FCH JU

HD activities

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Executive Director,

Fuel Cells and Hydrogen

Joint Undertaking

#PRD2020
#CleanHydrogen

Demonstration projects

Long haul and urban applications

Long haul

- At least 400 km autonomy;
- Tractor and rigid configurations;
- Integration in the daily operations of end users with different operations(Air Liquide, BMW, Carrefour, Colruyt)
- 2021/2022 deployment of the trucks;

30 trucks
13 demonstration sites
7 countries

Refuse trucks

- Daily back-to-base missions;
- Design standardization towards mass production;
- Fleet operation: 120.000 hours;
- First truck already deployed in Breda;

Validation of FC and hydrogen technology for heavy-duty applications in real-life conditions.

Components & infrastructure

Custom development for HD applications

NEW

Durability-Lifetime of stacks for Heavy Duty trucks

- Understanding of degradation mechanisms;
- Aim 30.000 hours durability;

NEW

Scale-up and demonstration of innovative hydrogen compressor technology for full-scale hydrogen refuelling station

- Upscale and integrate innovative compressor in HRS;
- Demonstration in HRS ≥200kg/d H2;

NEW

Standard Sized FC module for Heavy Duty applications

- Joint effort between FC suppliers and OEMs;
- Fostering economies of scale, “plug & play concepts” and competition;

Feasibility of liquid H2 on-board storage for heavy-duty vehicles

- Evaluate feasibility through a design study and demonstration test bench;
- No projects in 2021!

Study and protocols

Business models safe and rapid refuelling operations completing the picture

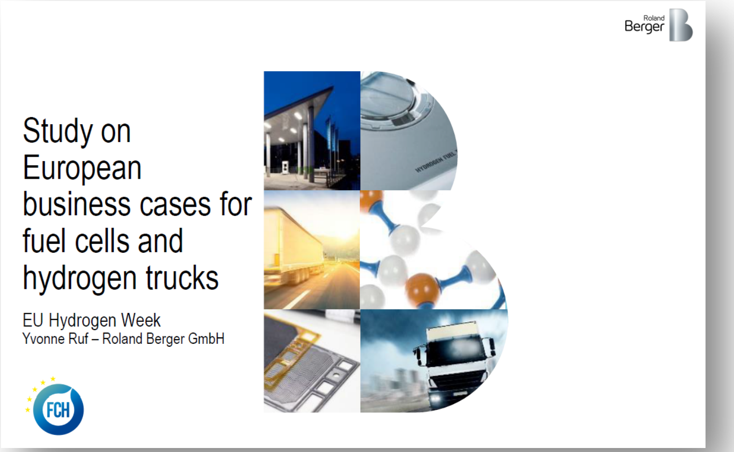
Safe & rapid refueling operations

H_2 PRHYDE
Protocol for heavy-duty Hydrogen refuelling

Protocol for heavy-duty hydrogen refuelling

- ➢ Develop refueling protocol(s) for vehicles with Compressed Hydrogen Storage System >250litre, >10kg;
- ➢ Identify factors limiting the refueling rate (120g/s) and propose solutions for larger flow rates;
- ➢ Findings and recommendations should be shared with relevant sectors and standardization committees;

Business models



1. State of the art;
2. Business cases and market potential;
3. Case studies;
4. Recommendations;

Roland Berger

Study on European business cases for fuel cells and hydrogen trucks

EU Hydrogen Week

Yvonne Ruf – Roland Berger GmbH

FCH

November 23, 2020

This presentation introduces the results of a study conducted on fuel cells and hydrogen in heavy duty trucks

Project objectives

Objectives of the project

- Development of **business cases and market potential analyses for the use of FCH technologies** based on use cases (e.g. different range and load profiles)
- Development of **case studies by fuel cell and hydrogen application** (different composition, freight load, route and range) expressing potential opportunities
- Identification of **technical and not technical barriers** for the implementation of fuel cell and hydrogen technologies
- Identification of **needs in research and innovation (R&I), regulation, and standards**
- *On a higher level:*
  - *Creation of a **platform for** the **collaboration of** key **stakeholders** of commercialising FCH heavy duty road transport applications*
  - *Conduct **analytical ground work** in support **of future R&I** funding from EU sources*

Source: Roland Berger

We mobilised a balanced Advisory Board with 56 companies and organisations across 15 European countries

Advisory Board Members

	Vehicle OEMs	Technology providers	Infrastructure and H_2 providers	Truck operators / Logistics users	Associations and others
AB member base	10	13	10	13	10

