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Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities

Consolidated preliminary business case analyses

Brussels and Frankfurt, September 2017

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Summary of findings

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Initially, we summarize a set of general conclusions and comparative results of the preliminary business case analysis

Objectives and underlying premises of comparing FCH applications

Main objectives

> **Help participating Regions and Cities navigate** the large pool of applications – in terms of key decision-making dimensions

> **Identify common challenges and opportunities** – to start discussions about integrated deployment approaches

> **Provide first orientation for individual strategic fit** assessment

> **Identify further areas for detailed analysis** in Phase 2

Key premises for comparing FCH applications

> **Time horizon:** focus on the next 2-3 years – a realistic deployment timeline following this project

> **Alternative technologies:** benchmark FCH applications against conventional and/or other 0-emission technologies

> **Markets:** focus on Europe as market environment, e.g. in terms of commercial availability and regulation

> **Use cases:** attempt to abstract from specific use cases and consider a "representative" deployment context (e.g. operators' requirements, fleets, energy prices) – regionalisation in Phase 2

> **Financing:** exclude any specific public support schemes in the initial, general analyses

Source: Roland Berger

The FCH applications in scope are heterogeneous – Different tech. readiness, economic competitiveness and deployment complexity

Evaluation of 10 FCH applications[1] across seven dimensions

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Category	Application	1 TRL	2 Economic competitiveness	3 Environmental benefits	4 Unique selling propos.	5 Ease of deployment	6 Direct procurement	7 Visibility as "show-case"
Transport applications	(Urban) Buses	High	Medium	High	High	Medium	High	High
	Cars	High	Medium	High	High	High	Medium	High
	Delivery vans	Medium	Low	High	Medium	Medium	Low	High
	Heavy-duty trucks	Medium	Low	High	Medium	Medium	Low	High
	Trains	Medium	High	High	High	Medium	Medium	High
	Port operations	Low	Medium	High	Medium	Low	Low	Low
Stationary applications	Power to H_2	High	Medium	Medium	High	Low	Medium	Low
	H_2 injection into gas grid	High	Low	Medium	High	Low	Medium	Low
	Residential mCHP	High	Medium	Medium	Medium	High	Medium	Medium
	Off-grid power	High	Low	High	High	Medium	Medium	Medium

Legend: High / Medium / Low

1) Please note that the selection only contains the ten top-ranked applications as stated by the Regions and Cities in the initial self-assessment survey (June 2017)
2) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration
Source: Roland Berger

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TRL range from 4 to 9 – Forklift trucks, cars and mCHPs have the highest TRL; they are fully commercially available

TRL and commercial availability compared to alternative technologies[1]

INDICATIVE

Key question

To what extent is the FCH application **technologically mature** and can be considered **commercially available** in Europe compared to competing technologies?

Key metrics

> Technology Readiness Level (TRL)
> Industrial capacities
> Deployable volumes
> …

… Lower TRL — 4 — 5 — 6 — 7 — 8 — 9 — … Higher TRL

TRL 5:
> Aircraft
> Airport ground handling equipment
> Port operations equipment
> Ships

TRL 6:
> Ferries
> Boats
> Heavy-duty trucks
> Construction mobile equipment

TRL 7:
> Bikes
> Delivery vans
> Garbage trucks
> Sweepers
> Scooters
> Commercial building CHP
> Trains

TRL 8:
> Urban Buses
> Back-up power
> Gen-sets
> Industrial CHP/PP
> Off-grid power
> Grid services
> Hydrogen injection into gas grid
> Power to Hydrogen

TRL 9:
> Cars
> Forklift trucks
> Residential mCHP

WG1 WG2 WG3 WG4 WG5

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration

Source: Roland Berger

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Forklift trucks are among the few applications that can build a business cases on a stand-alone basis; trains are not far behind

Economic competitiveness compared to competing technologies[1]

INDICATIVE

Key question

How **economically competitive** is the FCH application from the user's/operator's perspective compared to key (0-emission or conventional) competitors?

Key metrics

> Total cost of ownership (TCO), levelized cost of energy (dep. on typical economic decision making process)
> Estimated cost of system / purchase price
> Cost premium
> ...

Low	Medium	High
Significant cost premium for FCH application [generally >100% TCO][2]	Moderate cost premium for FCH application [generally 30-100% TCO]	Small or even no cost premium for FCH app. [generally <30% TCO]
> Heavy-duty trucks [+10-200%] > Construction mobile equipment > Delivery vans [+100-400%] > Scooters > Ships > Aircraft > Back-up power > Comm. CHP [100-300%] > Gen-sets > Off-grid power	> Cars [+80-100%] > Garbage trucks [+30-50%] > Sweepers > Urban buses [+60-80%] > Airport ground equ. > Boats > Ferries [+40-60%] > Port op's equipment > Ind. CHP/PP [-30-200%] > Res. mCHP [30-60%] > Power to H_2 [-10-400%] > Grid services (add-on) > H_2 injection into gas grid (add-on)	> Bikes > Forklift trucks [-5-15%] > Trains [+10-20%]

