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PACE

Pathway to a Competitive European Fuel Cell micro-CHP Market

REPORT

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PACE - Report from Regulatory Barriers Working Group

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Pillar 1: Financial Incentives

Chapter Summary

The barriers related to Financial Incentives for FC mCHP are as follows:

- No common subsidy scheme exists to assist the commercialisation of FC mCHP in Europe;
- FC mCHP technology is not considered eligible for existing subsidy schemes that it should be eligible for (ie. it would help to meet the aims of the scheme if included).

The case study shows that a governmental grant for capital expenditure (CAPEX) to support the purchase of FC mCHP in Germany has led to a significant uptake of the technology.

Key recommendations to address these barriers were identified:

- Government should work with national FC mCHP stakeholders to design requirements of an appropriate FC mCHP financial incentive scheme (required subsidy rate and scope etc).

Inclusion of FC mCHP as a specific technology worthy of financial support in relevant regulations (such as the Energy Efficiency Directive).

Pillar 2: Electricity Tariffs

Chapter Summary

Electricity tariff regulation can act as a barrier to the uptake of FC mCHP as they prevent FC mCHP units from achieving additional revenue streams by providing high value export services such as grid frequency balancing. This limits FC mCHP utility to self-consumption only. Challenges related to electricity tariffs can be broken down are as follows:

- Different incentives for the export of electricity for FC mCHP units to the grid exist in different countries. These lack both prevalence and standardisation;
- The process for reaching an agreement with customers' DSOs to export electricity is often long and arduous, lacking consistency across the European countries

The case studies of Germany, Belgium and the Czech Republic shows that current policies incentivise self-consumption as the best opportunity for monetisation. For Germany and Belgium, only minimal gains from exporting and participating in grid services are added, whereas Czech scenarios show that a respectable income stream can be added from exporting.

Key recommendations to address these barriers were identified:

- Mapping of member states that have incentives for electricity export to the grid.

Mapping of member states that require DSO agreements and how the required agreements differ.

Pillar 3: Grid Connection

Chapter Summary

The grid connection regulatory barriers to FC mCHP are as follows:

- The process for connecting FC mCHP units to the electricity and gas grid needs to be simplified and standardised across European countries;
- Evolving grid codes standards can impact the ability to deploy FC mCHP or confidence in the market;

The case study on the different installation procedures across European states shows how lack of standardisation brings uncertainty in the installation process and time required, favouring competing technologies.

Key recommendations to address these barriers were identified:

- Provide best practice examples of paperwork forms and processes.
- Implement Directive EN 50549:2019, avoiding the implementation of more restrictive requirements.
- Consider exempting FC mCHP <5 kW from generators regulations and grid impact assessments.
- Promote standard paperwork forms and processes for all member states.

Equate FC mCHP to Heat Pumps (HP) in regard to grid impact.

Pillar 4: Building Standards

Chapter Summary

The building standards regulatory barriers to FC mCHP are as follows:

- The potential for FC mCHP technology to operate on green gases (e.g. green hydrogen and biomethane) is unrecognised in regulation;
- FC mCHP units are often unfairly penalised in regulations using calculations of the carbon intensity factor of different low-carbon heating options.

The case study of CO_2 emissions from a typical German household shows that electrification of heat doesn't necessarily deliver the best solution in terms of emissions reductions.

Key recommendations to address these barriers were identified:

- Engage potential prosumer highlighting advantages of the system vs separate heat+power.
- Include FC mCHP in technologies under EED Energy Savings Obligation.
- Implement EPBD taking into account cost-effectiveness and emissions reduction of FC mCHP.

- Promote emission counting methodologies assessing the combined effect of heat and power production.

Provide a level playing field for technologies supporting different scenarios for decarbonising the building sector.

Pillar 5: Customer Information

Chapter Summary

The barriers to FC mCHP uptake related to customer information are as follows:

- Unfounded penalisation of FC mCHP technology in primary energy factor calculations made for regulation concerning unit labelling;
- Regulation that leads to labelling of FC mCHP units that fails to recognise their true energy efficiency and decarbonisation potential.

The case study of the ErP Lot1 energy labelling directive shows that the methodology used can affect greatly the energetic class assigned to mCHP, affecting their uptake.

Key recommendations to address these barriers were identified:

- Continue monitoring FC mCHP performances to build a strong set of data to back-up energy labels decisions.
- Build a data-collection infrastructure to be used for future revisions of EL/ED directives.
- Implement labelling methodologies fully taking into account system integration.
- Ensure labelling provides exhaustive information to customers on savings and building efficiency.

2. Introduction

The PACE project's primary objective is to further the commercialisation of fuel cell micro-combined heat and power (FC mCHP) technology and to promote the technology as a key part of the decarbonisation of energy in Europe. A study by the German National Organisation of Hydrogen and Fuel Cell Technology has noted that the heating market is currently responsible for 40% of total German CO_2 emissions. This figure will be consistent with other industrialised, service-based countries across Europe, which highlights the importance meeting this objective to achieve significant reductions in CO_2 emissions. In order to meet this objective, it is not enough to just incentivise technology uptake through subsidy funding.[1] In addition, structural barriers to the uptake of FC mCHP in households and businesses across Europe need to be identified, and strategies for overcoming these barriers developed.

This rationale has led to the creation of a **dedicated Regulatory Barriers Working Group within the PACE project.** The working group is comprised of all members of the PACE consortium (including five FC mCHP technology manufacturers, three technical and research partners, and the European Cogeneration industry association), and it provides a forum within which all aspects of regulation affecting FC mCHP uptake can be discussed. The Working Group meets biannually to analyse the European regulatory landscape for FC mCHP and to explore new problems and solutions.

In undertaking these discussions, **the Working Group's objective is to identify particular best practice and worst practice for allowing easy rollout of FC mCHP technology in different European countries.** The Working Group thus analyses policy at both a European and member state level. This task is required as, despite FC mCHP technology offering a persuasive use case for decarbonising domestic and small business energy use, regulations governing its sale, installation and use vary significantly across member states. Furthermore, regulations still exist at a pan-European level that hinder uptake of the technology. FC mCHP offers overall efficiencies of over 90% due to its ability to output both useful electric and heat energy, and is also a technology fit for the transition to green gas (as it is able to be powered by hydrogen and LPG as well as natural gas). In offering both immediate reductions in

[1] PACE – D5.3 CHALLOCH ENERGY: Executive Report & Conclusions

domestic greenhouse gas emissions and the potential to meet net-zero domestic emissions in the future, the technology is a vital piece of the European energy transition puzzle. The task of the Working Group, therefore, is to outline how the technology can receive the desired support it needs to be rolled out without being hindered by regulatory barriers.

This report comprises the major output of the Working Group in the PACE project over the period of 2016-2021. Its structure, contents and conclusions are described below:

1.1 – Scope and use of the report

This **Regulatory Barriers report is structured as follows:**

- **Section 2 provides an overall descriptive framework**, summarising the regulatory barriers that currently apply to FC mCHP. The framework is divided into 5 'pillars'.
- **Sections 3-7 explore each of these pillars in turn, exploring the nature of the barriers identified in terms of the problems at hand and potential solutions to them.** These sections also offer illustrative examples and best practice cast studies to make these points.

The main objective of the report is to provide a clear picture of the regulatory barrier landscape for FC mCHP in Europe. However, it is worth noting the regulatory barriers identified are cross-cutting through both different regulatory 'pillars' and different industries, and so the removal of barriers to FC mCHP may have co-benefits for other decarbonisation technologies. But additionally, the consumer decision as to whether to buy a FC mCHP for their home or business is motivated by numerous intertwining factors that mean any approach to regulatory barrier removal must be holistic and approach the system as a whole. Consequently, taking a partial approach to the resolution of some barriers but not others might not lead to the desired effect of commercial uptake of FC mCHP as a key technology to bring in a net-zero world.

Material from both internal discussions within the PACE consortium and from learnings highlighted in associated literature has been used in this report. In particular, the Working Group has kept a close dialogue with the **HyLAW project**, another project funded by Horizon 2020. Other material analysed includes reports from the preceding **ene.field FC mCHP deployment project.**

In keeping with the aims of the PACE project, **this report is designed to be accessible and useful for a variety of different stakeholder types**. Primarily, the report is targeted at **policymakers** due to the ability this group has to remove regulatory barriers. However, the report is also aimed at **industry players and citizen-led organisations** who wish to understand more about FC mCHP technology and the different European policies governing its use. Ultimately, the level of detail in the report is such that anyone with an interest in understanding more about the technology can learn some useful information.

3. FC mCHP Regulatory Barrier Framework

2.1 – Regulatory Barriers

There is no single European Union Regulation or Directive that governs the use or uptake of FC mCHP technology in Europe. Whilst FC mCHP is recognised as a 'promising technology' under the Energy Efficiency Directive (EED) (2012/27/EU) and the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) has specific provisions relating to the technology, neither of these outline a clear set of standards for how FC mCHP should be governed. Instead, the jurisdiction to develop policies relating to FC mCHP is largely devolved to Member States.

Consequently, there is significant national variation in regulations, codes and standards (RC&S) applying to FC mCHP between Member States.. Whereas some countries have created regulations which the PACE Regulatory Barriers Working Group would consider to be best practice, some have created regulations or regulatory gaps that would be considered worst practice. For the impact of this to be understood in detail, it is necessary to consider the different ways in which policy governs the use and uptake of FC mCHP.

The following framework categorises the impacts of regulation on FC mCHP technology into 5 different 'pillars':

- Financial Incentives
- Electricity tariffs
- Grid connection
- Building standards
- Customer information

Each of these pillars contains a number of specific regulatory barriers that apply to FC mCHP, and the pillars represent a summary of the core problems that attempts to deploy FC mCHP technology face. As categories, they represent the common issues that the PACE project partners continually encounter in their work promoting FC mCHP as a decarbonisation option.

2.2 – The framework

The table on the next page shows the PACE regulatory barriers framework model in full, with the regulatory barriers to FC mCHP use and uptake encountered in each 'pillar' outlined. The blue crosses (**X**) represent the main pillar under which each regulatory barrier is considered to fall, but additional black crosses (**X**) identify how a specific barrier can cut across a number of different areas of policy and regulation. A customer, for example, may decide to not invest in a FC mCHP unit because in their country there is significant bureaucracy involved in reaching an agreement with their electricity distribution system operator (DSO) for electricity export. It is tempting to view this as solely an issue with the paperwork for grid connection and thus belonging only to the 'Electricity Tariffs' pillar. In fact, it is a financial problem too as if these agreements are hard to reach, then it is difficult for a customer to calculate an individual business case for purchasing a FC mCHP unit. Therefore, it is important whilst reading this report to consider the impact of regulatory barriers holistically, and to consider that the benefits of their removal are likely to be larger than just the removal of one 'pillar' to FC mCHP use and uptake.

