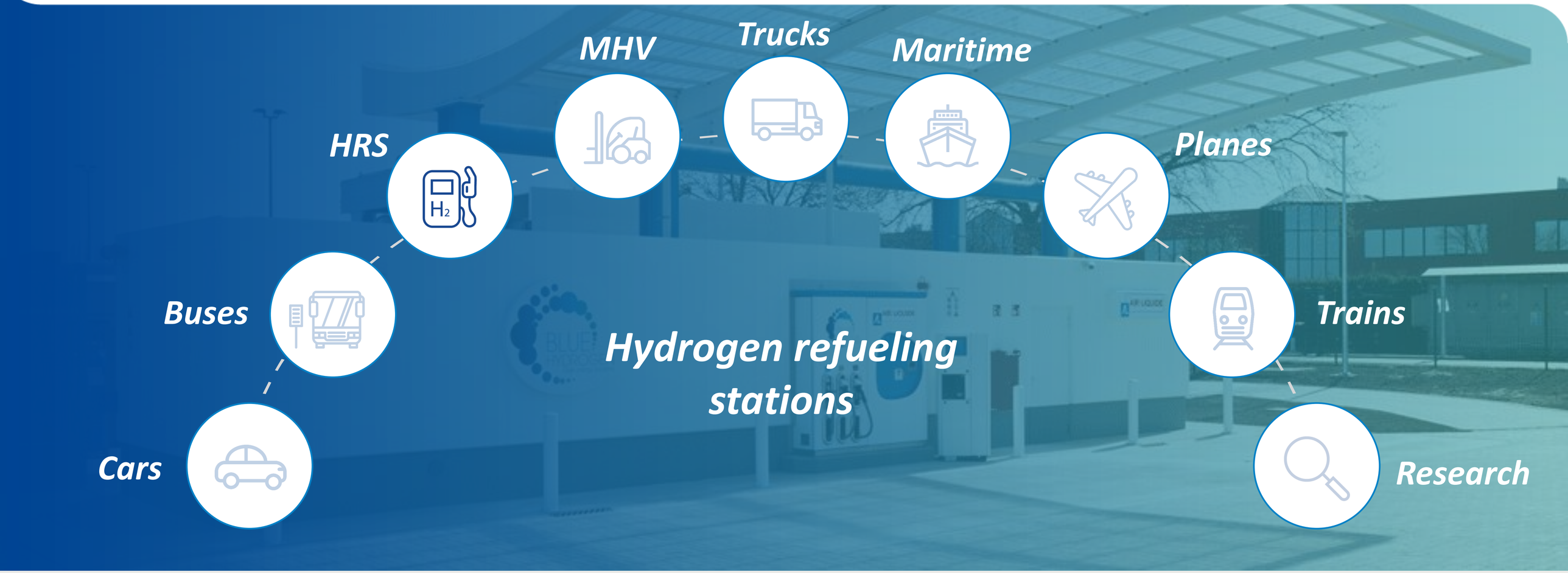




"Waste to wheel", from waste incineration to hydrogen for mobility

Paving the way for FCEV deployment in Europe

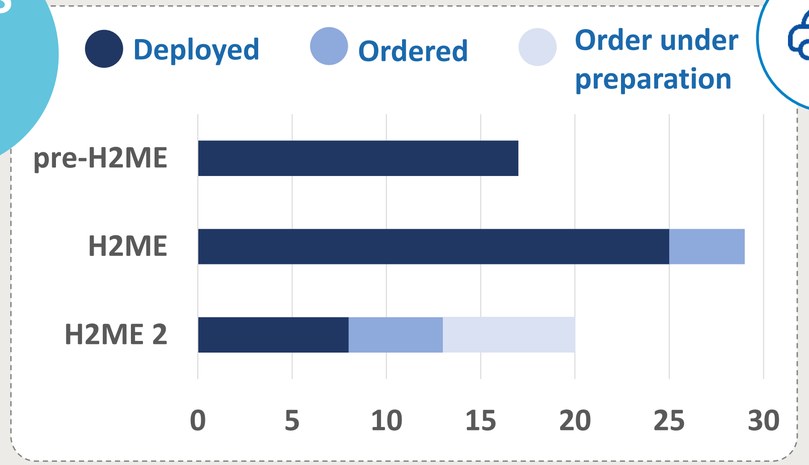
Exporting technology

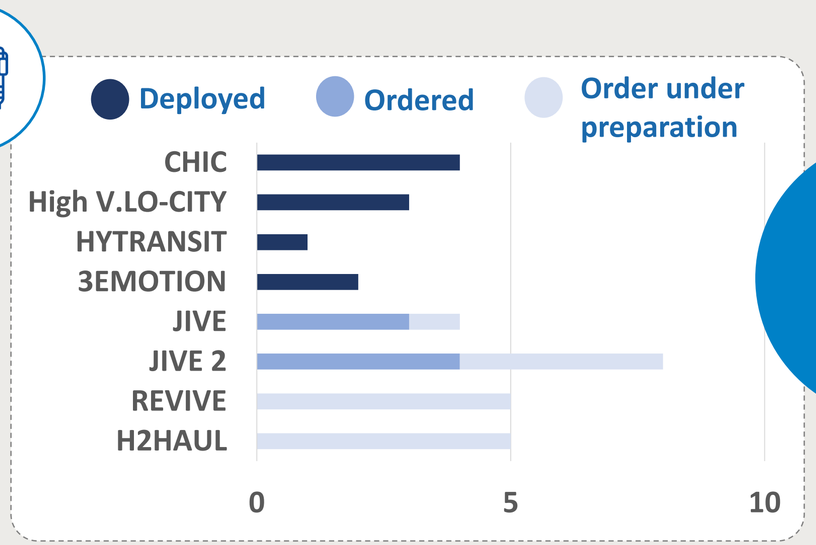


Making FCEV deployment possible

