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

FCH Construction mobile equip.


Brussels, Fall 2017

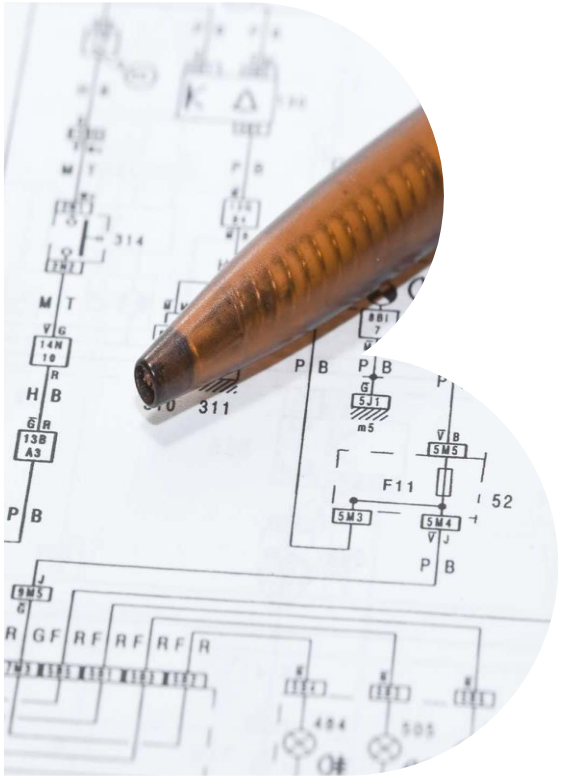
This compilation of application-specific information forms part of the study ***"Development of Business Cases for Fuel Cells and Hydrogen Applications for European Regions and Cities"*** commissioned by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU), N° FCH/OP/contract 180, Reference Number FCH JU 2017 D4259 .

The study aims to **support a coalition of currently more than 90 European regions and cities** in their assessment of fuel cells and hydrogen applications to support project development. Roland Berger GmbH coordinated the study work of the coalition and provided analytical support.

All information provided within this document **is based on publically available sources** and reflects the **state of knowledge as of August 2017**.

# Table of Contents

# A. Technology Introduction



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# FCH construction equipment offers zero emission and low noise polluting opportunities, e.g. for inner-city civil works and O&M

## Fuel cell construction mobile equipment & tractors




**Brief description:** Fuel cell construction mobile equipments such as tractors or excavators typically use fuel cells as a range extender for batteries (hybrid concept) or to fuel the complete machine including drivetrain and auxiliary systems

**Use cases:** Cities and regions can use/promote fuel cell electric construction machinery for building public infrastructure such as roads and paths, water and sewage networks, district heating networks, digital networks, as well as for the construction of public buildings

**Fuel cell construction mobile equipment**[1]

| | |
|---|---|
| Key components | Fuel cell stack and system module, hydrogen tank, batteries, 2 electric motors (power to traction, power to PTO and auxiliaries) |
| Output | 75 kW |
| Fuel | Hydrogen (diesel at hybrid models) |
| Reduction of noise | -10 dB (out-) /-20 dB (inside) compared to diesel peers |
| Approximate capital cost | n.a. |
| Original equipment manufacturers | Volvo, Hyundai, New Holland |
| Fuel cell suppliers | Symbio FCell, Hyundai |
| Typical customers | Building and road construction companies, farmers |
| Competing technologies | Diesel powered & battery powered drivetrains |

1) Specifications mainly based on the New Holland NH2 tractor prototype
Source: Roland Berger

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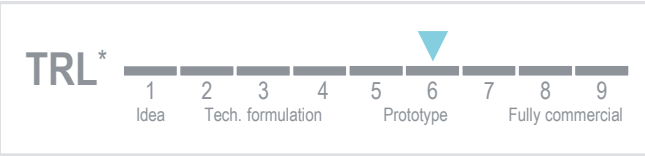
# So far, only limited but advanced prototype demo projects for construction mobile equipment and tractors in Europe, mostly in SE

## Fuel cell construction mobile equipment & tractors 2/4

**Overall technological readiness**: So far, systems are in the prototype stage undergoing trials in real-life environment (demonstration projects); no wide-spread deployment of commercially available products so far