Fundamentally, as this report aims to highlight, it should not be made unnecessarily difficult for customers to adopt low-carbon technologies. It is hoped that through this report and the barriers it highlights, policy-makers and other stakeholders are able to better understand why it is more or less difficult for different customers in different European countries to make the decision to purchase and install a FC mCHP unit. The following sections explore each barrier pillar in detail.

Diagram 1 – PACE Regulatory Barriers Framework Model

Barriers \ Pillars	Financial Incentives	Electricity Tariffs	Grid Connection	Building Standards	Customer Information
Standardisation of financial incentive regimes applying to FC mCHP	X	X			
Ineligibility of FC mCHP under existing financial incentives	X	X			
Standardisation of market incentives for electricity export	X	X			
Standardisation of DSO agreements for electricity export	X	X	X		
Electricity grid connection standardisation		X	X		
Gas grid connection standardisation			X	X	
Standardisation of installation requirements				X	
Recognition of FC mCHP future readiness for green gas				X	X
Carbon intensity factor penalisation of FC mCHP				X	X
Unit Labelling - LOT1 PEF/CC Calculation				X	X
Unit Labelling - Energy Label Categories				X	X

4. Pillar 1: Financial Incentives

Chapter Summary

The barriers related to Financial Incentives for FC mCHP are as follows:

- No common subsidy scheme exists to assist the commercialisation of FC mCHP in Europe;
- FC mCHP technology is not considered eligible for existing subsidy schemes that it should be eligible for (ie. it would help to meet the aims of the scheme if included).

The case study shows that a governmental grant for capital expenditure (CAPEX) to support the purchase of FC mCHP in Germany has led to a significant uptake of the technology.

Key recommendations to address these barriers were identified:

- Government should work with national FC mCHP stakeholders to design requirements of an appropriate FC mCHP financial incentive scheme (required subsidy rate and scope etc).
- Inclusion of FC mCHP as a specific technology worthy of financial support in relevant regulations (such as the Energy Efficiency Directive).

3.1 – Pillar Outline

The first regulatory barrier to the uptake of FC mCHP technology in Europe is related to financial incentives. Two barriers will be addressed: the **lack of appropriate financial incentive schemes in some countries**; and the **presence of financial incentive schemes that exclude FC mCHP** where they should not. The effect of these barriers in reducing the advance of FC mCHP commercialising will be explained, before a best practice case study of the KfW 433 scheme in Germany is provided to explain the benefit that a well-designed financial subsidy scheme can achieve. The need for more schemes like this in Member States beyond Germany will be emphasised.

The table below shows **the funding schemes that currently exist** for FC mCHP in 10 European countries:

Table 1 – Funding schemes for FC mCHPs in different countries[2]

Country	Feed-in-tariff	CAPEX support	Tax incentives	Others
Austria	No	If electrical output >100kW and supplies the public heating district	No	No

[2] PACE – D5.3 Report

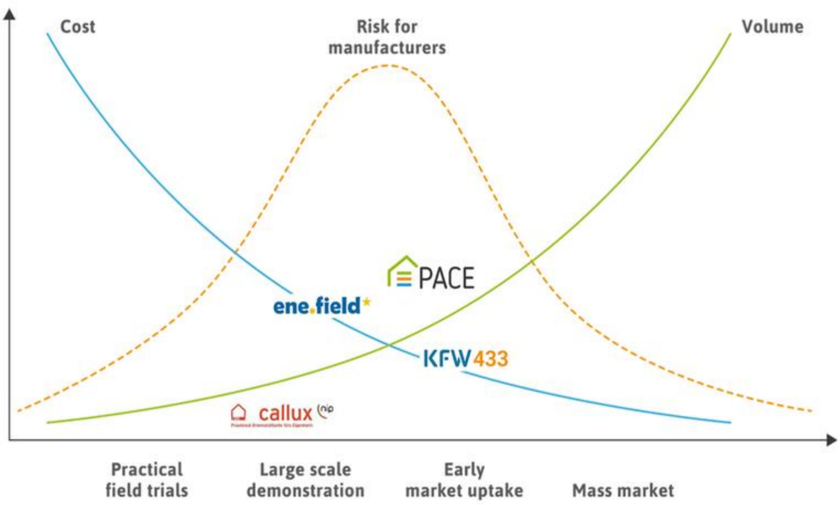
Belgium (Flanders region)	**Yes, for systems >10kW if biogas is used.**	No	No	**Up to 30% of costs if installation <10kW**
France	No	No	No	No
Germany	**Yes**	**Yes**	**Yes, tax relief based on the Energy Tax Act**	No
Italy	No	No	**Tax exemption on any self-produced gas used**	No
Luxembourg	**Yes**	No	**Yes, mCHP plants between 1- 6kW subsidised by the state**	No
The Netherlands	No	No	No	No
Poland	**Yes**	No	No	No
Switzerland	No	No	No	No
UK	**Yes**	No	No	No

This table suggests the following: that **financial incentive support for FC mCHP is currently limited**; that the financial **incentives that exist vary significantly** between countries; and that **a number of different mechanisms can be used to deliver these financial incentives**. The biggest barrier to the uptake of FC mCHP units at the moment is their upfront cost. Hydrogen Europe[3] estimate that the cost of a unit in Europe is currently at the level of around €17 000/kW, which, without subsidies, puts the unit out of the purchasing potential of most consumers (especially with incumbent fossil fuel CHPs costing up to 4 times less). As has been well established with numerous technologies over time, to achieve significant market uptake, price levels need to be competitive for consumers. Subsidies are key to achieving this as they allow the first consumers to buy units, which drives down the price of production, making subsequent units cheaper and more consumers able to buy them. This theory (known in economic history as 'Wright's Law': the relationship that as production volume increases, the cost per unit decreases) is shown visually in table 2. The PACE project exists as a "bridge to large scale market uptake" for FC mCHP technology[3] by acting as such a subsidy for 2 800 units across Europe, and as table 2[4] shows, the aim of the project is to move FC mCHP technology from being at the stage of 'large scale demonstration' to 'early market uptake'. However, for the technology to be able

[3] PACE Standard Presentation
[4] HE Strategic Research and Innovation Agenda (2020)

to **progress further to 'mass market uptake' (or 'commercialisation'), greater financial support is required** so that the total cost of ownership (TCO) for a FC mCHP unit is at the point of parity (or just above) with incumbent small-scale distributed heat and power technologies. The PACE project is ultimately limited in that it can only support close to 3 000 units over a limited time period. Further financial support schemes are therefore required.

Table 2 – Cost curve for FC mCHP[4]



Traditionally, technology has been financially supported in this way through national schemes. As table 1 shows, there are several different mechanisms through which this support can be delivered. This can either offer consumers support at the **'capital expenditure' (CAPEX) stage** of purchasing the FC mCHP unit up front, as is the case in Germany (which will be covered in this chapter's case study), or at the **'operational expenditure' (OPEX) stage**. CAPEX support scheme examples include feed-in-tariffs and traditional CAPEX subsidies (such as eliminating VAT on purchase); and OPEX support schemes include fuel incentives or self-production incentives which make it cheaper to run the units throughout the year, as it will described more into details under the "Electricity Tariffs" pillar. There are also other support schemes which can offer support falling outside of these categories, such as installation subsidy support. Regardless of how schemes are structured, however, they need to be of adequate scale that they allow the average European consumer to afford the purchase of FC mCHPs.

At this point, policymakers might question why they should support FC mCHPs more than or equally to any other low-carbon technology deserving of subsidy support. The answer to this question is twofold: the technology is **now poised to fully commercialise** (so a relatively small-scale scheme could make a large difference to the market); and the technology **offers something that other low-carbon technologies do not**. Addressing the first point, a major theme that emerged from regulatory policy workshops with the PACE OEMs was the fact that, in policy, FC mCHPs should now be seen as a fully mature technology rather than a 'nascent' technology. With around 400 000 units having been deployed in Japan under the ene.farm project and around 10 000 units having been deployed in Europe to date, the technology has developed to the point at which European OEMs have been able to launch 'generation 2' units with even further improved performance and reliability on the previous (already reliable and highly performing) generation 1 units.[5] Regarding the offering of FC mCHPs, also, the units offer up to 90% total efficiency (of conversion of feedstock to heat and power), are fuel flexible, and enable distributed energy system integration. The units also allow for a clean carbon reduction pathway of 30-50% currently, and scaling up to 100% in the near future as gas grids become greener, which offers an easy transition. Whilst each of these points will be expanded upon in further chapters of this report, it is clear that the technology is one that is worthy of support by policymakers.

A final point worth noting, based on these advantages of FC mCHP technology, is that the technology is currently **not always or regularly supported by existing grants which are targeted at low-carbon heating or electricity generation technology**. The UK is a good example of this, where a recently announced Green Homes Grant targeted at improving energy efficiency in homes supports heat pumps and insulation measures, but does not support FC mCHP technology which would meet the aims of the grant (quickly improving energy efficiency) and is also within the grant's scope (£5 000 max. grant per household).[6] Often such omission of FC mCHPs is due to a lack of awareness of the technology amongst policymakers, but it may also be fuelled by a misperception that the technology is not ready for mass market uptake. As this chapter has outlined, it is only through inclusion in such schemes that mass market uptake for FC mCHPs can be achieved, so they should not be excluded this way.

3.2 – Case Study: the KfW 433 programme

Germany is the country in Europe which currently has the most developed subsidy support scheme for FC mCHP: the **KfW 433 programme**. This section will outline the structure of the scheme, it's aims and indicative outcomes, and the case for other countries to replicate similar schemes.

The KfW 433 programme (administered by the German public development bank, KfW) has been running since 2016, and it is a strong case study for showing the positive benefits that can be achieved through a well-designed FC mCHP financial support scheme. The programme provides a **CAPEX grant of 40% of the cost of FC mCHP unit purchase, installation and maintenance** (for 10 years) up to a maximum contribution of 6 800€ + 550€/100W. For a hypothetical FC mCHP unit with a 1kW output, the scheme would provide a subsidy of 12 300€[7].

As of mid-2021, **18 251 systems had benefitted from the grant[8]**, all being FC mCHPs up to an output of 5kW. This has allowed Germany to become the single largest market for FC mCHP in Europe, followed only by Belgium which has a similar CAPEX support scheme in the region of Flanders. No country in Europe without such a subsidy scheme has seen the deployment of over 100 FC mCHP units

[5] PACE Gen 2 unit deliverable
[6] *https://www.gov.uk/government/news/quality-assurance-at-heart-of-new-2-billion-green-homes-grants*
[7] Merkblatt - Energieeffizient Bauen und Sanieren –Zuschuss Brennstoffzelle, 2021
[8] KfW-Förderreport & BMWi

under the PACE project, whereas Germany currently has a forecast deployment of 1 491 units in PACE. The positive effects of this can be illustrated in terms of CO_2 abatement. Each 1kW unit installed results in an average saving of 1.08 mCHP tonnes of CO_2 emissions per year, in comparison to a gas boiler and electricity from the grid[9]. This means that with the installation of 18 251 systems as a result of the grant, Germany will save approximately 19 711 tonnes of CO_2 emissions per year through the KfW 433 programme. Although this figure is a broad estimate, due to the CO_2 abatement of a unit being dependent on a number of factors (including the output of electrical power, electrical efficiency and operational hours per year), it can provide a useful basis for understanding the positive effects of the scheme.