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

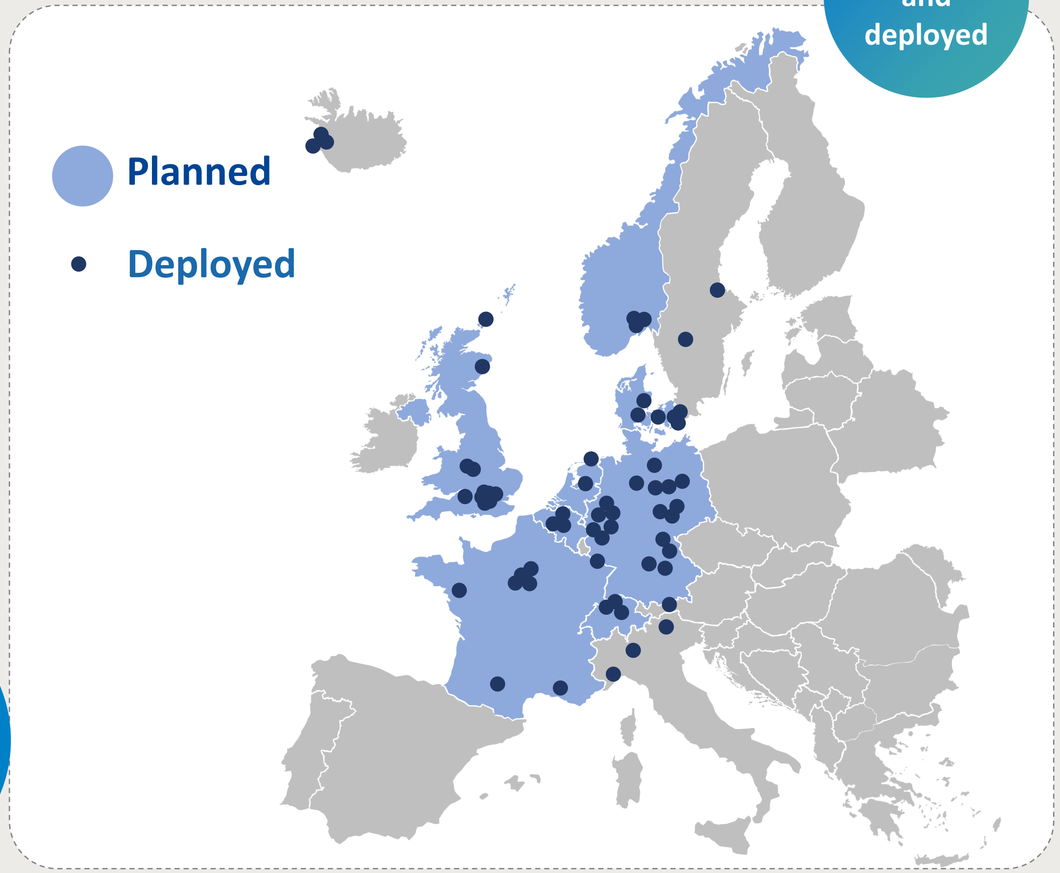
66 HRS for cars





32 HRS for buses / trucks

Planned and deployed



[CEF supports HRS deployment as well]

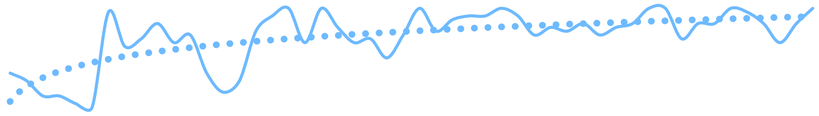
Developing technology for everyday customer

