ene.field project

Grant agreement No: 303462

Non-economic barriers to large-scale market uptake of fuel cell based micro-CHP technology: preliminary report

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(PU – Public, PP – Restricted to other programme participants, RE – Restricted to a group specified by the consortium, CO – Confidential)

EXECUTIVE SUMMARY

The large-scale market introduction of fuel cell (FC) based micro combined heat and power (micro-CHP) systems in applications such as residential use faces a broad range of challenges, including non-economic barriers, which require special attention. This report identifies the non-economic barriers in terms of product perception by consumers or installers, policy and political environment and the performance of the system in operation and proposes actions to address them for a market uptake of FC micro-CHPs.

The market uptake of FC micro-CHPs requires a coherent, steady and predictable policy framework, which rewards the European heating sector's contribution to a more efficient, reliable and cleaner energy system, through advanced products and new business models.

Currently FC micro-CHPs are penalised by the way grid connection and grid use costs are calculated. It is suggested that these costs should in the future reflect that CHP generated power does not use any high-voltage infrastructure.

At the national level, lengthy and bureaucratic permission procedures to connect a FC micro-CHP to gas and electricity grid can represent a real barrier to uptake. Here, inspiration can be drawn from the "install and inform" connection standard in the UK. In addition, EU member states should provide a fair reward proportional to the benefits, including primary energy savings, electricity and heat decarbonisation, as well as reduction in grid stress and integration of intermittent renewables. This can be achieved through tariffs, deemed payments, or even up-front one-off subsidy, which will reduce capital cost for interested consumers.

A higher awareness about fuel cell micro-CHP technologies among policymakers at national level would ensure a favourable regulatory framework for the further uptake of this technology.

A lack of a common framework of European standards is seen as a great hindrance to market uptake. Manufacturers point to the need to update, improve and revise a large amount of the current standards, in order to ensure consistency between them. Issues include lack of consistency between different standards dealing with similar topics and standards that refer to too general systems. The shear amount of standards that are in some way relevant to FC micro-CHP installation makes it hard for the manufacturers to keep an overview.

Lastly, it is important to identify a suitable method for the assignment of Energy Labelling of CHP systems. Calculations show that the currently used scheme penalises the FC-based micro-CHP devices when compared to competing technologies.

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1. Introduction

1.1 Aim of this work

The aim of this report is to review current non-economic barriers to mass uptake of the fuel cell (FC) micro combined heat and power (micro-CHP) technology. The report considers technical, consumer acceptance and perception, and political barriers and is based on experience from the ene.field[1] trial programme and drew on the knowledge and expertise of the ene.field project partners.
This report seeks to shed light on these market uptake barriers which are limiting the wide spread adoption of the FC micro-CHP technology. Furthermore, the authors and partners of the ene.field project seek to, based on analysis and expertise, deliver clear recommendations for actions to address these barriers at national and European level.

The market barriers discussed in this paper relate to the Installer, consumer, product performance, supply chain, regulations codes and standards, and political barriers.

Analysis of consumer and installer barriers was done by Energy Savings Trust (Andrew King), input on regulation codes and standards was delivered by Polito (Massimo Santarelli and Davide Drago) and politics analysis was supplied by COGEN Europe (Alexandra Tudoroiu-Lakavičė).

A later version of this report will include performance analysis by GWI and DBI (Frank Erler and Michael Schmidt), input on supply chain barriers by Element Energy and will have a much expanded section on consumer and installer barriers.

This report was curated and partly written by the Technical University of Denmark (Carsten Brorson Prag, Jonathan Hallinder and Eva Ravn Nielsen).

This report is a preliminary version of a more extensive work, that will be made available by the end of year 2016. Some subjects within the scope of this report rely on information which cannot be gathered at this stage in the project. This is information such as performance and satisfaction data, for a significant amount of more than one year old installations. Therefore, a comprehensive work on non-economic barriers to market uptake of the FC micro-CHP technology will not be possible at this stage. This preliminary version of the work is release in order for the information, which has already been collected and analysed, to be disseminated. It is the authors hope that this will be beneficial to anyone with a vested interest in FC micro-CHPs.

1.2 About the ene.field project

This report is a part of Europe's largest demonstration project for fuel-cell-based micro-CHP (micro combined heat and power) systems, ene.field (*European-wide field trials for residential fuel cell micro-CHP*, grant no. 303462). The aim of the project is to demonstrate small stationary fuel cell systems for residential and commercial applications. The project will deploy up to 1000 micro-CHP units in 12 EU member states. This is a step change in the volume of fuel cell micro-CHP deployment in Europe and an important step to push the technology towards commercialization. The project

1 *European-wide field trials for residential fuel cell micro-CHP*, grant no. 303462

involves 27 partners. Besides the manufacturers of the FC systems, several research institutes as well as utilities are also involved as partners in the project.

2. TECHNICAL PERFORMANCE BARRIERS

2.1 Data collection and analysis

This section will be based on technical performance data collected during the ene.field project field trails. The results, when they become available, will be based on data from units in operation, supplying an end-user with heat and power

The data being collected falls into three categories: standard monitoring, detailed monitoring and issues encountered.

All installed units are subject to standard monitoring. Here monthly data regarding gas use, heat production, electricity production, operation hours and on/off cycles is collected. 10% of the installed units are equipped with detailed monitoring capabilities. Here data regarding electricity and head production and consumption, electricity import and export, inside and outside temperature, and more is collected every 15 min. Issues encountered is reported by manufacturers and installers during installation and operation at the end-user.

All installed units are identified by an anonymous unit-ID, consisting of three letters, identifying the manufacturer and four random numbers.

All data from the individual units is transmitted to GWI and DBI. Here the data is collected and anonymised in a cleanroom process before being distributed to other partners in the project. The manufacturer of a given systems are entitled to the un-anonymised data for said system. In the clean room process the data is agglomerated based on technology type (SOFC and PEM) and normalised.

Analysis requiring un-agglomerated data will be carried out by DBI and DWI and subsequently anonymised.

2.2 Performance

The material this section will be based on is not available yet. This section will be included in the final version of this report.

2.3 Production versus end-user demand

The material this section will be based on is not available yet. This section will be included in the final version of this report.

2.4 Operation and Failures encountered

The material this section will be based on is not available yet. This section will be included in the final version of this report.

3. Consumer and installation barriers

3.1 Introduction

The following analysis provides an illustrative breakdown of results and initial analysis from the pre- and post-installation surveys gathered from the Ene.field fuel cell (FC) mCHP trial. The pre-installation survey results are intended to provide an overview of the type and range of participants taking part in the trial, both in terms of: property, incumbent heating system, environmental attitudes and future expectation from FC units. The results should not be taken as indicative of a trend in the European consumer base at large. The installer survey, whilst limited in scope, aims to provide a brief overview of the installers' feedback from installing the FC units.

3.2 Data collection and analysis

Questionnaires were used to collect information about end-user and installer expectations and experience with the FC micro-CHP technology. Data on previous and current energy use, domestic information (e.g. type of house, size and household details) were collected as well. This work was carried out to investigate demography, perceptions and behaviours in order to locate barriers to market uptake of the technology.

Three questionnaires were developed in total. One polled the installer about technical details of system and installation. The second polled the end-user on household data, expectations and data on current method of power and heating supply. This questionnaire was distributed to the end-user just prior to FC micro-CHP installation. The last questionnaire was distributed to the end-user one year after installation and polled satisfaction with the FC micro-CHP, as well as production, economics and perceived performance of the system. Household data was also verified in this questionnaire.

All questionnaires were distributed using the anonymous unit-ID (see 2.1 Data collection and analysis") and collected and stored using the online tool Questback. All data was delivered to GWI and subjected to a clean room process before being made available for use in analysis. The clean room process stripped the data of the anonymous unit-ID, and thus manufacturer identification, country and postal code in order to protect the identity of the end-user. The remaining datasets were made available to EST and DTU for analysis.