WG1 WG2 WG3 WG4 WG5

Economic competitiveness

1) Results differ depending on time horizon (here short-term horizon of next 2-3 years, excl. public support schemes), benchmark as well as specific use case
2) Values in parentheses "[ ]" are based on results of the prel. business case anylsis; they indicate the relative TCO premium of the FCH application over the conventional benchmark
Source: Roland Berger

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Environmental benefits differ, e.g. dep. on efficiency, fuel, size/scale of typical deployments and technologies that are replaced

Environmental benefits compared to competing technologies[1]

INDICATIVE

Key question

How significant are the **environmental benefits[2]** of a an FCH application in a typical use case / deployment compared to the main (conventional) competing technologies, considering both relative emissions savings and absolute abatement (e.g. vehicle fuel consumption, fleet sizes)?

Key metrics

> Greenhouse gas emission savings (especially CO_2)
> Pollutant emission savings (especially NO_x)
> Noise emission savings

Moderate
Relatively moderate environmental benefits

> Bikes
> Construction mobile equipment
> Garbage trucks [25-35%][3]
> Scooters
> Sweepers
> Gen-sets
> Airport ground handling equipment

Significant
Significant environmental benefits

> Forklift trucks [n/a]
> Boats
> Back-up power
> Comm. CHP [5-35%]
> Ind. CHP/PP [5-65%]
> Res. mCHP [10-50%]

Very strong
Very strong environmental benefits

> Cars [30-40%]
> Delivery vans [15-75%]
> Heavy-duty trucks [20-30%]
> Urban buses [20-30%]
> Trains [15-25%]
> Aircraft
> Ferries [15-30%]
> Port op's equipment
> Ships [25-35%]
> Off-grid power [-20-30%]
> Power to Hydrogen
> Grid services
> Hydrogen into gas grid

Please note: All hydrogen-fuelled FCH applications have zero local (TTW) emissions. When considering green hydrogen as medium-long term hydrogen supply options , local (TTW) and total (WTW) emissions fall to zero for all applications.

WG1 WG2
WG3 WG4
WG5

Environmental benefits

1) Results differ depending on time horizon (here short-term horizon of next 2-3 years, benchmark as well as specific use case
2) This indication is based on a typical use case for FCH applications, considering emissions savings of a typical use case (single unit or fleet), based on cons. of "grey" hydrogen
3) Values in parentheses "[ ]" are based on results from the prel. business case analysis and indicate the potential CO_2 emission savings compared to conventional (fossil-fuel) technologies
Source: Roland Berger

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Several applications, e.g. forklifts, trains and buses, have already found a clear USP and focus on specific use cases

Unique Selling Proposition (USP) compared to alternative technologies[1]

INDICATIVE

Key question

Does the FCH application have a **unique selling proposition** (e.g. refuelling time, range, use case fit) compared to other low or zero emission technologies – from a user`s/operator`s point of view?

Key metrics

> Proven, tailored, viable use case
> Operational advantages
> New business models / opportunities
> Regulatory incentives
> …

Improvable
Application use case and USP still to be fully defined

> Construction mobile equipment
> Scooters
> Aircraft
> Boats
> Ships
> Port operations equipment

Moderate
Application-specific use case, USP to be sharpened

> Bikes
> Delivery vans
> Heavy-duty trucks
> Airport ground handling equ.
> Back-up power
> Commercial building CHP
> Gen-sets
> Industrial CHP/PP
> Residential mCHP

Strong
Proven use case with distinct FCH USP

> Urban Buses
> Trains
> Cars
> Forklift trucks
> Garbage trucks
> Sweepers
> Ferries
> Off-grid power
> Grid services
> H_2 injection into gas grid
> Power to Hydrogen

WG1 WG2 WG3 WG4 WG5

Strength of USP

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration

Source: Roland Berger

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Implementation-related ease of deployment differs and depends e.g. on infrastructure requirements and necessary stakeholder buy-in

Implementation-related ease of deployment

INDICATIVE

Key question

How **easy** is the implementation of the application in comparison to competing technologies? Or in other terms – how complex is it?

Key metrics

> Setup time and cost
> Infrastructure requirements
> Number of stakeholders to be involved per project
> Project management requirements
> Completeness of FCH regulation
> Workforce training requirements

Low Relatively complex deployment	**Medium** Moderate complexity	**High** Straightforward implementation
> Aircrafts > Port operations equipment > Ships > Back-up power > Grid-services > Hydrogen injection into gas grid > Power to Hydrogen	> Heavy-duty trucks > Trains > Urban buses > Cars > Construction mobile equ. > Delivery vans > Garbage trucks > Scooters > Sweepers > Airport ground handling equ. > Ferries > Off-grid power	> Bikes > Forklifts > Boats > Commercial CHP > Gen-sets > Industrial CHP/PP > Residential mCHP

WG1 WG2 WG3 WG4 WG5

Ease of deployment

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration

Source: Roland Berger

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Regions & cities have several options to engage directly in the deployment of FCH applications, e.g. in public transportation

Potential for Regions & Cities to act as direct customers, operators, etc.[1]

INDICATIVE

Key question

How are the possibilities for regions and cities to **implement** FCH applications as users/operators? Do they act as direct customers or are they rather indirect facilitators/enablers for private users?

