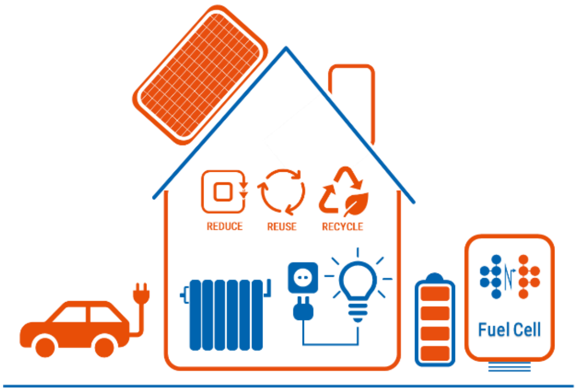
2021

UPTAKE OF INTERNATIONAL STANDARDS IN THE DEPLOYMENT OF STATIONARY FUEL CELL SYSTEMS IN DIFFERENT COUNTRIES



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IEA Technology Collaboration Programme
Advanced Fuel Cells

Technology Collaboration Programme
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TECHNOLOGY COLLABORATION PROGRAMME ADVANCED FUEL CELLS
ANNEX 33 – FUEL CELLS FOR STATIONARY APPLICATIONS

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1. INTRODUCTION

1.1. GENERAL INTRODUCTION

This study has been funded by IEA Technology Collaboration Programme Advanced Fuel Cells in 2021, and it is focused on an overview of the applicable regulations, codes and standards for the installation of stationary fuel cell systems in different countries: which standards are international, what obstacles there are to a global market for individual stationary fuel cell stack and system developers/manufacturers, how it is possible to overcome these leading to reducing costs and improving performance of a number of the components of FC stacks, and how these will change if hydrogen becomes the new international fuel vector.

In particular, the proposal focuses on the analysis of the IEC 62282-3-300 "Stationary fuel cell system- installation" International Standard and IEC 62282-3-400 “Small stationary fuel cell power system with combined heat and power output”, comparing its uptake in different countries where stationary FC applications are relevant.

The main objective is thus to understand how the deployment of stationary fuel cell systems is governed by common standards that can facilitate the few industrial manufacturers in cornering emerging markets across the globe, thereby accelerating the achievement of scale and cost reductions. The countries analysed are: Japan (Asia) and Germany, Austria and Italy (Europe).

1.2. STATIONARY FUEL CELL SYSTEMS 1

Fuel cell systems are open thermodynamic conversion systems that directly convert chemical energy of a fuel gas to electrical energy as a power output via electrochemical reactions occurring within the fuel cell constituents. The electrochemical conversion pathway allows to reach very high conversion efficiencies around 50-70% (well above the Carnot efficiency which limits thermo-electrical energy conversion pathways) with a variety of fuel gases according to the fuel cell system technology.

A fuel cell stack is composed of a series of membrane electrode assembly (MEA) repeating units whose characteristics (operating temperature & pressure, ionic species conduction, material properties, etc.) define the design specifications/requirements and operational capabilities of each fuel cell technology. Although most fuel cell technologies are ultimately based on the electro-oxidation of H_2, the fuel which can be supplied externally to the fuel cell system can vary according to the technology. Low temperature fuel cells require a highly pure H_2 feedstock while high temperature fuel cells can process a variety of hydrocarbon fuels thanks to the internal reforming processes.

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[1] IEA - International Energy Agency Technology Roadmap Hydrogen and Fuel Cells; 2015
IEA - International Energy Agency The Future of Hydrogen, 2019
Ramadhani, F.; Hussain, M.A.; Mokhlis, H. A comprehensive review and technical guideline for optimal design and operations of fuel cell-based cogeneration systems. Processes 2019
Slater, J.D.; Chronopoulos, T.; Panesar, R.S.; Fitzgerald, F.D.; Garcia, M. Review and techno-economic assessment of fuel cell technologies with CO2 capture. Int. J. Greenh. Gas Control 2019, doi:10.1016/j.ijggc.2019.102818
Staffell, I.; Scamman, D.; Velazquez Abad, A.; Balcombe, P.; Dodds, P.E.; Ekins, P.; Shah, N.; Ward, K.R. The role of hydrogen and fuel cells in the global energy system. Energy Environ. Sci. 2019

From a system level point of view a fuel cell system provides the opportunity for a highly flexible Combined Heat and Power (CHP) generator which can operate on both H_2 and hydrocarbon feedstocks with extremely high overall efficiency with respect to other technologies, reducing (in case of fossil fuel feedstock) or completely abating (if fed by renewable feedstock) carbon emissions other than completely eliminating other harmful emissions (NOx, SOx, PM, etc.) generated by the combustion processes.

1.3. MARKET OVERVIEW – CHP SECTOR [2]

Thanks to the wide range of available technologies and thanks to their modularity, stationary fuel cell systems can cover different segments of the heat and/or power generation market. On one end, MW-scale fuel cell plants can be deployed at city/district level to produce electricity to be distributed via a local grid and/or heat for distributed heating and cooling networks to serve various households and commercial users. On the other end, single kW-scale fuel cell units can be integrated in single apartment/building power systems in order to locally produce power and/or heat (for domestic hot water and/or space heating) in micro-Combined Heat and Power (m-CHP) modes [3]. In this section, the main applications and accessible market segments for stationary fuel cells are summarized (small- and large-scale heat and/or power generation) and a brief development overview is provided for the main geographical hubs (Asia, North America and Europe).

Large scale Heat and/or Power generation

More than 800MW large stationary fuel cell systems with rated power above 200 kW have been installed globally for distributed generation and combined heat power applications. The largest shares of the installations are found in the US and South Korea. Figure 1 shows the relative shipments of the different fuel cell technologies installed up to the end of 2020 [4].

For sizes above 200 kW, the market is dominated by three technologies, with Molten Carbonate Fuel Cells (MCFC) having the largest share, followed by Solid Oxide Fuel Cells (SOFC) and Phosphoric Acid Fuel Cells (PAFC). In the last 5 years, deployment trends indicate the strongest growth rate for PAFC, although plans for several multi-megawatt MCFC installations in the U.S. have also been announced. Large stationary fuel cell units have been deployed by utilities and provide power for distributed generation and Combined Heat and Power (CHP) applications, the latter, particularly in Asia. Whilst a large number of the installed units generate both heat and electricity, there is also a market for electricity-only systems, as an instance, those installed to provide backup power for US customers.

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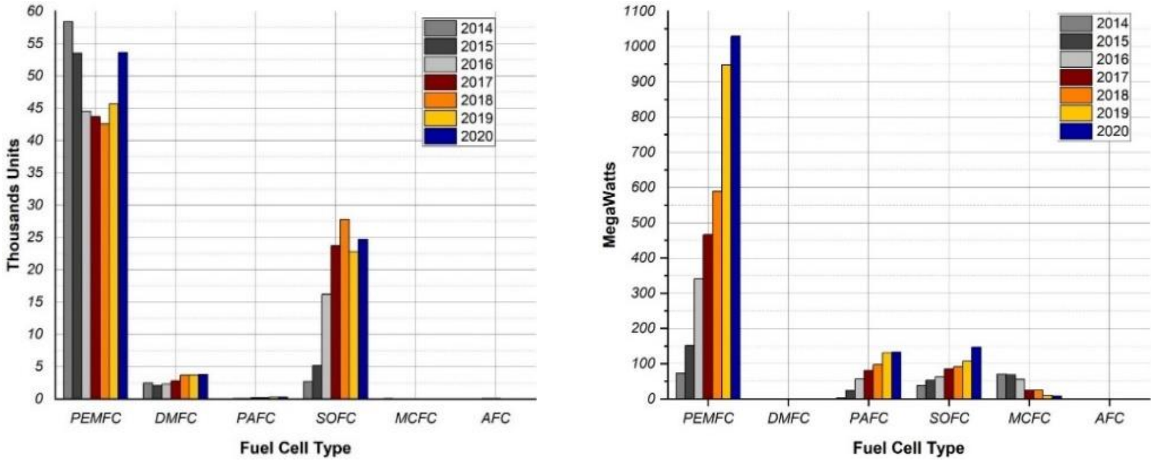
[2] Cigolotti, V.; Genovese, M.; Fragiacomo, P. Comprehensive Review on Fuel Cell Technology for Stationary Applications as Sustainable and Efficient Poly-Generation Energy Systems. Energies 2021, 14, 4963. https://doi.org/10.3390/en14164963

[3] FCH JU, Advancing Europe's energy systems: Stationary fuel cells in distributed generation; 2015; Felseghi, R.A.; et al. Hydrogen fuel cell technology for the sustainable future of stationary applications. Energies 2019

[4] Weidner, E.; Cebolla Ortiz, R.; Davies, J. Global deployment of large capacity stationary fuel cells – Drivers of, and barriers to, stationary fuel cell deployment; 2019;



(a) (b)

Figure 1 (a) Fuel Cell Shipments; (b) Fuel Cell Size Installations

In Table 1, deployment data is shown per geographical area. North America (mainly the U.S.) and Asia (Japan and South Korea) have completely dominated in the past with regards to the installation of fuel cell systems, while Europe is the main growing region with a steadily increasing contribution; other geographical locations only present a limited deployment.

Country/State	2016	2017	2018	2019	2020
Europe	27.4	38.9	41.2	113.0	148.6
North America	213.6	331.8	425.3	339.2	252.7
Asia	273.8	285.8	337.9	743.9	912.4
RoW	1.7	2.1	1.2	0.2	5.0
Total	**516.5**	**658.6**	**805.8**	**1,196.3**	**1,318.8**

Table 1: Fuel Cell Systems installations (MW – all technologies)

Small scale Heat and/or Power generation

For lower sizes, less than 200 kW, while PEMFC seems to have a steady decreasing trend until 2018, in 2019 and 2020 PEMFC installations increased, thanks to new demand required by the mobility sector. The market is showing how big efforts are ongoing to strengthen the market for SOFC given their better performance and wide range of applications. For the residential micro-CHP applications (based on PEMFC and SOFC), Europe and Japan are leading the market, thanks to ad-hoc subsidies and programs as shown in Table 2. Several manufactures are involved in the market, as shown in Table 3.

Country/State	Technology	Cumulated Installed Capacity (MW)*	Installations (Thousands of Units)	Price per sale (k€)
Europe	PEMFC/SOFC	7.5	~10	10
Japan	PEMFC/SOFC	270	~360	7-8.8

**Calculated by considering an average installation size of 0.75 kW*$_{el}$

Table 2: PEMFC and SOFC, micro-CHP Installation

Country	Manufacturer	Technology	Electrical output [kW]	Electric efficiency [%]	Total efficiency [%]
Europe	SenerTec	PEMFC	0.75	38	92

	Remeha	PEMFC	0.75	38	92
	Bosch	SOFC	1.5	60	Up to 88
	SOLIDpower	SOFC	1.5	Up to 57	Up to 90
	Sunfire	SOFC	0.75	38	88
	Viessmann	PEMFC	0.75	37	92
Japan	Panasonic	PEMFC	0.7	40	97
	AISIN	SOFC	0.7	55	87
	Kyocera	SOFC	0.4	47	80

TABLE 3: PEMFC AND SOFC, MICRO-CHP PERFORMANCE

Europe has installed more than 4,100 fuel cell units for combined heat and power applications, thanks to three main projects and actions[5]: Callux, PACE, and ene.field. The three programs have been key actions for the technology rolling out. Only in the ene.field program, 603 PEMFC micro-CHP units have been installed, and 403 SOFC. In Germany, an incentive program[6], namely KfW, is supporting micro-CHP early market, at different levels: 5,700€ as a fixed amount for a new fuel cell, and other additional amount and flat-rate supplement. For every 100 W_e, another 450 € are added, up to 6,750€. When used in CHP mode, a subsidy is paid for each kWh of electricity produced: 4 c€/kWh for electricity that is consumed and 8 c€/kWh for electricity that is fed into the grid. The program aims to provide funding for the installations of about 60,000 CHP units by 2022. The current cost of fuel cells in Europe for micro combined heat and power production is about €10,000/kW, with more than 2,000 µ-CHP fuel cell-based adopted on the field, and another 2,800 planned by 2021[7]. Japan is the main leader in fuel cell-based micro combined heat and power unit installations, with the ENEFARM program. They have been able to decrease the price per sale to US$7,000/unit for PEM, and US$8,800/unit for SOFC. The overall installations can be counted for 360,000 units in 2020[8], almost 62% of them are PEMFCs and 38% SOFCs. The program supported also subsides, from 50% of the cost to US$730/unit for SOFC and no more subsidies for PEMFC, since the commercial price could now be competitive.

Asia resulted to be the more active area in installing fuel cell units, above all for commercial micro-CHP application, particularly Japan in the last five years, which have lived an increase of almost 30% in 2018 (55,500 installed units) than 2014.

1.4. OVERVIEW OF MAIN GEOGRAPHICAL HUBS OF DEVELOPMENT AND DEPLOYMENT OF STATIONARY FUEL CELL SYSTEMS

The main geographical hubs for stationary fuel cell development and deployment have historically been East Asia (Japan, South Korea) and North America (U.S. and Canada), both for the strong presence of fuel cell technology providers/developers and due to favourable

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[5] PACE Pathway to a Competitive European Fuel Cell micro CHP Market Programme Review Days 2018; Nielsen, et al Status on Demonstration of Fuel Cell Based Micro-CHP Units in Europe. Fuel Cells 2019; Nielsen, E.R.; Prag, C.B. Learning points from demonstration of 1000 fuel cell based micro-CHP units. 2017.

[6] KfW 433 programme; Brennstoffzellen Branchenführer Deutschland 2018; Energie, V. Brennstoffzelle : Strom und Wärme maximal effizient

[7] Fuel Cell and Hydrogen Joint Undertaking Multi - Annual Work Plan; 2018; ISBN 1496312627865; Hydrogen Europe Hydrogen Europe - TECHNOLOGY ROADMAPS FULL PACK; 2018; Hydrogen Europe Hydrogen Europe Strategic Research & Innovation Agenda, Final Draft; 2020

[8] Japan LP Gas Association Home-use Fuel Cell (ENE-FARM) https://www.j-lpgas.gr.jp/en/appliances/; Japan Hydrogen & Fuel Cell Demonstration Project http://www.jhfc.jp/e/index.html

market conditions, such as availability of substantial funding programmes aiding deployment (i.e. East Asia), existence of remote areas of weak grid connection for which fuel cell deployment is favourable (i.e. North America), abundance of low gas prices, high technological readiness of energy networks, etc. In the decade 2010-2020 also Europe has pushed for deployment of several funding programmes to fast-track the deployment of natural gas fuelled stationary fuel cells, especially in Northern Europe (Germany, Belgium, Denmark, etc.) and Central Europe (Austria, Northern Italy, etc.), although the focus has recently been shifting towards hydrogen production and hydrogen-fuelled fuel cells.