This CO_2 benefit is, of course, only an illustration of the positive effect of the scheme, as the **actual co-benefits will be much larger** in terms of improving FC mCHP R&D, driving down the price of units and creating a market for FC mCHP to thrive in Germany. NOW (the German National Organisation of Hydrogen and Fuel Cell Technology) noted when they were aiding the design of the programme that the heating market is responsible for 40% of German CO_2 emissions, a figure that will be consistent with other industrialised, mostly service-based countries in temperate regions (ie. much of Europe). Through its potential to create a transition pathway to decarbonise this large proportion of German CO_2 emissions, FC mCHP is clearly an important technology that deserves support.

It should be noted in these discussions, however, that **Germany already has a strong use case** for consumers to purchase FC mCHPs. Not only does Germany have a very high electricity price and a relatively low gas price compared with other European countries,[10] but there are also a large number of higher-income 'green pioneer' consumers who act as a 'benchhead market' for new environmentally-friendly technologies, as outlined in the first FC mCHP consumer profile deliverable of the PACE project[11]. These factors make a gas-fed FC mCHP unit which reduces the need to purchase grid electricity particularly economically sensible for consumers in a way that may not be the case in other countries. Consequently, when designing similar schemes for other countries **local factors should be taken into account** (the business case and the consumer profile in particular) in order to determine the exact rate of financial support that is required to make the scheme a success.

A final point that has fed into the success of the KfW 433 programme is its **administrative design**. A white paper released by the European Copper Institute on similar financial incentive schemes for heat pumps[12] stated, through the experience of scaling heat pump technology in Europe, that this administrative design should be addressed as a priority in programme design, rather than as an afterthought. The specific recommendations of this white paper state that programmes should be

[9] *https://pace-energy.eu/benefits/*
[10] *https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistic*
[11] PACE consumer survey deliverable 1.
[12] ECI Heat Pump White Paper

transparent in what technology is being supported, have a clear duration and level of support, quickly disperse funds to qualifying consumers, have a strong effect on the total cost of ownership of a technology, and require limited (or well thought through) paperwork. KfW pledge that a standard homeowner (in a one or two-family house) will aim to receive a response within 1-4 working days of the KfW 433 application being received – this should be seen as an industry standard.

3.3 – Recommendations to address barriers identified

The following **recommendations** have been identified to unlock opportunities in the **short term**:

- The **continuation of successful FC mCHP financial incentive programmes** in Germany.
- Market development activities to **design new FC mCHP incentive schemes** in member states beyond Germany.
- **Identification of existing schemes** for low-carbon heating/electricity in European member states into which FC mCHPs could already fit.

Opportunities for different stakeholders to **address this regulatory barrier** to FC mCHP uptake in the **longer term** are summarised below:

FC mCHP Stakeholders	Member States	European policy makers
• Continued **market development activities** to make the case for FC mCHP incentive schemes in additional member states • Publication of **business cases** to show the impact of financial incentives to FC mCHP uptake	• Work with national FC mCHP stakeholder organisations to inform the **specific design requirements of an appropriate FC mCHP financial incentive scheme** (required subsidy rate and scope etc)	• Inclusion of FC mCHP as a specific technology worthy of **financial support in relevant regulations** (such as the Energy Efficiency Directive)

5. Pillar 2: Electricity Tariffs

Chapter Summary

Electricity tariff regulation can act as a barrier to the uptake of FC mCHP as they prevent FC mCHP units from achieving additional revenue streams by providing high value export services such as grid frequency balancing. This limits FC mCHP utility to self-consumption only. Challenges related to electricity tariffs can be broken down are as follows:

- Different incentives for the export of electricity for FC mCHP units to the grid exist in different countries. These lack both prevalence and standardisation;
- The process for reaching an agreement with customers' DSOs to export electricity is often long and arduous, lacking consistency across the European countries

The case studies of Germany, Belgium and the Czech Republic shows that current policies incentivise self-consumption as the best opportunity for monetisation. For Germany and Belgium, only minimal gains from exporting and participating in grid services are added, whereas Czech scenarios show that a respectable income stream can be added from exporting.

Key recommendations to address these barriers were identified:

- Mapping of member states that have incentives for electricity export to the grid.
- Mapping of member states that require DSO agreements and how the required agreements differ.

4.1 – Pillar Outline

This pillar considers the inhomogeneity of the tariffs landscape across the European countries. A crucial aspect for the FC mCHP success involves adequate tariffs for electricity produced and sold to the network, as well as rewards for providing capacity for grid services from FC mCHP users. As shown by the work provided in a PACE report[13], without adequate tariffs or incentives the greatest opportunity for monetisation of mCHP is provided by self-consumption, mainly due to the savings provided by converting gas into electricity rather than buying from the grid.

This doesn't allow consumers/businesses to fully exploit the potential of FC mCHP, which could offer a valuable grid balancing service. Using FC mCHP for ancillary service is an underdeveloped capability, currently stopped by the need for aggregating many FC mCHPs to reach the required power -in the

[13] PACE - Economic value of mCHP's participating in power and grid service markets - Germany

order of at least 1MW, compared to 1-5 kW typically offered by a single FC mCHP-, and by the regulatory landscape, currently categorizing FC mCHPs as generators despite the very low impact that a single FC mCHP can have on the network, forcing compliance with strict regulations designed for larger generators.

As already mentioned, aggregating FC mCHP is necessary to reach an adequate power to offer ancillary service, which in Europe requires reaching approximately 1MW, which corresponds to aggregating around 1000 units. This can be done by developing a Virtual Power Plant (VPP), which consists in a portfolio of Distributed Energy resources (DER) (generation, storage or controllable demand) that are controlled collectively and remotely by a central entity. By creating a VPP it is possible to provide high-value ancillary services, specifically:

- Energy services – This can include (1) optimisation of day ahead and intraday trading, where the flexibility offered by VPP can reduce the demand when prices are high and increase it when it is low, allowing a monetisation when extreme prices are reached; (2) optimisation of the position in imbalance market, where Balance Responsible Parties (BRPs) trade after the wholesale market has closed to balance supply and demand in real time, allowing a flexible resource such as VPPs to be highly valuable; (3) maximise auto-consumption within a community rather than a single household, allowing balancing local microgeneration and demand.

- Capacity services – In order to meet the demand predictions and guarantee adequate generation capacity, a capacity market or strategic reserves are used. The flexibility offered by VPP could offer a source of revenue, however under the EU clean energy package, reserves are to be preferred over capacity remuneration mechanisms.

- Balancing services – VPPs could be used by Transmission Systems Operators (TSO) to balance the electricity system by offering reserves in the form of (1) Frequency control reserve, to be activated within 30s and to be sustained for ~15min; (2) Frequency Restoration Reserve, to be activated between 30s and 15min and to be sustained for 15min to hours; (3) Replacement Reserves to be active after 15min and to be sustained for hours.

- Network services –VPP flexibility could be used to balance local supply and demand to avoid network congestion, by managing capacity and reducing peak loads.

While many companies are currently developing VPPs in Europe, none of them make use of FC mCHP, instead using batteries, EV, PV, storage heaters and other technologies. The pillars discussed highlight the issues preventing larger uptake of VPPs with FC mCHP. If many barriers revolve around technical difficulties, on the regulatory side the lack of standardised incentives for export is hindering a large uptake of this solution. To be viable, markets must allow equal participation of aggregated DERs and large scale generation, without forcing the strict level of compliance to norms designed to individual units. Additionally, DSO must be allowed to use flexibility to defer networks upgrade, while currently methods to make use of flexibility are not established or prohibited in some countries.

An additional barrier is given by the lack of standardised DSO agreements for export. There is currently a large variation in the administrative effort required to install and connect FC mCHP to the network, varying from 'fit and inform' policies adopted in Austria to the 5-11 forms needed in Germany. More will be addressed in section 5, but a lack of standardisation introduces challenges for the manufacturers who will need to ensure their product is compliant with local regulations in different countries.

To illustrate a potential example of how the revenue streams described above can be realised and what impact policies on tariffs can have on the potential revenue from grid services, a case study is presented in the next section.

4.2 – Case Study: Grid services provided by FC mCHP in Germany, Belgium and the Czech Republic

To show the potential impact of income streams for mCHP technologies, the report D4.3 "Economic value of mCHP's participating in power and grid service markets" models quantitatively the potential revenue from grid service markets in Germany, Belgium and the Czech Republic. The report analyses the two fuel cell technologies deployed in PACE field trials: PEM and SOFC fuel cells.

A first analysis shows the energy cost savings of a FC mCHP operating to optimise self-consumption compared to the situation without mCHP, where all electricity is purchased from the grid and heat is generated by a gas boiler. This is assessed in a "base case" representing a typical house in which the hot water storage is only used for domestic hot water consumption, a "big storage" scenario similar to the previous one, with the addition of hot water storage tank to be also used for space heating, a "old house" scenario representing a house built between 1949 and 1969, and a "three houses" scenario where the FC mCHP is shared among three houses.

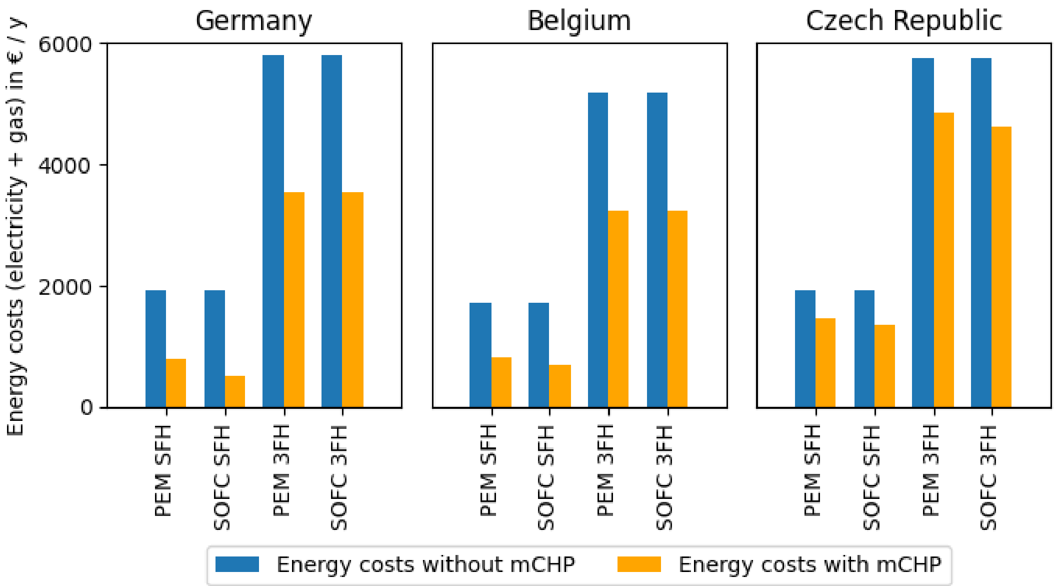


Figure 1: Savings in yearly energy costs for gas and electricity

The graph in Figure 1 summarises the cost-savings obtained in the 4 scenarios for each FC technology and it illustrates the main driver that currently pushes consumers to install FC mCHP. It is clear that substantial savings of more than 1000 €/y can be obtained in every scenario for both Germany and Belgium, making it a compelling option from the consumer point of view. Savings are, however, considerably less in the Czech Republic.

