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

FCH Bikes

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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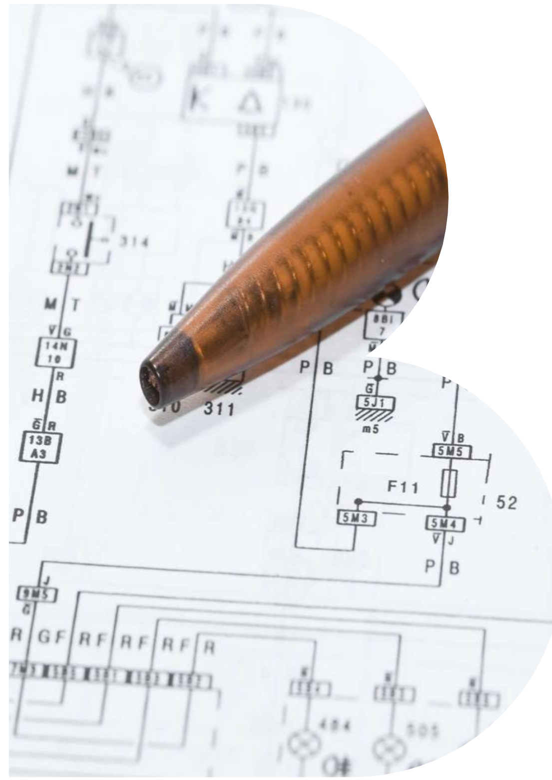
Roland Berger

A. Technology Introduction



FC bikes offer almost 2.5 times the operating range of traditional e-bikes – Refuelling time only 2-6 minutes instead of up to 8 hours

Fuel cell electric bikes

Brief description: Fuel cell electric bikes use compressed hydrogen gas as a fuel to generate electricity via an energy converter (fuel cell) assisting the rider's pedal power through an electric motor

Use cases: Cities and regions can use/promote fuel cell electric bikes for bike sharing offerings and inner city services (e.g. police patrolling, deliveries, courier services, individual mobility of municipal staff, etc.) and integrate concept into local tourism strategy

Fuel cell electric bicycles	
Key components	Fuel cell stacks, hydrogen tank, electric motor
Output	0.1 – 0.25 kW
Top speed; range	25-35 km/h; >100 km
Fuel	Hydrogen (storage at 200-350 bar)
Fuel cell efficiency	~50%
Weight	23.6 kg (Linde H_2 Bike) – 34.6 kg (Gernweit bike)
OEMs & system integrators	Gernweit, Linde, Clean Air Mobility, Pragma Industries, Atawey (infrastructure)
Fuel cell suppliers	Linde, Pragma industries
Typical customers	Private costumers, postal/delivery services, bike sharing services
Competing technologies	Battery powered e-bikes, conventional bikes and scooters

Source: Roland Berger

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Fuel cell electric bikes are generally still in the (advanced) prototype phase and preparing for first demonstration projects

Fuel cell electric bikes

Overall technological readiness: Fuel cell electric bikes are generally still in the advanced prototype phase and first demonstration projects and larger field tests and first commercial projects are ongoing (esp. in FR)

TRL* (marker at 7): 1 Idea – 2 – 3 Tech. formulation – 4 – 5 – 6 Prototype – 7 – 8 – 9 Fully commercial

Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Gernweit "Ped-Hy-lec"	Germany	2008	Prototype development with two separate tanks to refuel has started in 2008 in cooperation with the ministry for innovation, science and research of the state of North Rhine-Westphalia	n.a.
HyChain Minitrans	EU	2006	Development of low power fuel cell vehicle fleet to initiate an early market for hydrogen applications that are optimised in design and functionality	n.a.
UNSW Hy-Cycle	Australia	n.a.	First Australian fuel cell powered pedelec developed by UNSW researchers allowing range of up to 125 km and a maximum speed of 35 km/h	n.a.