In the following subsections an overview of the market development is given in terms of available technologies and stakeholders (OEMs, developers, etc.) for Japan, South Korea, North America (U.S. and Canada) and Europe. In the following sections of this report, the focus is put mainly on Italy, Austria, Germany and Japan which are the countries part of the scope of the analysis presented in this work.

Japan

Deployment in Japan reflects the longstanding commitment of both Government and industry to Japan's Hydrogen Society ambition. New stationary fuel cell developments and products have been announced in 2020, with a strong commercial proposition enabling faster deployment. Japan has the world's largest fleet of micro-CHP fuel cell systems. Deployment of these Ene-Farm units since 2011 has been about getting the volume required to drive the technology along the learning curve and generate substantial economies of mass production. The most installed units are PEM technology from Panasonic and SOFC from Aisin Seiki. The flagship products are both rated at 0.7 kW (electrical output), operate on natural gas or LPG, and are supplied via Japan's gas companies, notably Tokyo Gas and Osaka Gas. Official figures suggested 360,000 Ene-Farm units in total had been deployed by March 2021. For more detail on the Ene-Farm project, see Section 2.1 dedicated to the Japanese m-CHP market overview.

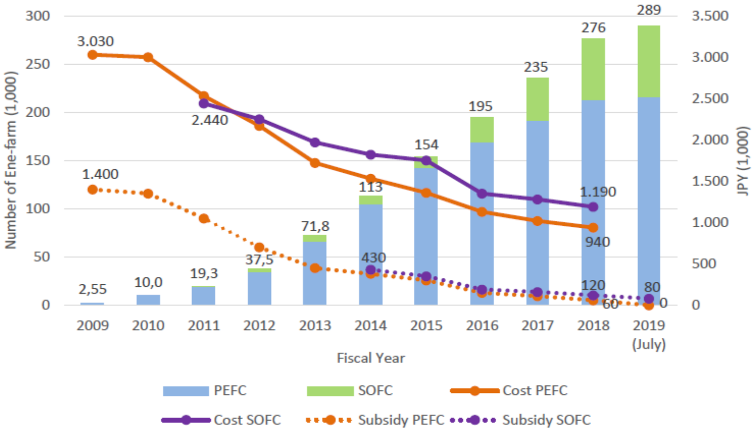
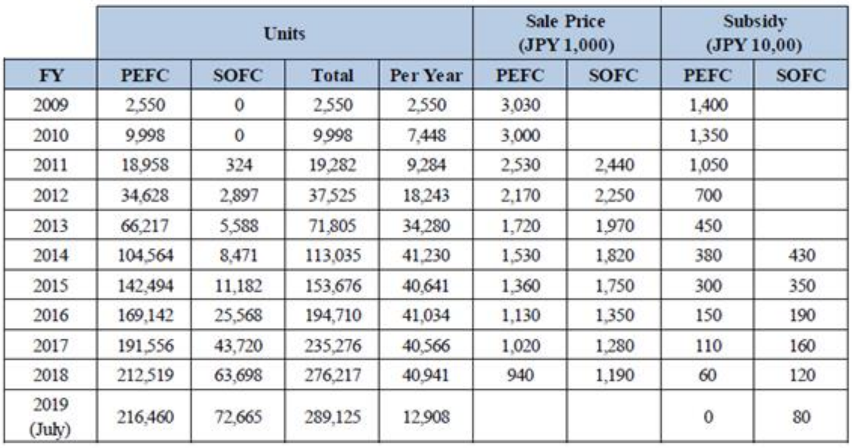


Figure 2 Fuel Cell Installations and Cost Evolution in Japan (METI elaboration)

Government subsidies allowed PEM systems to reach the target price of ¥800,000 (Ca.US$7,040) per unit. In 2018, subsidies for PEMFC ended under the reason why enough outcome was obtained, although SOFC systems still qualify for a modest subsidy, as they have yet to reach the target price of ¥1,000,000 (Ca.US$8,800).



	Units				Sale Price (JPY 1,000)		Subsidy (JPY 10,00)	
FY	PEFC	SOFC	Total	Per Year	PEFC	SOFC	PEFC	SOFC
2009	2,550	0	2,550	2,550	3,030		1,400	
2010	9,998	0	9,998	7,448	3,000		1,350	
2011	18,958	324	19,282	9,284	2,530	2,440	1,050	
2012	34,628	2,897	37,525	18,243	2,170	2,250	700	
2013	66,217	5,588	71,805	34,280	1,720	1,970	450	
2014	104,564	8,471	113,035	41,230	1,530	1,820	380	430
2015	142,494	11,182	153,676	40,641	1,360	1,750	300	350
2016	169,142	25,568	194,710	41,034	1,130	1,350	150	190
2017	191,556	43,720	235,276	40,566	1,020	1,280	110	160
2018	212,519	63,698	276,217	40,941	940	1,190	60	120
2019 (July)	216,460	72,665	289,125	12,908			0	80

Table 4: Units, Costs, and Subsidies of Ene-farms in Japan (METI elaboration)

While this leaves installations some way short of the aspirational 2020 target of 1.4 million units announced at the start of the programme, the market is now close to self-sustaining, and a 2030 target of 5.3 million remains.

The industry continues to invest, and different fuel cell solution providers are now available on the market:

- **Aisin Seiki**, working with **Osaka Gas** and **Kyocera**, released a new model Type S (SOFC) system, with increased electrical efficiency of 55%, up from 53%, and overall efficiency of 87%. Service life is up from 10 to 12 years. While PEM is considered mature and has received no subsidy since 2019, SOFC support remains.
- **Panasonic**'s new PEM micro-CHP system for apartments came out in June 2020 and can handle 200-700 W electrical output and operate in blackout mode, with an electrical efficiency now up to 40% and overall efficiency claimed at 97%. Like Aisin's unit, it is lighter and smaller than the previous model. Panasonic is also working on the deployment of hydrogen-fuelled PEM systems (5 kW) with 57% electrical efficiency. The deployment was planned starting from the Tokyo 2020 Olympic Games, despite the postponement of the event to 2021.
- **Toshiba** Energy Systems and Solutions has been a pioneer in the commercial deployment of hydrogen-fuelled PEM systems for stationary power and heat. Its H2Rex system has been deployed at 120 sites across Japan, at power ranging from 700 W through 3.5 kW to 100 kW. Hotels, stores, and markets are customers. The system claims 50-55% electrical efficiency, and 95%+ total efficiency in CHP mode. Renewable hydrogen is entering the mix, with 2020 seeing an H2Rex system deployed at Michinoeki-Namie in Fukushima, using hydrogen from the Fukushima Hydrogen Energy Research Field, an electrolyser plant powered by 10 MW Solar PV plant. Toshiba is relocating its H_2 energy production facility from Yokohama City to the

Ukishima area, upscaling production ten-fold to meet demand. Toshiba even announced a 1 MW PEM system, comprising ten of its standard 100 kW modules.

- **Miura** and **Ceres** have announced a joint specialist maintenance team for these systems in Japan’s metropolitan areas, which tends to suggest a higher number of fielded ~5 kW units than published.
- Other producers such as **Denso**, **Hitachi Zosen**, **Brother Industries** and **Fuji Electric** exist but the status of SOFC deployment from such providers remains unclear.

Interestingly, in mid-2020 METI announced projects with four utilities to build virtual power plans using customer-side assets. Osaka Gas intends to use 1,500 Ene-Farm units, with the Internet of Things capability, as a source of additional power when required by the grid. The value proposition of micro-CHP systems should be enhanced if such virtual power plants become mainstream.

Bigger commercial scale fuel cell systems of ~5 kW to 100 kW have lagged the smaller units. More expensive to develop, they came later to the market and have not been supported by policy in the same way. Published Japanese data suggest fewer than ten SOFC systems operating in early 2020, including Miura’s FC-5B 4.2 kW SOFC system using Ceres SOFC technology. Fuji still manufactures PAFC based FP-100i systems of 100 kW, but sales have been slow.

In contrast to the SOFC and PAFC systems, interest in hydrogen-fuelled commercial-scale PEM increasing. Using pure hydrogen as a fuel eliminates the expensive natural gas reforming system and substantially raises the electrical efficiency, to more than 50%. For now, the challenge is a reliable and sufficient supply of hydrogen, which at present mostly comes from ‘brown’ sources – natural gas using steam methane reforming. But with a global drive for green hydrogen, change is expected.

South Korea

South Korea remains the leader in the deployment of stationary fuel cell systems at the industrial/grid scale. The world’s largest fuel cell park, 59 MW of Fuel Cell Energy/POSCO MCFC systems, is in Gyeonggi, and 2020 saw it joined by the world’s largest 50 MW facility fuelled purely by hydrogen, in Daesan. South Korea is the only country to clearly set quantitative targets in the national industrial hydrogen strategy, published by the Ministry of Industry Trade and Energy (MOTIE)[9]. The government sees hydrogen and fuel cells as an enabler of emissions reductions, energy diversification, and both domestic and export-led economic growth.

A target capacity of 50 MW of stationary FC for m-CHP applications is foreseen for 2022 and to be upscaled substantially to 2.1 GW by 2040 to provide power and heat for buildings. Up to now, deployment has been driven by a Renewable Portfolio Standard which includes fuel cells, and which ratchets up annually. It looks like 2022 will also see a Hydrogen Portfolio Standard, separating hydrogen and fuel cells from typical renewables like solar and wind, which should further boost demand.

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[9] Ministry of Industry Trade and Energy (MOTIE). Accelerating the Establishment of Public-Private Hydrogen Vehicle Industrial Ecosystem. 2018.

Sector	MW	Places
Power gen.	307.6	41
Homes/Buildings	7.05	3,167

(as of December 2018)

(a)

(b)

Figure 3: (a) Fuel Cell Installations in South Korea; (b) largest fuel cell plant[10]: 59 MW Gyeonggi Green Energy fuel cell park

The main companies deploying stationary fuel cell systems are local (Doosan, POSCO, and SK Engineering and Construction), although the technology has primarily been acquired from non-Korean technology suppliers (Fuel Cell Energy, Bloom Energy, etc.).

- **Doosan** acquired the former UTC PAFC technology, and SK E&C has partnered with Bloom Energy for SOFC systems. Doosan Fuel Cell has been installing its PureCell PAFC units as fast as it can manufacture them. At the end of 2019, 318 units (140 MW) were under construction, supplied by factories in Iksan, South Korea, and South Windsor, Connecticut, USA. The 2020 target across South Korea is 142 MW. The Incheon Fuel Cell development, supported by Korea Hydro and Nuclear Power, ordered 39.6 MW. Doosan has its sights set high – the 2023 global sales target has been raised to 300 MW – up from 184 MW in 2019. The Iksan plant capacity will increase to 260 MW per annum. And ambitions go beyond its current PAFC technology: it wants to be "Hydrogen Energy Global No. 1 Player", adding both PEM and SOFC technology to its portfolio. The SOFC roadmap, built around a technology agreement with the UK's Ceres, includes a 50 MW manufacturing plant, breaking ground in 2021.
- **Bloom Energy**, for a long-time firmly US-focused, and its South Korean partner **SK E&C**, are working on a factory in Gumi to manufacture 50 MW of Bloom's SOFC systems under their JV. 2020 saw two Bloom-powered facilities start operation in Gyeonggi: 19.8 MW at Hwasung and 8.1 MW at Paju. Korea Midland Power has ordered 6 MW and another 900 kW will go to KT Corporation, the telecoms business. South Korea now features strongly in Bloom's long-term technology strategy with hydrogen-fuelled SOFC systems to be deployed in 2021 in partnership with SK E&C, as well as electrolysers. One home for the hydrogen-powered units will be the Changwon RE100 Project, which will install 1.8 MW. Solid Oxide electrolyser systems will be added from 2022.
- **POSCO Energy** and **Fuel CellEnergy** remained locked in stasis, with FCE terminating its marketing agreement with POSCO in summer 2020.

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[10] Xing Zhang, Current status of stationary fuel cells for coal power generation, Clean Energy, Volume 2, Issue 2, October 2018, Pages 126–139, https://doi.org/10.1093/ce/zky012

- **Hyundai**, like Toyota, is planning the launch of the PEM-based FCEV NEXO to the market, and in September 2020 it shipped systems to Switzerland's GRZ Technologies as part of power supply systems for buildings.
- Smaller local companies such as **S-Fuel Cell** has started exporting fuel cell units to China for buildings applications and **Bumhan** was reported to be sourcing PowerCell PEM systems for applications in South Korea.

North America

North America is a major hub for stationary fuel cell technologies, both in terms of deployment and technology provider presence. In the U.S. the current deployment counts 814 installations with an installed capacity of 524.4 MW, mainly located in California. The majority of the stationary fuel cell technology are SOFC, followed by MCFC and PAFC.

Active installations		
Units (#)	***State***	***Installed Capacity (MW)***
546	California	318.6 MW
96	Connecticut	83.5 MW
87	New York	48.4 MW
85	Other states	73.9 MW
Active installations by fuel cell type		
Units (#)	***Technology***	***Installed Capacity (MW)***
706	SOFC	403.1 MW
65	PAFC	38.4 MW
43	MCFC	82.9 MW

TABLE 5: NUMBERS OF INSTALLATIONS AND FUEL CELL TYPES IN U.S.[13]

Deployment has been – and continues to be – driven by a mix of Federal and State regulations, capital subsidies, tariffs, and tax breaks. End-user interest in green, self-energy generation is growing though; attractive to the USA's larger corporations with declared environmental policies and targets. In States with weaker or congested grids, on-site self-generation is also an interesting solution. The deployment of stationary systems in North America in 2020 was down, perhaps linked to political uncertainty or due to the impact of coronavirus on general US economic activity and investment decisions.

