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

FCH Aircraft

Brussels, Fall 2017

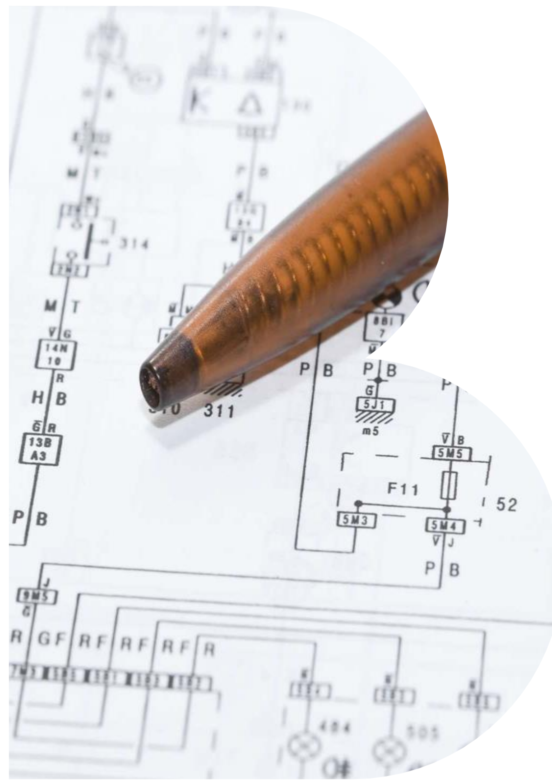
This compilation of application-specific information forms part of the study ***"Development of Business Cases for Fuel Cells and Hydrogen Applications for European Regions and Cities"*** commissioned by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU), N° FCH/OP/contract 180, Reference Number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



Current research and development focuses on small-scale airplanes (< 5 passengers) and auxiliary power for conventional aircraft

Fuel cell powered aircrafts

Brief description: Fuel cell powered aircraft use compressed hydrogen gas as a fuel to generate electric power via a fuel cell for propulsion or auxiliary power; ***current concepts and prototypes mainly focus on non-essential aircraft applications for conventional aircraft***

Use cases: Cities and regions can use/promote fuel cell aircraft to reduce carbon emissions and noise pollution

Fuel cell powered aircraft [1)]

Key components	Fuel cell stack and system module, hydrogen tank, battery, electric motor
Output	80 kW
Fuel	Hydrogen
Top speed, range	200 km/h, 750-1500 km
Battery capacity	21 kWh
Approximate capital costs	n.a.
Original equipment manufacturers	Boeing, Airbus, Lange Aviation, Pipistrel
Fuel cell suppliers	Hydrogenics, NuCellSys
Typical customers	Airline operators
Competing technologies	Battery powered and conventional aircraft (kerosene)

1) Based on "HY4" project by DLR

Source: Roland Berger

Until now, only small-scaled aircraft with fuel cell powertrain in prototype stage as well as testing of auxiliary power units

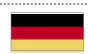
Fuel cell powered aircrafts

Overall technological readiness: Experiments and early prototyping of fuel cell technology as auxiliary power unit (APU) on large conventional aircraft or as propeller powertrain for smaller aircraft

TRL*

1 Idea | 2 | 3 Tech. formulation | 4 | 5 | 6 Prototype | 7 | 8 Fully commercial | 9

Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Demonstration of "HY4"-aircraft		2016	Demonstration of world's first 4 seat passenger aircraft powered by fuel cell technology, operation by DLR spinoff H2FLY with future vision of "electric air taxi network"	n.a.
Hydrogen Cells for Airborne Usage (HYCARUS)		2013	European research project led by Zodiac Aerospace to develop a Generic Fuel Cell System (GFCS) in order to power non-essential aircraft applications; objective is to establish alternative sources to power non-propulsive aircraft systems, funded by FCH2 JU with EUR 5,2 m	EUR 12 m
DLR, Airbus and Michelin fuel cell testing		2008	Testing of various fuel cell application on A320 e.g. fuel cell powered electric nose wheel to significantly reduce noise and emission levels at airports when moving/taxiing on the runway	n.a.
Project Hydrogenius		2008	Cooperation of University of Stuttgart (Germany) and Slovenian small aircraft OEM Pipistrel to construct fuel cell powered two-seater aircraft	n.a.
Environmentally Friendly Inter City Aircraft powered by Fuel Cells (ENFICA-FC)		2006	Designing of a fuel cell powered manned intercity aircraft as part of aeronautics and space priority of the Sixth Framework Programme (FP6)	EUR 4.5 m