Products / systems available (selection)

Name	OEM	Product features	Country	Since	Cost
H_2-Bike	Linde	Pre-commercial demonstrational prototype series of fuel cell powered pedelec bike based on "Cannondale Contro E"-chassis, pedal support for up to 100 km	Germany	2017	~4.000€
Alpha	Pragma Industries	Small scale production and testing of fuel cell powered pedelec bikes using modified FC systems from Toyota including a Li-Ion battery as bridging energy, market introduction of two models planned for 2017	France	2016	~6.500€

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

Source: Roland Berger

A

FC bikes can be environmentally advantageous compared to battery-powered bikes, especially when fuelled with green hydrogen

Fuel cell electric bikes

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Use case characteristics

Stakeholders involved

- Bike-sharing operators, bike rental providers – especially in tourism applications
- Postal and other delivery services
- Municipal service providers
- OEMs, infrastructure providers

Demand and user profile

- Touristic areas with good cycling infrastructure, touristic bike rental services
- Potentially especially mountainous or otherwise challenging terrain – driving support for longer range and uphill terrain

Deployment requirements

- Hydrogen refuelling infrastructure, incl. production, distribution, storage and refuelling stations
- Compliance with local road traffic regulation and associated certifications

Key other aspects

- Reliable theft protection required due to high investment cost
- Superior operability at low temperatures compared to battery powered bikes

Benefit potential for regions and cities

Environmental

- Compared to battery powered bikes, significant environmental advantages due to avoidance of ecologically harmful disposal of batteries
- Zero-emission potential with "green" hydrogen

Social

- n/a

Economic

- Longer lifetime compared to battery-powered bikes
- Potentially lower OPEX and hence Total Cost of Ownership advantage vis-à-vis battery-powerd bikes (once investment costs have come down)

Other

- Extended operating range and better fit with certain long-range use cases (e.g. deliveries, couriers, tourism), short refuelling time
- No self-discharge as it is the case with conventional batteries

Source: Roland Berger

Technology readiness of FCH scooters has to be improved – use cases and associated value propositions need to be further refined

Fuel cell electric bikes

Hot topics / critical issues / key challenges:

> **Refinement of use cases** and **value proposition**, i.e. focus on bike sharing, touristic or other bike rental services, delivery services, etc.

> **Hydrogen infrastructure** , location and coverage of hydrogen refuelling stations; high cost for hydrogen and its distribution/storage as hurdle for overall commercial attractiveness

> **Technological readiness,** most models still in prototype phase; models of Linde, Atawey and Pragma Industries in (pre-) commercial stage

> **Environmental sustainability,** with well-to-wheel emissions largely dependent on resources used in hydrogen production

Further recommended reading:

> Linde H_2 bike booklet: http://www.linde-gas.com/internet.global.lindegas.global/en/images/19279_H2_bike_handbook_English17_176415.pdf

> Hychain Minitrans Project Overview: http://www.ap2h2.pt/download.php?id=19

> Pragma H_2 bike booklet: http://www.pragma-industries.com/company/press-releases/alter-bike/

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

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Fuel cell bikes are a highly flexible medium range option for public transport with a variety of potential use cases

Value propositions of fuel cell hydrogen bikes

High daily ranges
… of up to 100 km without refuelling

Variety of use cases
… e.g. for (postal) delivery fleets, public and private tourism, bike renting/sharing

Low entry barriers
… due to low CAPEX requirements for bikes and infrastructure compared to fossil fuel motorization

Fast refuelling
… less than 1 min per bike possible – several refuelling cycles per day possible

High visibility
… due to mobility and direct interaction of citizens with H_2 technology

Close to full technological maturity
… with several companies commercially offering FCH bikes and the respective infrastructure

Source: Roland Berger

We considered the touristic deployment of 20 new bikes from one station, covering a typical distance of ~50 km per bike and day

Use case assumptions and exogenous factors – SIMPLIFIED

Use case

> **Tourism operator** offering his service **~90 days** a year, plans to provide **sight-seeing tours** on FCH/BE bikes. The operator therefore considers the deployment of **~20 new** FCH/BE bikes, with **~50 km** of distance covered on average per operational day and bike, resulting in annually **~4,500 km** per bike

> The HRS for FCH bikes consists of an **on site electrolyser**, producing up to **0.5 kg H_2 per day**

> The charging of the batteries for the BE bikes takes place at the depot and includes a central transformer and cable charging infrastructure for BE bikes

Exogenous factors

> Financing costs for bike operator: 5% p.a.