The report then compares the additional revenues provided by grid services. Under current regulations, the most established markets involve frequency balancing services, making it immediately available for use by mCHP. There is limited availability to operate in other markets such as capacity, therefore frequency balance services are the only ones being simulated in the case study. Results from the potential revenue from automatic Frequency Restoration Reserve service (aFRR) and manual Frequency Restoration Reserve (mFRR) are shown in Figure 2. It is immediately clear that for Germany and Belgium, cost savings only reach few percentage points, with income of ~50 €/yr in the best case, making revenue from TSO grid services less attractive when compared to self-consumption, with current policies preventing the exploration of additional grid services such as capacity. However, cost savings are far more significant in the Czech Republic, with income of up to ~300€/yr. Although it is true that for all three countries, the best opportunity for monetisation of mCHP flexibility comes from maximising self-consumption, in some countries the additional income from providing aFRR is also significant.

Country	Scenario	Cost savings from self-consumption in €/y	Additional income from aFRR+/- in €/y	Additional income from mFRR+/- in €/y
Germany	PEM SFH	1'139	51.64	-
	SOFC SFH	1'429	8.41	-
	PEM 3FH	2'239	13.64	-
	SOFC 3FH	2'239	8.09	-
Belgium	PEM SFH	904	-	39.64
	SOFC SFH	1'034	-	4.84
	PEM 3FH	1'951	-	0.25
	SOFC 3FH	1'951	-	1.78
Czech Republic	PEM SFH	447	301	271
	SOFC SFH	564	208	178
	PEM 3FH	905	218	281
	SOFC 3FH	1'127	172	182

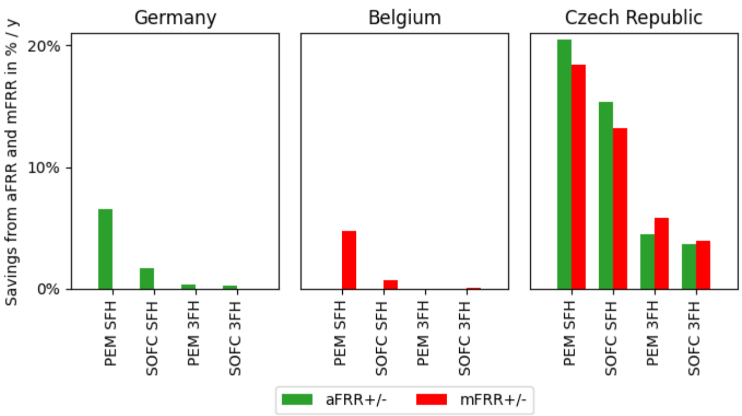


Figure 2: Additional energy cost savings from providing aFRR or mFRR in relation to self-consumption. Reproduced from [14]

4.3 – Recommendations to address barriers identified

The following recommendations were identified to unlock further opportunities in the short term:

- Mapping of member states that have incentives for electricity export to the grid.
- Mapping of member states that require DSO agreements and how the required agreements differ.

Opportunities for stakeholders to address barriers in the longer term are summarised below:

FC mCHP Stakeholders	Member States	European policy makers
• Encourage customers to evaluate opportunities for optimised self-consumption by identifying factors increasing savings • Lobbying to ensure that FC mCHPs are recognised as eligible technologies under	• Provide better access to aggregators to participate in the that grid service market • Simplify bureaucracy involved with installing and set up DSOs agreements	• Facilitate electricity grid standardisation (development of common forms and processes) • Facilitate access to the capacity market

electricity export incentives that reward similar technologies	• Promote tariffs to incentivise flexibility as a way to prevent network upgrades

6. Pillar 3: Grid Connection

Chapter Summary

The grid connection regulatory barriers to FC mCHP are as follows:

- The process for connecting FC mCHP units to the electricity and gas grid needs to be simplified and standardised across European countries;
- Evolving grid codes standards can impact the ability to deploy FC mCHP or confidence in the market;

The case study on the different installation procedures across European states shows how lack of standardisation brings uncertainty in the installation process and time required, favouring competing technologies.

Key recommendations to address these barriers were identified:

- Provide best practice examples of paperwork forms and processes.
- Implement Directive EN 50549:2019, avoiding the implementation of more restrictive requirements.
- Consider exempting FC mCHP <5 kW from generators regulations and grid impact assessments.
- Promote standard paperwork forms and processes for all member states.
- Equate FC mCHP to Heat Pumps (HP) in regard to grid impact.

5.1 – Pillar Outline

The third pillar addressed by this report involves barriers related to the electricity and gas grid connections. A detailed analysis was conducted and is described in the PACE report D5.3.[14] The report identifies the areas where standardisation would facilitate the uptake of FC mCHP. The need of standardising requirements and processes to connect the systems to the gas and electricity grids, both on the technical and administrative side, was a key recommendation.

The main issue lies in the electricity grid connection, as the current landscape of relevant **regulations is fragmented and inconsistent across Europe**. While a European standard for grid connection has been published (EN 50549:2019), the national implementation of the norm showed variations between different countries. As an example, Challoch mention the British implementation of the norm, which regulates the Rate of Change of Frequency (ROCOF) in the technical requirements for generators, while the German version of the same norm never mentions this parameter. There is also a **lack of specificity**

[14] PACE D5.3 - CHALLOCH ENERGY: Executive Report & Conclusions

for FC mCHP, as **some of the requirements** (such as undervoltage and overvoltage ride, which are important for PV systems) **are not relevant for these units,** however the norm doesn't mention exceptions, forcing FC mCHP manufacturer to also test for these parameters.

This can lead to complications in the development of FC mCHP units, since their design has to comply with the varying national and sometimes regional requirements. The design, production and installation costs are inevitably affected.

In addition to the varying technical requirements in design, **current regulations also show inconsistency in the administrative obligations** for connecting units to the grid as illustrated by the table below. The administrative procedures are regulated on a State level, resulting in large variations across Europe. Furthermore, some countries such as Poland, Austria and France have insufficient regulations, with procedures varying between the local DNOs. This causes a variation in the number of steps required to complete an installation and time required for installing a FC mCHP, ranging from 2-5 days in Germany to 2 days-3 months in the UK.

Table 2 – Regulations governing FC mCHP electricity grid connection in 5 European countries[15]

Country	Regulation Name	Regulation Description
Denmark	**Teknisk Forskrift 3.2.1**	Requires electrician to install a bidirectional meter – no CHP-specific electrician qualifications required. In order to feed electricity into the grid, an agreement must be sgned between the producer (FC mCHP owner), the Distribution System Operator (DSO) and Transmission System Operator (TSO). The DSO is responsible for registering metered data and reporting plant data to the TSO. Agreement paperwork typically takes 1-2 weeks to clear.
France	**Decree No. 2008-386**	Requires qualified electrician to install a circuit breaker with public access; electronic meters (two/bidirectional if selling electricity to the grid); and a signed agreement between the producer and the DSO that typically takes a month to clear.
Germany	**KWG-G, Kraft-Wärme-Kopplungsgesetz**	Enshrines the right for all CHP units to be connected to electricity grids.
	VDE-AR-N 4105: 2011-08	Outlines requirements for FC mCHP electricity grid connection and distributed generation integration (ie. Requirements to sell electricity to the grid). Forms G1, G2, G3, F2 and a Scheme Plan must be completed before installation. Form F1 must be completed after commissioning. Electricians require specialist training on CHP units and grid connection.
Italy	**CEI 0-21**	Defines the criteria for domestic electrical installation of FC mCHP units, including how to complete a compliance certificate for electrical installation.
	CEI 64-8	Outlines specific requirements for connecting CHP units to the grid: a circuit breaker and a bidrectional smart meter (which must be installed by DSO

[15] PACE – D5.3 CHALLOCH ENERGY and Ene.Field Reports

		personnel). An agreement must also be completed between the DSO and producer (on average this takes 20 days to complete).
UK	**EREC G83/2**	Requires electrician to be certified under the Microgeneration Certification Scheme (MCS). Installation operates on a 'fit and inform' basis through which unit is connected to the grid and then DSO is informed afterwards (a 'G83 notification'). The FC mCHP unit must be certified under the Microgeneration Certification Scheme.

A standardisation and simplification effort so that administrative steps follow similar procedures across Europe could provide an important drive to facilitate the deployment of the technology. This has been key for heat pumps, that despite having a larger impact on the grid than FC mCHP[16], are treated as any other household appliance, requiring no declaration to the grid operators. On the contrary, FC mCHP are classified as generators, forcing more stringent requirements (such as grid impact studies) despite their lower impact in the case of typical residential units (<2 kWel). **If FC mCHP are to be treated as generators, the administrative steps should be standardised and simplified.**

A more favourable situation is seen on the gas grid connection requirement, as shown in the examples of Table 3. In this respect, **FC mCHP are treated as any other gas appliance** such as boilers.

Table 3 – Regulations governing FC mCHP gas grid connection in 5 European countries[17]

Country	Regulation Name	Regulation Description
Denmark	**Gasreglementet**	Same requirements for FC mCHP gas grid connection as a conventional boiler – must be undertaken by a certified plumber.
France	**Arête du 2 aout 1977; Arrêté du 30 novembre 2005**	Same requirements for FC mCHP gas grid connection as a conventional boiler – must be undertaken by a certified plumber.
Germany	**DVGW G2000 (2011)**	To connect the FC mCHP unit to the gas grid, it must be registered with the gas grid operator by both the qualified installer and the user. Fees vary for this process as there are c. 730 different operators.
Italy	**UNI 7129 (2008) / UNI 7140 (2013)**	Same requirements for FC mCHP gas grid connection as a conventional boiler – must be undertaken by a certified plumber (compliant with CEI and UNI regulations).
UK	**Gas Safety Regulations (1998)**	Same requirements for FC mCHP gas grid connection as a conventional boiler – installer must have undertaken a CCN1 Gas Safety Assessment and be on the Gas Safe Register.