Geographical distribution

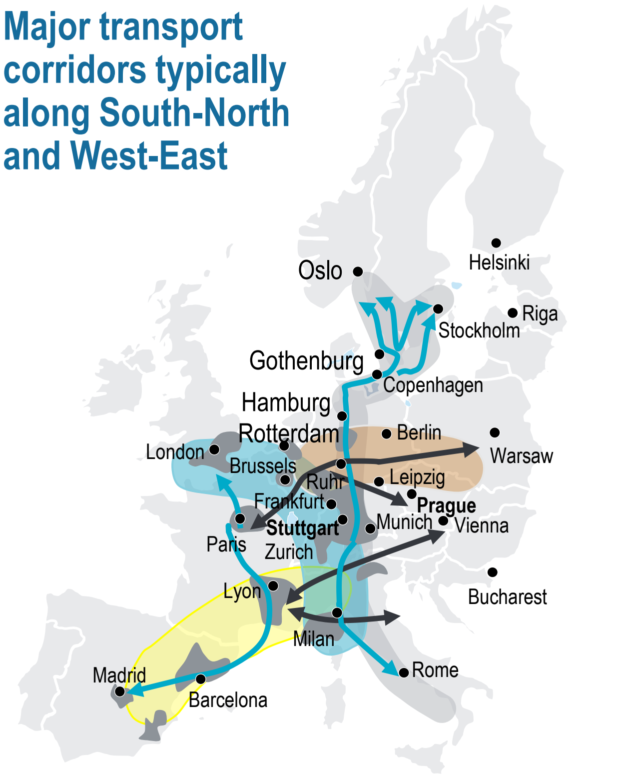
15 countries in Europe

Source: Roland Berger

The road freight sector is an important pillar of the European economy, yet a significant source of CO_2 emissions

Road freight sector in the EU

Major transport corridors typically along South-North and West-East



6,6 m **trucks drive in the EU** (medium- and heavy-duty)

300 k **new heavy-duty trucks** are sold in Europe **every year**

~5% **of total EU CO_2 emissions** come from heavy-duty road transport

~27% of specific **road transport CO_2 emissions** in the EU come from **lorries, buses and coaches**

Transportation North-South
Transportation East-West
Conurbations and logistics hubs
Scandinavia-Mediterranean-corridor
'Blue Banana'-corridor (UK-BE-NL-GE-CH-IT)
'Golden Banana'-corridor (Mediterranean cost)
New East-West corridors, e.g. Germany-Poland

Source: European Commission; EEA; ACEA; Colliers; Savills; desk research; Roland Berger

The EU Green Deal aims for a 90% reduction in transport emissions by 2050 and national regulation prompts the uptake of technologies

Selected examples of emissions and air quality regulation

European Union

> Two **EU Ambient Air Quality (AAQ) Directives**[1] set air quality standards and requirements for Member States (incl. monitoring, obligation to adopt national air quality plans, accountability in court)

> The **National Emissions Ceilings (NEC) Directive** (2016/2284/EU) sets national emission reduction commitments for 2020 and 2030 targeting six main pollutants[2]

> **National Air Pollution Control Programmes** (NAPCPs) are required in all EU Member States since 2019

> For HDT, the EURO VI regulation sets stricter **type approval standards** aimed at improved air quality through
  - Not-to-exceed emission limits
  - Stricter testing cycles
  - Independent market surveillance

National approaches

France / Paris

> **Low emission zones in place in several cities**, excl. access for vehicles below Euro 4

> **Access regulation for delivery trucks** in several cities with time restrictions

> **Plan to ban all diesel cars in 2024** in Paris**,** exemption for delivery trucks

UK / London

> **Plan to ban new petrol, diesel and hybrid car sales** from 2035, trucks not covered

> **Ultra Low Emission Zone** (ULEZ) in the City of London since 2019 and complete **ban of petrol and diesel cars** since March 2020 in **selected central parts**

Germany / Stuttgart

> **National framework of low emission zones in place** incl. vehicle bans

> **Transit bans** in several cities for **medium- and heavy-duty vehicles**

> 'Smog alarm' programme in Stuttgart for times of high particulate concentration

Spain / Madrid

> **Low emission zone in place in several cities** with eased restrictions in Madrid (2019)

> **Weight restricted access** for trucks during daytime and holidays incl. bans for heavy-duty trucks to access central city areas