> Cost of electricity: 0.21 EUR/kWh

Strongly dependent on specific regional circumstances

Source: FCH2 JU, Roland Berger

B

Within our analysis we benchmark FC with BE bikes in a current use case scenario, partially also depicting future potential of FC bikes

Application-related assumptions – SIMPLIFIED

CURRENT / POTENTIAL	**FCE bike**	**BE bike**
Technical specifications		
Infrastructure	FCH on site electrolysis	Overnight charging
Weight (kg)	25 kg	20-25 kg
Max. operating distance (km)	~100	~50-100
CAPEX (EUR)		
Purchase price (bike)	7,500 / 3,500	4,000
Refuelling station	150,000 / 90,000	10,000
Fuel		
Fuel type	Hydrogen (200 bar[2])	Electricity
Consumption (per 100 km)	~35 g	~0.7 kWh
Maintenance costs (EUR)		
Bike per year	250	250
Refuelling station p.a.	~8,000	~500
Replacements[1] (EUR per unit)	-	~800 (per battery)

1) Additional battery pack per bicycle due to extended charging time and limited action range
2) Pressure of tanks increasable, resulting in higher operating distances

Source: FCH2 JU, Roland Berger

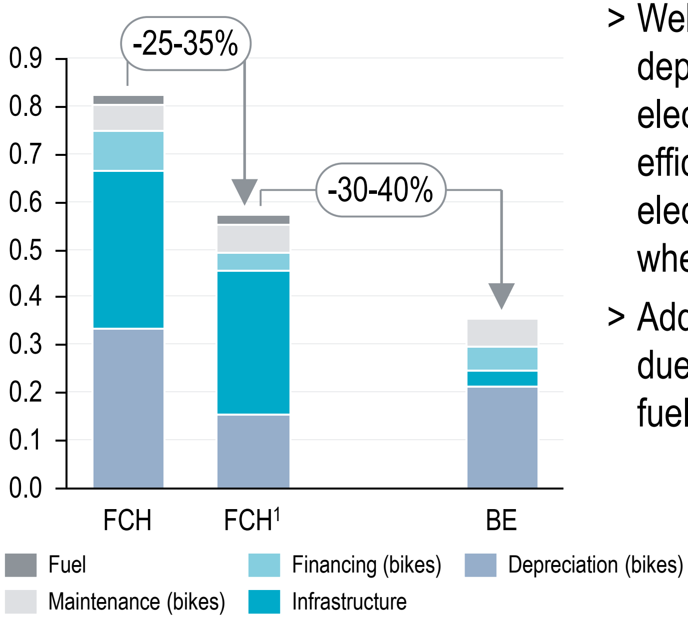
B

FCH bikes offer a 0-emission transport app. with a cost premium that has the potential to decrease significantly in the medium run

Business case and performance overview – INDICATIVE

Economic

Total Cost of Ownership [EUR/km], annualised at 2017 prices



Environmental

> Zero tailpipe emissions of CO_2, pollutants (NO_X, SO_x) and fine dust particles

> Well-to-wheel CO_2 emissions depend on fuel source (source of H_2, electricity mix, etc.) and vehicle efficiency, green H_2 or 100% green electricity would reduce well-to-wheel CO_2 emissions to zero

> Additional potential emission savings due to switching from other fossil fuelled transportation to FCH bikes

Technical/operational

> Fuel cell electric bikes are generally still in the advanced prototype phase but first demonstration projects, larger field tests as well as first commercial projects are ongoing (esp. in FR)

> FCH bikes have an operating range of up to 100 km

> Fast refuelling times of <1 min per bike vs. BE bikes up to 7 hours

1) The potential scenario is partially based on economies of scale, especially affecting the price per bike as well as the infrastructure costs

Source: FCH2 JU, Roland Berger

Please do not hesitate to get in touch with us

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Source: FCH2 JU, Roland Berger