**Demonstration projects / deployment examples** (selection)

| Project | Country | Start | Scope | Project volume |
|---|---|---|---|---|
| Elexc | | 2015 | Proof of concept of an electric excavator that combines battery and fuel cell system used as a range extender. Fuel cell from Symbio. Other partners: Volvo, Elbi, EFS, Prollion, Bonfigliolo, Ampère, ViaMéca, Tenerrdis. | n.a. |
| HF (Hyundai Future) Excavator | | 2013 | Design study of Hyundai in cooperation with design house tangerine of a crawler that can transform its shape and can be used in any terrain. Special design for rock fracture | n.a. |
| SFINX Crawler Excavator | | 2009 | Radically altered excavator concept from Volvo. Use of a fuel cell frees up space in the superstructure and allows engine to perform as "active counterweight" | n.a. |
| NH2™ | | 2008 | Prototype based in a T6000 tractor of New Holland. Has undergone practical trials of New Holland's Energy Independent Farm concept "La Bellotta" in Venaria (Turin), Italy. Project consortium: New Holland, Elasis, Envi-Park, ENEA, CNR, Verderone, Tonutti, API-COM, CRF, Ferrari Costruzioni Meccaniche, Roter Italia, Sapio and Zefiro. Total project budget: EUR 11m, of which EUR 500.000 for tractor. Fuel cell: Nuvera; Part of Industria 2015 program "New technologies for Made in Italy", sponsored by the Italian Ministry for Economic Development | EUR 0.5 m |

*) Technology Readiness Level ▽ ≤ 5 ▽ 6-7 ▽ 8-9

Source: Roland Berger

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# Besides $CO_2$ and $No_x$ emissions, FCH construction equipment reduces noise exposure – facilitating inner-city deployment

## Fuel cell construction mobile equipment & tractors



### Use case characteristics

**Stakeholders involved**

> Municipality-owned as well as private construction companies involved in construction of roads and paths, water and sewage networks, district heating networks, digital networks, as well as for the construction of public buildings
> Farmers

**Demand and user profile**

> Operational in buildings or tunnels or densely populated areas
> 24/7 operation possible due to fast recharging
> Operation in challenging terrain necessary

**Deployment requirements**

> Refuelling infrastructure within reach of construction site –suitable for inner city areas. Otherwise decentralised / mobile supply and refuelling of hydrogen necessary

**Key other aspects**

> Engines only produce very few excess heat, therefore in some environments additional heating of the diver's cabin necessary

### Benefit potential for regions and cities

**Environmental**

> No hazardous emissions, e.g. diesel leaks
> No direct $CO_2$ or $NO_x$ emissions
> Quiet in use, ideal for busy public areas like pedestrian zones
> Less hazardous waste compared to batteries

**Social**

> Health benefits for employees due to lower emissions and noise exposures
> Public health benefits due to lower adverse impact on residents adjacent to major inner-city construction sites

**Economic**

> Completely redesigned machines, e.g. eliminating hydraulics lead to lower maintenance cost in the medium- to long-term
> Low noise emissions, therefore possibility to work in the night leading to higher utilisation of vehicles

**Other**

> -

Source: Roland Berger

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# Limited deployments so far narrow empirical evidence of use case, but additional demonstration projects might mitigate bottleneck

## Fuel cell construction mobile equipment & tractors



### Hot topics / critical issues / key challenges:

> **Hydrogen infrastructure deployment**, i.e. expensive distribution logistics, local storage, refuelling stations and respective costs

> **Limited deployments**, low number of (demonstration) vehicles deployed so far, reducing empirical knowledge about usability of application

> **Well-to-wheel emissions**, uncertain reduction potential largely depends on resources used for hydrogen production

> **Long-term procurement and services contracts**, e.g. concessions with private construction companies, limiting the scope of direct action for local public authorities

> **Lack of standardisation**, induced by individual fit-for-purpose modularisation, hinders large scale production and additional economies of scale for regions and cities

### Further recommended reading:

> Additional information regarding the Volvo prototype: http://www.symbiofcell.com/elexcpoc/

> Additional information regarding tractor prototypes: New Holland Tractor

### Key contacts in the coalition:

*Please refer to working group clustering in stakeholder list on the share folder*

*https://sharefolder.rolandberger.com/project/P005*

Source: Roland Berger

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# Material handling equipment comprises a large variety of systems, we focus on FCH-relevant applications (as currently anticipated)