1) Directives 2008/50/EC and 2004/107/EC 2) Sulphur dioxide, nitrogen oxides, volatile organic compounds, ammonia, methane and fine particulate matter

Source: European Commission; Desk research; Roland Berger

While multiple alternative powertrain options exist, FCH offer a 0-emission alternative with operational and payload flexibility

High-level comparison of powertrain technology portfolio for HDT

	Reference		Project focus			
	Fossil powertrains			Zero emission[1]		
	Diesel	**LNG/CNG**	**e-fuels**	**Battery-electric**	**Fuel Cell-electric**	**Catenary / Trolley**
						
Description	Combustion engine powered by diesel	Combustion engine powered by LNG/CNG	Combustion engine powered by e-diesel	Electric motor powered by chemic. stored energy in a rechargeable battery	Electric motor powered by a fuel cell, combined with a battery	Electric motor powered by DC from overhead lines using a pantograph
Strengths	> Established technology with widespread infrastructure > Long daily driving ranges	> Fuel cost advantage compared to diesel > Lower particulate emissions than diesel	> Use of existing infrastructure > Use of existing HDT combustion engines	> Meet emission restrictions > High powertrain efficiency	> Meet emission restrictions > Possibility for long daily driving ranges > Quick refueling compared to BET	> Charging while driving, i.e. no stops needed > Smaller batteries and good CO_2 footprint
Potential constraints	> CO_2 and NO_x emissions and related regulation	> Infrastructure availability > Limited emission reduction potential > Relatively low fuel efficiency (~25%)	> Production cost not on competitive level: ~3.5 x diesel price > Remaining local emissions (e.g. NO_x) > CO_2 sourcing	> Cost, size and weight of batteries > Range limitations > Recharging time and space required > Vehicle cost	> Availability of infrastructure > Production cost of H_2 > Vehicle cost	> Availability of infrastructure > Limited flexibility of routes > Early development stage

1) With primary energy derived from renewable sources

Remaining local emissions (dotted shading: e-fuels column)

Source: Desk research; Roland Berger

The technological readiness level of FCH in heavy duty trucks is comparable to battery electric technologies

Overview technological readiness level

Outside-in view

> Interest and action on FCH trials and demonstration projects is increasing

> Other alternative powertrain technologies are being promoted in parallel

Alternative powertrain technologies for HDT	TRL* (1 Idea – 2/3 Tech. formulation – 6 Prototype – 8/9 Fully commercial)	Refuel. / charg. infrastructure	Emission red. potential
Fuel cell electric	7 (6-7)	1/4	full
Battery electric	7-8 (8-9)	1/4	full
Lower-carbon fuels[2]	9 (8-9)	1/2	1/4
Synthetic fuels / e-fuels[3)]	8 (8-9)	full	3/4
Catenary and trolley	6 (6-7)	empty	full

1) Emission reduction potential: Tank-to-Wheel 2) Low carbon fuels (e.g. CNG, LNG), liquid biofuels fuels 3) Sustainable e-fuels from renewable sources