Different stationary fuel cell technology providers are located between the U.S. and Canada:

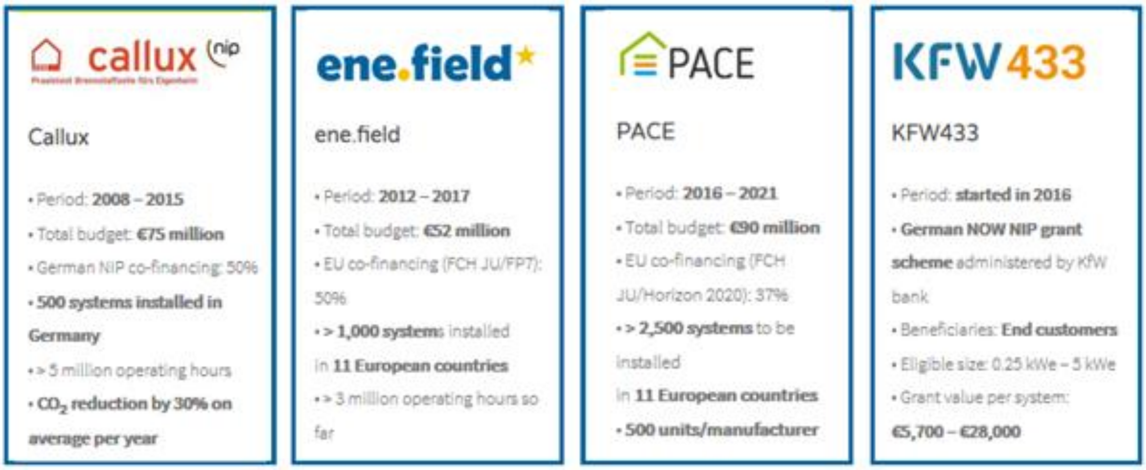
- **Bloom Energy** had already reported 92 MW of new acceptances by Q3 2020. New US orders or intentions included retail chain Stop & Shop, planning to convert 40 of its stores to Bloom's AlwaysON microgrid system. Fuel cell systems were also delivered as COVID response units to Vallejo and Sacramento medical facilities in California, to two Southern California Gas facilities in Los Angeles and to the Gillette Stadium in Massachusetts.
- **FuelCell Energy** still seems to be rebuilding after its crisis in 2019, focusing on Power Purchasing Agreements. The order backlog remains substantial, with around 10 MW in the pipeline for different end users. FCE's Torrington facility, shut in March due to the Coronavirus crisis, resumed production in June. The new orders announced were for SureSource 3000 (4x2.8 MW) units for four sites across Connecticut, under the

Shared Clean Energy Facility sponsored by the State and will be operated under 20-year PPAs.

- **Doosan Fuel Cell America** (originally developing systems by UTC in Connecticut) now operates in the shadow of its South Korean sister plant Iksan but is producing at or close to capacity. New units included those for the New Britain development in Connecticut, and a proposed tri-generation unit for Toyota Long Beach, CA remains on plan.
- **Plug Power** has had some interest in smaller size systems for telecoms applications, and now has its new GenSure High Power Platform for stationary power applications of between 500 kW and 1.5 MW for high power end-users, such as data centres. These will use 125 kW ProGen Systems packaged in standard ISO containers.
- **Ballard Power Systems** (Canadian based) has largely scaled back its stationary activity to its smaller FCgen-H2PM systems for back-up and remote applications, including telecoms, though it does have a 1 MW PEM stationary system using by-product hydrogen at a refinery in Martinique in the West Indies. Ballard has a Product Development Agreement with Hydrogène de France to develop and manufacture PEM systems as part of HDF Energy's Renewable power generation system which integrates the fuel cell with electrolysers, hydrogen storage, and renewable power.
- **Cummins**, owners of Hydrogenics for a year now, Hydrogenics offers its Hy-PM XR units from kW to MW scale with focus in recent years has been almost exclusively mobility. Cummins may be focusing its stationary ambitions on the SOFC technology, acquired from GE.

Europe

The European market is more fragmented, grids are typically stronger and more reliable, and subsidy regimes and regulations less favourable. But European businesses continue to develop and invest in a range of stationary power technologies. Deployment to date has hinged on European Union initiatives led by the Fuel Cell and Hydrogen Joint Undertaking 2 (FCH 2 JU), or country level-support, the most important of which is Germany's Federal KfW 433 grant, as illustrated in the following figure.



Callux

- Period: **2008 – 2015**
- Total budget: **€75 million**
- German NIP co-financing: 50%
- **500 systems installed in Germany**
- > 5 million operating hours
- **CO_2 reduction by 30% on average per year**

ene.field

- Period: **2012 – 2017**
- Total budget: **€52 million**
- EU co-financing (FCH JU/FP7): 50%
- **> 1,000 systems** installed in **11 European countries**
- > 3 million operating hours so far

PACE

- Period: **2016 – 2021**
- Total budget: **€90 million**
- EU co-financing (FCH JU/Horizon 2020): 37%
- **> 2,500 systems** to be installed in **11 European countries**
- **500 units/manufacturer**

KFW433

- Period: **started in 2016**
- **German NOW NIP grant scheme** administered by KfW bank
- Beneficiaries: **End customers**
- Eligible size: 0.25 kWe – 5 kWe
- Grant value per system: **€5,700 – €28,000**

Figure 4: Fuel Cell micro-CHP programmes in Europe

The FCH 2 JU's PACE programme is a five year, €90M initiative supporting 2,800 m-CHP fuel cell systems across ten countries and involving five of Europe's leading domestic micro-CHP developers: BDR Thermea, Bosch, SolidPower, Sunfire, and Viessmann.

Manufacturer	Technology	System Lifetime (years)/ Stack Lifetime (h)	Electrical output (kW)	Electrical Efficiency (%)	Total Efficiency (%)
BDR Thermea	PEMFC	Up to 20/ 80,000	0.75	37	92
Bosch	SOFC	Min. 10 / 90,000	0.7	45	85
SOLIDpower	SOFC	Min. 10 / 40,000	1.5	Up to 57	Up to 93
SOLIDpower	HT-SOFC	15 / 60,000	1.5	60	85
Sunfire	SOFC	Min. 10/ NA	0.75	38	88
Viessmann	PEMFC	> 10 / 80,000	0.75	Up to 40	92
Viessmann	SOFC	> 10 / 35,000	1	40	90

TABLE 6: PEMFC AND SOFC, MICRO-CHP PERFORMANCE OF IMPORTANT MANUFACTURES IN EUROPE

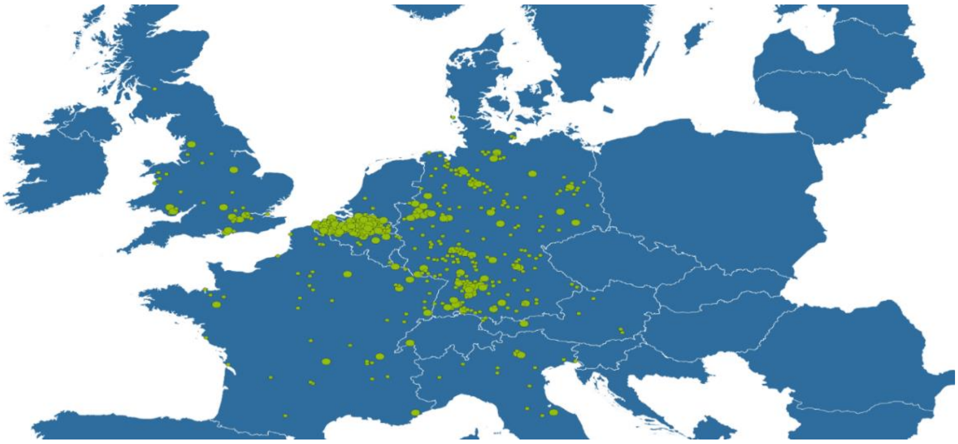


FIGURE 5: FUEL CELL MICRO-CHP INSTALLATIONS AND LOCATIONS IN EUROPE

In Germany, KfW 433 will support systems of between 250 W and 5 kW electrical with up to €28,800. Not surprisingly, most fuel cell deployments in Europe have been in Germany, though Belgium has seen substantive deployment in Flanders, where both PACE and some smaller regional Government support are available. Other countries receiving PACE units include Italy, Netherlands, and the UK. But PACE is due to end in 2022 and some suppliers have nearly met their commitments. No plan for a successor has yet emerged, though KfW 433 will be continued, possibly even with slightly higher support, and Italy has a programme which, under certain circumstances, promises to offer 110% of the capital cost of a system and a 65% tax deduction up to 100,000 € with the installation of the stationary fuel cell system.

Several European developers offer both PEM and SOFC m-CHP units, most of which having introduced new products for 2020:

- **BDR Thermea Group** Dutch subsidiary Remeha's eLecta 300 proposes a PEM stack for domestic systems with supplementary heat generator. Remeha subsidiary also began trials of a pure hydrogen boiler system in Rozenburg in June, with plans for a larger trial in the UK.
- **Sunfire** The SOFC stack, the PowerCore, is also used in the Sunfire-Remote system available at 400 W to 1.2 kW, and optionally to 3. 6kW operating on propane/natural gas or other intermediate chemical vectors. These systems are targeted for remote locations such as sensors on oil and gas pipelines, and railway infrastructure, including

that of Deutsche Bahn.

- **Viessmann**'s offering (together with Vitovalor) is based on Panasonic's PEM module and incorporating a boiler and hot water tank to boost the thermal capability. Bucking what is a trend towards SOFC, June 2020 saw Viessmann sell its Hexis SOFC business to mPower GmbH, a subsidiary of India's h2e Power Systems business. Viessmann retains a right to use Hexis SOFC technology, however, in its stated its role as a system integrator, a useful route to market for mPower, which also has access to IKTS SOFC technology developed in Dresden.
- **SOLIDpower** has been focused on improving and developing the BlueGEN technology merging the acquired Australia's CFCL with its in-house technology. The BlueGEN units are produced in Heinsberg, Germany, whilst larger scale SOFC stacks (up to 25 kW) come from the 25 MW capacity factory in Mezzolombardo in Italy, which opened in August 2020. The BlueGEN technology is also used in Bosch's Buderus brand SOFC micro-CHP system, replacing the Japanese Aisin Seiki unit formerly used. SOLIDpower is reported to be working on two further commercial-scale systems: a 6 kW BlueGEN (BG-60) system with 60% efficiency for 2022, and a 180 kW system, incorporating 30 x 6 kW stacks. The market focus for this will include data centres and other power-intensive applications in grid congested locations. SOLIDpower has also been working on a 25 kW Solid Oxide electrolyser.
- **Bosch** increased its equity stake in **Ceres** from 4% to 18% in 2020, for £38m (US$49m). The technology is destined for commercial-scale applications, and Bosch has started manufacturing Ceres cells and stacks at a pilot facility in Germany. 10 kW SOFC systems for five sites in Germany. Its business model is different from most other developers, as it is based on licensing agreements with systems integrators.
- **Elcogen**, in Estonia, manufactures SOFC cells and stacks in Tallinn for system integrators. In 2020 Elcogen finalized an agreement with Magnex, a Japanese SOFC stack and system developer, and with South Korean companies E&KOA, an SOFC stack manufacturer, and P&P Energytech, a system integrator. Elcogen plans to expand its European cell manufacturing capacity to 2 MW by 2021/22. The agreement with Convion is for 50 kW C50 fuel cell systems, the first of which was to be installed at the LEMENE project in Finland as part of a microgrid.
- **Convion**, a Finnish system integrator spin-off of Wartsila, mainly focuses towards the integration of commercial systems (5 kW to 100 kW market segment), sourced from Elcogen as OEM. The COMSOS project focused on developing and demonstrating products for this market, and brings together Convion, Sunfire and SOLIDpower to deploy several commercial scale SOFC systems.
- **Proton Motor**, which operates across both stationary and mobile applications, was reported to have an order for a 36 kW PEM system for a residential property developer in Bochum, Germany. Proton Motor offers stacks and systems in two sizes, up to 8 kW and up to 25 kW.
- Significant overseas partners include **Miura** and **Honda** in Japan, **Weichai** of China and South Korea's **Doosan**. The agreement with Doosan for Ceres' SteelCell technology, for commercial scale units of 5 kW to 20 kW, was extended in October 2020 for £43m plus licence fees. And in the UK Ceres opened its new Redhill pilot cell and stack plant, already earmarked for a capacity upgrade from 2 MW to 3 MW per annum.

2. STATE OF THE ART – NATIONAL REGULATORY FRAMEWORK

2.1. JAPAN

Market Overview

The market for stationary fuel cell systems in Japan is well established thanks to extensive subsidizing programmes which have enabled the market penetration of m-CHP fuel cell systems. PEFC and SOFC systems within the Ene-Farm programme went on sale in 2009 and in 2011 respectively, after the large-scale field test started in 2005. The units deployed in the Ene-Farm programme basically consist of fuel cell power unit and supplementary heat generator which includes a back-up boiler and a hot water tank. Rated electric power of the Ene-Farms are between 0.4-0.7 kW. The system is intended to produce electricity and thermal energy. The system is used to produce hot water supply only or both hot water supply and space heating by changing the capacity of the supplementary boiler. It is estimated that more than 393,000 units are installed at the end of 2020, mostly installed outdoor. In the case of installation in apartment buildings, the system is generally installed at the pipe space which is located near the entrance door of each dwelling.

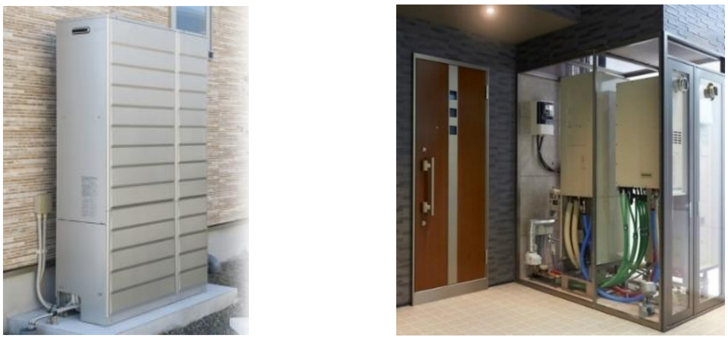


FIGURE 6: EXAMPLE OF OUTDOOR/INDOOR INSTALLATIONS

The Japanese Ministry of Economy, Trade and Industry (METI) has provided subsidies from 2009 to 2020. PEFC and SOFC systems were subsidized from 2009 to 2018 and from 2014 to 2020, respectively – gradually phasing out the subsidy with the evolution of cost curves with respect to target prices. In 2018, subsidy for PEFC ended and the one for SOFC ended in 2020. Subsidy to SOFC started two years after the one for PEFC but with a similar amount. Figure 7 shows the accumulative number of the units deployed and the subsidy provided for each year.

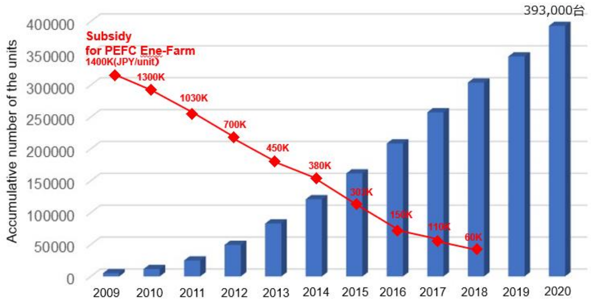


FIGURE 7 ACCUMULATIVE NUMBER OF THE UNITS INSTALLED AND SUBSIDY [11]

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[11] Advanced Cogeneration and Energy Utilization Center JAPAN

Main Stakeholders

Currently there are three manufacturers of the Ene-Farm, which are Panasonic, AISIN and Kyocera. The main stakeholders are shown in Table 7. Manufactures of Ene-Farm and the performance of their products are shown in Table 8.

