Consolidated preliminary business case analyses

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

Brussels and Frankfurt, September 2017
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Summary of findings
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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**Note:**
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
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

**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
- ...
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

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
Significant cost premium for FCH application [generally >100% TCO]²

- 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

Medium
Moderate cost premium for FCH application [generally 30-100% TCO]

- 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 H₂ [-10-400%]
- Grid services (add-on)
- H₂ injection into gas grid (add-on)

High
Small or even no cost premium for FCH app. [generally <30% TCO]

- Bikes
- Forklift trucks [-5-15%]
- Trains [+10-20%]

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

Key question
How significant are the environmental benefits\(^2\) of a 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.

Source: Roland Berger

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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
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

**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
- ...

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<th>Strength of USP</th>
<th>Improvable</th>
<th>Moderate</th>
<th>Strong</th>
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<tr>
<td></td>
<td>Application use case and USP still to be fully defined</td>
<td>Application-specific use case, USP to be sharpened</td>
<td>Proven use case with distinct FCH USP</td>
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<td>Construction mobile equipment</td>
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<td>Power to Hydrogen</td>
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</table>

Source: Roland Berger

1) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration
Implementation-related ease of deployment differs and depends e.g. on infrastructure requirements and necessary stakeholder buy-in.

### 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
- Aircrafts
- Port operations equipment
- Ships
- Back-up power
- Grid-services
- Hydrogen injection into gas grid
- Power to Hydrogen

#### Medium
Moderate complexity
- Heavy-duty trucks
- Trains
- Urban buses
- Cars
- Construction mobile equ.
- Delivery vans
- Garbage trucks
- Scooters
- Sweepers
- Airport ground handling equ.
- Ferries
- Off-grid power

#### High
Straightforward implementation
- Bikes
- Forklifts
- Boats
- Commercial CHP
- Gen-sets
- Industrial CHP/PP
- Residential mCHP

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

Source: Roland Berger
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

**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
- H₂ injection into gas grid

**FCH leads mainly public**

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

- Urban buses
- Garbage trucks
- Sweepers

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

Source: Roland Berger
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

**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
- ...

<table>
<thead>
<tr>
<th>Limited</th>
<th>Moderate</th>
<th>Strong</th>
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<tr>
<td>Relatively limited visibility</td>
<td>Moderate public visibility</td>
<td>Strong public visibility</td>
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<td>&gt; Forklift trucks</td>
<td>&gt; Construction mobile equipment</td>
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<td>&gt; Ferries</td>
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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

What applications can I deploy tomorrow?

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

Implementation-rel. ease of deployment:

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