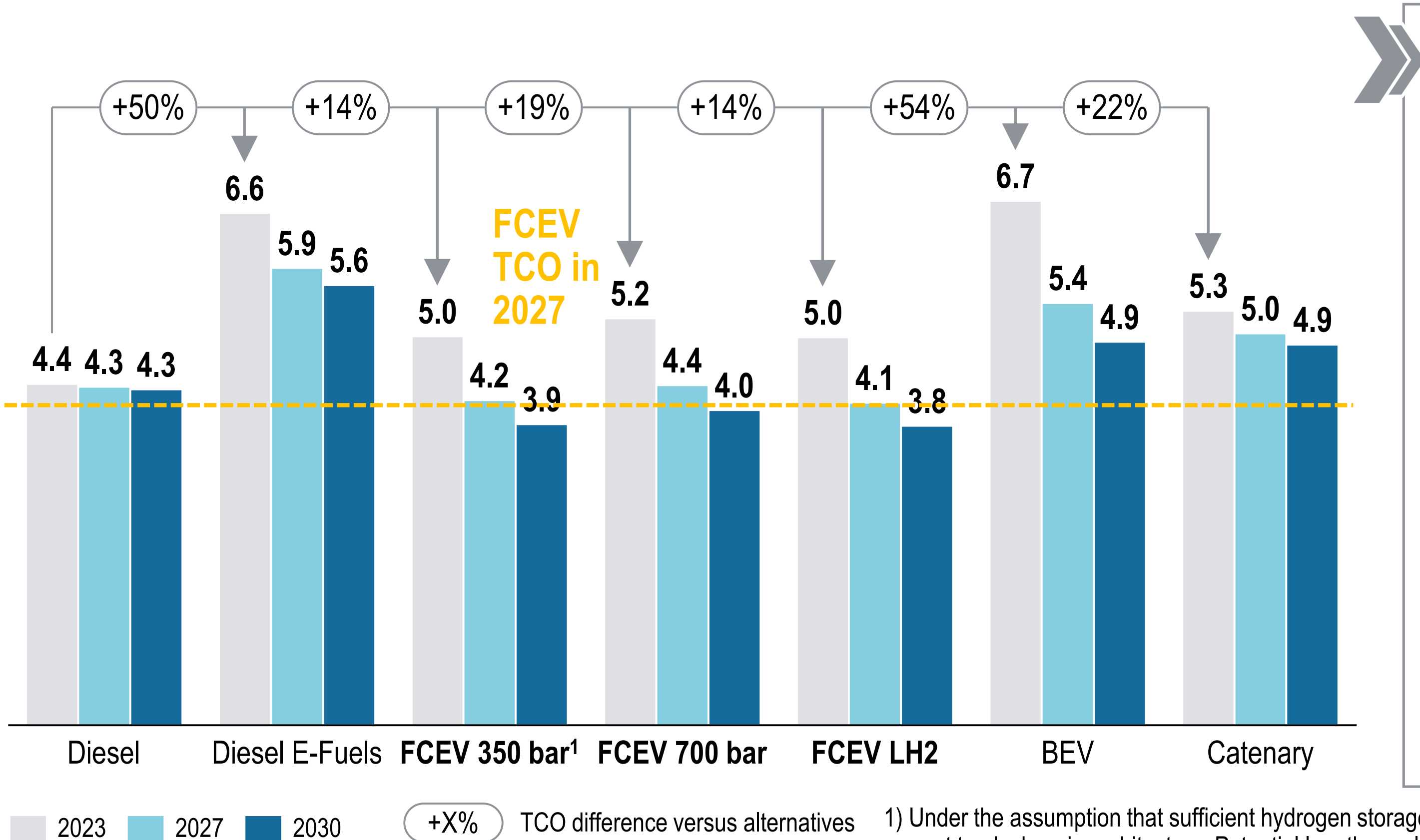
*) Technology Readiness Level of truck ▼ ≤ 5 ▼ 6-7 ▼ 8-9 Legend: ○ low level ● high level

Source: Roland Berger

From a TCO perspective, FCH HDT can become cost-competitive with diesel by 2027 if production volumes are ramped up swiftly

High-level TCO assessment – Use case I [EUR ct/tonne-km; 1st & 2nd life]