Table 7 Main stakeholders in Japan

Stakeholder	Content of implementation
METI	• Subsidy related to cogeneration introduction program/introduction support business for residential fuel cell systems • User subsidy (from 2009 to 2018 for PEFC Ene-Farm and from 2014 to 2020 for SOFC Ene-Farm)
Manufacturers	• Three main stationary FC systems manufacturers (Panasonic, AISIN, Kyocera) deployed within Ene-Farm project
Gas companies	• Sellers and installers of Ene-Farm systems • Grid connection (electrical and gas network) and system start-up

Table 8 Manufacturers and performance of Ene-Farm systems [12]

Manufacturer	Product name	Type	Electrical output (kW)	Electric efficiency (%)	Total efficiency (%)
Panasonic	Ene-Farm	PEFC	0.7	40	97
AISIN	Ene-Farm	SOFC	0.7	55	87
Kyocera	Ene-Farm	SOFC	0.4	47	80

Gas companies sell and install the Ene-Farm systems. Major gas companies in Japan are Tokyo Gas, Osaka Gas, Toho Gas and Saibu Gas. Other gas companies like as Hokkaido Gas, Shizuoka Gas, Hiroshima Gas etc. also treat the Ene-Farm systems. Gas companies have a responsibility to connect Ene-Farm to natural gas line and to the distribution board of the house. After the installation, they carry out the start-up of the system.

Legal and regulatory framework

Large system was covered by Electric business Art and JIS had been prepared for the large system based on Electric business Art. However, adoption of Electric business Art is not preferable for the small stationary fuel cell systems, because for example, constant monitoring by experienced personnel and purging with inert gas etc. are required.

A new JIS specializing to small stationary fuel cell system less than 10kW was developed referring Electric business Art and relevant regulation and using the results of large-scale field test:

- JIS C 8822 (2008) “General safety code for Small Polymer Electrolyte Fuel Cell Systems“
- JIS C 8823 (2008) “Small Polymer Electrolyte Fuel Cell Systems – Safety and Performance testing methods“
- JIS C 8824 (2008) “Testing Methods for Environment Small Polymer Electrolyte Fuel Cell Systems”
- JIS C 8841-2 (2011) “Small solid oxide fuel cell power systems - Part 2: General safety

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[12] https://panasonic.biz/appliance/FC/lineup/house01.html ; https://www.aisin.com/jp/product/energy/cogene/enefarm/products/; https://www.kyocera.co.jp/news/2019/1005_ssfv.html

codes and safety testing methods“
- -JIS C 8841-3 (2011) “Small solid oxide fuel cell power systems - Part 3: Performance testing methods and environment testing methods“

JIS C 8822, JIS C 8823 and JIS C 8824 were developed for PEFC Ene-farm based on the experience of large-scale field test which was carried from 2006 to 2008. These JISs were published in 2008. JIS C 8841-2 and JIS C 8841-3 were developed for SOFC Ene-farm based on the experience of large-scale field test which was carried from 2007 to 2010. These JISs were published in 2011.

At present these JISs have been merged with modification to the following JISs which are based on IEC 62282-3 series:
- JIS C 62282-3-100(2019) “Stationary fuel cell power systems-safety”
- JIS C 62282-3-200(2019) “Stationary fuel cell power systems-performance”
- JIS C 62282-3-201(2019) “Stationary fuel cell systems-Performance test methods for small fuel cell power systems”
- JIS C 62282-3-300 (2019) “Stationary fuel cell power systems-installation”

Related JIS for the Ene-Farm are followings:
- JIS S 2092 (2010) “General constructions of gas burning appliances for domestic use“
- JIS S 2093 (2019) “Test methods of gas burning appliances for domestic use“

Japanese related law and regulations are follows.
- Japan Law “Electricity business Act”
- “Fire service Act”
- And related Ministerial ordinances etc.

It is mandatory for electric equipment following both the ministerial ordinance that establishes technical standards concerning electrical equipment and the Electricity business Act. As for the supplementary heat generator, hot water supply type shall comply with JIS S 2075 and space heating type shall comply with JIS S 2112.

The Japan Electrical Manufacturers’ Association developed certification criteria for small stationary fuel cell power system based on Japanese Industrial Standards and Japanese relating regulations. This certification criteria is used for the certification of Ene-Farm at present. The main stakeholders for this certification criteria are FC system Manufacturers, Gas companies, METI program and certification body. Certification for the Ene-Farm is carried by JET (Japan Electrical Safety & Environment Technology Laboratories), JIA (Japan Gas Appliances Inspection Association) and JHIA (Japan Heating Appliances Inspection Association) in Japan, Certification for a grid connection protection device is carried out by JET or JIA.

<u>Procedure to follow in terms of stationary fuel cell system grid connection</u>

In order to apply the Ene-Farm to new houses, gas companies also promote sales to housing manufacturers and home builders. There is a gas company started the power supply business. They currently buy electricity generated by Ene-Farm. Before the introduction of Ene-Farm to the market, stationary fuel cell power system was large sized more than 100kW of power output.

By these achievements, Ene-Farm can be installed at present without various restriction like as constant monitoring by experienced personnel and purging with inert gas and so on which are not suitable for a small stationary fuel cell systems.

In Japan, there is no legal & administrative procedures considered a barrier for the technology deployment. The average lead time & cost for the installation of Ene-Farm are reasonable and acceptable.

Economic framework

There are no economic benefits in Japan like as feed-in tariff, feed-in premium, quota obligation and certification scheme, CAPEX support, tax incentives, incentives to self-production at present. The business case of Ene-Farm has been proven sustainable, where the consumers can save money, which is spent for gas charges and electricity charges, as compared with conventional system.

Although subsidy from the government finished, there are some economic benefits available:

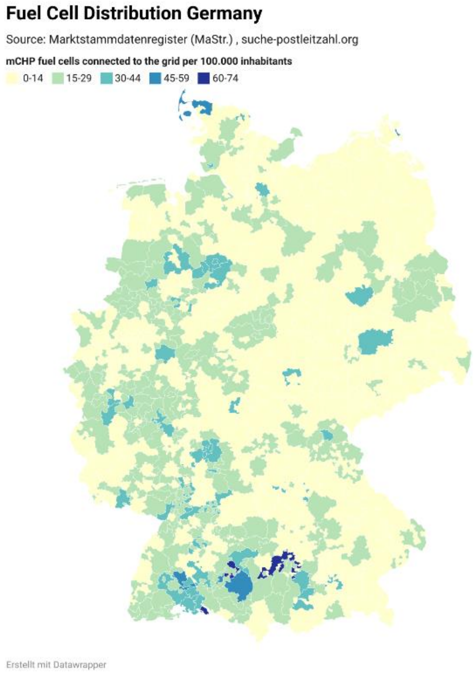
- Local government subsidies for the installation of Ene-Farm.
- Gas companies have their special program for Ene-Farm users.

There is no certification scheme for carbon emission in place. (natural gas vs. bio-syngas, grey/blue/green H2, etc)

2.2. GERMANY

Market Overview

In Germany the stationary fuel cell market is quite well established, thanks to some supporting programmes throughout the years. It is estimated that more than 16,000 units are installed, as alone 15,559 applications for the KfW 433 funding program were deployed in the years 2016 – 2020 [13]. In total there were 10581 fuel cells registered, in operation and connected to the grid on the 6th of September 2021[14]. The installations of stationary fuel cells are spread across the country. In Germany, indoor installations are common, mostly located in the basement. There are already a few installations of the company "Home power solutions", which operate energy self-sufficient. Photovoltaic power, a battery, an electrolyser and a fuel cell work together to produce, store and convert energy. With a long-term storage for hydrogen, which is installed outdoors, energy can also be provided in winter.


Fuel Cell Distribution Germany

Source: Marktstammdatenregister (MaStR.) , suche-postleitzahl.org

FIGURE 8: FUEL CELLS REGISTER, IN OPERATION AND CONNECTED TO THE GRID PER 100.000 INHABITANTS BY 3-DIGIT POSTAL CODE AREAS

The average unit size is between 0.75 kW and 1.5 kW, with a total installed capacity of 12-24 MW. The main application of stationary fuel cell systems in Germany is in well-insulated one and two-family houses with low heating requirements. The devices are connected to the grid and have an additional heating system to cover peak loads. The system is intended to produce electricity and thermal energy, which is used for space heating and to provide hot water.

Main Stakeholders

The main stakeholders of the stationary fuel cell m-CHP sector are network operators, federal funding programs, energy suppliers, federal network agency, which are summarized in Table 9, while the main manufacturers are reported in Table 10.

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[13] Teuffer 2021

[14] Aktuelle Einheitenübersicht MaStR www.marktstammdatenregister.de/MaStR/Einheit/Einheiten ; Kostenlose Postleitzahlenkarte https://www.suche-postleitzahl.org/plz-karte-erstellen

Stakeholders	Function
Kreditanstalt für Wiederaufbau (KfW)	Funding program for the CAPEX support
Federal Office for Economic Affairs and Export Control (BAFA)	Funding program according to the CHP law
NOW GmbH	Funding program for R&D and market uptake
Federal Network Agency	Provision of the MaStR, an official register for the electricity and gas market
German Hydrogen and Fuel-Cell Association (DWV)	Active engagement in politics, business and public awareness
Deutsche Verein des Gas- und Wasserfaches (DVGW)	A standardization body for the gas and water industry
Initiative Brennstoffzelle (IBZ)	Competence centre for fuel cell heating devices

TABLE 9: MAIN STAKEHOLDERS IN GERMANY

Manufacturer	Product name	Type	Electrical output (kW)	Thermal output (kW)	Total efficiency (%)	Investment Cost (€/unit) incl. VAT
SOLIDpower	BlueGEN BG-15	SOFC	1.5	0.85	89	25.000 - 29.750 €*
Viessmann	Vitovalor PT2	PEMFC	0.75	1.1	92	23.600 - 28.500 €*
Senertec	Dachs InnoGen	PEMFC	0.75	1.1	92	28.000 - 31.890 €**
Remeha	eLecta 300	PEMFC	0.75	1.1	95	23.000 €**
Sunfire	Sunfire-Home 750	SOFC	0.75	1.25	89	20.000 €*
BOSCH	Buderus GCB	SOFC	1.5	0.85	88	31.460 *,+
Inhouse Engineering	BHKWinhouse 5000+	PEMFC	4.2	7.5	92	66.800€ +
						* gas boiler not included ** gas boiler included + installation included

TABLE 10:MAIN FUEL CELL MANUFACTURERS IN GERMANY

<u>Legal and regulatory framework</u>

From a legal point of view, stationary fuel cells fall under the law for the maintenance, modernization and expansion of combined heat and power[15].

- The law „EEWärmeG" obliges to meet part of the heating demand for new buildings with renewable energy to receive energy performance certificates. The heating and cooling demand can also be covered by at least 50% from waste heat or CHP plants. Therefore, it can be possible to comply this obligation by installing a stationary fuel cell CHP system.
- The Federal Network Agency provides the Marktstammdatenregister (MaStR) as an official register for the electricity and gas market, based on the law on electricity and gas supply. A registration is mandatory for all power generation

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[15] KWKG 2020; EEWärmeG 2009; MaStR; EnWG 2005; KWKG 2020

systems connected to the public grid, including stationary fuel cells. Figure 1 shows the distribution of fuel cells connected to the grid and registered in Germany’s Marktstammdatenregister.

According to the CHP law, network operators need to connect highly efficient CHP plants to the network with priority. They have to purchase, transmit and distribute the CHP electricity generated in these systems immediately.

Procedure to follow in terms of stationary fuel cell system grid connection

Based on the current funding program, the installation procedure is as follows[16]:

1. At first, an expert of energy efficiency must be consulted and a technical concept must be drafted before applying to the KfW 433 funding program. To apply, the consulted expert must be on the list of energy efficiency experts for federal funding programs.
2. A grid connection and a grid connection usage contract for natural gas and for electricity are required. These have to be carried out with a network operator. In addition, a fuel and electricity supply contract with the gas/electricity supplier is necessary. It is possible that a network access fee must be paid.
3. According to the Energy Industry Act (Sections 12 and 14), the network operators are obliged to guarantee the security and reliability of the electricity supply in their network; controlling the grid compatibility before connecting an electricity supply system to the grid.
4. Further, for the connection of customer systems to the public energy supply network, the technical connection rules (TAR) must be observed (especially VDE-AR-N 4105). They contain forms that are used to compile the data required for a generating plant, from planning the grid connection to commissioning the generating plant.
5. Before commissioning the fuel cell, a measuring concept and the operation of the measuring point must be defined. Most commonly, the operator of the measuring point is the local energy supplier. However, it is also possible to transfer this obligation to a third party or to do it as the operator of the fuel cell. For the measuring concept, the law on metering point operation and data communication in intelligent energy networks has to be considered.

It is mandatory for the electricity grid connection to observe the technical connection rules and the low voltage connection regulation. The regulation also contains the conditions for the grid connection (usage) contracts. For the connection to the natural gas grid, the situation is similar. The low-pressure connection regulation contains the conditions for the grid connection (usage) contracts. The DVGW worksheet G 2000 describes the minimum technical requirements with regard to interoperability and connection to gas supply networks. In addition, it is suggested to use the standard DIN 18012: Service connections for buildings - General planning criteria.

Since most of the fuel cell systems are installed indoor, the exhaust gases represent the most critical component and the exhaust system have to be inspected in accordance with local

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[16] KfW 2021; BDEW 2020; EnWG 2005; VDE-AR-N 4105; VDE 2021; BDEW 2020; VDE-AR-N 4105, VDE-AR-N 4100; DVGW e.V. 2021;

regulations [17] by the chimney sweep:

1) Fireplaces and exhaust systems (combustion systems) must be reliable and fireproof.
2) Fireplaces may only be set up in rooms if the type of fireplace and the location, size, structural condition and use of the rooms do not pose a risk.
3) Exhaust gases from fireplaces must be discharged through exhaust pipes, chimneys and connecting pieces (exhaust systems) in such a way that no dangers or unreasonable nuisances arise. Exhaust systems are to be placed in such a number and location and in such a way that the building's fireplaces can be properly connected. They must be easy to clean. Requirements for exhaust systems are contained in the respective building regulations of the federal states as well as in DIN V 18160-1: 2006-01.
4) The combustion regulations do not apply for fuel cells.