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

Source: Roland Berger

A

Significant decrease of emissions and much lower noise pollution as major benefits – especially for airports in densely populated areas

Fuel cell powered aircrafts

3/4

Use case characteristics

Stakeholders involved

- Airline operators
- OEM & Fuel Cell Suppliers
- Airport operators
- Public regulators

Demand and user profile

- Range, performance and refuelling service offerings ideally similar to conventional aircraft, however not yet technologically ready

Deployment requirements

- Hydrogen refuelling infrastructure
- High safety standards for hydrogen storage and transportation

Key other aspects

- Short distance regional transport as potential entry scenario

Benefit potential for regions and cities

Environmental

- Zero local emissions as substantial advantage
- Significantly lower noise pollution than with using conventional aircraft

Social

- Higher standard of living in areas near airports which are significantly polluted by noise and emissions
- Improved public consent for aircraft
- Health benefits for workers and passengers through reduced noise and pollution

Economic

- Extended interval of engine maintenance due to less activity if nose wheel[1)] or the auxiliary power unit (APU) is run by a fuel cell, which replaces the engine on ground
- Higher power efficiency for auxiliary power generation

Other

- Depending on the production type of hydrogen, reduction of dependency on fossil fuels or energy imports

1) as tested by DLR, Airbus and Michelin since 2008

Source: Roland Berger

Technological readiness as well as product cost as major challenges for large-scale implementation of fuel cell powered aircraft

Fuel cell powered aircrafts

Hot topics / critical issues / key challenges:

> **Technological readiness and system/product definition** (until now, no entirely fuel cell powered commercial aircraft available and current propulsive applications limited to very small aircraft; evolution to the next development stage necessary going beyond prototyping for auxiliary power supply; very specific operational requirements regarding the various potential use cases of fuel cells in aircraft)

> **Product cost** (reducing the cost of fuel cells and batteries; significantly higher CAPEX than for conventional aircraft)

> **Technical standards** (derivation of technical standards for different types of aircraft varying concerning systems and performance)

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

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

Further recommended reading:

> Official website of HY4: http://hy4.org/

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

Roland Berger

B. Preliminary Business Case

Auxiliary Power Units can further add to airport emissions and noise reductions while being more fuel efficient than traditional engines

Fuel Cell Powered Aircrafts

Background

> The aviation industry is currently shifting towards the concept of **'more-electric aircrafts'**, meaning electric power should be used for non-propulsive systems

> Here, **on-board auxiliary power units (APUs)** are mostly used during ground as well as on-flight times. Traditionally, they use jet fuel and consist of a gas turbine combined with an electrical generator

Technical characteristics

> **Fuel cell APUs** are an attractive alternative since they display **higher efficiencies** than jet-fuelled engines

> Hypothetical fuel cells designed for aircrafts of around 140 – 180 passengers typically have a designed capacity of 300 – 600 kW – real-life aircraft energy demand might be much higher, depending on the type and electrification level of the aircraft

Environmental considerations

> Up to **10% of airport emissions can be traced to APU systems** – hence, significant reductions of CO_2 emissions, pollutants and fine dust particles can be realized

Economic considerations

> No **TCO information disclosed** so far since fuel cell APUs are not pre-commercialised yet – demonstration projects are ongoing but fuel cell weight poses a major challenge

Source: Eurocontrol, American Institute of Aeronautics and Astronautics, Roland Berger

Please do not hesitate to get in touch with us

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Source: FCH2 JU, Roland Berger