Managing a network of HRS for demanding customers

HRS tuned for demanding customer experiences

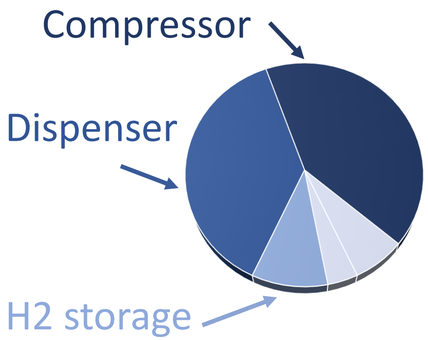
- Higher usage is resulting in more station damage
- Frequent driver changes means training
- Communication sources are vital to ensure drivers are redirected to available HRS
- Users need real time support to assist 24/7/365

HRS availability in London area



Summer 2018 **Summer 2019**

Cause of downtime



Achieved from 2016 (1 HRS) to Sept. 2019 (25 HRS reporting)

- Availability > 96%
- >35,000 refuelling operations
- > 72 t H2 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%

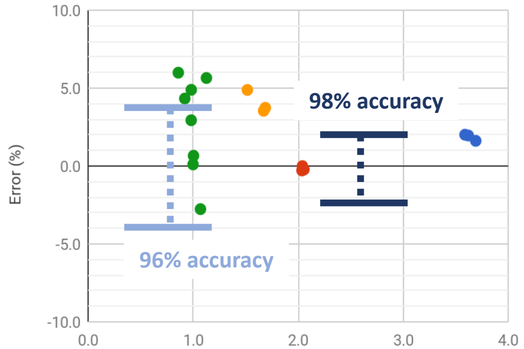
*National Fire Protection Association

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



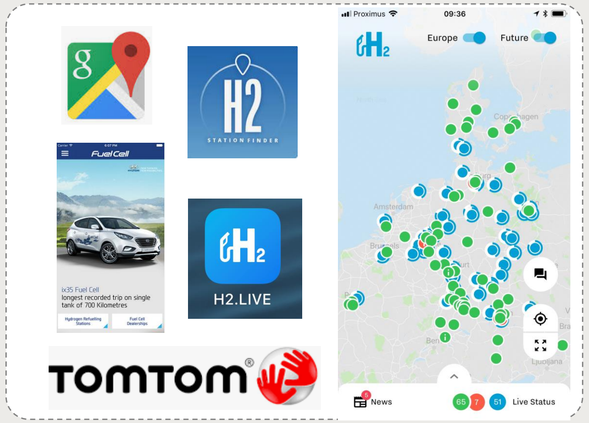
Development of a system for HRS availability in the EU

139 HRS connected sending live data

https://h2-map.eu/

Status definition

Possible end users



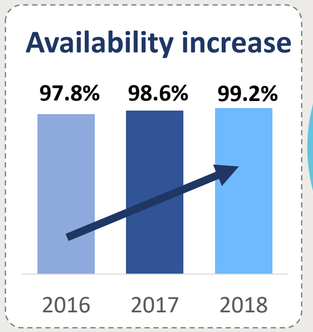
First steps into the business case

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

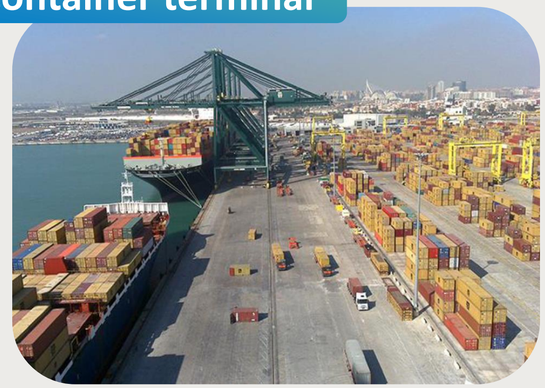
Diversity of vehicle types

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)