Economic framework

Through extensive funding, the typical barrier of high investment cost is reduced. Apart from that, the KfW 433 program specifies a clear path from purchase to installation and maintenance of the product for 10 years. However, the business case is slightly negative influenced by the CO_2 tax and the resulting higher gas prices in the future.
Stationary fuel cells can access to the following economic benefits[18]:

- Funding program KfW 433: Since 2016, there is an investment support for installations of stationary fuel cell systems. The funding is for systems with an electrical output from 0.25 to 5.0 kW. The subsidy consists of a fixed amount of 6,800 € and an additional bonus of 550 € per 100 W of electrical power. The payout goes up to 34,300 €, with a maximum grant of 40% of the total eligible costs. The subsidy covers the costs for the system itself, as well as the installation costs and a 10-year service contract. Until 2020, the total funding volume was around 210 million €. To receive the funding, the system has to meet the following requirements:
    - The fuel cell has to be integrated into the building's heat and power supply.
    - When installing the fuel cell, a hydraulic balance must be done. Pipelines must be insulated in accordance with the requirements of the Building Energy Act (GEG).
    - A specialist company must carry out the installation of the fuel cell system, ideally instructed by the manufacturer.
    - At the time of commissioning the fuel cell, the overall efficiency must be at least 82% and the electrical efficiency at least 32%.
    - The manufacturer has to ensure the operation of the fuel cell for a period of 10 years.
    - A full maintenance contract for at least ten years must be issued, which guarantees the customer an electrical efficiency of at least 26% as well as repair work.
- The **Combined Heat and Power Act** offers a feed-in tariff for CHP installations. The tariff for CHPs until 50 kWe is 8 c€/kWh for feeding-in electricity and 4 c€/kWh for self-

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[17] BDEW 2020; MBO 2019; DIN V 18160-1: 2006-01
[18] KfW 2021; KWKG 2020; EnergieStG 2006; BDEW 2020

consumption. This support scheme cannot be combined with the KfW 433 funding program.

- The Energy Tax, which is 0.55 cents/kWh for natural gas, can be refunded at the main customs office, according to the Energy Tax Act section 3. This support scheme also cannot be combined with the KfW 433 funding program.
- The operation of a CHP in a single-family house can meet the requirements for entrepreneurial activity. The operation must serve to generate income, which means that the CHP has to feed the electricity into the grid fully or partially and on a regular basis. In this case, the CHP operator has the right to deduct input tax for all costs such as investment, purchase of fuel, maintenance and repairs. However, this also means that the heat and electricity generated by the system are accordingly subject to sales tax. For electricity fed into the network, the operator receives the sales tax back from the network operator, so that the CHP operator is only charged for the energy remaining in his own property.

CO_2 pricing: since January 1, 2021, CO_2 emissions from fossil fuels have a price. Companies, which sell these fuels, have to buy emission rights in form of certificates. The tax started with a price of 25 euros per tonne of CO_2, corresponding to 0.6 cent/kWh of natural gas. The price will gradually increase towards 55 euros per tonne of CO_2 until 2025. Therefore, the energy price will rise accordingly for the end consumer[19].

A certification for generating green hydrogen can be issued by the TÜV SÜD Standard CMS 70, version 01/2020. It is only valid if the hydrogen is produced in one of the following ways[20]:

- Electrolysis of water using electricity from renewable energy
- Steam reforming of bio methane
- Pyro reforming of glycerine, if it is provided as a by-product of the production of biodiesel in accordance with the Biofuel Sustainability Ordinance
- Electrolysis of a saline solution using electricity from renewable energy
- The generated hydrogen has to have a greenhouse gas reduction potential of at least 50 percent compared to fossil fuels or conventional hydrogen and at least 75 percent, if the hydrogen is from electrolysis.

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[19] BMU 2021

[20] Biokraft-NachV; TÜV SÜD 2021

2.3. AUSTRIA

Market Overview

The market development of stationary fuel cell systems is only moderately developed is Austria. 33 systems were installed during the ene.field and PACE programs[21]. Apart from these programs, no data is available. It is estimated that no more than 100 units are installed. FC CHPs systems for residential applications are mainly installed indoors. Often there is a special room for the heating devices.

Similarly to Germany, most of the existing fuel cell systems are connected to the electricity grid and have an additional heating system. The stationary fuel cells produce electricity and thermal energy for space heating and hot water. However, due to the high share of renewable energy in the electricity grid in Austria, the usage of natural gas as fuel for a FC-CHP does not necessarily contribute to a reduction of CO_2 emissions in the building sector. Therefore, the focus of applications is shifted towards integrated concepts consisting of electrolysers, hydrogen storage capacities and stationary fuel cells. Fronius presented a concept in which green hydrogen is generated from surplus solar power and stored centrally. When heat or electricity is required, the stationary fuel cell can use the available hydrogen. Elements Energy and Clean Energy offer similar solutions with decentralized storage for residential applications.

Main Stakeholders

The main stakeholders of the stationary fuel cell m-CHP sector (network operators, energy suppliers and relevant associations) are summarized in Table 11, while the main manufacturers are reported in Table 12.

Stakeholders	Function
AVL	Product engineering company in the field of stationary SOFCs
Vereinigung Österreichischer Kessellieferanten (VÖK)	Association of Austrian boiler suppliers
Fachverband der Gas- und Wärmeversorgungsunternehmungen (FGW)	Representation of the interests of all companies in the gas and heat supply in Austria
Österreichische Vereinigung für das Gas- und Wasserfach (ÖVGW)	A standardization body for the gas and water industry
Wasserstoffinitiative Vorzeigeregion Austria Power & Gas (WIVA P&G)	The Hydrogen Initiative Flagship Region Austria Power & Gas aims to demonstrate a hydrogen based energy system
Österreichischer Verband für Elektrotechnik (OVE)	A standardization body for electrical engineering

TABLE 11:MAIN STAKEHOLDERS IN AUSTRIA

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[21] Ene.field https://enefield.eu/ ; PACE https://pace-energy.eu/

Manufacturer	Product name	Type	Electrical output (kW)	Thermal output (kW)	Total efficiency (%)	Investment Costs (€/unit) incl. VAT
SOLIDpower	BlueGEN BG-15	SOFC	1.5	0.85	88	25.000 - 29.750 €*
Viessmann	Vitovalor PT2	PEMFC	0.75	1.1	92	23.600 - 28.500 €*
BOSCH	Buderus GCB	SOFC	1.5	0.85	88	31.460 €**,+
Elements energy	JOHANN	-	9	-	60 - 90	25.000 Renewable energy sources included + peak load operation
						* gas boiler not included ** gas boiler included + installation included

Table 12: Manufacturers in Austria

Legal and regulatory framework [22]

There is no dedicated regulatory framework for stationary fuel cells in place. Fuel cell CHP units for residential applications must meet the requirements set out in the Agreement on Placing on the Market of Small Combustion Plants and the Inspection of CHP Plants.

The Electricity Industry and Organisation Law includes regulations for the organisation of the network access. Network operators are obliged to grant network access under the approved general conditions and certain system usage fees. The network operator has to measure the feed-in and the purchased electricity with a load profile meter or with a smart meter.

Further, the Technical and organizational rules for operators and users of networks (TOR) have to be considered. In addition, it is suggested to work with the "Technical connection conditions for connection to public supply networks" (TAEV), which serves as a complement to the standard OVE E 8101, electrical low voltage systems. According to the Gas Industry Law, the network operator to whose network the customer requests an access is obliged to grant network access in accordance with the general terms and conditions and the system usage fee set out in the ordinance.

The Austrian Association for the Gas and Water Industry has drawn up a set of rules for customer natural gas systems (GK). The GK - set of rules consists of 14 guidelines, for example G K11: Terms, symbols and tables; G K21: Construction, modification and completion testing of pipes or G K41: Construction and modification of the exhaust gas system and condensate drainage.

The Agreement on Placing on the Market of Small Combustion Plants and the Inspection of CHP Plants was established between all federal states. Among other things, it deals with emission limit values, permissible fuels, inspections and measurements for small combustion plants and CHPs. There is a specific heating and air conditioning law for every federal state, which is based on the agreement.

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[22] LGBl Nr 1/2013; ElWOG 2010; E-Control 2021; OVE 2021; GWG 2011; ÖVGW 2021; LGBl Nr 1/2013; EEffG 2014; ÖNORM H 5056-1 2019

Within the initial inspection of small firing plants, it is checked whether they have the required nameplate and the required CE marking, whether the technical documentation is enclosed and whether technical changes have been made to the combustion system. An inspection where the emission values are measured must be carried out annually for CHP units .

According to the Energy Efficiency Law, energy utilities have to take measures to improve energy efficiency, document them and report them to the monitoring body. CHP systems can be implemented as an energy efficiency measure where the energy savings of the CHP system compared to separate electricity and heat production are calculated. These measures had to be taken for the years 2015 to 2020. A revision of this law is currently being prepared and is expected to be finished in the beginning of 2022.

Considering the legal & administrative procedures, a substantial barrier for the deployment of FC CHPs in residential applications are the energy performance certificates. Energy performance certificates must be submitted to the building authority when constructing a new building or carrying out a major renovation. Additionally, it must also be presented when renting or selling a building. Regional laws in each federal state regulate the contents, calculation rules and requirements of the energy performance certificates. However, common technical guidelines and standards have been developed and are issued by the Austrian Institute of Construction Engineering.

As the heating system has an impact on the energy performance certificate, ÖNORM H 5056 specifies the principles for calculating the input from different heating systems for the energy performance certificate. In its newest revision, this standard also includes calculation principles for FC mCHP applications. However, the methodology for FCs has not yet been integrated into the software tools for the creation of energy performance certificates. Therefore, it is currently not readily possible to issue an energy performance certificate for buildings that use fuel cells systems, creating a substantial barrier.

Political framework

In order to achieve the goal of climate neutrality by 2040, the use of fossil fuels for space heating needs to be phased out by 2040. Amongst other measures, the Austrian government plans a ban on the installation of gas boilers in new buildings starting from 2025 [23] . The extent to which this ban will also affect stationary fuel cells in residential applications is not clear.

To be in line with the policy plans, fuel cells would need to use renewable gases as fuel. However, the role that renewable gases (incl. green hydrogen) will play in decarbonizing space heating has not yet been clarified. However, current discussions prioritize the use of green hydrogen primarily as a substitute for fossil hydrogen, in industry and for heavy transport applications.

This uncertain political framework represents a barrier to the deployment of stationary fuel cells. In particular, the planned ban on gas boilers in new buildings from 2025 is a substantial barrier if it results in new connections to the gas grid no longer being possible. This would also prevent the installation of grid-connected fuel cells in new buildings from then on.

Procedure to follow in terms of stationary fuel cell system grid connection [24]

The current legal & administrative procedure to follow in terms of gas grid connection is the following:

- Electricity grid connection: The network operator determines the technically suitable connection point in the existing public network, taking into account possible network disruptions. The network operator sends the customer a grid connection contract. The customer has to pay for the work within his property boundary and has to pay a network access fee for feeding-in electricity. The customer has to select an energy supplier. An electrician installs the electrical system. Then the network operator installs a measuring device and puts the customer's electrical system into operation. Because the customer is now a “Consumer” and a “Producer”, he is called a “Prosumer”. The Prosumer needs a contract with a supplier who buys the surplus energy from the generating plant.
- Gas grid connection: Every gas network operator is obliged to respond to requests for network access within a maximum of ten working days. The operator shall indicate the further procedure, including in particular a contact person, the expected duration of the installation and a target date. A rejection of network access must be justified. When connecting for the first time, the network operator connects the system to a technically suitable network connection point. The consumer has to provide all structural requirements for the proper construction of the house connection. The consumer has to select a gas supplier and to conclude a supply contract. This procedure is identical to the grid connection for the installation of a gas boiler.

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[23] Bundeskanzleramt Österreich 2020

[24] E-Control 2021

Economic framework

The investment costs for stationary fuel cell CHP systems are considerably higher than for conventional systems. As there is currently no CAPEX support scheme, the high upfront payment is a barrier for the technology deployment.

Considering the savings generated during operation of the CHP due to the reduced demand for grid electricity, the situation in Austria is different from Germany. In Germany, the spark spread (difference between electricity and natural gas prices) is in favour of self-generation of electricity from natural gas, since electricity is quite expansive compared to natural gas. In Austria, the spark spread is lower, meaning that generating electricity from natural gas is less profitable than in Germany. Therefore, the annual savings in energy costs due to the reduced demand for grid electricity are usually not sufficient to compensate for the high investment costs and to become cost-competitive with other heating applications.

Stationary fuel cells can access to the following economic benefits:

- According to the Law on Green Electricity, the feed-in tariff can be added up by 2 cent/kWh if a minimum of 50% biogas, upgraded to natural gas quality, is used in the power generation plant. This is only valid for highly efficient CHP plants, which are defined in the CHP law, section 8 through following formula [25]:

$$\frac{2}{3} * \frac{\mathrm{W}}{\mathrm{B}} + \frac{\mathrm{E}}{\mathrm{B}} \geq 0{,}6$$

W = usable thermal energy in kWh
B = total fuel consumption in kWh
E = electrical energy output in kWh

This threshold is easily reached by commercial fuel cells. The calculation for two popular systems yields:

SOLIDpower BlueGEN BG-15

$$\frac{2}{3} * \frac{0.85}{2.67} + \frac{1.5}{2.67} = 0{,}77$$

Viessmann Vitovalor PT2

$$\frac{2}{3} * \frac{1.1}{2.01} + \frac{0.75}{2.01} = 0{,}74$$

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[25] Ökostromgesetz 2012

2.4. ITALY

Market Overview

In Italy the m-CHP market is quite limited, there are about 30 FC m-CHP units installed. The systems are mainly located in North and Central Italy and are typically indoor installations in as local thermal power station. The FC m-CHP installations in Italy are all grid connected and in parallel to gas boilers or Heat Pumps. All heating systems can also produce sanitary hot water.

Main Stakeholders

The main stakeholders are pre-normative research institutions, standard development organizations, regulatory bodies and manufacturers. In particular, Universities and Research Institutes (PoliMi, PoliTo, Sapienza, UniCAL, UniGE, UniMORE, UniNA, UniPd, UniPE, UniSa,, UniTO and ATENA, CNR itae, ENEA, EnviPark (Torino), FBK, Hydrogen Park Venezia); regulatory bodies are public administrations and organizations that create regulatory frameworks regarding the design, manufacturing, installation or usage of any technology, product or service like Ministry of Economic Development, Local grid distributor (i.e. ENEL), Local Gas Distributor (i.e. SNAM), Grid operator (i.e. Terna), Local Custom Agency, Fire Department; Manifacturers: Arco fuel cell, CTS H2, Elettronica Todescato, Enapter, Engie-EPS, Genport, McPhy, NextEnergy, Pure Energy, SolidPower, SPI Consulting and boiler manifacturers like ICI Caldaie, Baxi and Giacomini. Finally, there are involved also standars development organization as UNI, CEI, RINA.

Legal and regulatory framework

There is not a dedicated regulatory framework addressing stationary fuel cell technology, rather such technologies are considered equivalent to thermal appliances (e.g. boilers or conventional CHP units) or electrical generators according to a case-by-case evaluation. The regulatory framework in Italy is complex and cumbersome. Typically, the support frame and the subsidies to energy installations, and moreover in the case of cogeneration, due to its complexity, lack of clearness and contradictory aspects, results in an administrative burden for the company operators that turns to be a deterrent to consider the installation of a new fuel cell cogeneration plant or refurbishment of an existing plant.

