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

FCH Sweepers

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**.

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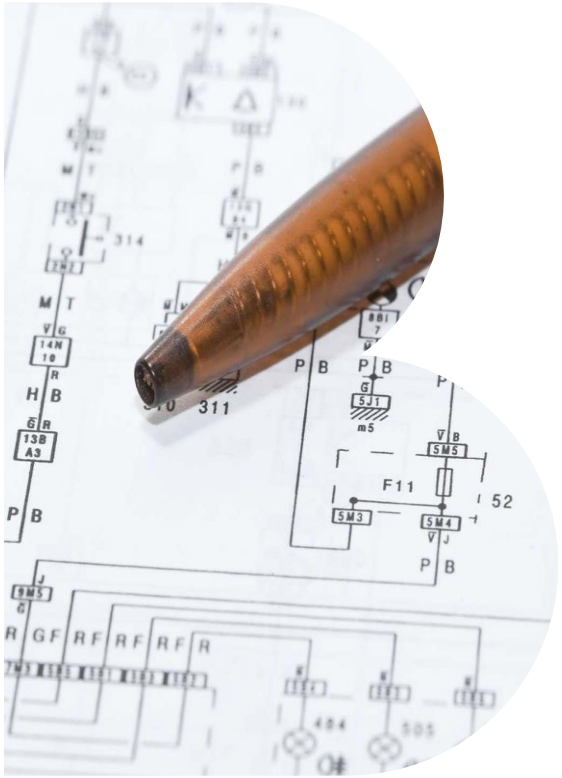
A. Technology Introduction



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Hybrid and fully hydrogen-powered sweepers are a viable, efficient, zero emission and low-noise option for municipal services

Fuel cell sweepers

Brief description: FCH sweepers use fuel cells to power propulsion as well as brushes and vacuum cleaner; hybrid models where the fuel cell only drives the brushes/suction unit are also being pursued

Use cases: regions and cities can use fuel cell sweepers for cleaning streets as well as warehouses; regions and cities can promote zero-emission fuel cell sweepers e.g. through respective tender requirements

Fuel cell sweepers[1]	
Key components	Fuel cell stack and system module, hydrogen tank, battery, electric motor (for propulsion and brushes/suction unit)
Output	~30 kW (electric hydraulic drivetr.), 12 kWh lith.-ion battery
Range	1.5 days operating time (~one refuelling per day)
Fuel	Compressed hydrogen (350 bar)
Approximate capital cost	n.a.
Original equipment manufacturers and integrators	Bucher Municipal, Stock Sweepers, Global Environmental Products, Holthausen, Empa, Visedo
Fuel cell suppliers	Nedstack, Hydrogenics, US Hybrid
Typical customers	Offices of municipal sanitation, city cleaning companies
Competing technologies	Battery electric vehicles, diesel-combustion vehicles

1) Example based on fully hydrogen powered Bucher CityCat H_2 as well as a Holthausen model converted in cooperation with Visedo

Source: Roland Berger

A

After successful demonstration deployment of prototypes, first pre-commercial orders show the TRL progress of FCH sweepers

Fuel cell sweepers

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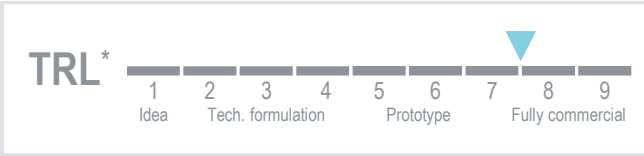
Overall technological readiness: advanced prototype/demo stage; several prototypes have been deployed in demonstration projects, including fully hydrogen powered sweepers; first commercial orders by California Department of Transportation (Caltrans) in May 2017



Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Fuel cell sweeper demonstration with municipality of Groningen		2017	Conversion of Holthausen diesel model into fuel cell electric sweeper in cooperation with municipality of Groningen, Netherlands and system integrator Visedo from Finland. Single hydrogen charge allows for 1.5 days of operation and noise pollution was reduced by half	n.a.
LIFE + ZeroHytechpark Project Street Yet Washer		2014	Aragon Hydrogen Foundation developed and deployed a fuel cell sweeper. Project funded by the EU's LIFE programme	n.a.
hy.muve CityCat 2020 H_2		2009	Test of CityCat H_2, a hydrogen-powered street sweeper in the cities of Basel, St. Gallen and Bern. From August 2016 to August 2018 the sweeper is in use in the city of Duebendorf, Switzerland. Project partners: Bucher Municipal, research institutes EMPA and the Paul Scherrer Institute (hy.move consortium)	n.a.