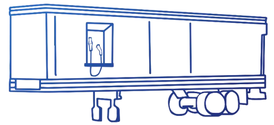
Container terminal



~ 20 kgH2/d

Yard tractor

Mobile HRS



Reach stacker

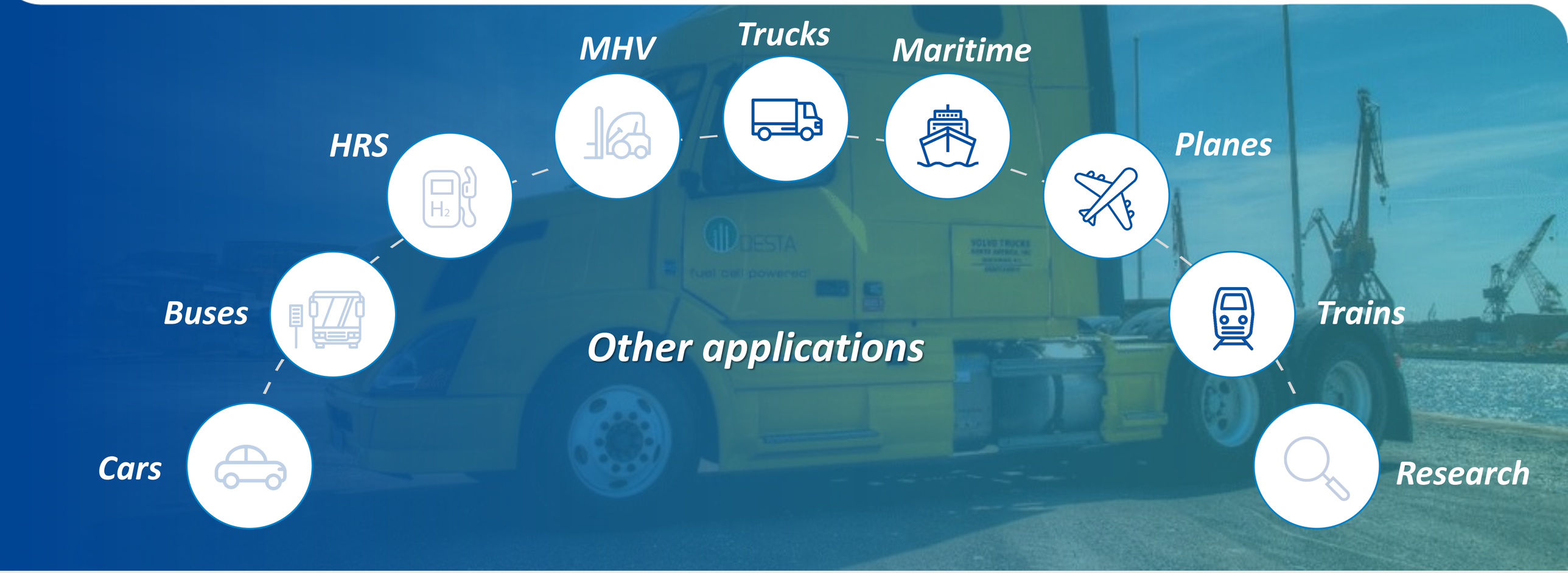
~ 35 kgH2/d

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)

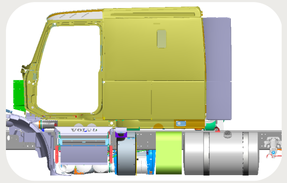
Penetrating municipal garbage collection, logistics operations for industry and supermarkets chains

From APU to truck fleets

2018 – 15 HD trucks

2017 – 15 garbage trucks

2013 - APU for diesel truck



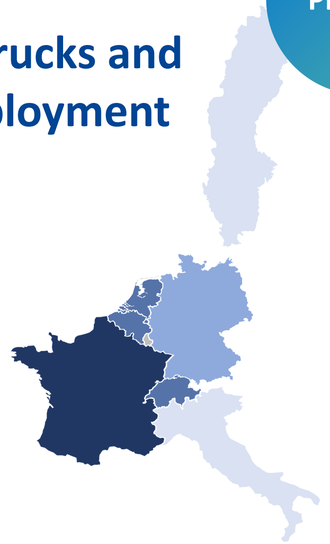
April 2019: New EU legislation for HDVs CO2 emissions

Year	2025	2030
CO2 reduction	15%	30%

Garbage trucks and trucks deployment

Planned

- 8
- < 4-8
- < 2-4
- 1



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)

“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

“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

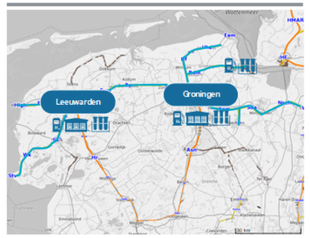
- Shunting and short distance
- 200-1,000 km
- 35 years

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 »

	Mult. units	Shunter	Main. loco
Overview	Groningen & Friesland, Netherlands	Riga Node, Latvia	Kalmar – Linköping, Sweden
			
Results in EUR/km$_{train}$			
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
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**

Decarbonizing the European transport sector

Allowing to meet the European CO_2 targets

- Advancing on “fleet case” deployments
- Towards larger fleets demand
- Moving towards heavy-duty mobility
- Reaching out new markets for specific uses
- Supporting the best fits per application

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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