The following sections draw on the data from the pre-installation questionnaire and the installer questionnaire, as a sufficiently large number of post-installation questionnaire responses will not be available before summer 2016. Therefore, the analysis presented in the following does not lend itself well to identification of barriers. Such barrier identification will be available in the final version of this report. The analysis and data presented below is included with the objective of making it readily available to anyone with an interest even though this falls outside the scope of this report, in a strict sense.

3.3 PRE-INSTALLATION SURVEY RESULTS

Property Type

52 % of the total surveyed homes were found to be detached properties, followed by 20% semi-detached and 12 % classified as 'non-residential'. The vast majority of detached homes surveyed (47%) were built from 1976 - 2000; the other significant share (20%) were built from 2001 onwards. Of the detached properties, 60% used gas boilers and 31% used oil as their primary fuel use.

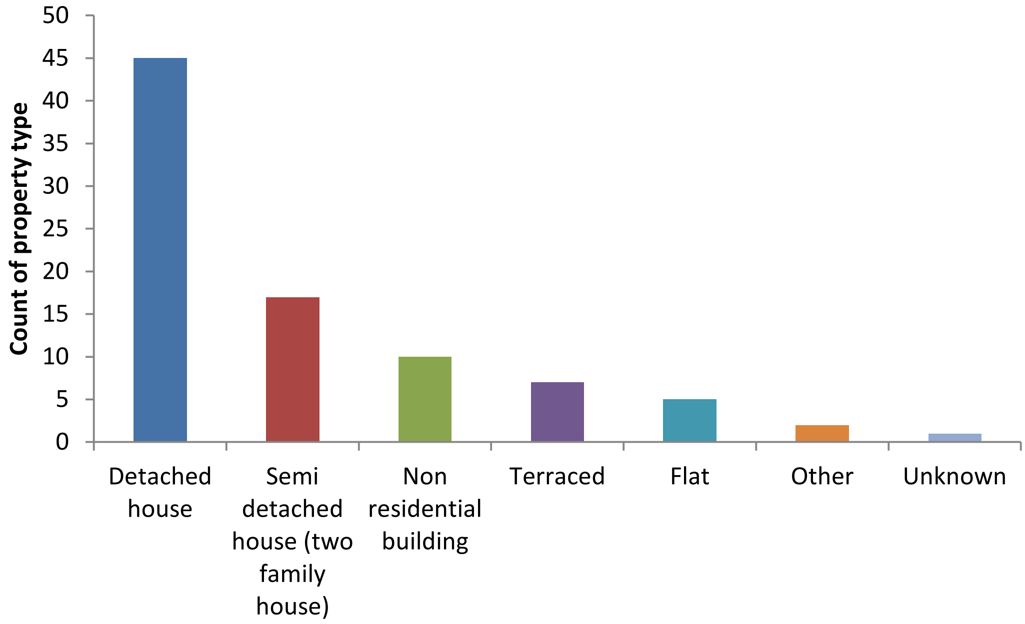

Figure 1: Count of House Type

Demographics

With respect to overall demographics, the below bar chart indicates that the vast majority of participants (56%) were registered aged from 18-59 years old.

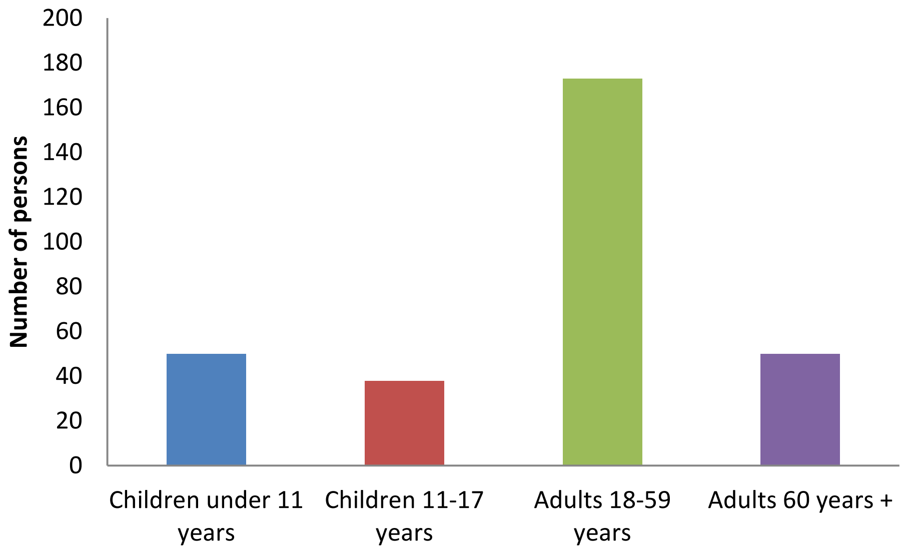

Figure 2: Breakdown of age demographics

Figure three reveals that a significant proportion of families who took part in the survey (43%) did not have any children. For families that did have children, there was a fairly even split between those considered as 'young families' (with children aged 11 or under) and more 'mature' families with children aged from 11 – 17.

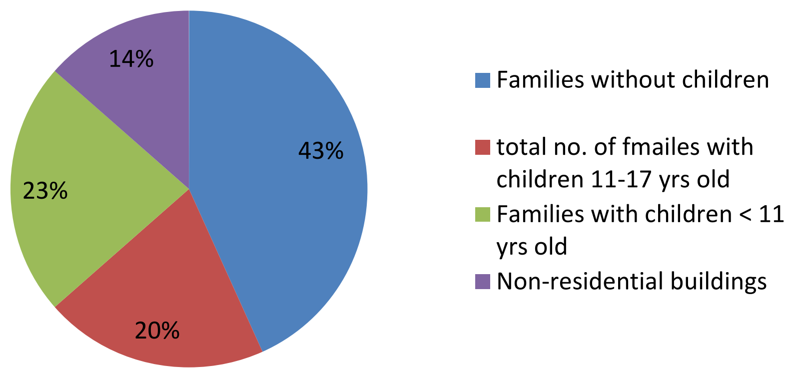

Figure 3: Breakdown of family demographics

Figure four reveals that the majority of trial participants are either working full or part-time and have at least one family member in education. The overall number of retired individuals within the trial stands at 11%; and households with only retired occupants represents 6% of total survey sample. The lower number of children in day care versus those in schools or university suggests that there are less 'nascent' families taking part in the trial.