The current legal framework regarding the requirements for installation of heating and electric appliances are based on the following laws:

- Decree no. 412 (amended by Decree no. 551/99) – Regulation of heating systems in buildings (the design, installation, operation and maintenance of heating systems in buildings), with the objective of energy savings).
- Ministerial Decree April 16th, 2008 - Technical rule for the design, construction, testing, operation and monitoring of works and distribution systems and of direct natural gas lines with a density of up to 0.8.
- Legislative Decree no. 20, published on 8th of February, 2007, applies on the promotion of the cogeneration, provides the identification of measures to promote the extensive use of high-efficiency cogeneration to increase energy efficiency and to protect the environment.
- The national regulations regarding the installation of heating appliances in Italy are based

on Ministerial Decree no.37, published on 12th of March, 2008 [26]. This decree applies to heating appliances located within buildings. If the plant is connected to the distribution networks, it applies from the point of delivery of the supply. The national decree also provides the professional and technical requirements concerning activities on the plant, which the technical expert must have. A design is required for the installation, extension or modification of the plant, a design is requested and it must be elaborated in accordance with current standards. One of the most important aspects of the document is the declaration of conformity, which must be provided by the installation company, when the activities have been completed. Furthermore, the national decree contains information regarding: the owner's and client's obligations, as well as about fines incurred for violations and attachments for the declaration of conformity. Ministerial decree no. 37/2008 also deals with aspects related to the connection of plants to different kinds of distribution networks, but only from the point of delivery of the supply, with reference to the connection to natural gas networks.

- Decrees of the President of the Italian Republic, August 1st, 2011, no. 151 - Plants with a total electrical power of less than 25 kW are not subject to fire regulations.
- Ministerial Decree published on 5th of September, 2011, recognizes to a CHP plant as "high efficiency" a series of incentives and procedural facilities:
  - the possibility of issuing energy efficiency certificates (TEE), or White Certificates;
  - the possibility of having access to the dedicated withdrawal system of the electricity injected into the grid;
  - the possibility of access to the exchange system on the spot for the electricity produced;
  - simplifications for the connection of the plant to the electricity grid;
  - simplifications for the construction, connection and operation of micro-cogeneration plants;
  - the priority of dispatching the electricity produced over that of traditional installations;
  - any regional or local incentive measures.
- Ministerial Decree published on 16th of March, 2017, introduces the use of Unique Models for the installation, connection and operation of high-efficiency micro-cogeneration plants and micro-cogeneration powered by renewable sources with the aim of simplifying the bureaucratic process for their implementation.

Procedure to follow in terms of stationary fuel cell system grid connection

In Italy, the installation requirements for a FC μ-CHP are no different from those for any other CHP unit to be installed in a building and connected to the gas grid. The administrative procedures are numerous and need long time to be completed. There are several authorities to contact, lot of documents to prepare and long waiting time. It is a barrier for the technology deployment. The connection to the building electricity system and the installation/exchange of the energy meter is in charge of the local electricity distributor (i.e. ENEL). The electricians must be certified according to Ministerial Decree No.37/2008. There are several functional procedures necessary to deploy a stationary

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[26] available at http://www.energia.provincia.tn.it

fuel cell technology such as permitting license, permission for grid connection, etc.:

- First of all the agreements are required from:
    - Local grid distributor (i.e. Enel; “regolamento di esercizio” – operational agreement);
    - Grid operator (i.e. Terna);
    - Agenzia delle Dogane.
- The documentation is according to
    - “Testo integrato delle connessioni attive - Integrated text of active connections”, for the grid connection with local grid distributor
    - and “sistema Gaudì - system for the data management of the production plants and their units”, for the grid operator.
    - “Testo unico delle accise - Unique text of the excise”, concerning the taxes on production and consumption.
- Declaration to the "Officina Elettrica" of the local Custom Agency (Agenzia delle Dogane) the existence of the system, receiving a system identification code which will be used for the annual production declaration.

The technical requirements and administrative procedures for connection of FC micro-CHP units to the gas grids are set out by the gas network operators. Usually, the connection requirements are more general and address all types of heating appliances or cogenerators working on gas. If the gas connection is already available, there are no specific requirements. If the connection is not available yet, a connection request and an agreement with the gas operator are required. The gas operator is entitled to do the installation of the gas meter. Other connections have to be performed by a plumber certified in accordance with Ministerial Decree No. 37/2008.
The procedure is mandatory and the required time for the permitting procedure is estimated in 2 months, in a standard scenario without unforeseen events.

Economic framework

Stationary fuel cells m-CHP units can access some economic benefits, in particular:

- An eco-bonus for micro-cogenerators has been included as economic benefit (2018); in particular, FC can be eligible for the purchase and the installation of micro-cogenerator in replacing of existing plants with a primary energy saving (PES) ≥ 20%. It is possible to deduct 65% of the total costs, with a maximum deduction of 100.000€ [27]. Are no available feed in tariff and feed in premium.
- The White Certificates mechanism is the main instrument for promoting energy efficiency in Italy. White certificates or TEE Energy Efficiency Certificates are negotiable and certify the achievement of savings in the final uses of energy through interventions and projects to increase energy efficiency. A certificate is equivalent to saving a Tonne of Oil Equivalent (TOE). It acts both as an energy efficiency obligation scheme and as an incentive, due to the presence of a market to trade white certificates. The advantages of White Certificate are related to the plant size (is convenient for big size plant and not convenient for small size plant.

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[27] LAW December 27th 2017, n. 205, multi-year financial statements actually used

> Almost every project involving an improved efficiency in the final consumption of energy is eligible under the scheme – from boilers to lighting systems, from solar thermal to cogeneration from electric motors to industrial process projects – with the exception of projects aimed at increasing efficiency in electricity generation. If the project is approved the proponent receives a number of WhC corresponding to the recognized savings on its account (one White Certificate equals to one toe of additional savings). Average price TEE, January 2021: 260€/tep

Superbonus 110% mechanism: Art. 119 of the Legislative Decree 34 (May 2020) inserted a fundamental rule for the restart of the construction sector: the raising to 110% of tax deductions for the energy requalification of buildings from 1 July 2020 and until 31 December 2021 (now extended to December 2022). The main novelty of the Decree, in addition to the increase in the tax credit, consists in the possibility of opting, as an alternative to the direct use of the deduction, for the transformation of the corresponding amount into a tax credit, with the right to subsequently transfer the credit to other subjects, including credit institutions and other financial intermediaries, effectively eliminating the cost of the interventions. In particular, the purchase and installation of micro-cogenerators is facilitated to replace existing plants that lead to primary energy savings (PES) ≥ 20% with electrical power < 50 kWe and the maximum allowable deduction limit is to 100.000 €. The main technical requirements of the intervention are:

1. The intervention must lead to primary energy savings (PES) ≥ 20%, as defined in the Minister of Economic Development decree (4th August 2011);
2. All the thermal energy produced must be used for the thermal demand by the air conditioning of the rooms and the production of domestic hot water.
3. The construction, connection to the electricity grid and the operation of micro-cogeneration plants requirements are referred to the Minister of Economic Development decree (16th March 2017).

Currently, there isn't a certification scheme in place for stationary fuel cell m-CHP units.

3. ANALYSIS OF IEC INTERNATIONAL STANDARDS

In this section a summary and analysis of the IEC 62282-3 standard series[28] is carried out, providing general and specific critical considerations regarding the three purchased and analysed standards:

- IEC 62282-3-100 "Stationary fuel cell power systems - Safety"
- IEC 62282-3-300 " Stationary fuel cell power systems - Installation"
- IEC 62282-3-400 "Stationary fuel cell power systems - Small stationary fuel cell power system with combined heat and power output"

The IEC standards are intended as technical and non-technical guidelines to be implemented on voluntary basis as a wide and international regulative umbrella which can be applicable to all countries. On top of that, specific National regulations, codes and standards may be applied in compulsory or voluntary basis as well, according to the specific case.

The objective of this analysis is to identify possible barriers of each specific standards for the deployment of stationary fuel cell systems in different countries at all levels of stakeholders (OEMs, system integrators, installation companies, distribution grid owners and operators – both gas and electricity, permitting & authorization granting bodies, operators, etc.).

3.1. IEC 62282-3-100:2019 "STATIONARY FUEL CELL POWER SYSTEMS - SAFETY"

Publication type	International Standard
Publication date	2019-02-12
Edition	2.0
Available language(s)	English(RLV)/French
TC/SC	TC 105 - Fuel cell technologies
ICS	27.070 - Fuel cells
Stability date	2022
Pages	249

TABLE 13: IEC 62282-3-100:2019 "STATIONARY FUEL CELL POWER SYSTEMS - SAFETY"

The standard covers safety requirements for fuel cell power systems in order to mitigate potential risks and hazards towards people and damage to equipment external the fuel cell power system. The typical scheme of the fuel cell power system proposed in the standard is illustrated in Figure 9 below, as an assembly of subsystems, components & input/output interfaces.

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[28] Part of a group of 20+ active standards under the IEC TC/105 *Fuel Cell Technologies* available online: https://webstore.iec.ch/searchform&ComNumber=105

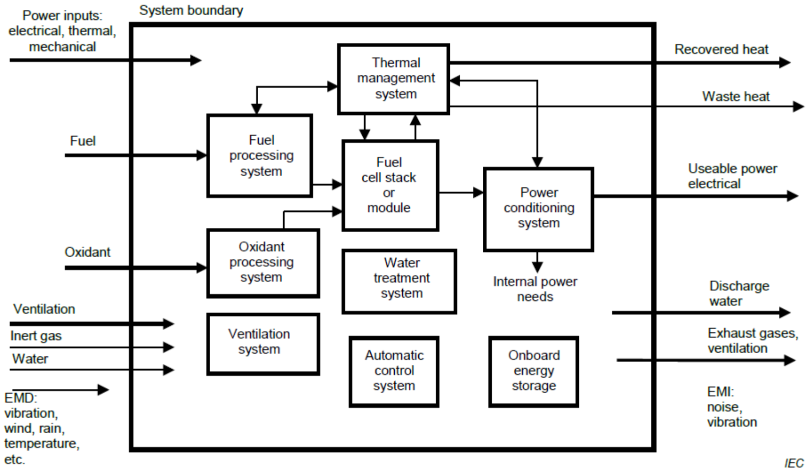


Figure 9: Scheme of the fuel cell power system

The standard is applicable to stationary fuel cell power systems which are:

- grid-connected or stand-alone intended to provide AC or DC power;
- with or without the possibility to recover waste heat;
- operated by methane based natural gas, oil derived fuels, other liquid fuels or hydrogen-based fuels (pure hydrogen, hydrogen containing mixtures, synthesis gas, etc.);
- installed indoor and outdoor;
- in industrial and residential applications.

The standard does not cover:

- micro fuel cell power systems;
- portable fuel cell power systems;
- propulsion fuel cell power systems.

In the first part of the document (up to §4), the standard is structured to address safety aspects of fuel cell power systems which are used under the conditions foreseen by the manufacturer, in which the manufacturer must implicitly guarantee a safe operating condition of the system. Operating conditions beyond the ones indicated by the manufacturer (related to unforseeable misuse or any other intentional bypass of the safe operating conditions) are not covered in the standard.

As general safety requirements and protective measures (§4) the manufacturer is required to perform in written form a comprehensive Risk Assessment (§Annex A – list of hazards) covering all possible hazardous situations and events and foreseeable misuse. The definition of the list of hazards within the risk assessment is defined by classical engineering approach to safety issues (Risk=Probability x Severity) via standard Failure Mode and Effect Analysis “FMEA” methodology. Acceptable risk levels are to be obtained by implementing *i)* inherent safe design and *ii)* active & passive protective devices (possibly with the capability to measure the risk-related physical quantities to activate/deactivate their protection means), other than *iii)* provisions such as labelling, warnings and specific training.

Following the outline of the standard, the fuel cell system is required to be capable of performing its intended function(s) and preserve its lifetime in relation to:

- The physical environment and operating conditions (electrical power input; physical environment; fuel input; water input; vibration, shock and bump; handling, transportation, and storage; system purging; moving parts, accessibility & safe operability)
- The selection of materials & coatings (suitable for physical, chemical and thermal conditions; mechanical stability; corrosion and wear resistance; electrical conductivity; impact strength, aging resistance, the effects of temperature variations, the effects of radiation, degradation effects of hydrogen on the mechanical performance of a material; erosion, abrasion)

Some specific limitations are provided, for example in terms of maximum allowable surface temperature rises (+50°C respect to ambient conditions) and carbon monoxide in the exhaust gases (CO<0.03%vol, excess air free), among others. Further indications are given in terms of pressure equipment, piping, flue gas venting systems, gas-conveying parts, etc.

Common measures to ensure fire/explosion prevention and protection are indicated, such as avoiding flammable atmospheres (<25% Lower Flammability Limit of the fuel gas), performing controlled oxidation and diluting with air of the normal internal releases, eliminating ignition sources, maintaining a positive pressure environment with respect to the adjacent compartments, maintaining a correct air-fuel ratio, implementing purge lines, connecting to a safe dispersal ventilation system of the exhaust gases, installing flame detectors, etc.

The electric system design and construction shall meet the requirements of the relevant electrical product application standard, as well as for electromagnetic compatibility. The single failure of a component should not cascade into a hazardous condition.

Automatic electrical and electronic controls of fuel cell power systems shall be designed and constructed so that they are safe and reliable. Correct operation from non-operating (cold, passive and storage) conditions in terms of start-up, pre-operating phase, operating phase and shutdown (emergency & normal) should be guaranteed. Complex installations (with other equipment) should coordinate the operations with the upstream/downstream equipment if needed.

Protection components include, but are not limited to: pressure limiting devices, temperature monitoring devices, gas detectors, gas sensor control loops, adjustable fuel cell parameters, manual levers/switches, shut of valves, fuel valves, etc.

