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

FCH Boats

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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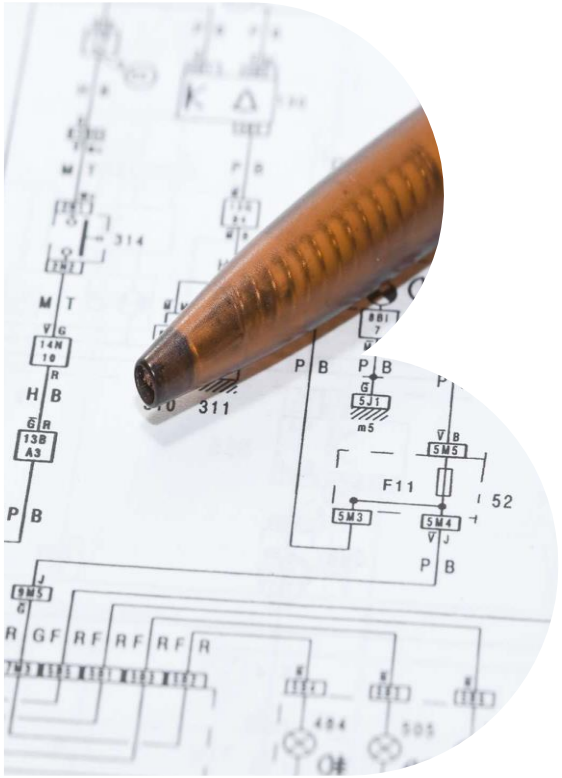
A. Technology Introduction



A

FC powered boats could significantly reduce emissions and noise pollution in recreational areas as well as densely populated regions

Fuel cell powered boats

Brief description: Fuel cell boats (< 500 tons) use compressed hydrogen gas as a fuel to generate electric power via an energy converter (fuel cell); the produced electricity powers an electric motor; t**echnical specifications are highly dependent on specific recreational or public transport use cases**

Use cases: Cities and regions can use/promote fuel cell boats for emergency service units, water taxis as well as tourist sightseeing and boat rentals; Cities and regions can establish harbours as "environmental zones"

Fuel cell powered boats[1] (typically use-case specific)

Key components	Fuel cell stack, system module, hydrogen tank, battery, electric motor
Output; efficiency	4 kW; up to 47% efficiency
Fuel	Hydrogen (350 bar)
Speed	5 kts
Refuelling interval; time of charging	80 km, < 5 min
Approx. capital cost	EUR 148,000 (excl. VAT)
Original equipment manufacturers	Frauscher, Bitter, Cheetah Marine
Fuel cell suppliers	Fronius, ITM Power, PowerCell Sweden AB, Proton Motor Fuel Cell, Hydrogenics , YC Synergy
Typical customers	Emergency units, water taxi and boat rental operators
Competing technologies	Diesel, battery-electric motors

1) Based on one example of Frauscher 600 Riviera HP

Source: Roland Berger

A

Various worldwide prototype demonstrations in operational environment since the early 2000s

Fuel cell powered boats

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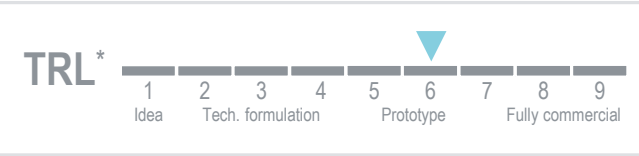
Overall technological readiness: Advanced prototype stage, albeit very diverse product segment with man different types of boats for a range of different recreational and public transport use cases; demonstration projects in operational environment have been completed or are currently ongoing



Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Energy Observer		2015	Lightweight ex-racing catamaran (30.5m length) using wind and solar power with on-board electrolysis to fuel a fuel cell. Round-the-world trip started in July	EUR 5 m
Ship as part of the Island Hydrogen (formerly known as EcoIsland)		2012	9.95 m fuel cell catamaran, completed 100 km around the Isle of Wight in 8 hours, average speed 7-8 kts (top speed 12 kts). Project funded by "Innovate UK"	n.a.
Future Project Hydrogen		2009	6 m boat "Frauscher 600 Riviera HP" powered by a 4 kW hydrogen fuel cell, funded by the state of Upper Austria	n.a.
Zero CO2		2009	CEA Liten zero CO2 12m hybrid electric sailboat with 30 kW PEM Fuel cell system and 15 kWh Li-ion battery	n.a.
Xperiance NX hydrogen		2006	12 person boat with a 1.2 kW PEM fuel cell propulsion system; designed to travel 2-3 days without refuelling, funded by the Province of Friesland and the Dutch Ministry of Economic Affairs	n.a.
Duffy-Herreshoff DH 30 Watertaxi		2003	30-day demonstration of a fuel cell/battery electric water taxi for up to 18 passengers and 4x 1.5 kW PEM fuel cell; partially funded by California's Center for the Commercial Deployment of Transportation Technologies (CCDoTT)	n.a.

