



Pathway to a Competitive European
Fuel Cell micro-CHP Market

The bridge to large scale market uptake

European-wide field trials for residential Fuel Cell micro-Cogeneration

Report on customer attitudes to fuel cell micro-CHP

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Context and overview of document

This document (D2.15) is the final of three reports analysing the customer attitudes to fuel cell micro-Cogeneration (FC mCHP) installations. The analysis is based on data from pre-operation and during operation questionnaires completed by customers of FC mCHP installations. Building upon the first two iterations of this report (D2.10 and D2.12), this iteration sets out the general profiles of customers, their motivations for purchasing a mCHP unit, their expectations compared to actual experiences of the technology, and the problems and breakdowns they have experienced.

Motivation

Overall **energy savings** is the main motivation for buying of FC mCHP (**22%**), followed by **cost savings** (**19%**) and **CO₂ emissions reduction** (**17%**).

Motivation varies slightly depending on the application:

- Customers in residential and non-residential applications are mostly concerned by energy savings.
- Customers in residential applications are more concerned with the aesthetics of their FC mCHP than non-residential.

Appraisals

Customers were, on the whole, **very satisfied with the performance and features** of their FC mCHP unit.

- Nearly **80%** of respondents reported having a **positive overall experience** with their FC mCHP unit.
- No non-residential respondents reported having a negative overall experience with their unit.
- Austria reported the highest number of “very positive” responses, and Belgium and Germany were the only two countries to report any “very negative” experiences.

Improvements

Respondents were generally positive regarding the improvements needed to FC mCHP units.

- Most parameters were consistently found to be “already sufficient” by the majority of respondents
- The following three parameters were considered most in need of improvements:
 - Cost of repair and maintenance
 - Effort of the installation process
 - Public visibility of FC mCHP

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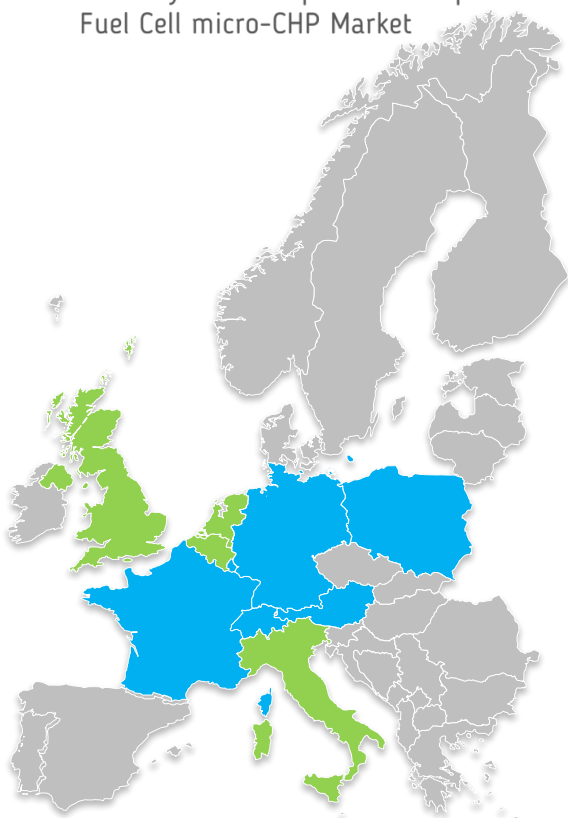
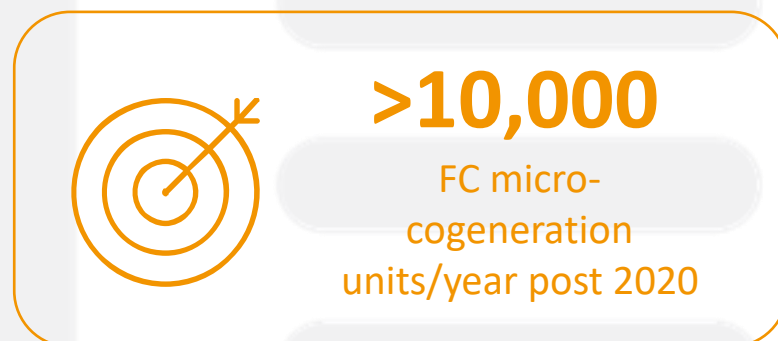
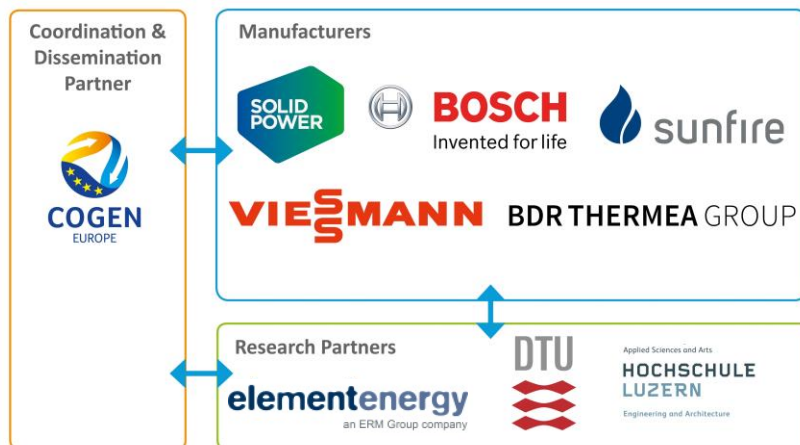
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Introduction to PACE and D2.15