Products / systems available (selection)

Name	OEM	Product features	Country	Since	Cost
Fuel Cell Electric Street Sweeper	GEP	80-Kilowatt FCe80 fuel cell, 200 kW driveline. The street sweepers are manufactured in San Bernardino CA by GEP, the electric powertrain and the fuel cell is manufactured by US Hybrid in Torrance CA and in South Windsor, CA		2017	n.a.

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

Source: Roland Berger

A

Their deployment promises environmental benefits through emission reduction and higher utilisation due to lower noise

Fuel cell sweepers

Use case characteristics

Stakeholders involved

> Users (municipality-owned & private cleaning companies, warehouse operators)
> Public authorities
> OEMs, FC and Power-Box manufacturers
> H_2 suppliers and infrastructure providers

Demand and user profile

> High vehicle uptime enabling a continuous utilisation of vehicles, including low refuelling times
> Low noise pollution for indoor use like in exhibition halls and railway stations

Deployment requirements

> Hydrogen storage and refuelling infrastructure along relevant routes or at base stations/depots
> High safety standards for fuel cell components

Key other aspects

> Engine only produces low excess heat, additional heating of the driver's cabin necessary

Benefit potential for regions and cities

Environmental

> Reduction of CO_2 emissions and No_x pollutant emissions, improving air quality
> Reduction of noise emissions (still, some noise emissions at breaking, emptying and compressing), also dependent on speed & road quality

Social

> Public health benefits (esp. urban areas near deployment route), higher standard of living
> Lower adverse impact on residents adjacent to major inner-city routes

Economic

> Reduction of power consumption by 50 to 70% compared to diesel, potentially lower TCO once CAPEX comes down
> Low noise emissions, therefore possibility to clean at night times leading to higher utilisation of vehicles

Other

> Potentially very visible FCH application for public demo purposes

Source: Roland Berger

A

Infrastructure deployment & low standardisation due to niche app. & specific requirements, partially inhibit fully commercial deployment

Fuel cell sweepers

Hot topics / critical issues / key challenges:

> **Niche application**, due to relatively low number of sweepers required by regions and cities, economies of scale for regions and cities have to come from synergies with other FCH applications

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

> **Current deployment**, roll-out of fuel cell sweepers prototypes as demonstration projects; first commercial orders, as in the US, need to proceed

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

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

Further recommended reading:

> Project description hy.muve:http://juser.fz-juelich.de/record/135720/files/TA1_pp_Schl_Schlienger_rev0604.pdf

> Project description Hoogezand: http://www.telegraph.co.uk/cars/news/clean-sweep-dutch-town-gets-hydrogen-fuel-cell-street-cleaner/

Key contacts in the coalition:

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

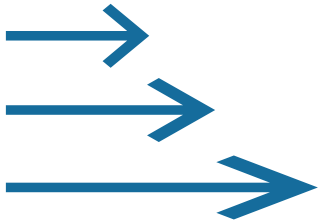
https://sharefolder.rolandberger.com/project/P005

Source: Roland Berger

B. Preliminary Business Case

FCH sweepers are a highly flexible zero emission option and have a comparatively high utilization rate

Value propositions of fuel cell hydrogen sweepers



Long ranges

… of 12-16 hours deployment without refuelling – range extension possible

Strong performance

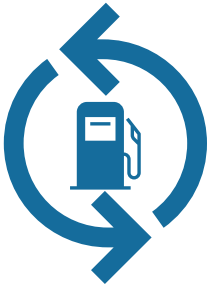
… comparable to diesel sweepers, e.g. acceleration or gradeability

High operational variability

… due to GHG and noise emission reduction, add. appl. areas like warehouses and railway stations feasible

High utilization

… compared to diesel powered alternatives due to strong reduction of noise and resulting overnight deployment options



Fast refuelling

… down to 5-7 minutes per vehicle possible – several refuelling cycles per day possible as well

