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

FCs in commercial buildings

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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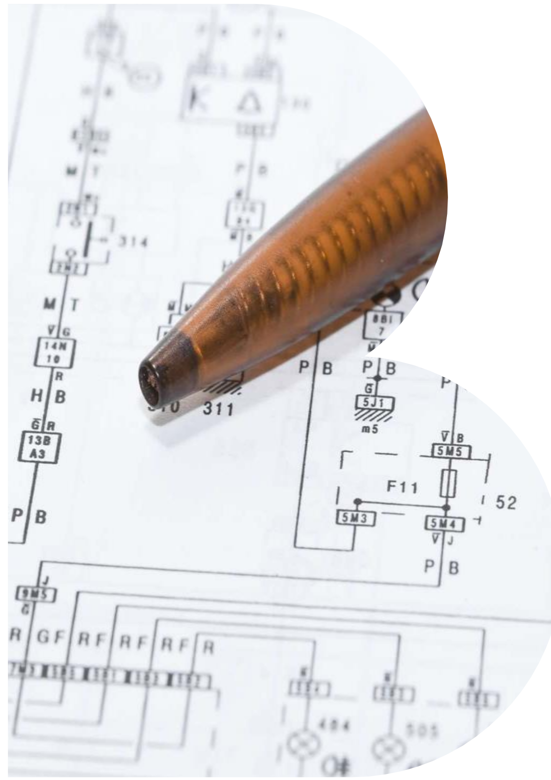
A. Technology Introduction



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Medium-size fuel cell CHPs can meet the growing demand for energy-efficient and independent solutions in commercial buildings

Fuel cells in commercial buildings (5-100 kW_{el} and up to 400 kW_{el})

Brief description: fuel cell combined heat and power systems (FC CHP) for commercial buildings use natural gas as fuel to generate electricity and heat through a fuel cell stack reforming natural gas on site to hydrogen – for distributed energy supply in office/public-sector buildings, buildings, hospitals, hotels, SMEs, etc.

Use cases: Cities and regions can promote fuel cells in commercial buildings to lower GHG and carbon emissions and increase resilience against unexpected power outages – particularly for commercial buildings such as small to medium size enterprises (SMEs) , hotels, hospitals, public sector buildings, etc.

Fuel cells in commercial buildings[1]

Key components	Fuel cell stacks, system module, inverter, heat transmission and storage
Fuel cell technology	likely mainly SOFC (possibly also PEM, MCFC, PAFC)
Fuel	Natural gas (possibly also biogas, hydrogen)
Efficiency	ca. $50\%_{el}$, ca. 85% combined
Output	5-100 kW_{el} (and up to 400 kW_{el})
Approximate capital cost	dep. on use case and market, ca. EUR 18,000-30,000 per kW_{el} (fully installed)[2]
OEMs, system integrators	TBD – e.g. Convion, Logan Energy, FuelCell Energy (FCES)
Fuel cell suppliers	FCES – e.g. Sunfire, mPower, elcogen, SOLIDpower, Ceres Power
Typical customers	Office building developers, public sectors, hotel/hospital operators
Competing technologies	Gas boiler & grid supplied electricity, conventional CHP

1) Focus on European market 2) Down to less than EUR 6,000 per KW_{el} if kW ~400)

Source: Roland Berger

A

ComSos project potentially to be added

In Europe, fuel cells in commercial buildings are still at a comparatively early stage in tech. development and deployment

Fuel cells in commercial buildings (5-100 kW_{el} and up to 400 kW_{el})

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Overall technological readiness: Limited range of products available in Europe that are mostly in advanced-prototype / demo-project stage (North American and East Asian markets are to some extent more mature), EU manufacturers however starting to develop products (prototype / demo or early commercial trial stage)

TRL*: 6 (scale 1 Idea – 2–3 Tech. formulation – 6 Prototype – 8–9 Fully commercial)

Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
First commercial deployment in hotel	Germany	2017	Installation of 400 kW fuel cell by FCES through e.on in Radisson hotel facility in Frankfurt. 3 GWh electricity production and 600 t of CO_2 reduction	n.a..
CHP fuel cell system in Fenchurch 20 Office Tower	UK	2014	Installation of 300 kW CHP fuel cell system running on natural gas to power major office tower in downtown London, reduction of carbon emission by 6-7% and awarded with BREEAM excellence rating	n.a.
MCFC deployment in Federal Ministry	Germany	2013	Installation of 250 kW MCFC of FCES in office building of Federal Ministry in Berlin, Germany as innovative concept for combined supply of electricity, heat and chilling (incl. power supply for data centre)	n.a.
Fuel cell CHP industrial demonstration by US Department of Energy	USA	2010	Installation of 15 CHP fuel cell systems in small commercial buildings to document market viability through engineering, environmental and economic data analysis	n.a
PEM fuel cells in real conditions (EPACOp)	France	2002	Assessment of performance of CHP fuel cell systems in public buildings (e.g. universities, city halls) and various testing conditions	EUR 2.4 m

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

Source: Roland Berger

Fuel cell CHP systems can improve the overall energy efficiency of commercial buildings and significantly reduce overall emissions

Fuel cells in commercial buildings (5-100 kW_{el} and up to 400 kW_{el}) 3/4

Use case characteristics

Stakeholders involved
- > OEMs of CHP systems and FC suppliers
- > Planners, architects, installers
- > SMEs, commercial/public operators, facility managers
- > Utilities, ESCOs, power/gas grid operators

Demand and user profile
- > Energy- and especially heat-intensive commercial buildings, e.g. hotels, hospitals, office buildings
- > Facilities with particular need for resilience against unexpected power outages, hence affinity for distributed energy supply

Deployment requirements
- > Connection to existing gas/electricity grid
- > Sufficient space for distributed energy system, (semi-)central heat distribution system

Key other aspects
- > -

Benefit potential for regions and cities

Environmental
- > Low emissions of pollutants and greenhouse gases (esp. CO_2) – significant reduction CO_2, virtual elimination of NOx and SOx emissions, reduction of primary energy consumption
- > Low noise pollution due to almost silent operation

Social
- > Promotion of distributed energy systems, lowering social cost of electricity grid expansion esp. by DSOs
- > Enabler for more renewables in electricity mix with complementary role of distributed CHP to e.g. heat pumps

Economic
- > With reduction of product cost due to volume uptake and learning effects, TCO-competitiveness with other distributed energy solutions in reach – esp. in markets with high electricity prices for SMEs (difference of gas and electricity prices)

Other
- > -

Source: Roland Berger

More fuel cell products are necessary in the commercial segment, most promising specific use cases need to be defined

Fuel cells in commercial buildings (5-100 kW_{el} and up to 400 kW_{el}) 4/4

Hot topics / critical issues / key challenges:

> Lack of fuel cell products in this size range (currently, there are very few fuel cell CHP products which target the 2-100 kW_{el} size range, and the limited development to date has focused on the smaller end of the range e.g. 2-5 kW_{el})

> Competition with lower electricity and gas prices from grid supply – more challenging business case for distributed CHP compared to other segments

> Identification of most promising commercial use cases and corresponding operating models – distinct role of planners, engineers, architects, etc. as key influencers on FC definition and adoption

> Awareness of technological and commercial viability among policy makers

Further recommended reading:

> "Advancing Europe's energy systems: Stationary fuel cells in distributed generation" http://www.fch.europa.eu/studies

> "Business models and financing arrangements for the commercialisation of stationary applications of fuel cells report" (forthcoming) http://www.fch.europa.eu/studies

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

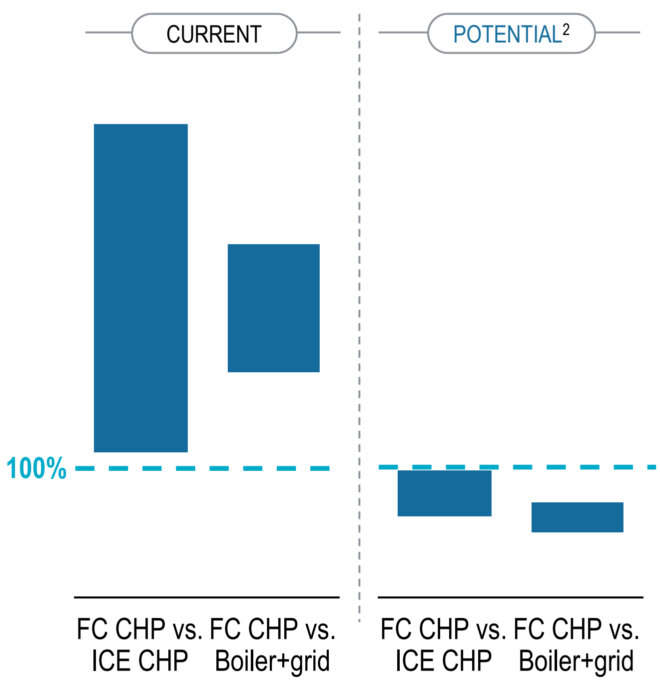
B. Preliminary Business Case

With growing volumes over the long term, FC CHPs can become competitive – Significant CO_2 and pollutant savings possible