Introduction to PACE

Promoting a successful transition to the large-scale uptake of Fuel Cell micro-Cogeneration across Europe

9	> 2,500	>500	10	4	€90m
Partners	Fuel Cell micro-Cogeneration units	Systems per manufacturer	Countries	Countries	Total budget
Representing manufacturers, utilities & research community	To be deployed across Europe between 2016-2023	Established production capacity per manufacturer	Where the units will be installed	Selected for policy & market development (Belgium, Italy, Netherlands and UK)	Including €33.9m Horizon 2020 funding via the Clean Hydrogen Partnership (previously FCH JU)



- Field trial + installer training + targeted market & policy development activities
- Field trial + local installer training

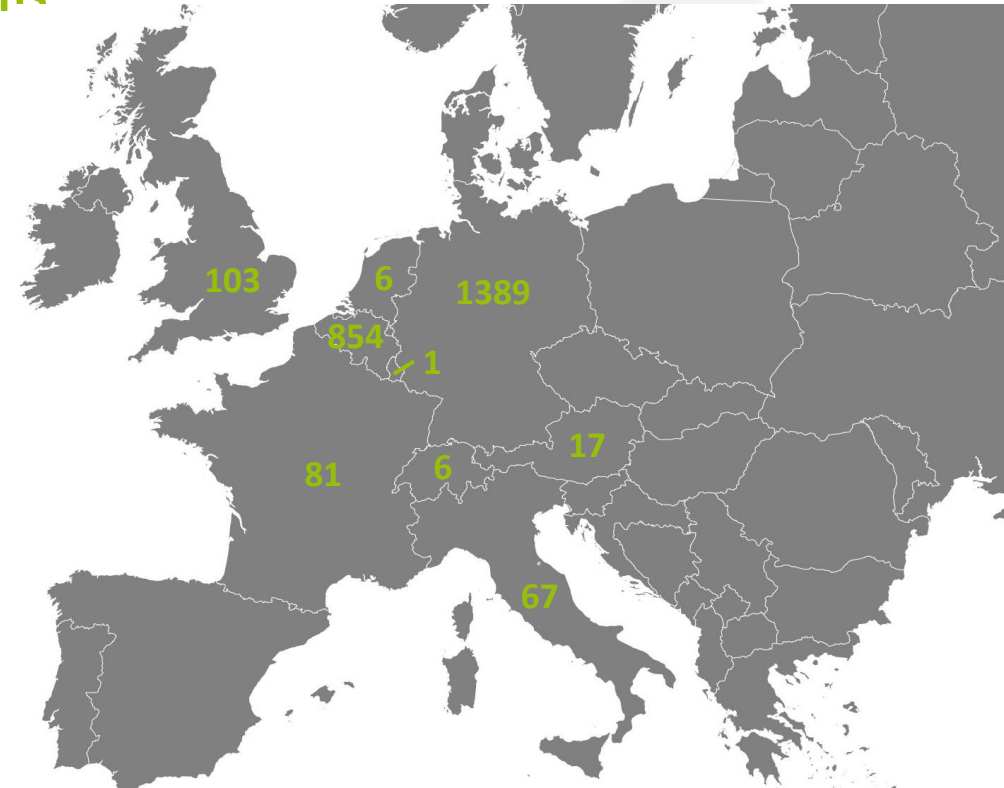
Introduction to WP2 and Task 2.5

PACE Work Package 2 – Performance Validation

- WP2 sets out the data collection protocols, and involves the process of data collection and management throughout the project.
- Technical operational data on the performance of units as well as customer feedback survey data is collected as part of the project.
- Task 2.5 encompasses the customer feedback survey, which collects qualitative and quantitative data on the satisfaction of customers with their units, positive and negative aspects of their interaction with the units, as well as their perception of the savings being made by the units and their willingness to pay for future equivalent products.