Key metrics

- Owner of technology purchasing decision (public vs. private)
- Common operating model
- Potential of regions and cities as multiplier/facilitator
- …

FCH leads mainly private

Regions & cities act indirectly – as facilitators, enablers and promoters

- Heavy-duty trucks
- Construction mobile equipment
- Delivery vans
- Forklift trucks
- Scooters
- Aircraft
- Airport ground handling equipment
- Boats
- Port operations equip.
- Ships
- Back-up power
- Industrial CHP/PP

FCH leads private and public

Regions have direct lines to buyers / can in some cases be direct customers

- Trains
- Bikes
- Cars
- Ferries
- Commercial building CHP
- Gen-sets
- Off-grid power
- Residential mCHP
- Power to Hydrogen
- Grid services
- H_2 injection into gas grid

FCH leads mainly public

Regions & cities can act (more or less) directly as customers

- Urban buses
- Garbage trucks
- Sweepers

WG1 WG2 WG3 WG4 WG5

Potential for direct implementation

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration

Source: Roland Berger

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Public transport applications are particularly visible to the public and hence have a great potential to act as FCH "showcases"

Visibility as public "showcase" to promote overall FCH technology[1]

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Key question:

How **visible** is the application in the every day life of European citizens? How large is its impact in promoting the acceptance of fuel cell and hydrogen technologies?

Key metrics:

> Degree of usage in public space and by European citizens
> Role in public infrastructure provision
> Location and size of application
> …

Limited Relatively limited visibility	Moderate Moderate public visibility	Strong Strong public visibility
> Forklift trucks > Airport ground handling equipment > Port operations equipment > Ships > Industrial CHP/PP > Grid services > Hydrogen injection into gas grid > Power to Hydrogen	> Construction mobile equipment > Aircraft > Boats > Back-up power > Comm. building CHP > Gen-sets > Off-grid power > Residential mCHP	> Heavy-duty trucks > Trains > Urban buses > Bikes > Cars > Delivery vans > Garbage trucks > Scooters > Sweepers > Ferries

WG1 WG2 WG3 WG4 WG5

Visibility

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration

Source: Roland Berger

Some applications can be deployed in the short term, as they are comm. available and implementation lies within in the public domain

Short-term deployment opportunities for Regions and Cities

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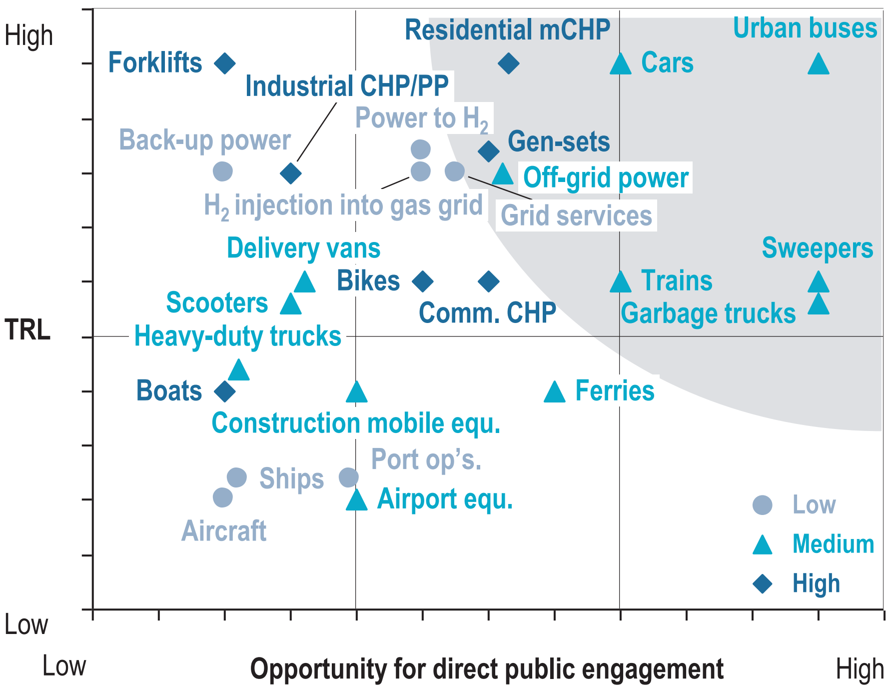
What applications can I deploy tomorrow?



Implementation-rel. ease of deployment:

Key considerations

> In the short term, Cities and Regions can look for **high TRL applications** for actual deployment projects

> **Public infrastructure sectors** are well suited for deployment of applications because of direct control of public authorities (e.g. publically-owned local/regional transport operators or utilities)

> Cities and Regions can reduce complexity in multi-stakeholder settings by acting as **direct customers** of industry

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration
2) Applications in parentheses are still to be discussed within Working Group Calls
Source: Roland Berger