1 Use case I – Tractor 4x2, 140,000 km annual mileage



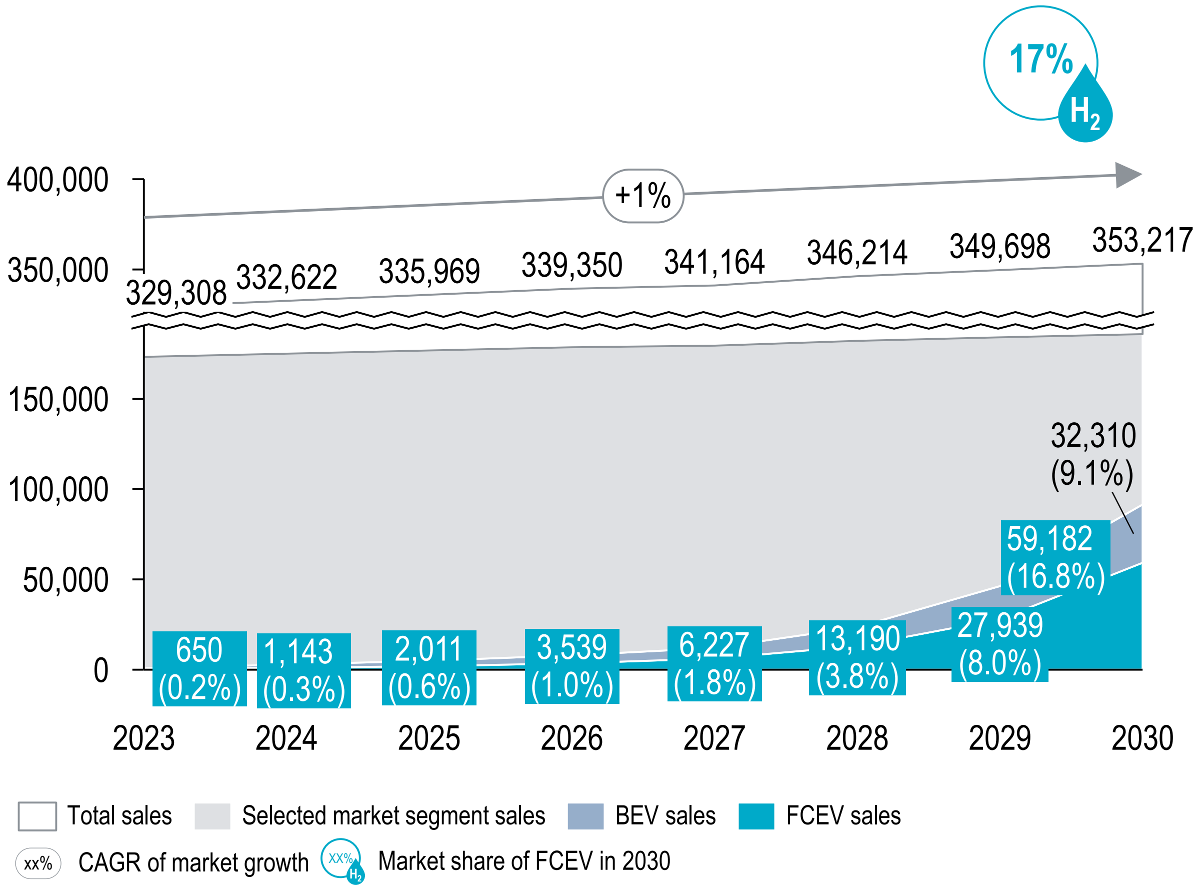
- FCH trucks for use case I have a **cost premium of up to ~19% in 2023 compared to diesel** and could become cheaper if implemented at scale
- **FCH truck technologies can be more competitive than the alternatives** Diesel E-Fuels, BEV and catenary on a tonne-km basis
- **When considering 1st and 2nd life,** a significant **cost down potential** for FCEV **at scale** exists

1) Under the assumption that sufficient hydrogen storage can be technically integrated in the current truck chassis architecture. Potential length regulation adjustments required.
2) The technical maturity is at a very early stage and needs to be demonstrated in a truck

Source: Roland Berger

The market potential of FCEV can increase to an overall sales share of 17% in 2030 – Strong uptake from 2027 until 2030

European market potential of FCEV [# of truck sales] – Total base scenario[1]