- Surveys are collected from customers at 3 times, both in pre- and during-operation (typically after 12 and 24 months of operation), in order to carry out longitudinal analysis of the way attitudes to the units may change through time.
- Fewer responses are expected for the during-operation questionnaires as fewer participants are eligible to respond to these at the time of writing.

D2.15 - Report 3 on customer attitudes to mCHP installations

- D2.15 is the final of three reports analysing the customer attitudes to fuel cell micro-CHP installations.
- As of December 2022, 1090 pre-operation questionnaires have been completed out of 2132* customers with units commissioned, representing a 51% completion rate for the overall trial.
- In addition, 670 during-operation questionnaires have been completed out of 1,425 customers* with units in operation for over 1 year, representing a 47% completion rate for the overall trial.
- Almost 500 additional questionnaire responses have been included in the analysis compared to Report 2, and 1,500 in additional to Report 1, strengthening the quality of analysis possible in this report.



*Note that this figure is adjusted to account for customers with multiple cascaded units in a single building.



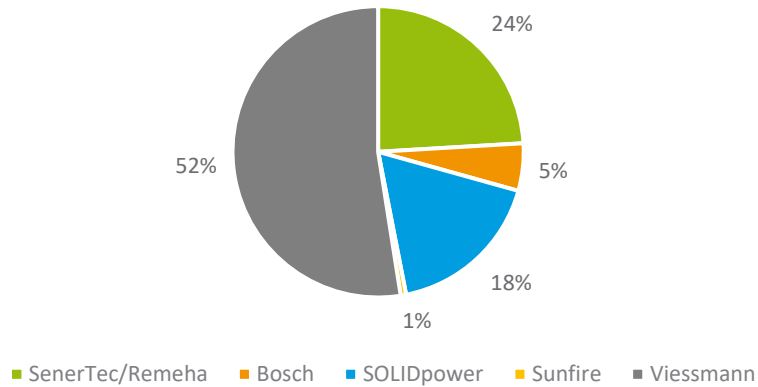
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Customer and building characteristics

Customer characteristics

The majority of the respondents having completed the questionnaires were located in Germany (54%) or Belgium (39%). Viessmann is the most represented make of FC mCHP in these results.