[16] A typical electrical load of a heat pump for a single-family home is 1.7kW
[17] PACE – D5.3 CHALLOCH ENERGY and Ene.Field Reports

5.2 – Case Study: Installation processes across Europe and the Belgian grid connection code C10/11

As demonstrated above, the inconsistency and lack of standardisation leads to a large variety in how efficient and streamlined the installation process is. However, the PACE report D5.3[18] offers a useful overview of which countries are considered the best- and worst-case scenarios for each step of the installation process. On that basis, this section will give an overview of the most relevant processes and the prevalent answers from OEMs reported in the report.

	Best-case scenario	Worst-case scenario
Electrical installation	**United Kingdom** - **no notification to the DNO is required** when the power output is below 2 kWel.	**Austria and France -** no specific requirement, with the responsibility to develop a process **delegated to the DNO**. This can therefore result in having a simple and efficient 'fit and inform' process, as well as complicated and inefficient systems involving many parties.
Parties involved in the process	**Belgium and the Netherlands** - only having **1 party.**	**Germany** - a minimum of 3 parties involved to **a maximum of 6-7 parties.**[19] **Austria** - from 2 parties to 5 parties (delegation to the DNO).
Bureaucracy (forms to be filled by customers)	**Austria** - **0 forms** are needed, only a registration on the DNO platform is required.	**Germany** - from 5 to more than 11 paper forms are required
Number of visits required by DNO	**UK** - 0 to 1. **Austria** - only 1.	**Germany** - from 1 or 2 in the best case to 5 for the worst case. **Belgium** - 2 to 3 visits.
Overall time to install (as a result of the issues outlined above)	**Germany** – usually 2-5 days **Belgium** - 2-3 day.	**UK (2 days – 3 months).**

[18] PACE – D5.3 CHALLOCH ENERGY: Executive Report & Conclusions
[19] It is worth noting that despite this inefficiency, Germany has the largest number of FC mCHP in Europe, stressing again the importance that incentives described in Pillar 1 can have.

This clearly outlines how the inconsistency and unnecessary inefficiency of the process affects the final customer, who might be stopped by the possibility of long waiting times and prefer competing technologies such as heat pumps or gas boilers.

Another example of issues arising from different implementations of the norms is given by the recent Belgian grid connection code C10/11. This recent modification required all generators to reduce active power at over frequency at a frequency threshold (50,2 Hz and 50,5 Hz) according to a droop (between 2% - 12%). This requirement also applied to units with power between 0 W and 800 W, despite the European grid code does not includes this units. This change could potentially bring hundreds of FC mCHP already installed to fail the homologation, and re-design for compliance would impact performances. While a derogation for FC mCHP systems has been agreed to allow units randomised disconnection, this is an example how national implementation diverging from European directives can affect the deployment of the technology and reduce confidence in the market. This issue led to a significant barrier within the Belgian FC mCHP market as, while discussions were ongoing, the sales and deployment of units was severely limited. Although only a temporary block, it is likely to have also led to a significant drop in confidence in the market for both consumers and manufacturers, resulting in a longer lasting barrier to FC mCHP technology.

5.3 – Recommendations to address barriers identified

The following recommendations were identified to unlock further opportunities in the short term:

- Advocate for best practice scenarios for procedures when DNO connecting FC mCHP to the grid (administrative forms).

Opportunities for stakeholders to address barriers in the longer term are summarised below:

FC mCHP stakeholders	Member State	European policy makers
• Provide best practice examples of paperwork forms and processes	• Implementation of Directive EN 50549:2019, avoiding the implementation of more restrictive requirements • Considering exempting FC mCHP <5 kW from generators regulations and grid impact assessments	• Promote standard paperwork forms and processes for all member states • Equate FC mCHP to Heat Pumps in regard to grid impact

7. Pillar 4: Building Standards

Chapter Summary

The building standards regulatory barriers to FC mCHP are as follows:

- The potential for FC mCHP technology to operate on green gases (e.g. green hydrogen and biomethane) is unrecognised in regulation;
- FC mCHP units are often unfairly penalised in regulations using calculations of the carbon intensity factor of different low-carbon heating options.

The case study of CO_2 emissions from a typical German household shows that electrification of heat doesn't necessarily deliver the best solution in terms of emissions reductions.

Key recommendations to address these barriers were identified:

- Engage potential prosumer highlighting advantages of the system vs separate heat+power.
- Include FC mCHP in technologies under EED Energy Savings Obligation.
- Implement EPBD taking into account cost-effectiveness and emissions reduction of FC mCHP.
- Promote emission counting methodologies assessing the combined effect of heat and power production.
- Provide a level playing field for technologies supporting different scenarios for decarbonising the building sector.

6.1 – Pillar Outline

The fourth pillar addresses **requirements related to the building sector,** especially with respect to the **Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD).** These directives promote policies to achieve a highly efficient and decarbonised built environment by 2050, considering climatic conditions and cost-effectiveness. However, the generic and sometimes simplified approach taken means **the potential benefits of FC mCHP systems are not recognised and the technology is not supported on equal measure with other low carbon technologies.**

At the European level, both energy efficiency and renewable energy are promoted to decarbonise the building sector. However, **a significant focus has been put on the electrification of heat, with some** countries such as the Netherlands and the UK **contemplating a full electrification** of heat via heat pumps, **even though this is not the most cost-effective approach** (and would therefore go against the cost-effectiveness principle enshrined in the directives). A study conducted by Policy Exchange on the UK provided evidence that a balanced strategy involving improvement on energy efficiency, efficient gas appliances and greener forms of gas could achieve an 80%+ reduction in emissions compared to a strategy based on full electrification of heat,[20] implying that other routes should be investigated.

Additionally, a full electrification strategy would increase substantially the electricity demand, **requiring costly grid upgrades**. FC mCHP have a double benefit in this respect, reducing the need for electricity for heat and reducing the need for network upgrades as they can provide ancillary services. In this respect, the ene.field project showed how a mix of heat-pumps and mCHP could offer the cost-optimal solution to ensure stability and reliability at times of peak demand.[21]

While FC mCHPs offer today significant CO_2 reduction, they are expected to support the transition of the energy system to integrate more renewable energies, and once this is achieved, allow even further CO_2 savings:

- **FC mCHP running on natural gas today already allow significant CO_2 abatement** as they produce low carbon heat and electricity, **reducing the electricity demand of households and commercial buildings while providing heat**. These savings are especially significant in countries with low penetration of renewable energies, resulting in CO_2 intensive electricity grids. Today, the carbon intensity of the EU gas grid (202 g CO_2/kWh[22]) is lower than the carbon intensity of the EU electricity grid (295 g CO_2/kWh[23]). This will remain the case for the countries that are the less advanced on the decarbonisation pathway until 2030, such as Bulgaria, Poland or Czech Republic where a path to coal phase-out has not yet been decided.[24]
- Even for countries more advanced on the renewable electrification pathway, **the majority of the heat demand in Europe will remain in the foreseeable future – because of existing buildings relying on the gas grid in areas less well-suited to heat networks and electrification.** These will need to be decarbonised through other means. This will require decisions to be made on whether the demand will be met through a low carbon electricity grid, a low carbon gas network or a combination of the two in a hybrid approach. This decision will have an important impact on the nature of the future electricity system, and on the ongoing viability of the gas distribution system. It is expected that eventually the carbon intensity of the EU electricity grid will have decreased significantly, as it is currently decreasing at a rate of 2.1% per year[25]. At the same time, we can also expect the carbon intensity of the EU gas grid will also decrease. FC mCHP can help alleviate the increase in the peaks in demand

[20] Richard Howard and Zoe Bengherbi „Too Hot to Handle? How to decarbonise domestic heating", Policy Exchange, 2016
[21] Pudjianto, Djapic and Strbac. Benefits of Widespread Deployment of Fuel Cell micro-CHP in Securing and Decarbonising the Future European Electricity System, ene.field, 2017
[22] IPCC, 2008
[23] https://www.eea.europa.eu/data-and-maps/data/co2-intensity-of-electricity-generation
[24] beyond-coal.eu
[25] https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-3/assessment

from the electricity grid while it manages the transition to increased integration of intermittent renewables and builds up the necessary supply capacity (resulting from increasing electric heating and also electrification of transport), while still delivering significant CO_2 savings.
- **Policy makers are today considering different options to decarbonise the gas grid,** with the main options being **biomethane and hydrogen**. In both situations, **FC mCHP would work with no or minimal technical upgrade**, adding the benefit of having a future-proof technology that will have even lower emissions when the gas grid will be decarbonised. This is currently not recognised in the regulations, penalising the technology by neglecting the potential for emissions reduction today and in the future.

An **additional issue is found in the implementation of the EED.** While at European level high efficiency cogeneration – including mCHP – is recognised as an energy efficiency principle, at a national level the implementation of the EED **has often neglected mCHP, failing to promote its introduction and simplify the grid connection procedures.**

Additionally, the Directive promotes energy efficiency through **Energy Savings Obligation**s on Member States, which requires the reduction of the final energy by 1.5% every year. **The current methodology** used to evaluate eligibility under the Energy Savings Obligation **doesn't recognise FC mCHP** because despite delivering primary energy and improving the system efficiency, they do not reduce final energy. **This creates a distortion by which competing technologies such as heat pumps or condensing boilers are recognised and favoured**, therefore failing to create a level playing field between competing efficient energy technologies.

To illustrate the benefits outlined above and demonstrate the need for a level playing field between FC mCHP and competing technology, a case study comparing the carbon intensity under different assumptions is presented in the next section.

6.2 - Case study : Environmental benefits of a FC mCHP (1-family German house)

To illustrate the potential reduction in emissions provided by FC mCHP, an analysis carried out by Roland Berger Strategy Consultants in their report[26] commissioned by FCH JU assessing fuel cells in distributed generation, is presented here.