Business case and performance overview[1]– INDICATIVE

Economic

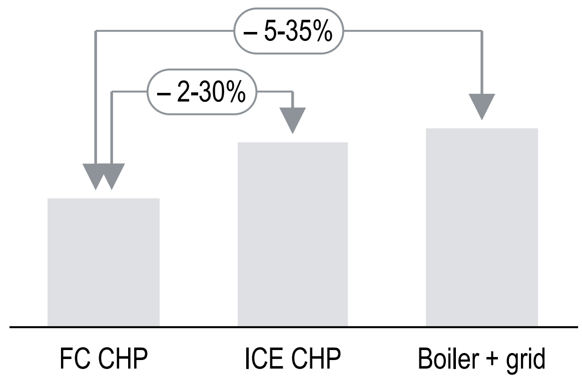
Multiples of FC CHP Total Cost of Energy (TCE) in different use cases (TCE of counterfactual at 100%):



Environmental

> Next to zero local emissions of pollutants NO_x, SO_x and fine dust particles

> Total attributable CO_2 emissions dep. on CO_2 intensity of electricity mix and gas grid and "accounting method" – CO_2 savings across different apartment use cases:



> Outlook: over the long term, the emissions performance will depend on the decarbonisation of the electricity and gas grids as well as increases in efficiency of FC CHPs

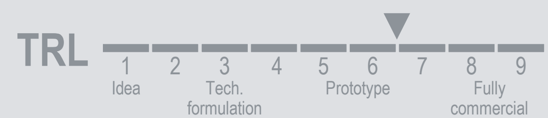
Technical/operational

> Limited range of products available in Europe that are mostly in advanced-prototype / demo-project stage (North American and East Asian markets are more mature), EU manufacturers starting to develop more products (prototype / demo or early commercial trial stage) **– initial focus on further demo projects**

> Ready for deployment as FC CHP would **build on existing natural gas infrastructure**

> For FC CHP, system and fuel cell stack lifetime currently below conventional heating systems, expected to catch up as systems progress along learning curve

> FC CHPs could e.g. be enabled by (in-house) power and heat contracting models to enable building owners & developers to shoulder (and finance) initial CAPEX



1) Based on 8 use cases across 4 EU markets (DE, IT, PL, UK) as of 2015; ICE = gas-fuelled Internal Combustion Engine
2) Requiring significant volume increases, here e.g. 5,000 cum. units per manufacturer (ideally supported by synergies from other stationary FC segments)
Source: FCH2 JU, Roland Berger

B

Strong business case, high spark spread, high efficiency and greener natural gas will help FC CHPs succeed in the market

Key performance determinants and success factors

Business case awareness – from CAPEX and TCO/TCE perspective

In commercial use cases, economics tend to play a larger role in the decision making process – (1) creating the potential to sell on a TCO/TCE-based value proposition (i.e. significantly lower OPEX offsetting higher CAPEX) and (2) triggering the need to reduce cost sufficiently as customers will be hesitant to pay a significant premium

Electrical efficiency

Potential increases in electrical efficiencies boost electricity production during CHP operations and hence reduce TCE (expected to grow to up 58% in future generation FC CHPs, i.e. significantly more than ICE CHP at ca. 28-38% or micro gas-turbines at ca. 28%)

STRONG REGIONAL DIFFERENCES

Business model for market penetration

FC deployment in the complex stakeholder landscape (incl. e.g. owners/developers, facility managers, residents/tenants, planners, installers, utilities, etc.) might be overcome by contracting models where building owners (e.g. housing associations) plan, finance and deploy a new system and sell electricity and heat to residents

Energy price levels / "spark spread"

High electricity prices and comparatively low gas prices support business case (grid parity betw. 10-20 ct/kWh_{el} especially when maximizing in-house power consumption)