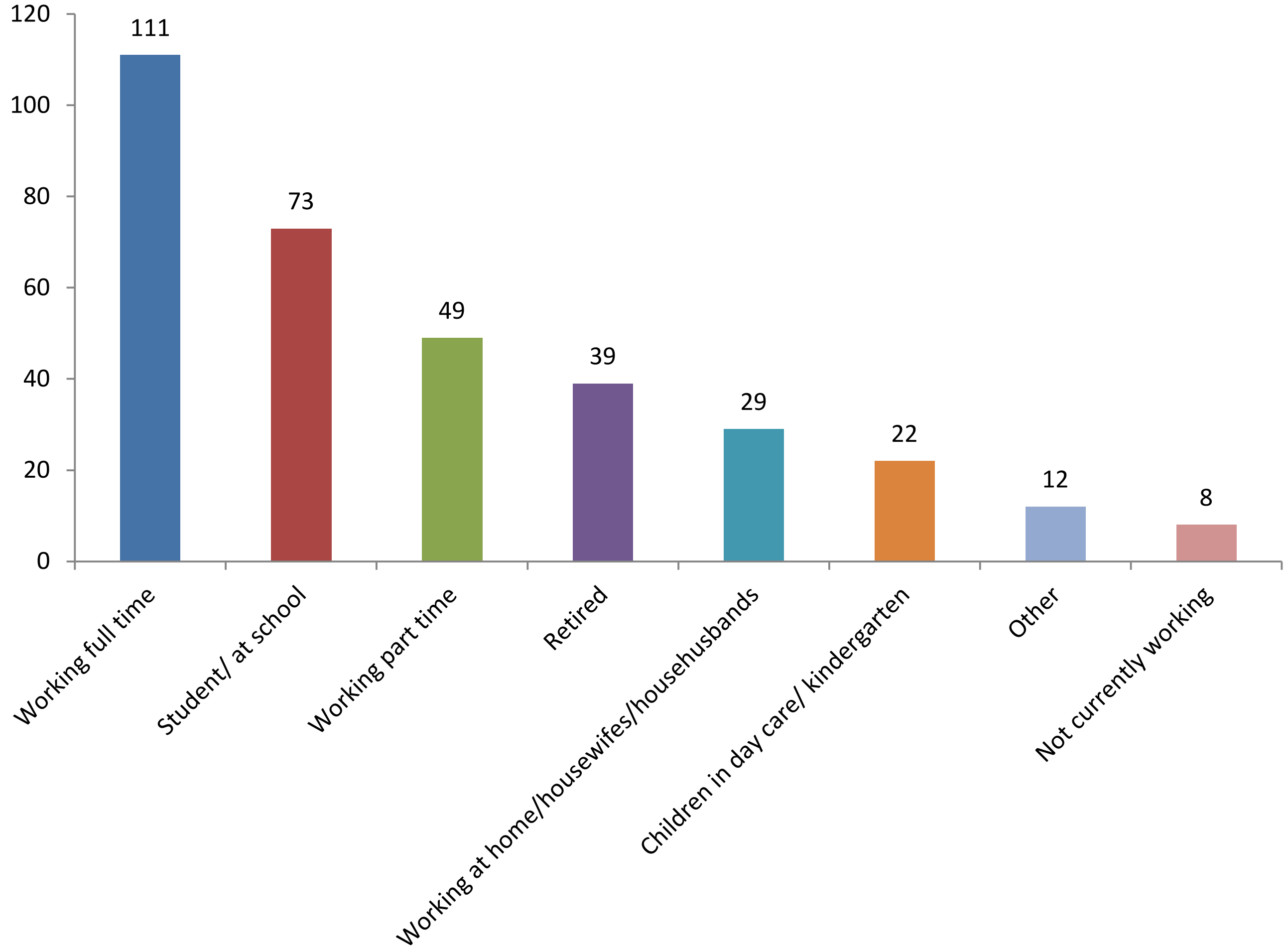

Figure 4: Employment status

The below pie chart illustrates the financial income of household in euros, before tax. Whilst the majority of those surveyed declined to state their income, the highest recorded responses were found to receive €61-€90,000 per annum. Given that the results are unable to identify the country of origin of each surveyed home, the report is unable to ascertain income levels against national averages.

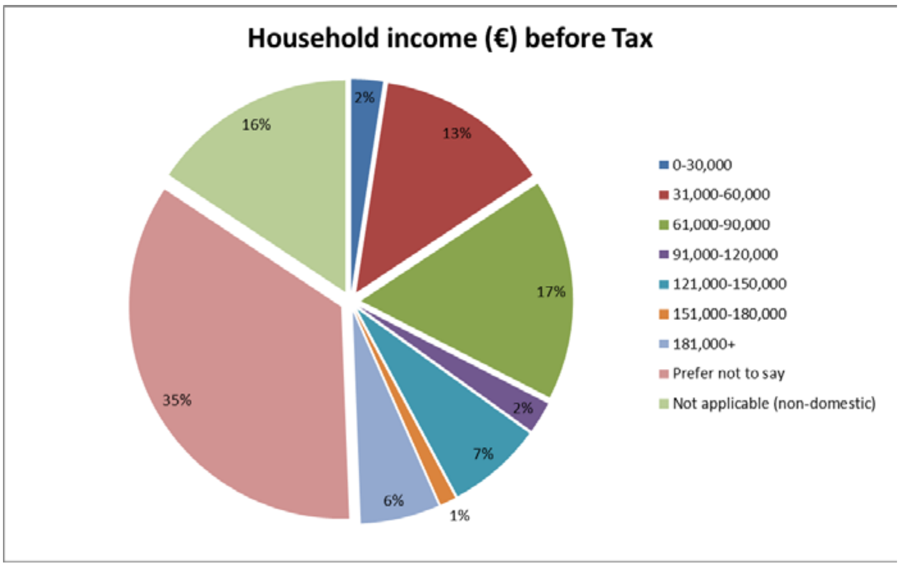

Figure 5: Household income (€) before tax

Environmental attitudes & behaviour

With zero rated as the least and five the most important – respondents were asked to rank the extent to which they are concerned about environmental issues. The results indicate that on average trial participants tend to be clearly concerned by environmental issues. These attitudes are reflected in respondents overall concern and need to reduce CO2 emissions.

Rating	Importance towards environmental issues	concern with family's carbon emissions?	Active in CO2 reduction
0	0%	8%	2%
1	1%	2%	4%
2	6%	12%	11%
3	26%	35%	34%
4	31%	27%	31%
5	36%	15%	19%

Table 1: Environmental attitudes

In reference to environmental behaviours, respondents were on average split evenly between positive and negative activities. However, recycling is noted as being particularly high amongst the survey sample.

Measure	No	Yes
recycle waste	8%	92%
compost	33%	67%
grow your own food	72%	28%
make your own clothes/goods	92%	8%
buy environmentally friendly products	42%	58%
buy local/organic food	42%	58%
reduce personal travel/use public transport	81%	19%
turn off lights when leaving a room	21%	79%
turn off appliances/gadgets when on standby	47%	53%
generally monitor energy consumption	27%	73%
re-use things, such as shopping bags	20%	80%
buy green electricity	71%	29%
buy biogas	93%	7%

Table 2: Environmental behaviour

Current heating system

When compared against typical UK values, surveyed participants revealed a slightly higher than average preferred temperature within their property, ranging from 20 – 22 degrees Celsius. However, the results are unable to ascertain whether this is an overall preferred average within the property, or within specific living areas of the home.

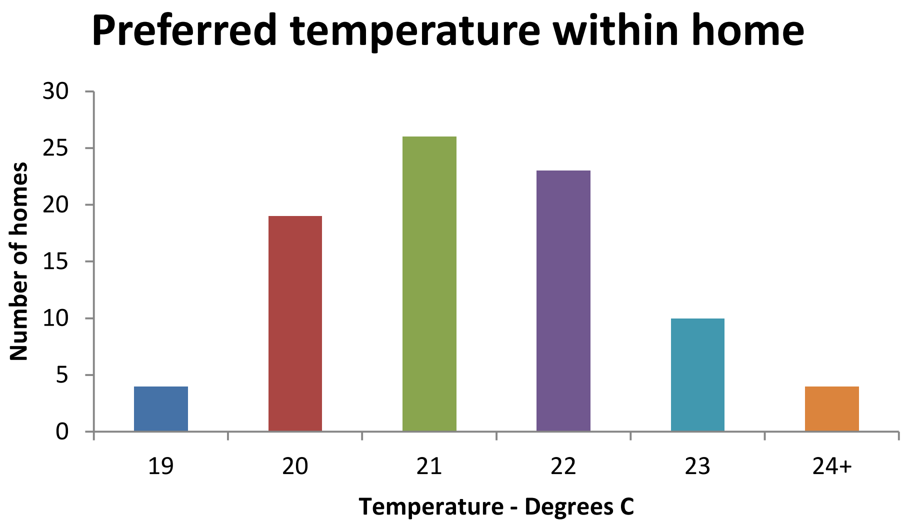

Figure 6: Target temperature – domestic homes

The breakdown of current heating systems was largely natural gas boilers, accounting for 67% of total installed units. Of the total surveyed participants, 85% of systems delivered space heating and hot water; and only 10% required back-up space heating and 14% back-up water heating.