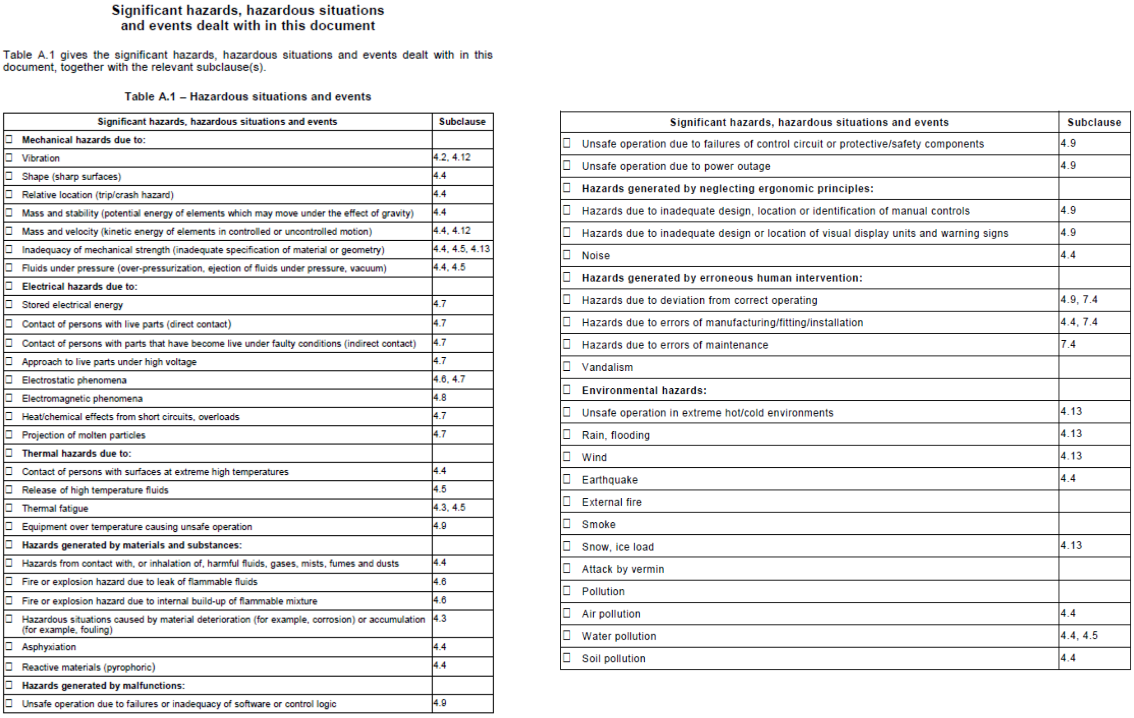
In §4.13-4.14 brief mentions of the requirements of enclosures (IP grade and accessibility) and thermal insulation subsystems (chemical compatibility, protection, fire safety, accessibility) are indicated. Input interfaces & utilities are defined (§4.15) in terms of water supply, fuel gas supply & electrical connections and electrical disconnection is addressed. Installation and maintenance issues are reported (§4.16), where the general rule that the manufacturer shall provide instructions for the proper installation, adjustment, operation, and maintenance of the fuel cell power systems is followed.

In the second part of the document (§5-§7), testing rules and requirements are provided, with regards to test arrangements, methods, pass/fail criteria, etc. to which the fuel cell power system should be checked, including marking labelling and packaging indications.

In Annex A the hazards, hazardous situations and events dealt in the standard are summarized.

Annex B covers the material compatibility with hydrogen environments, especially in terms of carburization, hydrogen corrosion, hydrogen embrittlement, and hydrogen attack.

Annex C defines specific replacement subclauses for small fuel cell power systems with rated electrical output <10 kW, and maximum pressure of <0.1 MPa(g) for fuel and oxidant streams; concerning type tests only and without considering the supplementary heat generator. The main variations respect to the main document body is related to: specialized personnel required for system restarts, change in IP ratings for outdoor use, explicitly specified normal operation test methods (3 hours in stationary conditions), catalytic combustion tests exempted and maximum exhaust gas temperature set at 260°C.



Significant hazards, hazardous situations and events dealt with in this document

Table A.1 gives the significant hazards, hazardous situations and events dealt with in this document, together with the relevant subclause(s).

Table A.1 – Hazardous situations and events

Significant hazards, hazardous situations and events	Subclause
☐ **Mechanical hazards due to:**	
☐ Vibration	4.2, 4.12
☐ Shape (sharp surfaces)	4.4
☐ Relative location (trip/crash hazard)	4.4
☐ Mass and stability (potential energy of elements which may move under the effect of gravity)	4.4
☐ Mass and velocity (kinetic energy of elements in controlled or uncontrolled motion)	4.4, 4.12
☐ Inadequacy of mechanical strength (inadequate specification of material or geometry)	4.4, 4.5, 4.13
☐ Fluids under pressure (over-pressurization, ejection of fluids under pressure, vacuum)	4.4, 4.5
☐ **Electrical hazards due to:**	
☐ Stored electrical energy	4.7
☐ Contact of persons with live parts (direct contact)	4.7
☐ Contact of persons with parts that have become live under faulty conditions (indirect contact)	4.7
☐ Approach to live parts under high voltage	4.7
☐ Electrostatic phenomena	4.6, 4.7
☐ Electromagnetic phenomena	4.8
☐ Heat/chemical effects from short circuits, overloads	4.7
☐ Projection of molten particles	4.7
☐ **Thermal hazards due to:**	
☐ Contact of persons with surfaces at extreme high temperatures	4.4
☐ Release of high temperature fluids	4.5
☐ Thermal fatigue	4.3, 4.5
☐ Equipment over temperature causing unsafe operation	4.9
☐ **Hazards generated by materials and substances:**	
☐ Hazards from contact with, or inhalation of, harmful fluids, gases, mists, fumes and dusts	4.4
☐ Fire or explosion hazard due to leak of flammable fluids	4.6
☐ Fire or explosion hazard due to internal build-up of flammable mixture	4.6
☐ Hazardous situations caused by material deterioration (for example, corrosion) or accumulation (for example, fouling)	4.3
☐ Asphyxiation	4.4
☐ Reactive materials (pyrophoric)	4.4
☐ **Hazards generated by malfunctions:**	
☐ Unsafe operation due to failures or inadequacy of software or control logic	4.9
☐ Unsafe operation due to failures of control circuit or protective/safety components	4.9
☐ Unsafe operation due to power outage	4.9
☐ **Hazards generated by neglecting ergonomic principles:**	
☐ Hazards due to inadequate design, location or identification of manual controls	4.9
☐ Hazards due to inadequate design or location of visual display units and warning signs	4.9
☐ Noise	4.4
☐ **Hazards generated by erroneous human intervention:**	
☐ Hazards due to deviation from correct operating	4.9, 7.4
☐ Hazards due to errors of manufacturing/fitting/installation	4.4, 7.4
☐ Hazards due to errors of maintenance	7.4
☐ Vandalism	
☐ **Environmental hazards:**	
☐ Unsafe operation in extreme hot/cold environments	4.13
☐ Rain, flooding	4.13
☐ Wind	4.13
☐ Earthquake	4.4
☐ External fire	
☐ Smoke	
☐ Snow, ice load	4.13
☐ Attack by vermin	
☐ Pollution	
☐ Air pollution	4.4
☐ Water pollution	4.4, 4.5
☐ Soil pollution	4.4

FIGURE 10: ANNEX A CHECKLIST

3.2. IEC 62282-3-300:2012 " STATIONARY FUEL CELL POWER SYSTEMS - INSTALLATION"

Publication type	International Standard
Publication date	2012-06-14
Edition	1.0
Available language(s)	English/French, Spanish
TC/SC	TC 105 - Fuel cell technologies
ICS	27.070 - Fuel cells
Stability date	2023
Pages	37

TABLE 14: IEC 62282-3-300:2012 " STATIONARY FUEL CELL POWER SYSTEMS - INSTALLATION"

This International Standard covers the installation of stationary fuel cell power systems (<10 kW and >10 kW) for indoor and outdoor applications that are built in compliance with IEC 62282-3-100. The standard is applicable to systems which are:

- intended for electrical connection to mains directly or with a readily accessible, manually
- operable switch or circuit-breaker;
- intended for a stand-alone power distribution system;
- intended to provide AC or DC power;
- with or without the ability to recover useful heat.

This standard specifically is limited to those conditions that may be created by the installation process and initial commissioning that can lead to personnel hazards or damage to equipment or property external to the fuel cell power system.

Additionally, this standard does not cover:

- fuel supply and/or fuel storage systems;
- auxiliary media supply and disposal;
- switches or circuit-breakers;
- portable fuel cell power systems;
- propulsion fuel cell power systems;
- APU (auxiliary power units) applications.

Provided that the fuel cell power system is installed following the manufacturer’s instructions, there is still a need to eliminate hazards to personnel or damage to equipment external to the fuel cell power system as far as rationally possible. In particular, the document addresses: *i)* mechanical hazards; *ii)* electrical hazards; *iii)* thermal hazards; *iv)* fire and explosion hazards; *v)* malfunction hazards; *vi)* material and substance hazards; *vii)* waste disposal hazards and *viii)* environmental hazards.

As far as siting considerations, the fuel cell power system is required to be sited in a suitable space with respect to environmental conditions and allowing correct accessibility. The fuel cell power system should be located outside of outside of potentially hazardous atmospheres (ATEX - Directive 2014/34/EU) and be equipped of a suitable ventilation system which prevents introduction of exhaust gases into the building.

Distances and clearances shall be according to regulations given by the Authority Having Jurisdiction (AHJ), which is a concept which can be found throughout the document since the

AHJ is the body which is responsible for applying prescriptions imposed by compulsory National Regulations, Codes & Standards (differently from the IEC International Standards, which represent guidelines to be adopted on a voluntary basis). Any possible alternatives to the fuel cell power system installation procedure with proven equivalent safety by suitable engineering analysis shall be proposed for permission by the AHJ.

Outdoor, rooftop and indoor installations are analysed (§5.2-§5.4) in terms of air intakes and exhausts, enclosures, purging, ventilation (natural & forced convection) and fire protection and detection (§6-§7). The areas around fuel-bearing outlets are valued according to ATEX standards and by applicable national standards & regulations. As an exemption, small fuel cell systems (<10 kW) are not required to have fire rated separations and can purge and exhaust directly into a utility shed provided that suitable siting and ventilation conditions are guaranteed.

All interconnections including piping, electrical wiring, disconnections and ducting between site interfaces and the fuel cell power system shall be in accordance to relevant national standards. A shut-off valve is required with increasing level of safety according to the siting and gas supply configuration (manual, manual within 1.8m and automatic shut-off valve for outdoor, indoor operated with odorized gas and indoor operated with non-odorized gas respectively). The interface with the auxiliary media (auxiliary combustible gases, inert gases, water, wastewater and condensate) are typically regulated by national standards, except for the auxiliary combustible gases which should be redundantly equipped by a quick action shut off valve controlled by the fuel cell power system main control system and a second manual valve.

Emissions (noise & material emissions) during installation and initial commissioning should be monitored and checked with local regulations. The approval tests should be performed for site installed piping only according to national standards and the operation of the specific shut down devices should be demonstrated. Suitable documentation has to be provided in terms of markings, instructions, inspection checklist & manuals.

The International Standard, other than the installation and first commissioning phase, covers also the maintenance tests to be performed according to the manufacturer’s instructions and carried out by authorized personnel only.

3.3. IEC 62282-3-400:2016 "STATIONARY FUEL CELL POWER SYSTEMS - SMALL STATIONARY FUEL CELL POWER SYSTEM WITH COMBINED HEAT AND POWER OUTPUT"

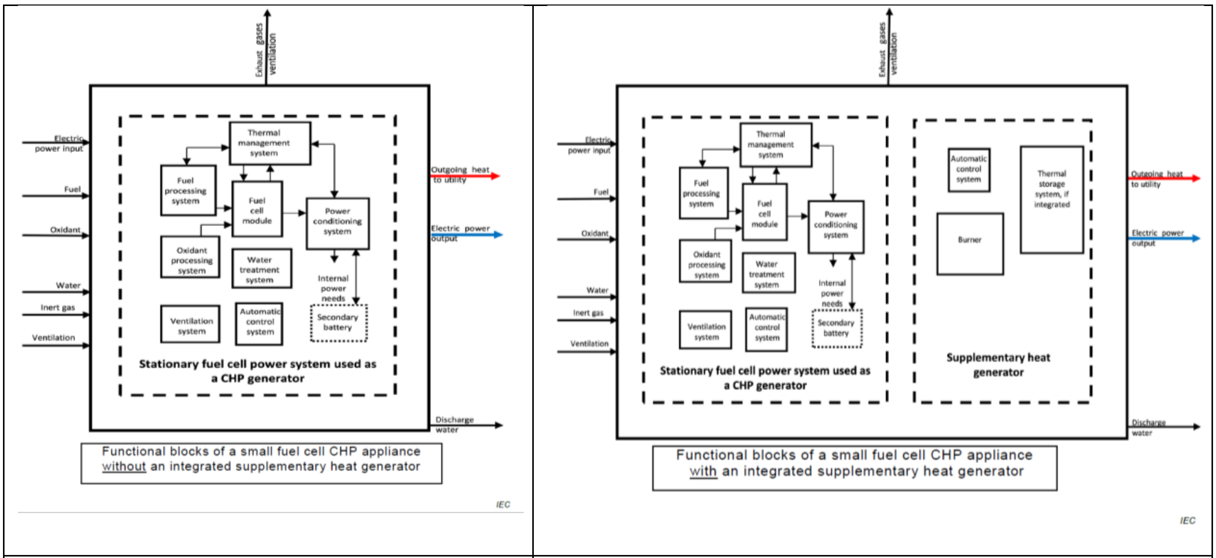
Publication type	International Standard
Publication date	2016-11-16
Edition	1.0
Available language(s)	English/French
TC/SC	TC 105 - Fuel cell technologies
ICS	27.070 - Fuel cells
Stability date	2023
Pages	399

TABLE 15: IEC 62282-3-400:2016 "STATIONARY FUEL CELL POWER SYSTEMS - SMALL STATIONARY FUEL CELL POWER SYSTEM WITH COMBINED HEAT AND POWER OUTPUT"

This part of IEC 62282 applies to indoor/outdoor small stationary fuel cell power systems (<70 $\text{kW}_{\text{th,input}}$ gas or liquid fuel) serving both as electrical generator (direct/parallel on-grid & stand-alone/off-grid) and as a heating appliance providing both electric power and useful heat with or without a supplementary heat generator providing peak load function. The heat transfer fluid is water or a mixture of water and additives, designed for operating in liquid phase with a pressure head of no more than 1-3 bar. The standard applies to both condensing and non-condensing conditions of the exhaust gases.

This standard specifies the requirements for construction, safety, installation, fitness for purpose, rational use of energy, marking, and performance measurement of these appliances. This standard also provides regional and country specific requirements to facilitate the worldwide application of this IEC standard. These essential regional and country specific requirements are given in Annex B for Europe, in Annex C for Japan and in Annex D for the USA.

The two possible functional block schemes of a fuel cell CHP appliance (without or with a supplementary heat generator) are reported in the following Figure 11, with equal inputs/outputs.