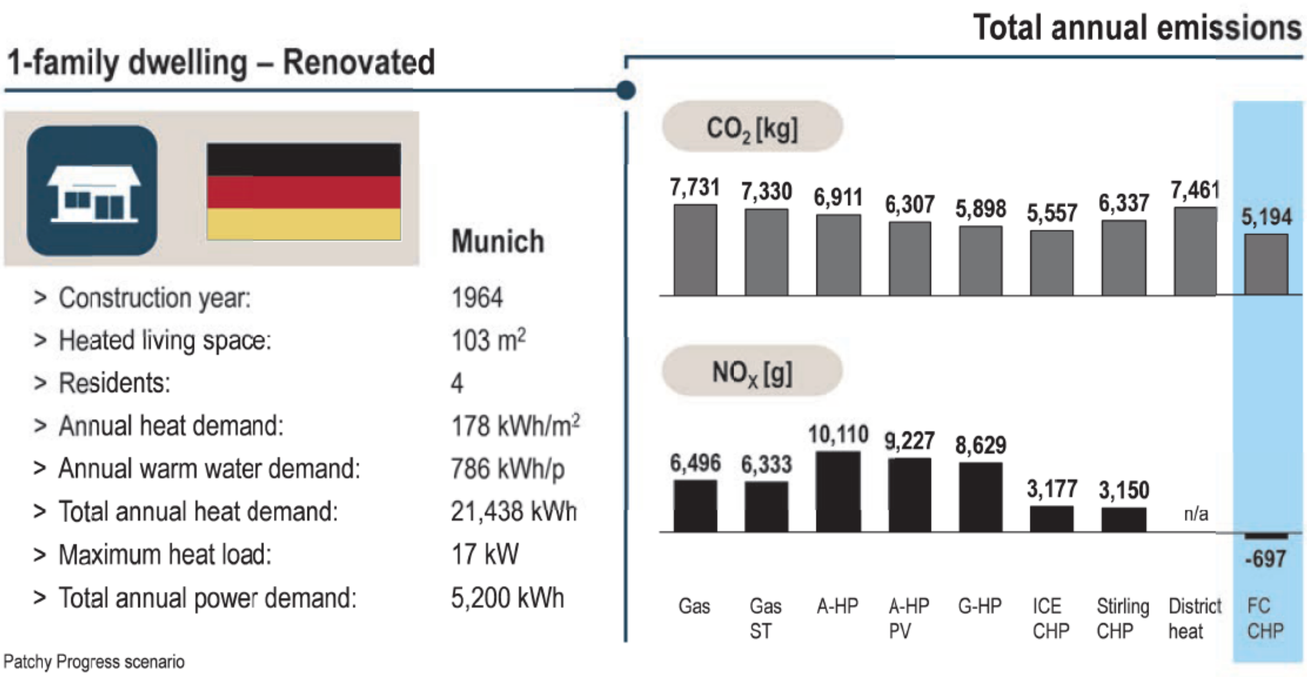


Figure 4: Environmental benchmarking in a 1-family German house. Reproduced from [24]

This will show the issue of carrying out a technical assessment to evaluate the environmental benefits of energy efficient technologies by just considering the single units individually - so for example by comparing the emission of a heat pump and a mCHP - failing to have a more holistic approach and assessing the impact of the units in the whole system, especially considering that a FC mCHP provide both electricity and space heat, while a Heat Pump only provides heat.

The analysis presented by Roland Berger assesses the needs for heat and electricity of applications in different scenarios, and calculated the resulting emission for the whole system. With this approach, three components are considered to assess the environmental benchmark: the fuel consumption (natural gas), the attributed emissions from the grid electricity consumption, and the emissions savings given by the electricity production. An example is shown in Figure 4 for a German house. The

[26] Roland Berger Strategy Consultants, Advancing Europe's energy systems: Stationary fuel cells in distribuited generation. FCH JU, 2015

total annual emissions result is lower when FC mCHP are used, and this is mainly due to the electricity production which allow to reduce or eliminate the electricity bought from the grid. This carries a carbon footprint depending on the power mix, which needs to be considered when compared to a FC mCHP producing electricity.

As an example, the same report compares the emissions offered by several technologies (Figure 5), clearly showing the impact that the energy provided from the grid can have on the overall emissions.

From Figure 5 is also clear how the national power mix emissions determine to what extent fuel cell power production from gas is attractive.

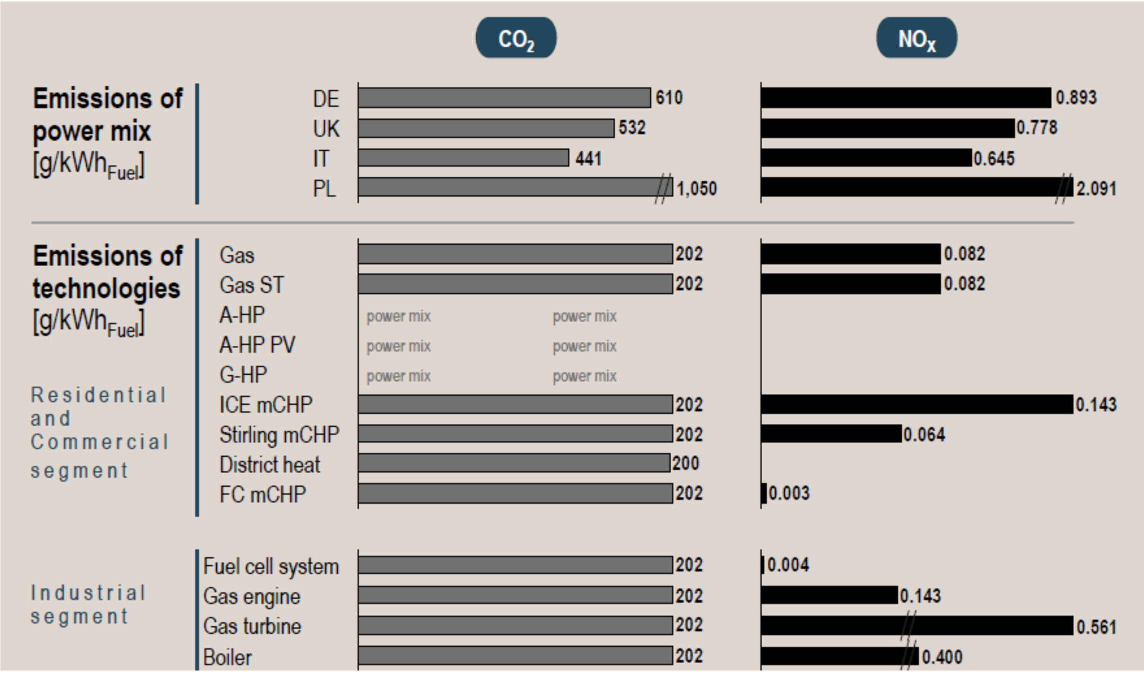


Figure 5: Power generation mixes and technology emission factors for the four focus markets as of 2014. Reproduced from [24].

6.3 – Recommendations to address barriers identified

The following recommendations were identified to unlock further opportunities in the short term:

- Disseminate the advantages of FC mCHP in terms of carbon reductions when the combined electricity and heat production are considered.
- Disseminate the advantages of FC mCHP as a future-ready technology.

Opportunities for stakeholders to address barriers in the longer term are summarised below:

FC mCHP stakeholders	Member State	European policy makers
• Engage potential prosumer highlighting advantages of the system vs separate heat and power	• Include FC mCHP in technologies under EED Energy Savings Obligation • Implementation of EPBD taking into account cost-effectiveness and emissions reduction of FC mCHP	• Promote emission counting methodologies assessing the combined effect of heat and power production. • Provide a level playing field for technologies supporting different scenarios for decarbonising the building sector.

8. Pillar 5: Customer Information

Chapter Summary

The barriers to FC mCHP uptake related to customer information are as follows:

- Unfounded penalisation of FC mCHP technology in primary energy factor calculations made for regulation concerning unit labelling;
- Regulation that leads to labelling of FC mCHP units that fails to recognise their true energy efficiency and decarbonisation potential.

The case study of the ErP Lot1 energy labelling directive shows that the methodology used can affect greatly the energetic class assigned to mCHP, affecting their uptake.

Key recommendations to address these barriers were identified:

- Continue monitoring FC mCHP performances to build a strong set of data to back-up energy labels decisions.
- Build a data-collection infrastructure to be used for future revisions of EL/ED directives.
- Implement labelling methodologies fully taking into account system integration.
- Ensure labelling provides exhaustive information to customers on savings and building efficiency.

7.1 – Pillar Outline

This pillar will address the regulatory issues involving the information provided to the customers willing to purchase a solution to provide heat and electricity for their needs. The energy efficiency of Energy-related products (ErP) is currently regulated by the Commission Regulation (EU) No. 813/2013 (Ecodesign), aiming to reduce the environmental impact of such products and regulate the energy consumption throughout their entire lifecycle, and the Commission Regulation (EU) No. 811/2013 (Energy Label), which promotes the most energy efficient products and uses a harmonised labelling system throughout the EU.

ErP are grouped into Lots, with FC mCHP being part of the space heaters Lot – also called Lot 1 – together with gas boilers, heat pumps and solar thermal systems. The rules on eco-design and labelling are periodically reviewed for each Lot to take into account technological progress and gradually phase out the least efficient products on the market, with most recent review being discussed in the Consultation Forum in the spring of 2021.

For space heaters, the seasonal space heating ηs is calculated, and a corresponding class is assigned.

class	Seasonal space heating energy efficiency ns in %		Class width (in %)		Examples of typical appliances
	TIER 1 (pef 2.1)	NEW TIER2, from 2026 (pef 2.1)	TIER 1	TIER 2	TIER 2
A+++	ns ≥180				
A++	140 ≤ ns < 180		25		
A+	99 ≤ ns < 140		27		
A	90 ≤ ns < 99	ns ≥205	8		void
B	82 ≤ ns < 90	166 ≤ ns < 205	8	40	ASHP(+), GSHP(+), mCHP(+)
C	75 ≤ ns < 82	143 ≤ ns < 165	7	23	ASHP(0), GSHP(0), mCHP(0), TDHP(+)
D	43 ≤ ns < 75	123 ≤ ns < 142	39	19	ASHP(-), GSHP(-), TDHP(0), HYB(+)
E	39 ≤ ns < 43	106 ≤ ns < 122	2	14	SOL(0), HYB(0), mCHP(-), TDHP(-)
F	35 ≤ ns < 39	87 ≤ ns < 105	4	18	HYB(-), Condens(-/0/+), SOL(-)
G	ns < 35	ns < 87			EL, non-condens

Figure 6: Energy label classes for all central space heaters except low-temperature heat pumps, NOW (to maintain in Tier 1 but pef-corrected) and NEW TIER 2 (2026 and beyond) proposed. Reproduced from the VHK-Delft (NL) report[25].

Figure 6 is reproduced from a recent report commissioned to VHK and TU Deflt by the EC[27] in preparation of the next review and it represents the proposed energy classes for each efficiency.

The new Tier 2 labelling system, in force from 2026, will rescale the available energy classes, moving from a scale A+++/G to a scale A/G, with revised efficiency levels.

The main issue related to labelling directive in respect of FC mCHP is their failure in recognising the primary energy savings delivered by this technology. FC mCHP represent a key mitigation technology as it can reduce CO_2 emissions by more than 30% compared to a conventional boiler,[28] as well as offer substantial gains by reducing the primary energy consumption and reduce transmission losses, resulting in a reduction of the primary energy needs in the order of 25%.