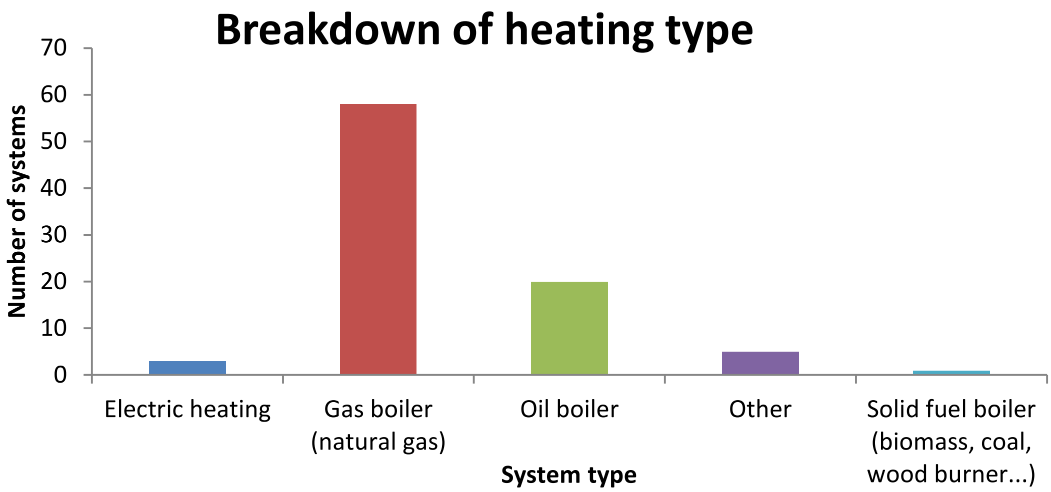

Figure 7: Heating type

Attitudes towards current and future energy

Table three details participant attitudes towards their primary space heating system. With 40 % of responses, households strongly agreed that their space heating system met their requirements. Furthermore, participants were overwhelmingly satisfied with the performance and ability to control their heating system.

Rating (0 strongly disagree - 5 strongly agree)	Meets requirements	Warm & Comfy	Ability to control heating system
0	5%	3%	3%
1	1%	1%	2%
2	9%	5%	3%
3	20%	15%	20%
4	26%	27%	27%
5	40%	47%	44%

Table 3: Attitudes towards primary space heating system[2]

Participants were equally positive about their current space and hot water heating system, both in terms of: ease of use, speed of performance and ability to provide comfort and warmth. However, running costs and environmental impacts were both noted as being of particular concern. A trend which is supported by the environmental attitudes expressed in table one.

Opinion	Comfort and warmth	Ease of use/controlability	Speed of performance	Running costs	Enviro Impacts	Reliability	cost of repair	cost of maintenance
Very dissatisfied	3%	7%	3%	10%	5%	5%	5%	3%
Dissatisfied	2%	8%	6%	23%	30%	5%	7%	6%
Neutral	16%	24%	28%	45%	40%	23%	34%	37%
Satisfied	40%	33%	38%	10%	12%	47%	36%	35%
Very satisfied	38%	28%	23%	7%	12%	17%	14%	14%

Table 4: Attitudes towards space and hot water system

Surveyed participants revealed that the highest level of satisfaction towards the incumbent space and hot water heating system were, as expected, found within the newest builds. Whilst system feedback on pre 1900 homes is also positive, properties built during this period represent only two per cent of total homes surveyed.

Rating	Pre 1900	1901-1925	1926-1950	1951-1975	1976-2000	2001+
0	0%	0%	10%	10%	0%	5%
1	0%	20%	0%	5%	10%	0%
2	0%	20%	10%	15%	21%	5%
3	0%	40%	20%	10%	28%	11%
4	50%	20%	30%	35%	24%	26%
5	50%	0%	30%	25%	17%	53%

Table 5: Property Age versus satisfaction with space and water heating system

In reference to future energy supply, the majority of residents tended to be broadly concerned about the security of future energy supply. However, in specific reference to cost, respondents were notable more concerned about an increase in energy prices.

[2] Please note that in instances in tables where columns do not sum to 100% - indicate cases where participants have not provided a response.

Rating	Concern with future energy supply	Notice future increase in energy prices	Concern with future energy prices
0	2%	2%	1%
1	7%	5%	1%
2	22%	3%	3%
3	33%	25%	28%
4	19%	26%	31%
5	16%	38%	36%

Table 6: Attitudes towards future energy

Table seven reinforces respondents' general propensity to adopt environmentally friendly attitudes, noted by a need to move away from fossil fuels. Furthermore, participants reflected both an eagerness to engage with renewable energy technologies (63%), with a further 71% stating that they consider renewable energy to be an important part of future energy infrastructure.

Rating	Very imp. Fossiul fuels are a finite resource	Renewable energy is too expensive	Renewable energy is not reliable	Renewable energy is important part of the future energy	Renewable energy technology excites me
0	1%	4%	21%	0%	3%
1	1%	13%	31%	0%	0%
2	4%	13%	15%	2%	5%
3	17%	36%	20%	2%	6%
4	21%	19%	9%	26%	23%
5	56%	15%	4%	71%	63%

Table 7: Attitudes towards renewable energy sources

Expectations from Fuel Cell mCHP

The results suggest that whilst respondents tended to be more positive about their prospective fuel cell system to meet their future heat and electricity demand; they were less positive about the fuel cell system to actually keep them warm versus their existing system.

Rating	Meet electricity demand	Meet heat demand	React to change in energy demand	Keep warmer than existing system
0	16%	15%	8%	23%
1	13%	7%	6%	14%
2	9%	6%	23%	8%
3	31%	17%	14%	16%
4	16%	15%	26%	17%
5	15%	40%	23%	22%

Table 8: Expected performance from FC mCHP unit

Table nine identified a strong belief that the fuel cell systems are expected to deliver both a reduction in energy consumption and fuel bill savings. However, in terms of reliability there was a more 'muted' response, with the majority of trial participants anticipating that their fuel cell system will be less reliable then their incumbent technology – at 21%. Furthermore, participants were less convinced about the fuel cell system to safeguard against future power outages – at 30%.

Rating	Result in decreased energy consumption	Total energy costs will decrease	More reliable vs older system	Suffer less from power outages
0	5%	2%	21%	30%
1	5%	3%	15%	14%
2	13%	10%	14%	15%
3	13%	13%	20%	19%
4	14%	20%	17%	8%
5	52%	52%	14%	14%

Table 9: Expected performance from FC mCHP unit (continued)

When broken down by fuel – homeowners on gas were less optimistic about their FC mCHP unit to meet their future heat and electricity demand versus those using oil. Furthermore, those on gas tended to be less positive about their FC unit to keep them warm compared with those on oil. Similarly, participants on oil had higher expectations that their FC unit will deliver future decreases in energy consumption.

3.4 Installer survey results

Type of fuel cell installed

To date the majority of systems installed (70%) have been SOFC system types, with a further 24% registered as low temperature PEM units.

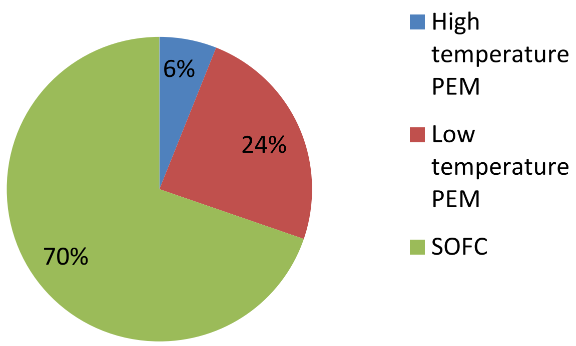

Figure 8: type of fuel cell installed

Installation time

The following three tables/figures provide an illustrative breakdown of installation times for complete fuel cell units. The majority of installed systems (38) were installed between three to five days and accounted for 20 – 29% of total installation time.