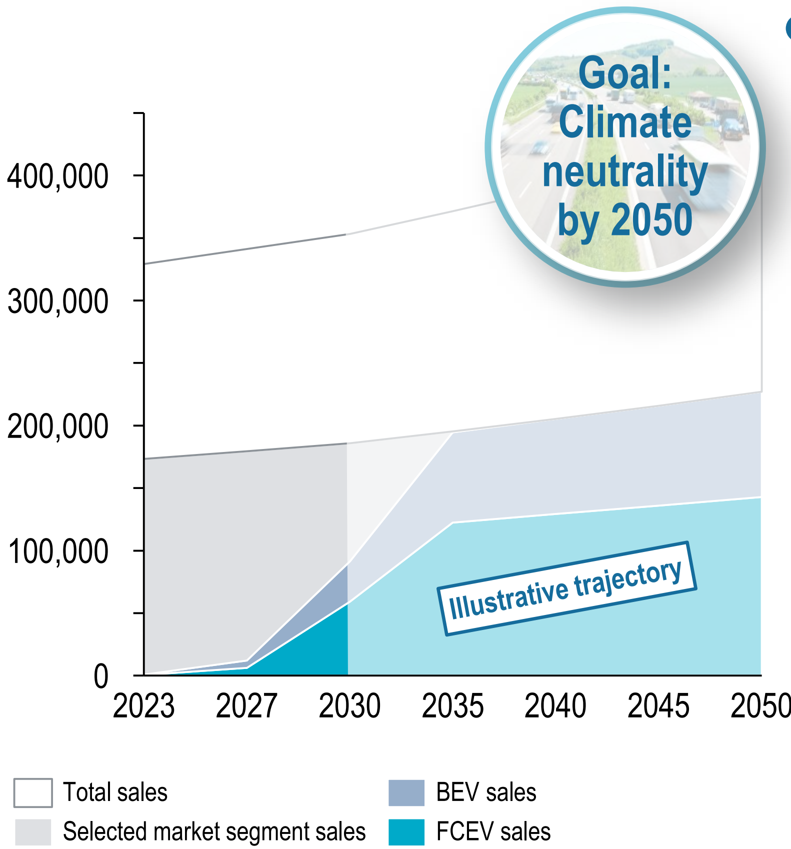


- The **market potential** analysis focuses on **selected market segments** that represent the most **relevant logistics industry** segments[2] (sales share of ~53% in the base year)
- In **2023,** the **sales share of FCEV is at 0.2%** due to assumptions made for **limited market maturity**, yet **increasing uptake opportunities**
- In **2027**, **a 1.8% sales share** is expected for FCEV
- In **2030**, the **FCEV sales share increases to ~17%**
- The **BEV sales share is increasing** overall and **establishes a market share of 9%** until 2030

1) The relative development of ZEV is based on the total number of truck sales in Europe, including the market segments selected for the market potential analysis (53% of total)
2) The market potential analysis refers to specific market segments: international logistics, national logistics, manufacturing industry, wholesale, retail and regional logistics
Source: IHS market forecast; Roland Berger

A fast market ramp-up over the next ten years is crucial for achieving the 2050 climate goals – Fleet replacement required

Assessment of 2050 market potential



> The **CO_2 emission reduction targets for 2050 in transport can be reached** for the heavy-duty truck segment – if the **growth rate of zero emission technology until 2030** materialises

> As **zero-emission trucks become cost-competitive,** new sales of diesel trucks and other **CO_2-intensive technologies** could be **replaced from 2035** onwards – this is necessary to replace the majority of the fleet of diesel trucks until 2050

> Critical factors:

- **Push to market** for zero-emission trucks to ensure **scaling effects for cost competitiveness** and market uptake
- **Enable infrastructure availability** to allow for widespread deployment
- **Change within fleets** and **diesel phase-out** until 2035 as diesel trucks have a total lifetime of 10+ years
- **Specific mandatory targets for all market actors** – OEMs in scope of HDT legislation, yet contribution across the whole sector necessary

Source: IHS market forecast; Roland Berger

Case studies demonstrate that requirements for logistics operations can often be satisfied with a flexible FCH zero-emission option

Overview of analyzed case studies

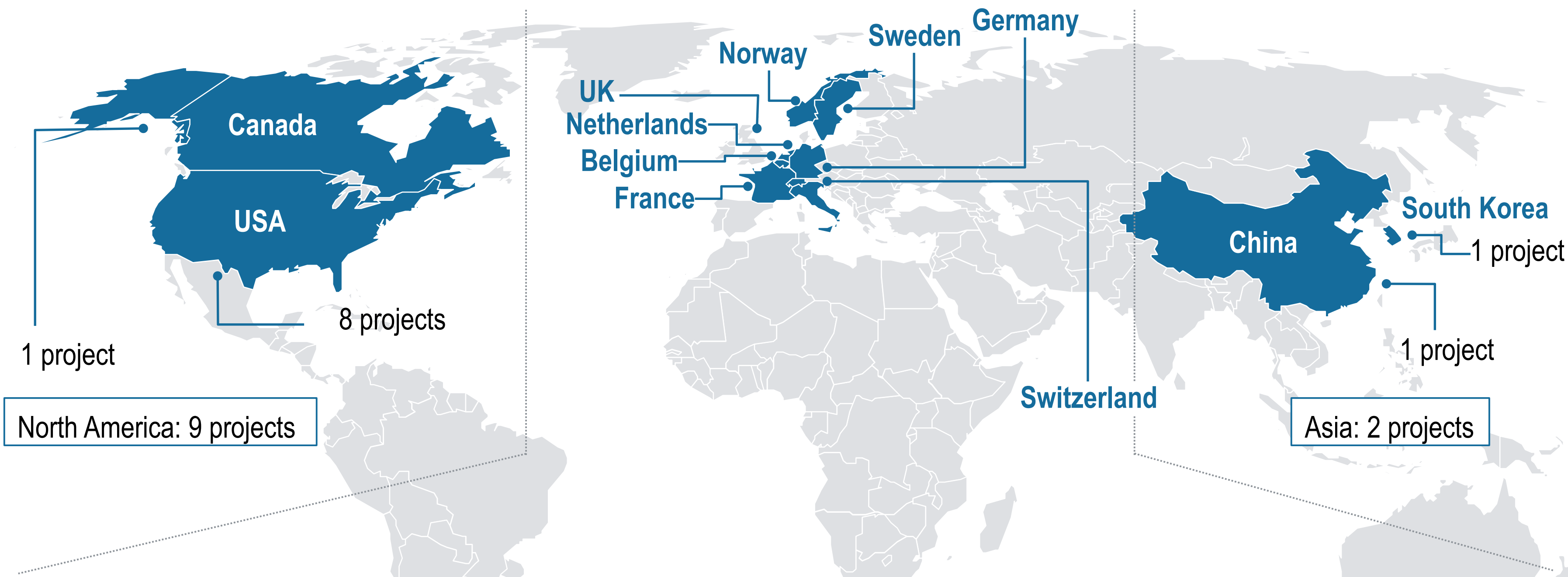
	Location	Truck type	Country	Company
Use case I	1 Košice-Bratislava		SK	Bioway
	2 Alsace region		FR	FM Logistic
	3 Zwickau-Emden		DE	Schnellecke
Use case II	4 Hof-Kladno		DE/ CZ	DACHSER
	5 Valencia region		ES	DISFRIMUR
	6 Bolzano-Munich		IT/ DE	FERCAM
Use case III	7 Hatfield		UK	DHL
	8 Leoben-Göss region		AT	Brau Union
	9 Flen-Stockholm		SE	Unilever