Decarbonisation of electricity and gas grid

Significant savings in CO_2 and primary energy with FC mCHP, especially over the medium term and when grid electricity supply is dominated by conventional power generation; long-term greening of gas grid (via green hydrogen, biogas, etc.) helps sustain env. edge of distributed, gas-based generation over grid supply (with conv. gas or electr. heating)

Source: Roland Berger

We primarily look at apartment buildings (or sets of family homes) that would use FC CHPs instead of gas boilers (or ICE CHPs)

Preliminary business case components and key assumptions – INDICATIVE

Application-related specification (selection)

current/*potential*	**Fuel Cell CHP (FC CHP)**	**Gas Boiler** (+ Grid)
Technical specifications	Combined ca. 5 kW_{el} / ca. 4 kW_{th} nat. gas FC CHP system in add. to <50 kW_{th} condens. boiler and grid power supply, larger combined heat storage	State-of-the-art <50 kW_{th} gas condens. boiler, grid power supply, comb. heat storage
CAPEX[1]	ca. 15,500 / *11,000* EUR/kW_{el}	EUR 5-7,000
Heating fuel	Natural gas	Natural gas
Ø net efficiency	$52\%_{el}$, $37\%_{th}$ / *$58\%_{el}$, $38\%_{th}$*	$90\%_{th}$
Lifetime	10 / *15* years with 1 / *0* fuel cell stack replacements	15 years
Maintenance	EUR 650-850 / *500-600* p.a.	EUR 110 p.a.
Other aspects	Heat-driven operations of the FC CHP acc. to standard load profiles, feed-in of any electricity not consumed in-house, some (peak) electricity demand covered by grid	All thermal energy from gas condensing boiler, all electrical energy from electricity grid

Use case and exogenous factors

Strongly dependent on reg. circumstances

- Apartment buildings (or set of family homes) (5-10 units, 20-30 residents) with 800-1,200 m^2 in building stock (possibly renovated) with single-source/central heating and DHW system
- Annual heat demand (incl. hot water): ~75,000-220,000 kWh – strongly dep. on size, degree of insulation, climate zone, etc.
- Annual electricity consumption: typically 900-1,500 kWh per resident
- Resulting annual operations of the fuel cell CHP in such use cases: 5,000-6,00 full load hours; dep. on load profile, ca. half of thermal energy covered by FC mCHP and majority of power demand supplied by FC CHP

Strongly dependent on reg. circumstances

- Cost of natural gas: equal or less than 0.04 / *0.07* EUR/kWh
- Cost of grid electricity: equal or less than 0.20 / *0.30* EUR/kWh
- CO_2 intensity of natural gas: 185 / *165* g/kWh
- CO_2 intensity of grid electricity: 510 / *350* g/kWh
- CO_2 balancing method for CHP: power feed-in credits at average CO_2 intensity of power grid
- No public support schemes considered (subsidies, tax credits, feed-in tariffs, CHP premiums, etc.)

1) Incl. installation and stack replacements as re-investments (e.g. short-term cost to be assumed at cost levels of 100 units per manufacturer, i.e. already significantly lower cost levels than actual current prices: system cost of 10,900 EUR/kW; installation cost 1,600 EUR/kW; stack replacement cost of 3,000)

Source: FCH2 JU, Eurostat, European Commission, Roland Berger

B

The larger the FC (i.e. >20 or even >50 kW_{el}), the more crucial the efficient use of heat and the robustness of the overall business case

Key considerations with regard to FC CHPs for commercial use cases >20 / >50 kW_{el}

Changing business models

More and different stakeholders involved, less off-the-shelf and more made-to-order systems that are tailored to individual use case (key role of engineers/planners and installers); different opportunities for business model innovation (e.g. contracting, Energy Service Companies (ESCOs))

Need for sufficient on-site heat consumption

To reap the benefits of CHP (i.e. allowing for long operating hours and efficient self-consumption) need for constant heat demand on-site that is supplied by FC CHP – e.g. in buildings such as hospitals, hotels, swimming pools

Tougher competition from grid electricity supply

Generally speaking, lower grid electricity prices for higher-volume off-takers (like operators of the aforementioned buildings) – hence pressure on distributed CHP to achieve parity (>10 ct/kWh)

Opportunities for regions and cities

Procuring FC CHP as low-emission, innovative systems for public buildings thereby broadening the European base of key demonstration projects and supporting initial volume uptake

Source: Roland Berger

Please do not hesitate to get in touch with us

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Source: FCH2 JU, Roland Berger