Number of days	No of installations
0-2	1
3-5	38
6-8	19
9-11	2
12-14	2
15-17	2
18-20	1
20 +	1

Table 10: Time taken (days) to install FCmCHP system

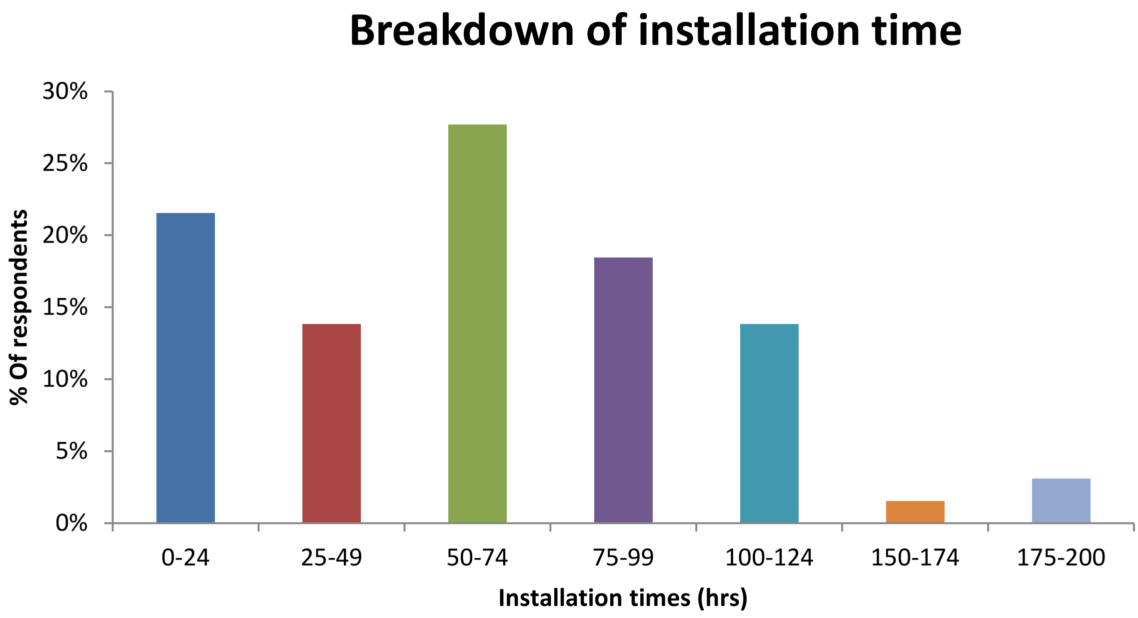

Figure 9: Time taken to install FC mCHP system (hours)

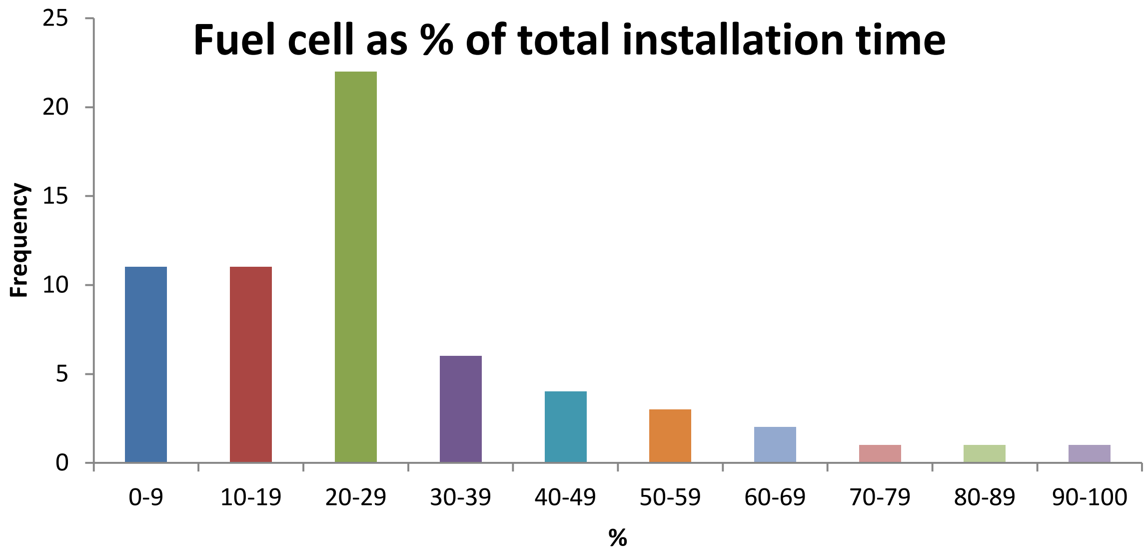

Figure 10: Fuel cell installation time as % of total installation period

Lastly, installers were asked to rank from 0 – 5 (with 0 being the most difficult) the level of difficulty when installing the fuel cell system; broken down by different stages of the installation process. However, when specifically asked to rank 'overall system installation difficulty', 82% of responses were registered between 0 – 2, indicating an overwhelming negative experience.

3.5 Conclusion on consumer and installation barriers

To conclude, those taking part in the trial are most likely to be dependent on gas for heating and hot water, live in detached homes built from 1976 - 2000 and have at least one family member who is in employment. In reference to environmental attitudes the surveyed participants are noted for being not only concerned about the environment but also taking an active role in energy conservation measures.

Participants are generally satisfied with their current heating and hot water system but are noted for being concerned about future costs and security of energy supply – therefore recognising a need to move away from fossil fuel based technologies. To this effect, attitudes towards renewable energy are positive, however, there was a marked concern around the perceived reliability of these technology types. This concern for reliability is extended to participants' less positive attitude towards fuel cell systems to meet future electricity and heat demand; particularly amongst those reliant on gas.

4. SUPPLY CHAIN BARRIERS

The material this section will be based on is not available yet. This section will be included in the final version of this report.

5. POLICIES AND POLITICS

The European Union, one of the global leaders in energy technology and innovation, is currently actively trying to get internal consensus among its Member States for its post-2020 climate and energy pledges, while taking a front seat in global climate change negotiations. The European Commission adopted in 2014 the Energy Union Strategic Framework for a "secure, sustainable, competitive and affordable" energy sector, which relies on five pillars[3] and aims to put consumers at the core of the energy system. 2016 is set to be the "year of delivery" on the Energy Union, as the Commission is to propose new and reviewed energy and climate legislation[4]. This will help reach the 2020 objectives and ensure a smooth transition to a 2030 framework. This effervescence is also reflected at the national level, with most Member States assessing objectives and choices to support their energy and climate transition. This very dynamic political environment can present both opportunities and barriers to emerging technologies like fuel cell micro-CHP.

Given the energy and climate priorities set at the EU and national levels, fuel cell micro-CHP can make an important contribution towards the decarbonisation, energy efficiency in the building sector and grid integration of intermittent renewables in Europe. Reaching total system efficiencies of over 90%, micro-CHPs represent a next generation solution for replacing traditional gas boilers in much of the built environment where deep renovation and renewable energy solutions are not feasible. Fuel cell micro-CHPs in particular represent a highly efficient alternative for new build. The roll-out of micro-CHP in households and small businesses gives consumers the opportunity to produce their own heat and electricity and become active participants in the energy sector. On-site electricity production and self-consumption can help support the grid, especially when controllable technologies like fuel cell micro-CHP are incentivised to support the integration of intermittent renewables.

The policy context is thus crucial for the fuel cell micro-CHPs achieving a swift transition into commercialisation: A coherent, steady and predictable policy framework should reward the European heating sector's contribution to a more efficient, reliable and cleaner energy system, through advanced products and new business models. Policy should inspire confidence in these market players to team up in the spirit of technological leadership and commercial innovation and develop a range of offerings to consumers and installers alike, empowering energy prosumers and creating green jobs.

Fuel cell micro CHP is currently a product at an early market stage where volumes are low and hence product cost is high. The weaknesses of standard market processes in increasing volumes on such an innovative product are well known. Only a supportive policy framework can accelerate the transition to mass commercialisation of fuel cell micro-CHP, which will bring important benefits to consumers and the energy system at large.

EU level policy and political environment

The recent developments at EU level, reinforced by the COP21 climate agreement at the end of 2015, confirm a strong commitment by EU institutions towards decarbonisation of the energy sector, while

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[3] The Energy Union is based on 5 pillars: Security, solidarity and trust; Internal energy market; Modulation of demand; Decarbonisation of the energy mix; and Research and innovation

[4] The European Commission is planning to issue legislative proposals for the following pieces of legislation: Energy Efficiency Directive, Renewable Energy Directive, Energy Performance of Buildings Directive, Electricity Regulation

improving energy efficiency and further increasing renewable energy share. With the recent publication of the Heating and Cooling Strategy[5], the European Commission is also prioritising energy efficiency actions and greening the energy supply for heating and cooling in buildings. In addition to headline energy and climate policies, the Energy Union also focused on research and innovation in the energy sector, ensuring there is sufficient investment in new technologies at R&D stage.