On the way to full technological maturity

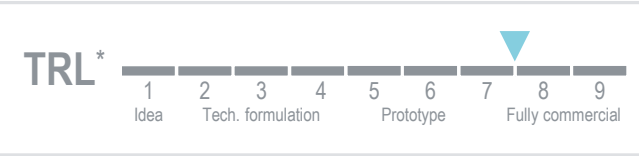
… with several FCH sweeper demonstration projects underway

Source: Roland Berger

After successful demonstration deployment of prototypes, first pre-commercial orders show the TRL progress of FCH sweepers

Fuel cell sweepers – updated abstract from Technology Introduction

Overall technological readiness: advanced prototype/demo stage; several prototypes have been deployed in demonstration projects, including fully hydrogen powered sweepers; first commercial orders by California Department of Transportation (Caltrans) in May 2017



Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Fuel cell sweeper deployment for California Department of Transportation (Caltrans)		2017	Manufacturing of fuel cell powered street sweeper by Global Environmental Products in California, for 24/7 deployment after successful five year testing of diesel hybrid solutions	n.a.
Fuel cell sweeper demonstration with municipality of Groningen		2017	Conversion of Holthausen diesel model into fuel cell electric sweeper in cooperation with municipality of Groningen, Netherlands and system integrator Visedo from Finland. Single hydrogen charge allows for 1.5 days of operation and noise pollution was reduced by half	n.a.
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Source: Roland Berger

Besides emission reduction, FCH sweepers offer higher utilization rates due to noise reduction and large operating ranges

Benchmarking with comparable street sweepers

INDICATIVE

	FCH Sweeper A	BE Sweeper B	Diesel Sweeper C
Description	Fuel cell hydrogen powertrain for propulsion and brush rotating system	Battery electric powertrain for propulsion and brush rotating system	Conventional, diesel-based powertrain for propulsion and brush rotating system
Specifications			
Costs[1]:	400,000 – 450,000	400,000	280,000 – 300,000
Powertrain:	30 kW FC with 108 kW (700 bar)	48 V, 1,000 Ah	50 – 80 kW
Range:	12 – 16 hours	4 – 9 hours	12 – 16 hours
Weight (unloaded):	5 – 6 t	4 – 5 t	5 – 6 t
Max. speed:	30 – 40 km/h	25 – 35 km/h	30 – 50 km/h
Key benefits and challenges	+ Zero local GHG and noise emissions + Fast recharging + Large operating ranges (e.g. at night) – CAPEX premium due to tech. maturity – Usually, add. charging infrastructure required	+ Zero local GHG and noise emissions + Usually no additional infrastructure required – Long recharging times – Limited operating ranges	+ Reliable technology + Fast refuelling + No additional infrastructure requirements – Local emission of CO_2 and NO_X among others – Noise pollution

1) CAPEX expenditure for the entire vehicle, including the base chassis as well as the conversion/integration

Source: Roland Berger

FC Sweepers are not fully commercialized yet, but large ranges and lower noise emissions emphasize their future potential

Business case and performance overview – PRELIMINARY & INDICATIVE

Economic

- **Higher system efficiency**, lower maintenance and operating costs are counterbalancing relatively higher capital costs of FC sweepers vs. conventional powertrains
- **Short refuelling times** and long ranges increase availability rates in comparison to battery-electric sweepers and hence potentially improve the profitability
- **Key business case drivers**:
  - CAPEX resulting from system integration
  - Additional infrastructure costs, esp. refuelling station CAPEX (incl. utilisation) and OPEX
  - Potential 24/7 operations significantly improve utilization rate (depending also on regulation and costs among others)

Environmental

- **Zero tailpipe (i.e. tank-to-wheel) emissions** of CO_2, pollutants such as NO_X and fine dust particles for FCH sweepers – key benefits for outside environment, including other workers, passer-by and residents
- **Lower noise emissions as key benefit for operations**, esp. during night time deployment in urban environments
- 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 sweepers with "green hydrogen"**

Technical/operational

- **Advanced prototype/demo stage**; several prototypes have been deployed in demonstration projects, including fully hydrogen powered sweepers; first commercial orders by California Department of Transportation (Caltrans) in May 2017 indicating close to technological maturity
- **Demonstration projects** in operational environment have been **completed** or are currently **ongoing**
- **Similar operational characteristics** to be expected as diesel-combustion sweepers (e.g. refuelling times, flexibility, ranges)

Source: Roland Berger

Please do not hesitate to get in touch with us

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Source: FCH2 JU, Roland Berger