[27] VHK - Draft Interim Report on Central Hydronic Space Heaters WG 1/2/3 (Dec 2020)
[28] Advancing Europe's energy systems: Stationary fuel cells in distributed generation, FCH JU Study, 2015. 30% less CO2 emissions for a partially renovated single-family house in Germany under the current power mix

This is particularly important to consider when pursuing an electrification of heat. While high-efficient appliances normally result in a reduction of electricity demand, in the case of heat, regardless of the energy class, an electrification will lead to an increased demand.

While labelling needs to be a homogeneous tool allowing customers to compare products by being able to make informed decisions, it is clear how two competing needs make the methodology very crucial. On the one hand having mCHP solutions in the space heaters category allows customers to compare them with alternative solutions to heat their homes, on the other hand, not taking appropriate account of the reduced consumption of energy from the grid will not show the real value in terms of savings and avoided emission to the customer.

To illustrate the issue more into details, the current methodology used by the European commission and the widely industry-used EN 50465 methodology will be compared in the next section.

7.2 – Case study: Impact of methodology on energy efficiency ratings

This section will compare two different methodologies used to assess the energy efficiency of FC mCHP. The current and proposed methodologies used by the directives will be compared against the standard EN 50465 widely used in industry, to show the differences and highlight the substantial effect that choosing the appropriate methodology for assigning the energy label can have.

$$\eta = \frac{\text{Heat output} + \text{PEF}\cdot\text{electricity output}}{\text{Gross calorific output of fuel}} \quad (1)$$

The current methodology is shown in Formula 1 and it calculates the efficiency of FC mCHP as a ratio of the heat output and the calorific value of the fuel, where the first term is adjusted with a fixed factor (currently PEF= 2.5) to take into account the primary energy displaced by the generation of electricity. While the avoided electricity from the grid is taken into account, a primary energy factor of 2.5 is an average value based on EU-28, Eurostat/ENTSO-e 2015 statistics[29] and as a result fails to take into account the seasonality and specific electricity mix available during the heating season.

A different approach to calculate the efficiency is widely adopted by FC mCHP manufacturers, and it uses the EN 50465 standard. In this case, the bonus for the avoided electricity used is taken into account in the denominator of the calculation:

[29] The Research Center for Energy Economics - EU Displacement Mix, A Simplified Marginal Method to Determine Environmental Factors for Technologies Coupling Heat and Power in the European Union, COGEN, 2018

$$\eta = \frac{\text{Heat output}}{\text{Heat input} - \text{Primary heat avoided for electricity}} = \frac{\eta_{\text{thermal}}}{1 - 2.5 \cdot \eta_{\text{electrical}}} \quad (2)$$

This has been further improved with the proposed 2018 revision which introduces the concept of Specific Energy Consumption (SEC):

$$\text{SEC} = \frac{\text{Net heat input}}{\text{Heat output}} = \frac{\text{Heat input} - \text{Primary heat avoided for electricity}}{\text{Heat output}} \quad (3)$$

which is being proposed to be used instead of space heating efficiency as the new calculation and communication vehicle for the ErP.

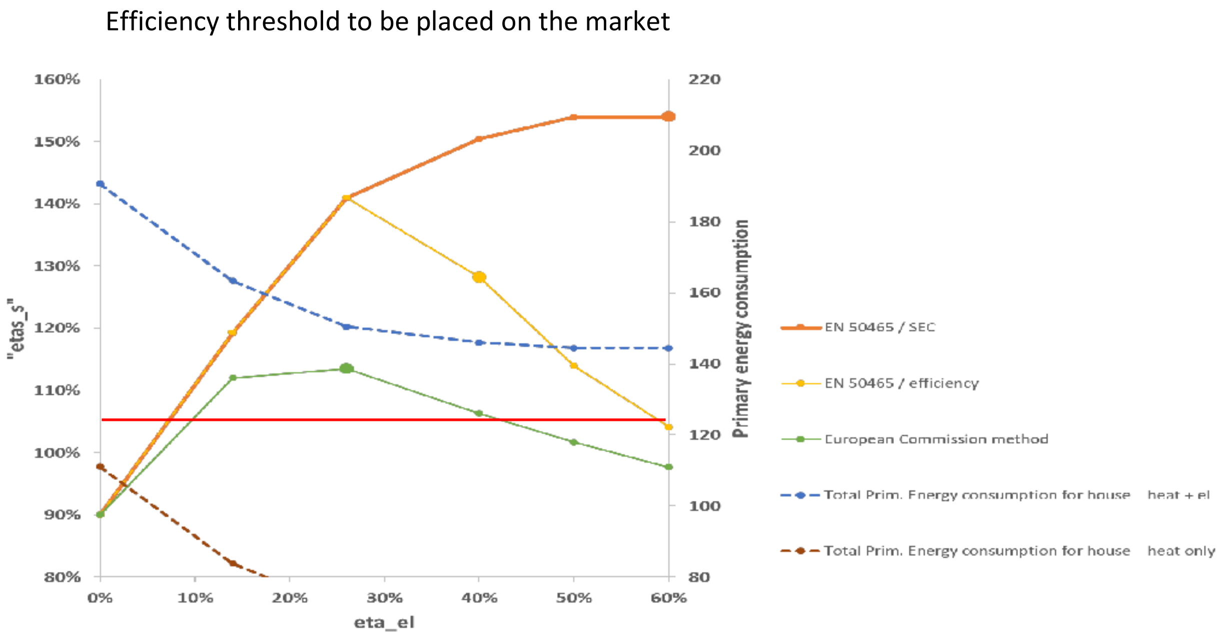


Figure 7: Comparison between the results obtained by the two methods analyzed with respect to the electrical efficiency of the FC-based microCHP device using a PEF factor of 2.65. Reproduced from COGEN Europe .[30]

The effect of the different methodologies can be seen in Figure 7, comparing the simulated efficiency and SEC for FC mCHP having different electrical efficiencies. It is immediately clear how different approaches deliver a large difference due to the different way the primary energy in the calculated efficiency. As a result, the energy class assigned to FC mCHP could vary a lot, penalising the technology depending on the formula used. This could create an artificial promotion to customers of alternative solutions that could deliver the same energy and cost savings, failing to deliver a label that

[30] PACE WP3 (COGEN Europe)

can be of real use for final users. More importantly, some appliances risk being taken out of the market for not reaching 100% minimum efficiency, market by the red line in Figure 7.

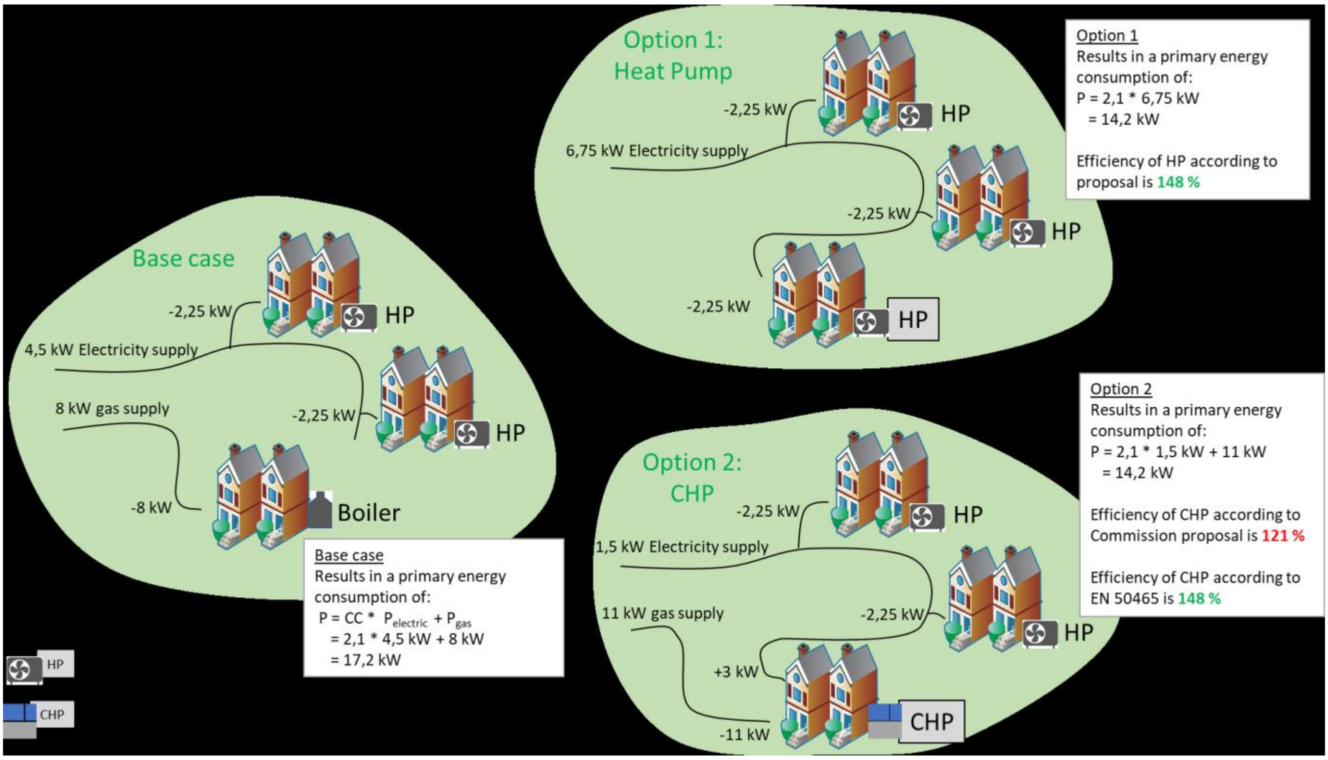


Figure 8 Comparison of primary energy consumptions using a boiler, heat pump or mCHP. Reproduced from COGEN Europe

This distortion is clear when considering the comparison against labelling for heat pumps, as shown in the example of Figure 8[31]. The picture shows the resulting primary energy consumption of three different scenarios.

The base case consists of two houses heated by a heat pump, requiring a power of 2.25 kW each, and a third house using conventional boiler, requiring 8 kW gas supply. Considering a Conversion Coefficient (CC) of 2.1, the total primary energy consumption is 17.2 kW.

The Option 1 represents the same situation, with the third house replacing the boiler with a conventional heat pump. The 8 kW gas supply is now replaced by a 2.25 kW electric supply, and again with a CC of 2.1 the total primary energy consumption is 14.2 kW. The current efficiency of a heat pump with such performance would be 148% according to the proposed methodology for Lot1.

[31] PACE WP3 (COGEN Europe)

The Option 2 shows again the same scenario, where the boiler of the base case has been replaced with a CHP unit. To perform similarly, the CHP would consume 11 kW of gas, which would satisfy the electricity and heating need of the house, and feed 3 kW of surplus electricity into the grid. The total primary energy consumption would be again 14.2 kW. However, while the EN 50465 methodology would label a mCHP unit with this performance with a value of 148%, the current proposed methodology for Lot1 would assign a value of 121%, despite the same final value of primary energy consumption.