(a) (b)

FIGURE 11: FUNCTIONAL BLOCK SCHEMES OF A FUEL CELL CHP APPLIANCE: **(A)** WITHOUT SUPPLEMENTARY HEAT GENERATOR; **(B)**

WITH SUPPLEMENTARY HEAT GENERATOR

Relevant Terms and Definitions

CHP Combined Heat And Power: "simultaneous generation of thermal and electric energy in one process"

Small Fuel Cell CHP appliance: "appliance which delivers both heat and electric power (and which can also provide domestic hot water service) and is comprised of a stationary fuel cell power system used as a CHP generator and the following components as relevant:

- supplementary heat generator
- flue ducts
- thermal storage"

CHP generator: "system that includes a fuel cell power system producing thermal and electric energy and is the preferential source of heat [29]"

Small fuel cell CHP appliances are classified by various constructive & operational characteristics, summarized in Table 16.

Category	Specifications
Used Gas(es)	Classification for the types of gas is as follows: • city gas; • liquefied petroleum gas; • hydrogen (pure-hydrogen or hydrogen-rich gas); • other gaseous fuels; • kerosene; • methanol; • gasoline; • other liquid fuels.
Mode of air supply and evacuation of combustion products	• Type A – outdoors installation: open air, no flue ducts • Type B – indoor installation: flue duct evacuating combustion products outside the room • Type C – indoor installation: sealed ducts
Maximum water side operating pressure	• Up to 6 bar (EU) • up to 7.5 bar (JP) with tests up to 17.5 bar for 1 min
Expansion system	• open vented system • sealed system
Output power characteristic	• DC or AC output power; • voltage/frequency; • phases and number of lines (e.g. single phase three lines); • grid connection; • island mode.

TABLE 16: FUEL CELL CHP SYSTEMS CLASSIFICATION BY CONSTRUCTIVE & OPERATIONAL CHARACTERISTICS

In terms of safety requirements and protective measures (§5) a similar approach to IEC 62282-3-100:2019 is used, where the manufacturer is generally requested to provide an intrinsically safe design, complemented by passive and active control systems to mitigate possible residual

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[29] The preferential vector of energy production is relevant from a regulatory point of view, especially for the 110% bonus – as reported in Section 2.4

risks to the best rationally achievable level. In this sense a comprehensive Risk Analysis (Annex A) should be provided, performed via consolidated & certificated risk assessment methodologies. Safety aspects are addressed in two steps, a first step in the construction/design phase and a following step in the operational phase.

Safety in construction/design phase

The risk assessment shall evaluate all safety aspects in terms of all used components/subsystems, materials, accessories, sealings, etc. operating in the recommended ambient conditions / chemical environment conditions. General safety recommendations are given in terms of easy accessibility and operability of the system by the user without disconnecting the system from the main utilities, markings & instructions are to be clearly indicated and safety shut-off systems should always be available.

For critical components (mainly related to the fuel, oxidant & flue gas lines, the stack itself and the cooling circuits) active protective measures are required.

Specific indications are given for mechanical hazards such as: conversion of used gas; connection to gas pipes; connection to water pipes; heated or process water circuits; drainage; depleted air and flue gas ducts and terminals; condensate management; gas tightness; insulation; . National requirements apply in all fields.

Electrical safety is treated according to “IEC 60335:2020 Household and similar electrical appliances - Safety” and national requirements for small fuel cell CHP appliances to be connected in parallel with low voltage distribution networks apply. Electrical and electro-thermal insulation shall be implemented, and accidental electrical contact and mis/disconnection shall be avoided. Electrical protection, in terms of overcurrents, shall be implemented both for personal protection and for equipment protection.

Potential burners or catalytic burners shall be sound, correctly piped and with suitable markings; the automatic control system shall allow correct operating conditions and procedures.

Safety in operational phase

During operation, the general approach is that any foreseeable operational state of the system shall be safe, and any unforeseeable operational states of the system shall be risk-mitigated by using sufficient measures. The operation of safety devices should be ensured in the foreseen operating conditions of the system over the reasonable lifetime of the component.

This approach is reflected in terms of gas piping soundness; fire and explosion protection; evacuation of combustion products; cooling circuit; heat transfer circuit; operating surface temperature rises; control devices; ignition devices; purging systems; CO handling and control and safety devices, other than taking into consideration siting aspects.

Testing methods for safety requirements are provided for setup of the fuel cell CHP appliance (ducts, gas carrying circuits, combustion circuits, control devices, etc.) with respect to testing conditions (gases, pressures, temperature, electrical output, etc.). Calculation methods are given to obtain heat input (gas); . Allowable thresholds are provided for electrical input/output supply; auxiliary power consumption; leakage rates; gas concentrations; etc., including allowed uncertainty factors for the measured quantities.

Performance parameters

The functional performance parameters and calculation methods are defined in §6, according to the input/output streams of the energy system. The energy efficiency is defined according to the classical definition as the ratio of the output useful energy (electrical energy + thermal energy) and the input used energy (chemical energy through fuel LHV) – as reported in Equation 1 and Figure 12. Test methods for such energy efficiency calculation are provided for different utilization rate (%) of the supplementary heat generator and according to different operating points.

$$\eta_{tot} = \eta_{el} + \eta_{th} = \frac{E_{el}+E_{th}}{E_{fuel}} \times 100\% = \frac{P_{el}\Delta t + c_{HR}\, q_{V,HR}\, \rho_{HR}(T_1 - T_2)\Delta t}{V_g\, H_{i,V}} \times 100\%$$

(1)

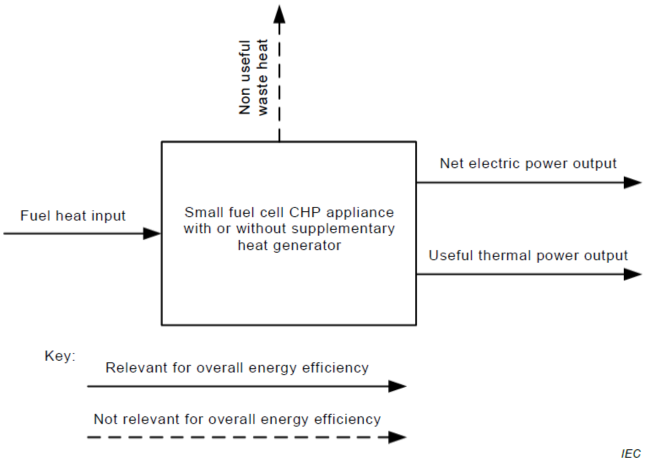

Figure 12: Fuel cell CHP system input/output energy streams

Also the NO_x emission calculation methods and thresholds are given for fuel cell operation with natural gas and LPG.

Additional safety issues are provided in §7 in terms of markings, data plates, eliminating possible hazards, siting considerations and technical instructions, following the general approach followed in IEC 62282-3-100 and IEC 62282-3-300.

4. EUROPEAN CONFORMITY MARKING

Before a product is placed on the market in the European Union, it has to meet the European safety, health and environmental protection requirements to receive the European Conformity (CE) marking. Fuel cell CHPs have to meet requirements of the following European Directives and Regulations:

- 2014/34/EU Directive on equipment and protective systems intended for use in potentially explosive atmospheres
- 2014/68/EU Pressure Equipment Directive
- 2014/35/EU Low Voltage Directive
- 2014/30/EU Electromagnetic Compatibility Directive
- 2006/42/EC Machinery Directive
- 2009/125/EC Directive on establishing a framework for the setting of ecodesign requirements for energy-related products
- REGULATION (EU) 2016/426 on appliances burning gaseous fuels
- REGULATION (EU) 813/2013 on ecodesign requirements for space heaters and combination heaters

Certification takes place either through self-declaration or through testing and evaluation by a notified body, depending on the directive. The manufacturer is responsible for the conformity of the product. He has to issue a Declaration of Conformity, which contains a list of EU directives and a list of standards with which he declares compliance [30].

As an example, Viessmann, a German stationary fuel cell manufacturer, listed the following regulations, directives and standards in its Declaration of Conformity:

Directives	
2016/426 EU	Gas Appliance Regulation
2014/30/EU	Electromagnetic Compatibility Directive
2014/35/EU	Low Voltage Directive
2014/53/EU	Radio Equipment Directive
2009/125/EC	Ecodesign Framework directive
2010/30/EU	Energy Labelling Framework Directive
Regulations	
811/2013	EU regulation "Energy efficiency label"
813/2013	EU regulation "Energy efficiency requirements"
Standards	
EN 300 328 V2.1.1:2017-02	Wideband transmission systems
EN 301489-17 V2.2.1:2012 11 01	ElectroMagnetic Compatibility (EMC) standard for radio equipment
EN 50465:2015	European product standard for combined heating power systems using gas fuel
EN 55014-1 & EN 55014-2	Electromagnetic compatibility. Requirements for household appliances, electric tools and similar apparatus

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[30] Bio-HyPP 2019

EN 60335-1:2012	Household and similar electrical appliances. Safety. General requirements
EN 60335-2-102:2016	Household and similar electrical appliances. Safety. Particular requirements for gas, oil and solid-fuel burning appliances having electrical connections
EN 61000-3-2:2014	Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions
EN 61000-3-3:2013	Electromagnetic compatibility (EMC). Limits. Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current 16 A per phase and not subject to conditional connection
EN 62311:2008	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)
EN 62479:2011	Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)
VDE-AR-N 4105:2011	Generators connected to the low-voltage distribution network

TABLE 17: DECLARATION OF CONFORMITY FOR VITOVALOR

The mentioned regulations and directives are mandatory, while standards provide technical information. In addition to the IEC 62282 series, which includes requirements for fuel cell applications, another standard is relevant for the EU. The EN 50465 is the only European standard that deals with the issues of designing and manufacturing fuel cell CHP systems.

5. QUESTIONNAIRES TO STAKEHOLDERS

A questionnaire has been delivered to relevant stakeholders from each analysed country regarding the impact of the general regulatory framework and specifically respect to the role of IEC 62282-3 standard series, in the national / European procedures (e.g. European Conformity marking). Several stakeholders with different roles based on their experience and expertise have been interviewed to obtain a wide and unbiased perspective on the stationary fuel cell sector (fuel cell manufacturers, national associations, market operators, etc.).

5.1. DISCUSSION OF THE QUESTIONNAIRE RESULTS

The outcome of the Japanese questionnaires shows an overall satisfaction with a well prepared, well organized national regulatory framework where national standardization bodies (JEMA, JIS) have taken the IEC 62282-3 series – specific for fuel cells – as reference for the harmonization of national regulations. There are still come contrasting opinions on technical aspects (mainly related to the interpretation of the standard), which could be improved according to some manufacturers. Cost and market size are seen as principal barrier for the technology uptake, since the subsidies from main demonstration programmes (ene.farm) are now concluded. The connection to the CE marking could provide a potential improvement, harmonizing the global regulatory framework with respect to fundamental references such as EN 50465 and National Grid Codes.

Responses in Germany show that there are still some regulatory barriers as seen by the fuel cell manufacturers. The reference regulation is based on EN 50465 while in the future IEC 62282-3 series could be the new reference, allowing a more homogeneous market penetration of FC systems at international level. There are possible differences between national, EU (EN 50465 – which is generic for all CHP appliances) and international regulations (IEC 62282-3 series which is specific for FC) which could represent a problem, also in terms of technical requirements. Having common criteria for all technologies (including FC) could be a shortcoming for the EN 50465, since the advantages of deploying a FC system could be not directly comparable to other technologies (e.g. heat pumps). IEC 62282-3-100 is the key product standard for fuel cell systems, setting the baseline for fuel cell safety in terms of component design. Fuel cells fueled by 100% H2 or via chemical carriers are seen as potential benefits for manufacturers, avoiding the reforming step, as well as the grid suport functionalities which can play a major role on cost. Scale-up is considered to be the major driver for cost reduction and technology uptake. Harmonization of regulations is seen as a positive aspect which could affect deployment with both major and minor impacts. In fact, currently the procedure is not straightforward and can represent a barrier also for the installation of small-scale units (u-CHP). De-regulating the procedures and having a single reference body could help for deployment. The importance of R&D is relative, mainly related to the level of maturity of the fuel cell products – additional funding is required, especially since there are no follow-up EU demonstration projects plannet yet after PACE and ene.field.

Outcomes for Austria are quite limited since the stationary fuel cell market is small and the fuel cell specific regulation is not well known. The current reference regulation framwork is based on EN 50465; based on the responses, the adaptation of CE marking could play a key role in harmonizing the standards in the short-term while IEC 62282-3 series could play a key role in the future. A big source of uncertainty derives from the political framework, where a potential ban of fossil fuels in the heating sector might entail a huge barrier for natural gas fuelled fuel cells. Cost is seen as the main barrier – due to low maket volume – and the responses report that further subsidy is needed. International standardization is seen as a positive aspect, but its impact on cost is not clear since it might introduce additional technical and non-technical requirements.

For Italy the questionnaire results show that the regulatory framework does represent a major deployment barrier, mainly due to the complex permitting and installation procedures. Currently the regulatory framework is based on Gas Appliance Regulation (which encompasses all CHP technologies, without specificalities for fuel cells) and on the National Grid Code (based on Low Voltage Directive and EMC rules). IEC 62282-3 series is currently not used as benchmark for any procudure, although it could be in the future. Still, the IEC series address all “small scale” fuel cell systems, but it is not specific for small-sized µ-CHP systems (<5 kW_e), which could be disadvantageous. Cost and regulation are seen as the two main barriers for deployment, as well as technology maturity. International standardization is seen as a positive aspect, especially if such harmonization can speed up authorization/permitting procedures and induce indirect cost reductions.

6. CONCLUSIONS

The absence of common & harmonized regulatory frameworks is a barrier for small scale fuel cell systems for stationary µ-CHP applications, leading to country-specific scenarios which does not favour market growth. The critical issue of the current regulations is the un-specificity with respect to the fuel cell technologies, which are generally under the gas appliance or conventional CHP unit regulatory framework.

The IEC 62282-3 series is mostly not familiar in EU, where it is applied on voluntary basis and is often overthrown by compulsory RCS at national level. However, the IEC 62282-3 series could represent a valid option for future harmonized regulation.

Countries which have uptaken the IEC 62282-3 series as basis in the certification process (Japan – harmonization with national JIS rules) have seen a simplification in the regulatory barriers for fuel cell installation (although subsidizing programmes have strongly driven the market growth). CE marking could be a step towards common standardization in Europe, although it is unclear if CE requirements would foster or not the deployment of stationary fuel cells.

Finally, cost (CAPEX) is still seen as major barrier for further uptake of fuel cell systems. The main driver for cost reduction is increasing sales volumes by increasing technology uptake. In assessing the commercialisation potential of stationary fuel cell systems, emphasis is placed upon cost targets which need to be met to achieve mass market success. These are most developed for the domestic micro-CHP products, and they have often been set by the public sector. Cost reduction can be achieved with the economy of scale, but research and prototyping are still needed for bigger sizes (MW) to guarantee robustness and manufacturability for the next-generation fuel cells, to build a valuable supply chain and to increase the technology maturity and readiness level.

7. ACKNOWLEDGMENT AND DISCLAIMER

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