While fuel cell micro-CHPs are recognised and funded as promising emerging energy technologies at the EU level, there is a need for more consistency between R&D priorities in the energy sector and the broader energy and climate EU framework. Aligning the two will ensure that investor confidence remains strong as fuel cell micro-CHP transition from demonstration trials to early commercialisation and the industry is delivering on its commitment to deliver on its cost reductions targets.

The following recommendations address the need for more consistency between R&D funding programmes and the other pillars of the Energy Union framework:

- The Heating and Cooling Strategy correctly identifies the heat sector, and buildings in particular, as having important decarbonisation and energy efficiency potential. At this stage of the process, it is important that the Strategy reflects the full potential of fuel cell micro-CHP technologies, and does not narrow its scope to a handful of possible solutions. Given their benefits in terms of emission reductions (incl. NOx) and energy efficiency gains, fuel cell micro-CHP technologies should be viewed as strong contenders and complementary to the electrification of heat and other preferred options.
- The position of fuel cell micro-CHP should be reinforced, as part of the tool-kit of supply-side measures that can help Member States meet building efficiency requirements under the Energy Performance of Buildings Directive (2010/31/EU), currently under review.
- Fuel cell micro-CHP systems are controllable technologies and can generate electricity during peak load times (or whenever the grid needs it), replacing a low efficiency and higher CO_2 intensity electricity mix compared to the average electricity sector. This should be considered in upcoming Electricity Market Design proposals and in the context of EU Primary Energy Factor review.
- Embedded generation technologies[6], like fuel cell micro-CHP, are connected to the grid at local distribution level and do not use any high-voltage grid infrastructure. The grid connection and grid use costs of CHP generated power should thus be calculated accordingly, taking into account and/or compensating users for the avoided grid costs[7]. These principles are particularly relevant for the Commission's work on the treatment of electricity self-consumption, which should be promoted when it comes to fuel cell micro-CHPs.
- The energy labelling methodology in Regulation No. 813/2013 should be clarified to fully reflect the primary energy savings of both the heat and electricity produced by fuel cell micro-CHP. Only by fairly assessing fuel cell micro-CHP efficiency, can consumers become more aware about the benefits of this technology.

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[5] European Commission, 16 February. Retrieved from: Commission Communication on an EU strategy for heating and cooling

[6] Embedded generation is defined as generating units that are installed on-site, with the owner producing and partly or fully consuming their own electricity.

[7] This principle is common practice in Germany. In addition, the recently adopted Delegated Regulation (EU) 2015/2402 rewards the benefits cogeneration brings to the electricity system by reducing grid losses and costs through generating the power close to the point of use.

- Innovation in technology is an important part of meeting Europe's Energy and Climate goals. There is a need for a sustained commitment at EU and Member State level to support field trials for emerging high efficiency technologies like fuel cell micro-CHP until a critical mass is reached in terms of scale beyond the products can compete in the market. Large scale demonstration should be put in place to continue initiatives like ene.field, co-financed by the FCH JU, with the goal to reach market-readiness by 2020

Addressing policy barriers at national levels

Policy support and political commitment for fuel cell micro-CHP is patchy at the Member State level. So far Germany has made a strong commitment to the technology through the Callux[8] field trial and a renewed dedicated support programme in 2016. Other EU countries support fuel cell micro-CHP as part of their broader CHP policies. Yet the majority of Member States do not support the market entry of fuel cell micro-CHPs.

A higher awareness about fuel cell micro-CHP technologies among policymakers at national level would ensure that the regulatory framework does not hinder further uptake of this technology.

- Ambitious implementation of the Energy Efficiency Directive (EED) (2010/31/EU) at the national level is key to realising the potential of fuel cell micro-CHP, in line with Article 14. In addition, Member States should do more to promote demand response and simplify grid connection procedures for fuel cell micro-CHP as recommended in Article 15 of the EED.
- Electricity grid connection procedures can be very burdensome for the consumer and installer. While in the UK the "install and inform" connection standard has been in place for some time, in other countries such as Italy and France the lengthy (e.g. up to several months) and bureaucratic permission procedures to connect can represent a real barrier.
- Member States should take into account the benefits of fuel cell micro-CHP when implementing the Energy Performance of Buildings Directive. Some countries, like France and Ireland, have developed methodologies which ensure that micro-CHP, including fuel cell micro-CHPs, are eligible technologies for improving the efficiency of buildings and meeting the renewable energy requirements for new buildings[9].
- The benefits of fuel cell micro-CHP are not fully recognised in most Member States. They should thus provide fair reward proportional to the benefits, including primary energy savings, electricity and heat decarbonisation, as well as reduction in grid stress and integration of intermittent renewables. This can be achieved through tariffs, deemed payments, or even up-front one-off subsidy, which will reduce capital cost for interested consumers.
- Field trial support and high level political commitment is needed at the national level for fuel cell micro-CHP to move faster into early commercialisation.

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8 http://www.callux.net/home.English.html

9 The Irish Building Regulations allow micro/small-CHP as an alternative to the requirement that at least 10KWh/m2 of heat demand for new buildings should to be derived from renewable sources. This is achieved through a methodology that calculates renewable heat contribution from CHP.

6. REGULATIONS, CODES AND STANDARDS (RC&S)

The knowledge of the current legislative panorama related to the FC-based micro-CHP technology, at the International, European and National level, is fundamental for the development of this technology sector. For this reason Polito, as part of the ene.field project, had the duty to perform an analysis of its status with the objective to identify all the possible existing barriers that can slow the spread of the FC-based micro-CHP technology in the European market. In the following, an abridged version of this work is presented in the form of the conclusions reached and the recommendations given.

6.1 RC&S analysis

Two questionnaires have been prepared and submitted to the FC-based micro-CHP manufacturers, involved in the Ene.field project, in order to collect their opinions related to the current status of, respectively, the International and European standards and the European Regulations and Directives and, if necessary, possible suggestions on how improve it.

At the same time, an accurate research has been conducted at a National level with the target to create a database containing all the legislative documents concerning FC-based micro-CHP systems installation. This activity was also a way for an evaluation of the existing legislative differences from country to country. The research was addressed only to the European Countries that are involved in the Ene.field installations.

Results and main barriers

The collection of the documentation from both the activities mentioned above allows us to get a clear view of the current legislative panorama.

Referring to the first questionnaire, the one focusing on the European standards, it has been structured according to 15 topics representing 15 typical issues related to the installation process of a FC-based micro-CHP system. In particular, the questions made had the aim to evaluate the quality and usability of a selected number of European standards chosen as representative of the topics.

Two main conclusions arose from the answers collected. The first one is the urgency of an **update** or, somehow, an **improvement** of the contents of current standards treating this technology. Limiting the speech on the standards used as reference for each topic of the questionnaire, the opinion of the manufacturers is that around 60% of them need to be improved under different point of view (Figure 1). The inadequacy appears in different aspects such as, **lack of consistency** between different standards dealing with similar topics and standards that refer to too much **general systems**.

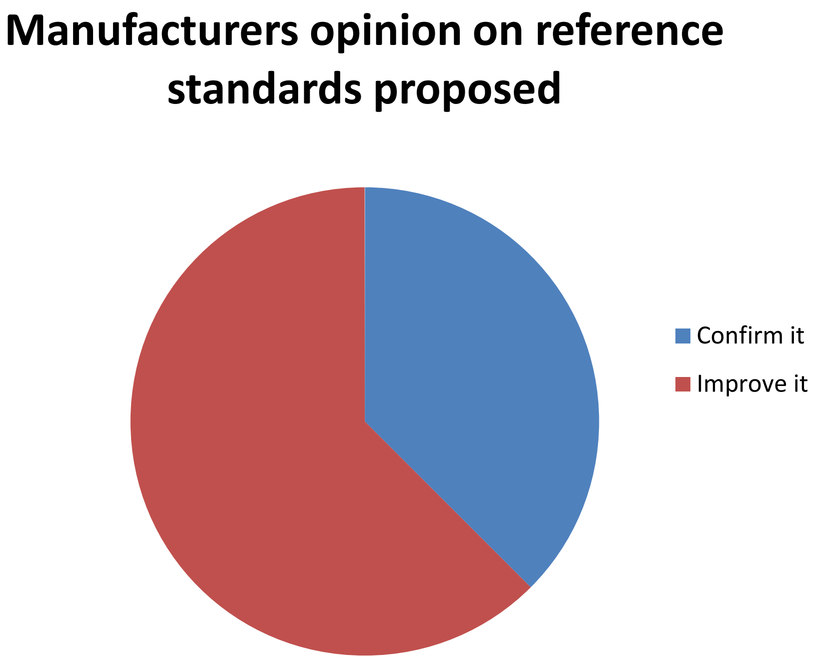

Figure 11: Opinions of the manufacturers on the reference standards proposed for the first questionnaire.