Tractor 4x2, 40 t   Rigid 6x2, 27 t   Rigid 4x2, 18 t

Source: Roland Berger

Europe is already at the forefront of FCH truck demonstration however cost reduction and addressing remaining barriers is key

Geography of key fuel cell hydrogen HDT trial and demonstration projects[1]



Europe: Overall, 12 relevant projects have been identified – many projects are conducted cross-nationally[2]

Belgium	France	Germany	Netherlands	Norway	Sweden	Switzerland	UK
5 projects (5)	5 projects (3)	5 projects (3)	6 projects (5)	1 project	1 project	4 projects (1)	1 project (1)

1) Finalised, ongoing and planned HDT trial and demonstration projects since 2015 until today 2) The number in ( ) signals the number of cross-national projects

Source: Desk research; Roland Berger

While still some remaining barriers exist at this stage of market development no roadblocks have been identified

Overview of barriers and priority for short-term R&I

Priority and need for action[1]	Truck design and powertrain	Fuel cell	H_2 storage	HRS	Service & maintenance	Non-technological
High	**1. Truck product development and system integration**		**7. Standardisation of H_2 storage technology**	**10. H_2 refuelling networks** **12. Standardised refuelling protocols**		**17. Financing and funding support** **19. Long-term plannability**
Medium	2. Truck performance 3. OEM development cycles	4. FC stack lifetime & FC degradation	8. Weight/volume limitation due to H_2 storage			13. CAPEX and OPEX of HRS 14. CAPEX of truck powertrain 18. Supplier diversity 20. Type approval 22. Stakeholder dialogue
Low		5. Thermo-dynamics		9. H_2 supply to HRS 11. Communication of truck and HRS	6. Service and maintenance requirements	15. H_2 cost development 16. 2nd life market 21. Safety and emergency measures[1]

Truck design and powertrain | Fuel cell | H_2 storage | HRS | Service & maintenance | Non-technological

1) Prioritisation, esp. with regards to safety & emergency measures, does not reflect the overall importance of the topic, but the perspective on main need for action in the HDT sector.

Source: Study analysis, Roland Berger

The study suggests four tailored R&I projects, with an estimated total budget of EUR 470 million to overcome remaining barriers