## Material-handling equipment – simplified overview

### 1 Transport equipment

- Conveyors
- Cranes
- Pallet jacks
- **Forklift trucks[1)]**
- Narrow-aisle
- Turret trucks
- Order pickers
- …

### 2 Positioning equipment

- Lift/tilt/turn tables
- Hoists
- Balancers
- Manipulators
- Industrial robots
- …

### 3 Unit load formation equ.

- Pallets
- Skids
- Slipsheets
- Tote pans
- Bins/basket
- Cartons, bags
- Crates
- …

### 4 Storage equipment

- Bin shelving
- Storage drawers
- Carousels
- A-frames
- Racks
- …

Potentially hydrogen fuelled applications  Exemplary application selected for technology introduction

1) Forklifts were selected due to their relatively advanced technological readiness and respective commercial diffusion of 10,000+ units in operation or in order globally

Source: Roland Berger

# B. Preliminary Business Case

# Use case of FC constr. mobile equ. and respective infrastructure req. are highly dependant and adjustable according specific needs

## Use case characteristics

### Description

> Fuel cell construction mobile equipment such as tractors, excavators or crawlers either use fuel cells as a range extender for batteries (hybrid concept) or to fuel the complete machine including drivetrain and auxiliary systems

> Vehicles are refuelled directly at the construction site, either by tank trucks or small independent refuelling stations

### Technical characteristics

> Changing the type of powertrain mostly requires to redesign the vehicle in order to ensure sufficient vehicle counterweight

> Necessary engine output is strongly dependent on the specific type of vehicle (e.g. 75 kW for a FC tractor)

> Significant noise reductions of ca. 10 dB out- and 20 dB inside compared to diesel counterfactuals can be realized

### Competing technologies

> Diesel, Battery-Electric, Diesel-battery hybrid

Source: Industry publications, Symbiofcell, Volvo, New Holland, Roland Berger

# FC construction mobile equipment is still in a prototyping stage and not fully commercialized yet, with several domo projects ongoing

## Business case and performance overview – PRELIMINARY & INDICATIVE

### Technical/operational

- So far, systems are in the **prototype stage** undergoing trials in real-life environment (demonstration projects)
- **No wide-spread deployment of commercially available products** so far
- Volvo, Hyundai and New Holland can be regarded as OEM pioneers while fuel cells are mostly supplied by Symbio FCell or Hyundai


### Economic

- **Higher system efficiency,** lower maintenance and operating costs are counterbalancing high CAPEX costs
- **Noise reductions** possibly enable construction companies to increase their operating hours and hence reduce overall construction times
- Additional infrastructure costs to set up a refuelling infrastructure are limited since construction mobile equipment is fuelled by tank trucks or independent on-side refuelling stations – **switch from diesel to hydrogen relatively easy**
- **Key business case drivers**:
  - Cost of hydrogen vs. cost of diesel
  - System CAPEX

### Environmental

- **Zero tailpipe (i.e. tank-to-wheel) emissions** of $CO_2$, pollutants such as $NO_X$ and fine dust particles as well as significant noise reduction for FCH construction mobile equipment – key benefit for workers as well as outside environment
- Well-to-wheel $CO_2$ emissions depend on fuel source, use case characteristics and efficiency (i.e. fuel consumption) – **potential for zero well-to-wheel emissions for FCH construction mobile equipment with "green hydrogen"**

Source: Roland Berger

# Since decarbonisation is high on the agenda of authorities, FC systems could to become part of the technology pool in the long run

## Key considerations concerning fuel cell mobile construction equipment

To be validated by demo projects

- **Authorities place increasing importance on decarbonisation and emissions reduction** and hence stimulate the development of zero-emission engines for construction mobile equipment – additionally, **supranational regulations** from EU-level will require $CO_2$ monitoring and 'cap and trade' policies might be introduced in a second step
  - **FC mobile construction equipment will not only help to achieve these targets, but also drastically reduce noise emissions,** thereby improving the quality of life of local residents affected by constructions, especially during the **night**
- **Necessary size /power ranges, capital cost and fuel supply** are among the major **hurdles** faced by fuel cell powered mobile construction equipment
- **Short refuelling times** and independent on-site refuelling stations facilitate the process of switching from diesel to hydrogen
- Further **demonstration projects** will be necessary to **increase technological readiness and foster commercial availability**

Source: Roland Berger

# Please do not hesitate to get in touch with us

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Source: FCH2 JU, Roland Berger