The second conclusion, instead, can be deduced from Figures 2 and 3 and is related to the large amount of standards and documents suggested by the manufacturers, as possible integration to the reference standards, proposed for each topic.

From the histogram it is possible to note that the number of standards mentioned in the answers of the manufacturers is more than twice the initial number of reference standards proposed. The presence of so many documents referring to installation aspects of FC-based micro-CHP devices, together with the problem of a low consistency among those treating the same topic, can constitutes a significant barrier as confusion is created on the side of the manufacturers who are interested in the spread of their products throughout the Europe. Another key factor, which can be deduced from Figure 3, is the fact that around the 23 % of all the documents suggested by the manufacturers consulted for the questionnaire are at a **National level**. Finally, it can also happens that each Country tends to partially accepts a European standard integrating it with an own version.

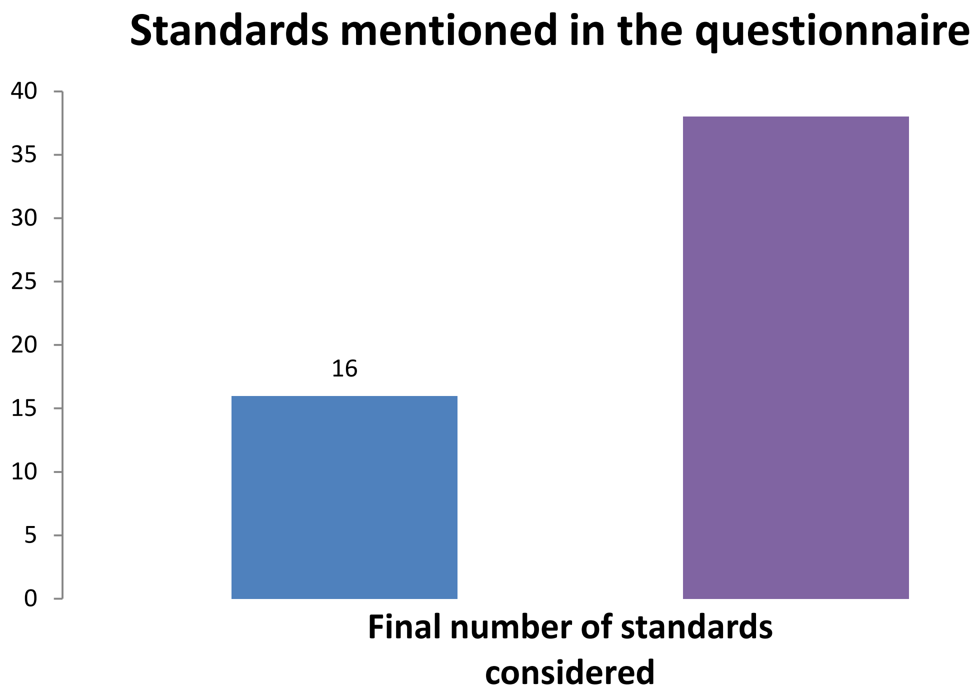

Figure 12: Total amount of standard/documents mentioned in the questionnaire with respect of those initially proposed.

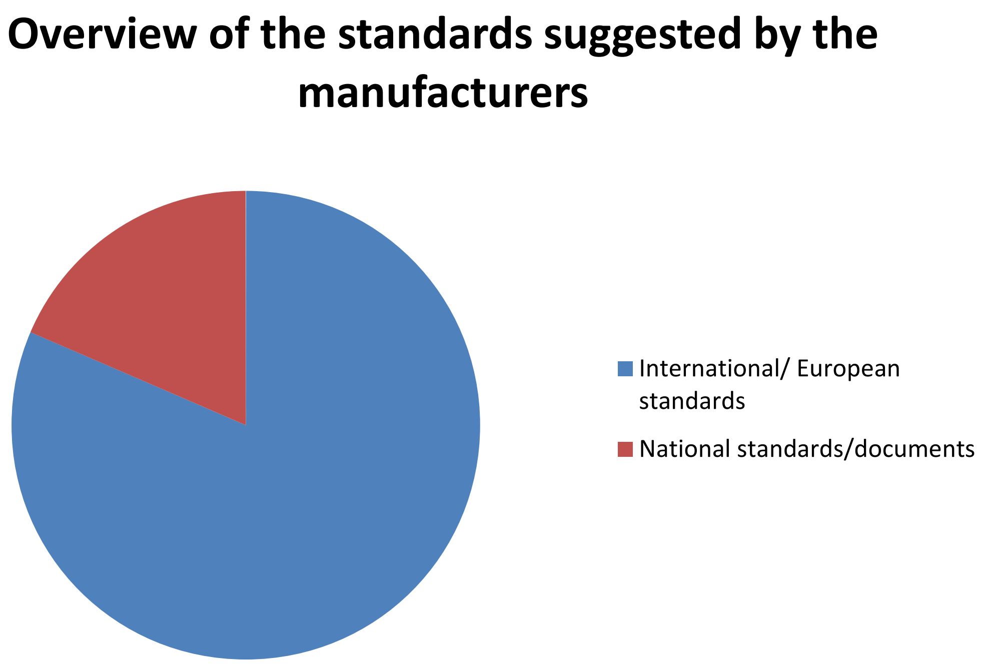

Figure 13: General overview of the standards suggested by the manufacturers with a focus on their origin.

This issue becomes more evident moving to the analysis at a national level: the first element that appears is the **heterogeneity of the standards**, particularly in terms of their range of applicability. The major consequence of this trend is that each manufacturer is forced to tune its products according to the country market in which it aims to enter.

The results obtained by this first questionnaire lead to consider the need of **common framework of European standards** that can be considered valid in every country as a possible solution to overcome the barrier due to the heterogeneity of the existing framework of European and national standards. In addition, all the existing connections among standards treating similar topics should be highlighted. This would be very helpful especially for the manufacturers that, in this way, can have a clearer view of the regulatory panorama referring to a certain specific topic.

Referring to the questionnaire dealing with the European Regulations and Directives, the key point to which all the critiques of the manufacturers have been addressed is the **Energy Labelling**. In other words, manufacturers complained about a penalization of FC-based micro-CHP devices because official methodologies, introduced by European Regulations, do not seem to be suitable for the specific features of the FC-based cogeneration devices. An accurate analysis has been carried out in order to better understand the problem arisen.

6.2 Energy labelling issue

As anticipated above, among all the outcomes coming from the RC&S analysis performed, the main point of discussion that rose was the one related to the **Energy Labelling**.

This topic has been examined accurately through the comparison of the two methods set by the European Commission together with an additional method described by a European Standard:

- the "**Commission communication in the framework of the implementation of Commission Regulation (EU) No 813/2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters, and of the implementation of Commission Delegated Regulation (EU) No 811/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device**" that has been released on the 3rd of July, 2014;
- the **"Commission delegated Regulation no. 811/2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labeling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device"** that has been released on the 18th of February, 2013;
- the **EN 50465:2015 standard "Gas appliances – Combined heat and power appliance of nominal heat input inferior or equal to 70 kW".**

The analysis was carried out on a reference system composed by a micro-CHP device coupled with a boiler as a supplementary heater. The system has been defined with some fixed parameters (Table 1) and was characterized by different configurations of thermal and electrical efficiency.