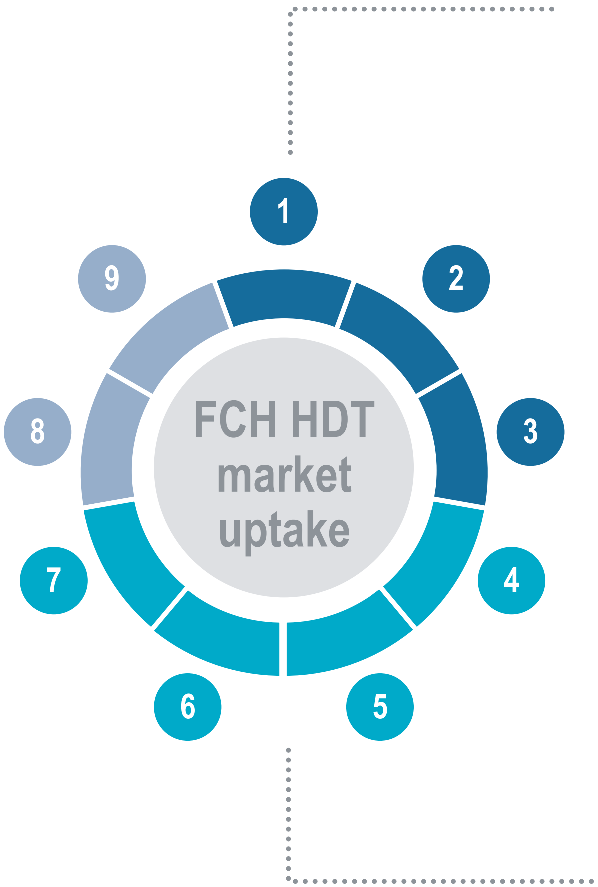
	A	B	C	D
	Technology development and optimisation for standardised on-board hydrogen storage systems for FCH HDT and refuelling protocol development	**Development of FC truck and powertrain prototypes for integration and standardisation of FCH technology**	**Cross-border multi-national demonstration of FCH HDT fleets**	**Technology development for high throughput, low footprint and high energy efficiency HRS for HDT**
High-level project scope	350 bar 700 bar LH_2 Other options: 500 bar ccH_2[1)]	5-20 units 5-20 units 5-20 units	500 20	GH_2 supply to gaseous refuelling On-site production to gaseous refuelling LH_2 supply to gaseous refuelling LH_2 supply to LH_2 refuelling
Objectives of project	> Integrated technology development for optimised hydrogen storage for FCH HDT > Optimisation and standardisation of filling pressure, tank size, tank location, filling protocol, etc. > Analysis of total value chain TCO	> Development of prototypes in the area of truck and powertrain design to improve integration and standardisation of FCH technology in existing truck architecture > Design of new truck models optimised for FCH applications	> Large scale demonstration of 500 or more FCH HDT could accelerate the roll-out of fleet sized FCH truck deployment > Potential split in several sub-projects	> Development of refuelling protocols, storage optimisation, refuelling time and frequency for the roll-out of a comprehensive HRS network across Europe and/or several regional hubs, e.g. hydrogen valleys > Analysis of value chain and TCO calculations
Est. budget before funding	EUR **10** m	EUR **100** m	EUR **350** m	EUR **5-10** m

1) Cryo-compressed hydrogen

Source: Expert interviews; Roland Berger

Structured market incentives offered at different political levels should provide the necessary framework for production at scale

Policy recommendations



EU

1. **Road toll exemption for zero-emission vehicles for longer time periods,** e.g. for 10 years, as well as considering road toll increases for higher emitting vehicles, such as in the Eurovignette Directive
2. **Government-driven base infrastructure coverage of countries,** e.g. as already in discussion as part of the Alternative Fuels Infrastructure directive
3. **Adjusted regulations on FCH heavy-duty truck dimension** to provide a legal framework for integrating alternative powertrains in trucks

National governments

4. **Exemption of levies and fees for production of green hydrogen** within an extended time period of up to 10 years and/or until binding targets of green hydrogen shares are fulfilled
5. **Subsidies for hydrogen refuelling station OPEX when stations are underutilised,** improving cost competitiveness of H_2 through higher plannability for station investors
6. **Tax breaks for logistics operators that transition to FCH HDT**, for example via stricter supply chain laws that incorporate provisions on CO_2 emission as an additional tax on logistics services and offerings
7. **Introduction of CO_2-related taxation in the logistics and delivery industry,** creating an additional incentive for logistics providers to speed-up a transition to zero-emission vehicles

Municipalities

8. **Preferred treatment for zero-emission vehicles,** e.g. through the establishment of lanes specifically dedicated to ZEV and guaranteed free parking zones for ZEV at refuelling stations and motorway rest stops
9. **Special permits for zero-emission vehicles to enter restricted areas,** e.g. city centre and urban areas during early morning or evening/night times

Note: Policy measures not in order of priority

Source: Roland Berger

With a concerted effort, fuel cells and hydrogen can play a leading role in decarbonizing transport in Europe

Source: Roland Berger

For further information, please feel free to reach out to…

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