There are a number of proposed solutions to this issue and discussions to solve it are ongoing. Within the PACE project, it has been proposed to reject the EC proposed methodology as it does not recognise the full benefits of FC mCHP units. The three principal proposed solutions are as follows: Option 1 is to not apply the proposed micro-CHP method to avoid that micro-CHP solutions are misrepresented to consumers and lose access to funding schemes; Option 2 is to use the “high efficiency CHP” methodology in the Energy Efficiency Directive to assess energy savings from micro-CHP systems in the context of Lot1 Energy Labelling and Eco-design Regulations; and Option 3 is to propose an energy label for micro-CHP within Lot1, reflecting the energy and cost savings delivered by micro-CHP systems, based on the EED method, as well as the total, electricity and thermal efficiencies. The position of the PACE project consortium is to not accept the proposed EC methodology, although discussions regarding a solution to this are still ongoing.

7.3 – Recommendations to address barriers identified

The following recommendations were identified to unlock further opportunities in the short term:

- Continue dialogue between EC and stakeholders to address issues arising from ED/EL reviews

Opportunities for stakeholders to address barriers in the longer term are summarised below:

FC mCHP stakeholders	European and national policy makers
• Continue monitoring FC mCHP performances to build a strong set of data to back-up energy labels decisions.	• Build a data-collection infrastructure to be used for future revisions of EL/ED directives. • Implement labelling methodologies fully taking into account system integration. • Ensure labelling provides exhaustive information to customers on savings and building efficiency.

9. Conclusions and Further Work

9.1 – Conclusions

The primary objective of the PACE project is to further the commercialisation of FC mCHP technology and this report has aimed to aid in this by identifying key structural barriers to the uptake of FC mCHP across Europe. The Regulatory Barriers Working Group within the PACE project has worked to not only identify these barriers, but to also consider best and worst practices across Europe and suggest new solutions.

Five key pillars have been identified as restricting the uptake of FC mCHP: financial incentives, electricity tariffs, grid connection, building standards and customer information. As there is no single European Union Regulation that governs the use of this technology, there is notable variation between EU member states in regards to regulations across the five pillars and this lack of standardisation is, in itself, as significant barrier for FC mCHP technology.

The primary barriers relating to financial incentives (Pillar 1) are that no common subsidy scheme exists to assist FC mCHP commercialisation in Europe and that subsidy schemes with targets that could be met using FC mCHP technology currently do not consider it eligible. This lack of financial incentives greatly limits the number of consumers able to invest in FC mCHP, and therefore is holding back the technology's development. The KfW 433 CAPEX subsidy scheme in Germany shows how governments can overcome this barrier, as this scheme has helped Germany to have the largest number of installed FC mCHP units in Europe and has supporting deployment in other European countries.

The second pillar concerns electricity tariffs. Electricity tariff regulations can act as a barrier to the uptake of FC mCHP as they prevent FC mCHP units from achieving additional revenue streams by providing high value export services such as grid frequency balancing. The key barriers being that different incentives for the export of electricity to the grid exist in different countries and that the process for reaching an agreement to export electricity is long and arduous.

The grid connection regulatory barriers to FC mCHP (Pillar 3) are that the process for connecting FC mCHP units to the grid needs to be simplified and standardised, and that evolving grid code standards can impact the ability to deploy FC mCHP. The case study for this pillar revealed how a lack of standardisation and constantly evolving grid codes across European states brings uncertainty in the process and in FC technology in general. This results in the favouring of competing technologies that have simpler and greater standardisation in codes across Europe.

The regulatory barriers relating to building standards (Pillar 4) are that the potential for FC mCHP technology to operate on green gases is unrecognised in regulation and that FC mCHP units are often unfairly penalised in regulations. A a case study of CO_2 emissions from a typical German household showed that electrification of heat doesn't necessarily deliver the best solution in terms of emissions reductions. The case study highlights that FC mCHP can provide better solutions for the reduction of emissions, but that current regulations do not reflect this which is therefore limiting the uptake of the technology.

The final pillar considered in this report is customer information, with the primary regulatory barriers being that there is an unfounded penalisation of FC mCHP technology in primary energy factor calculations made for regulation concerning unit labelling and that the regulation that leads to labelling of FC mCHP units that fails to recognise their true energy efficiency and decarbonisation potential. This leads to consumers receiving incorrect information and therefore greatly limits uptake of this technology.

A common theme identified throughout this report is that the lack of consistency and standardisation across member states in Europe is one of the most significant barriers to the uptake of fuel cell technology. In all five pillars considered, there is significant inconsistency across Europe. Although successful "Best Practice" examples exist for many of these barriers, no one country has successfully overcome all barriers. These extensive variations in regulations are limiting the uptake and overall success of fuel cell technology in Europe, as there is a lack of simplicity at all stages of the process.

9.2 – Further Work

In order to overcome many of the barriers identified by the PACE working group, further work is needed and has been recommended in this report. For each of the five pillars considered, several key recommendations of further actions have been made.

To overcome the lack of common and sufficient subsidy schemes across Europe, work needs to be undertaken to include FC mCHP as a specific technology worthy of financial support. Furthermore, governments must work with national FC mCHP stakeholders to design requirements of an appropriate financial incentive scheme.

Similar work needs to be undertaken to overcome barriers relating to the export of electricity from FC mCHP units to the grid. Policy currently varies extensively across Europe and therefore lacks simplicity and consistency. The key recommendations of this report for these barriers is the mapping of all member states that have incentives for electricity export to the grid and those that require DSO agreements to understand how these vary across Europe and to support discussions with relevant stakeholders. It is important that consistency in these incentives is achieved across the continent in order to overcome this barrier.

A lack of standardisation in the processes for connecting FC mCHP units to the grid is a significant barrier, as ever-changing grid code standards are affecting deployment of the technology. Several key recommendations have been made by the working group to address these barriers, including: providing best practice examples, the implementation of Directive EN 50549:2019 to avoid the implementation of more restrictive requirements and promoting standard paperwork forms and processes for all member states. As with many of the other pillars discussed, communication and consistency across Europe is essential to overcoming this barrier.

In addition to these problems, FC mCHP units are often unfairly penalised in regulations and significant work needs to be undertaken to ensure that regulations are updated to recognise the potential for FC technology. The key recommendations that have been identified to address this include: Engaging potential consumers highlighting advantages of the system, including FC mCHP in technologies under EED Energy Savings Obligation and promoting emission counting methodologies assessing the combined effect of heat and power production. It is important to ensure that customers can understand the benefits of FC mCHP while the regulations are updated. Further work needs to be undertaken to ensure that regulations are updated to fairly consider FC mCHP units and that consumers are presented with the correct information.

The final pillar considers customer information in more detail and highlights barriers such as an unfounded penalisation of FC mCHP technology in primary energy factor calculations which are used to create regulations for eco labelling. Further work that needs to be undertaken to overcome this barrier includes: continue monitoring FC mCHP performances to build a strong set of data to back-up energy labels decisions, build a data-collection infrastructure to be used for future revisions of EL/ED directives, and implement labelling methodologies fully taking into account system integration. This is an ongoing problem with regulations still being debated, so further work is needed to ensure that FC mCHP technology is correctly represented in its labelling.

In order for the barriers outlined in this report to be overcome, further actions need to be taken across all pillars. The recommendations given are a starting point for key work that should be undertaken to help limit these barriers and allow FC technology to develop further across Europe.

10. Annexes

10.1 Acronyms

aFRR - Automatic Frequency Restoration Reserve Service

ASHP – Air Source Heat Pump

BRPs - Balance Responsible Parties

CAPEX – Capital Expenditure

CC – Conversion Coefficient

CHP – Combined Heat And Power

DER – Distributed Energy Resources

DOW – Description Of Work

DSO – Distribution System Operator

EC – European Commission

EED – Energy Efficiency Directive

EPBD - Energy Performance Of Buildings Directive

ErP – Energy-Related Products

FC – Fuel Cell

GSHP – Ground Source Heat Pump

HYB - Hybrid

LPG - Liquified Petroleum Gas

mCHP – Micro Combined Heat And Power

MCS - Microgeneration Certification Scheme

mFRR - Manual Frequency Restoration Reserve

NOW - German National Organisation Of Hydrogen And Fuel Cell Technology

OEM - Original Equipment Manufacturer

OPEX – Operational Expenditure

R&D – Research And Development

RC&S – Regulations, Codes And Standards

SEC – Specific Energy Consumption

TCO – Total Cost Of Ownership

TDHP – Thermally Driven Heat Pump

TSO – Transmission Systems Operators

VPP – Virtual Power Plant

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About PACE

PACE is a major EU project unlocking the large-scale European deployment of the state of the art smart energy solution for private homes, Fuel Cell micro-Cogeneration. PACE will see over 2,500 householders across Europe reaping the benefits of this home energy system. The project will enable manufacturers to move towards product industrialisation and will foster market development at the national level by working together with building professionals and the wider energy community. The project uses modern fuel cell technology to produce efficient heat and electricity at home, empowering consumers in their energy choices.
PACE project, which stands for “Pathway to a Competitive European Fuel Cell micro-Cogeneration market”, is co-funded by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) and brings together European manufacturers, research institutes and other key energy stakeholders making the products available across 11 European countries.

For more information, visit *www.pace-energy.eu*
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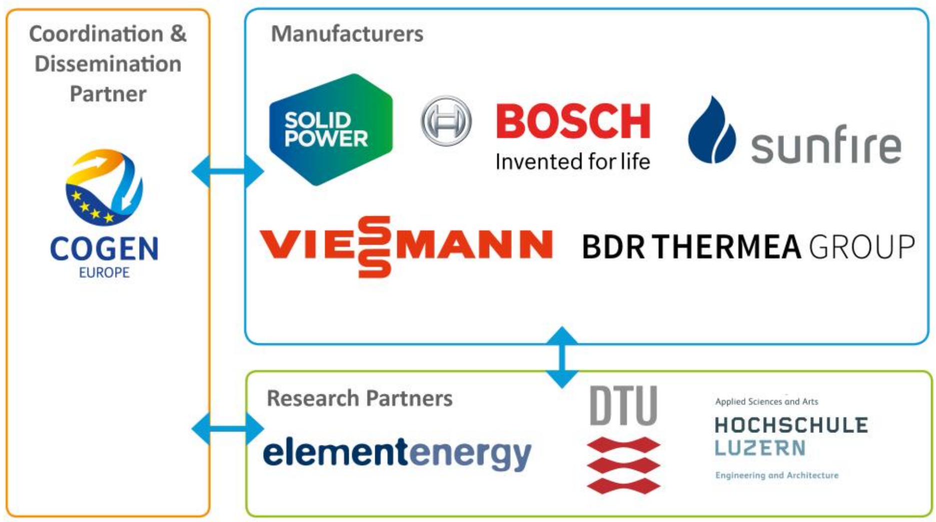
The PACE partners are



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