Parameter	Fixed value
Electrical output of the FC-based microCHP device ($P_{el,CHP100+SUP\ 0}$)	1 kW
Thermal output of the supplementary heater ($P_{th,SUP}$)	10 kW
FC-based microCHP device, total efficiency ($\eta_{tot,CHP}$)	90%
Supplementary heater, thermal efficiency ($\eta_{th,SUP}$)	95%

Table 1. Fixed parameters for the reference system used in the analysis.

Results and main barriers

The comparison among the three methods leads to the results shown in Figure 15: the **EN 50465:2015** standard proposes the best method for the calculation of the seasonal space heating energy efficiency because it seems to be affected from both electrical and thermal efficiency and not only from one of them.

This result demonstrates that, in fact, FC-based micro-CHP devices are penalized by the methods described in the European Regulation but, due to the binding nature of the European Regulations, these are the only ones that have to be followed for the assignment of the energy class to each energy-related product. This situation represents a significant barrier because customers are naturally discouraged from purchasing products with a worse apparent performance.

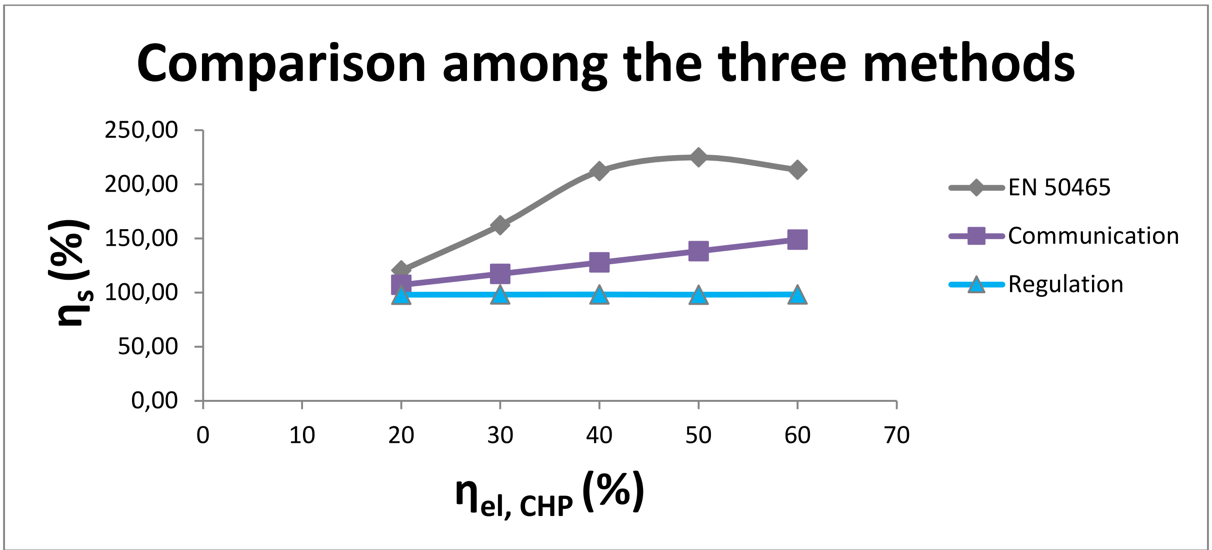

Figure 14: Comparison among the results obtained by the three methods analyzed, in terms of seasonal space heating energy efficiency, with respect to the electrical efficiency of the FC-based microCHP device.

6.2.1 'Re-scaling' of the energy label

On 15 July 2015 the European Commission published a proposal for a new Regulation with the aim of repealing the **Directive 2010/30/EU "*on the indication by labeling and standard product information of the consumption of energy and other resources by energy-related products*"**.

Among the different provisions proposed by the first draft of this new Regulation, there is also the update of the current labelling scale, whose energy classes range from **A+++** to **G** (as reported in the European Regulation no. 811/2013). The proposal is to re-introduce the original scale from **A** to **G** due to its ease of understanding. All the devices lying in the current scale will be rearranged in such a way that the highest class will be left empty[10]. This solution has been thought in order to incentivize competitiveness among manufacturers for the development of always better performing devices in terms of energy efficiency.

This new initiative is still at the beginning of the procedure for being accepted and published, but some issues can arise if it will not be carried out properly:

1. The rearrangement of all the current products available in the market in a smaller number of energy classes (from 10 to 6) is likely to face some disagreements. In fact, devices which were previously assigned to different energy classes could, with the introduction of the new scale, be shifted in the same class, due to general leveling of the existing products.
2. According to this proposal, during the transition period from the old scale to the new one, both the scales will be present for each product available in the market. If this change will not be accurately managed, this will result in a barrier for consumers that will be confused by the abundance of information supplied.

6.3 Recommended actions

According to the results obtained from the RC&S analysis, it appears evident the need for the creation of common European standards that can be accepted from each Country helping to overcome especially the National barriers still existing.

In addition, in order to avoid a penalization of the FC-based micro-CHP devices in the energy-related products market, it is important to identify a suitable method for the assignment of the Energy Labelling which takes into account the specific nature of this kind of devices. From this point of view, the method proposed by the EN 50465:2015 standard seems to be in the right way.

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[10] *"The Commision shall ensure that, when a label is introduced or rescaled, the requirements are laid down so that no products are expected to fall in energy class A at the moment of the introduction of the label and so that the estimated time within which a majority of models fall into that class shall be at least ten years later"*, art. 7 subparagraph 3, **Proposal for a Regulation of the European Parliament and of the Council setting a framework for energy labeling and repealing Directive 2010/30/EU (2015/0149)**, 27 November 2015.

7. Conclusion

The policy context is crucial for the fuel cell micro-CHPs achieving a swift transition into commercialisation: A coherent, steady and predictable policy framework should reward the European heating sector's contribution to a more efficient, reliable and cleaner energy system, through advanced products and new business models.

On a European level it is suggested that the grid connection and grid use costs of CHP generated power take in to account the lack of use of any high-voltage infrastructure. Additionally, the energy labelling methodology should be clarified to fully reflect the primary energy savings of both the heat and electricity produced by fuel cell micro-CHP. The position of fuel cell micro-CHP should be reinforced, as part of the tool-kit of supply-side measures that can help Member States meet building efficiency requirements and fuel cell micro-CHP technologies should be viewed as strong contenders and complementary to the electrification of heat and other preferred options.

On a national level, lengthy and bureaucratic permission procedures to connect can represent a real barrier to uptake. Here, inspiration can be drawn from the "install and inform" connection standard in the UK. EU Member States should also take into account the benefits of fuel cell micro-CHP when implementing the Energy Performance of Buildings Directive. The benefits of fuel cell micro-CHP are not fully recognised in most Member States. They should thus provide fair reward proportional to the benefits, including primary energy savings, electricity and heat decarbonisation, as well as reduction in grid stress and integration of intermittent renewables. This can be achieved through tariffs, deemed payments, or even up-front one-off subsidy, which will reduce capital cost for interested consumers. In conclusion: Field trial support and high level political commitment is needed at the national level for fuel cell micro-CHP to move faster into early commercialisation.

A higher awareness about fuel cell micro-CHP technologies among policymakers at national level would ensure that the regulatory framework does not hinder further uptake of this technology.

A lack of a common framework of European standards is seen as a great hindrance to market uptake. Manufacturers points to a need for updating, improvements or revisions for as much as 60% of the current standards. Issues include lack of consistency between different standards dealing with similar topics and standards that refer to too general systems. The shear amount of standards that are in some way relevant to FC micro-CHP installation makes it hard for the manufacturers to keep an overview.

In addition, in order to avoid a penalization of the FC-based micro-CHP devices in the energy-related products market, it is important to identify a suitable method for the assignment of the Energy Labelling which takes into account the specific nature of this kind of devices. From this point of view, the method proposed by the EN 50465:2015 standard seems to be in the right way.

Lastly, customers participating in ene.field were found to have a concern regarding the perceived reliability of renewable technology types. This concern for reliability extends to participants' less positive attitude towards fuel cell systems to meet future electricity and heat demand; particularly amongst those reliant on gas.