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

Source: Roland Berger

A

Low emission powertrain and low noise pollution bears significant benefit potential for regions and cities

Fuel cell powered boats

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Use case characteristics

Stakeholders involved

> Emergency organisations (police, fire service, rescue organizations)
> Municipalities and/or private operators offering water taxis and boat trips
> OEMs

Demand and user profile

> Sensitive ecologic environments requiring alternative (zero emission, low noise pollution) propulsion systems
> Peak demand in high seasons (need for fast refuelling)

Deployment requirements

> Refuelling infrastructure
> High safety standards for hydrogen storage and transportation
> Possibility of coupling with on-site electrolysis from solar or wind

Key other aspects

> Currently only single demonstration boats; no entire fuel cell fleet in operation

Benefit potential for regions and cities

Environmental

> Zero local emissions (CO_2, pollutants, fine dust particles)
> Reduced noise level, therefore suitable in sensitive environments
> Potential to reduce environmental risk of accidents

Social

> Increased public acceptance of boat services, especially in harbour cities (zero emissions)
> Ultimately thanks to low/zero emission footprint: higher standard of living in critical areas

Economic

> Depending on the development of oil prices, CAPEX reduction and cost of hydrogen – lower TCO in the long run than diesel-fuelled boats

Other

> Refuelling time of a few minutes vs. battery charging of 8-10 hours

Source: Roland Berger

A

Product cost and hydrogen refuelling infrastructure as most critical issues for implementation on a larger scale

Fuel cell powered boats

Hot topics / critical issues / key challenges:

> **Identification** of suitable use cases and customers/users

> **Hydrogen infrastructure** (storing and refuelling stations in harbours, challenging logistics of providing the infrastructure for remote areas)

> **Product cost** (reducing the cost of fuel cells and batteries; cost competitiveness with electric boats has not been achieved yet; economies of scale hard to achieve as boats mostly are very individualized products)

> **Lack of overall industry standardization, certification guidelines and regulation** (esp. for refuelling protocols, hydrogen dispensing, bunkering, etc.)

> **Technological readiness** (until now, only prototype demonstration projects in operation; esp. emergency services or water taxi operators require fast and agile boats)

> **Eco-friendliness** (well-to-wheel emissions largely depend on resources used in hydrogen production)

Further recommended reading:

> EMSA Study on the use of fuel cells in shipping, 2017
http://www.emsa.europa.eu/news-a-press-centre/external-news/download/4545/2921/23.html

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

Two possible application cases exist for smaller fuel cell boats – pleasure boats and commercial passenger boats

Possible use cases for FCH boats

INDICATIVE

	1 Pleasure boats	2 Commercial passenger boats
		
Description	Small boats for private usage, either sold directly to end-customers as pleasure boats or sold to boat rental companies	Smaller excursion boats to be used for sightseeing and other touristic/recreational activities on (urban or other inland) waterways, e.g. canal and river sightseeing tours
Type of boat		
- Size	Length: ~4-10 m, width: ~1.5-3 m	Length ~15-25 m, Width ~3-6 m
- Passengers	n.i.	~60-100 passengers
- Output	~2-6 kW fuel cell, ~50-90 km range	~50-100 kW fuel cell, ~8-12 hour range
Competing Technologies	Diesel, CNG, battery-electric, possibly solar-powered	Diesel, CNG, battery-electric

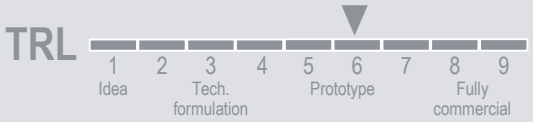
Source: Roland Berger, Fronuis, Simplyamsterdam, Rijksdienst voor Ondernemend Nederland

FC boats are not commercialized yet, but short refuelling times and zero local emissions emphasize their future potential

Business case and performance overview – PRELIMINARY & INDICATIVE

Technical/operational

- Advanced **prototype stage**, albeit very **diverse product segment** with different types of boats for a range of different recreational and public transport use cases
- **Demonstration projects** in operational environment have been **completed** or are currently **ongoing**
- **In principle, similar operational characteristics to be expected as diesel-combustion boats** (e.g. refuelling times, flexibility, ranges)



Economic

- **Higher system efficiency**, lower maintenance and operating costs are counterbalancing relatively higher capital costs of FC boat vs. conventional powertrains
- **Short refuelling times** and long ranges increase availability rates in comparison to battery-electric boats and hence improve the profitability of (battery-electric) boat rental companies
- **Key business case drivers**:
  - Cost of hydrogen vs. cost of diesel/electricity
  - Boat CAPEX
  - Infrastructure costs, esp. refuelling station CAPEX (incl. utilisation) and OPEX

Environmental

- **Zero tailpipe (i.e. tank-to-wheel) emissions** of CO_2, pollutants such as NO_X and fine dust particles for FCH boats as well as significant reduction of noise and vibrations – key benefits for passengers on board as well as outside environment
- **Lower noise emissions as key benefit for inland waterways**, esp. 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 boats with "green hydrogen"**

*) Technology Readiness Level

Source: Roland Berger

When identifying suitable use cases, Regions & Cities should look into the private and the commercial sector and leverage synergies

Key considerations concerning fuel cell boats

- **Increasing emphasize on decarbonisation, emissions reduction and water protection** is stimulating the development of zero-emission engines such as fuel cells for pleasure boats and small passenger boats
  - Already today, national legislations **ban combustion engines** on several environmentally **sensitive lakes,** urban waterways (e.g. canals) will be increasingly affected by local emission regulations as well
  - **Boat rental companies and commercial passengers boats** will also be affected by **supranational regulations** on EU-level such as CO_2 monitoring requirements as well as cap and trade policies
- **Capital cost and fuel supply** are among the major **hurdles** faced by fuel cell powered boats – a sufficiently extensive hydrogen **infrastructure available to commercial and private users** needs to be established
- **Gaps in the regulatory framework and industry standards need to be closed**, e.g. regarding the use of gaseous hydrogen on boats or refuelling protocols
- Further **demonstration projects** will be necessary to **increase technological readiness and hence commercial availability**

Source: Roland Berger

Please do not hesitate to get in touch with us

Contact information

Carlos Navas

FCH2 JU

Strategy and Market Development Officer

carlos.navas@fch.europa.eu

+32 2 221 81 37

Source: FCH2 JU, Roland Berger