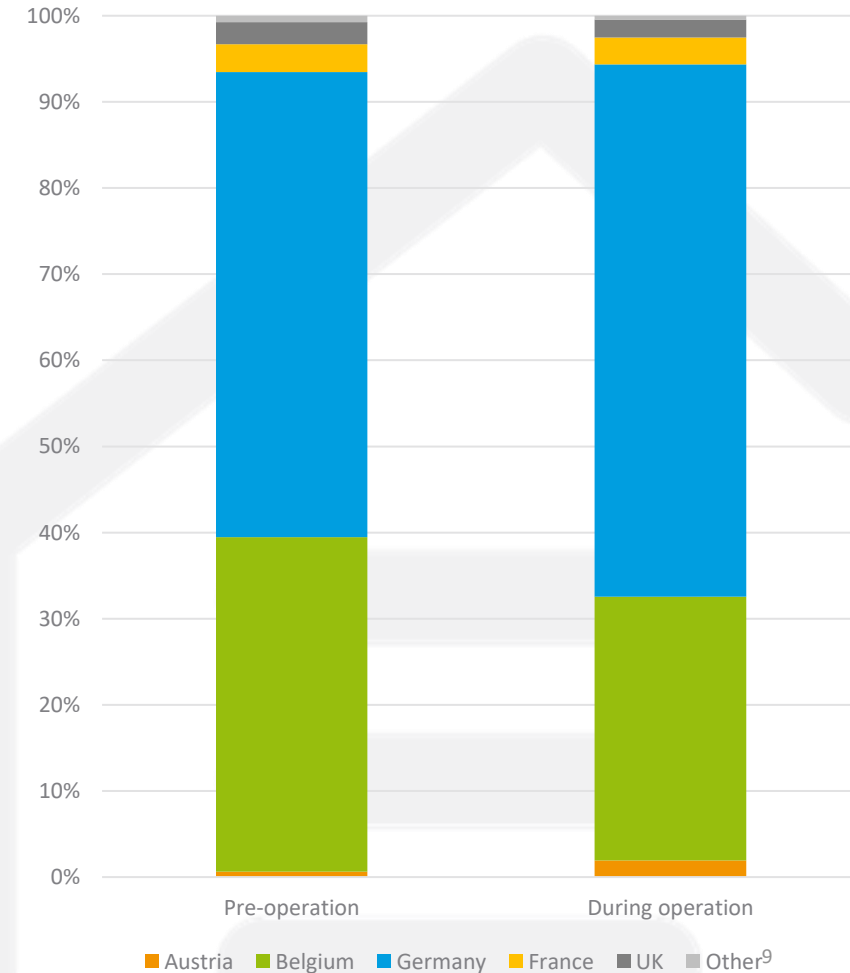
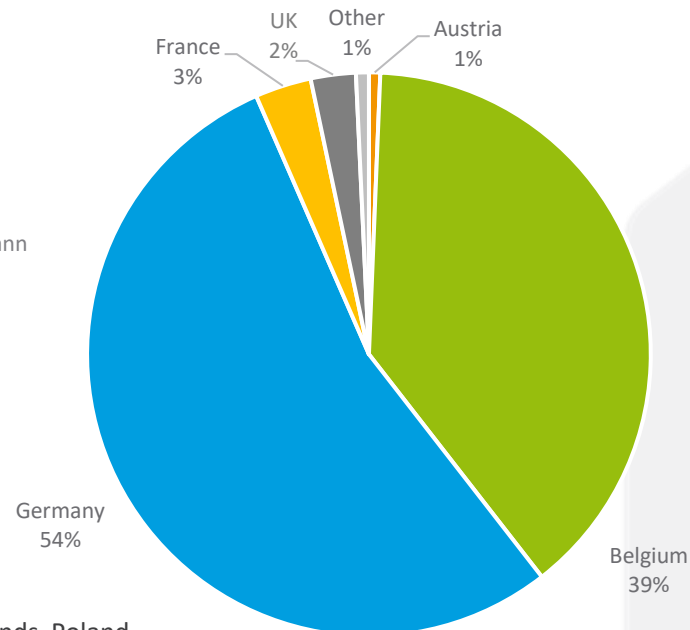
What make of FC mCHP do you have installed in your building?



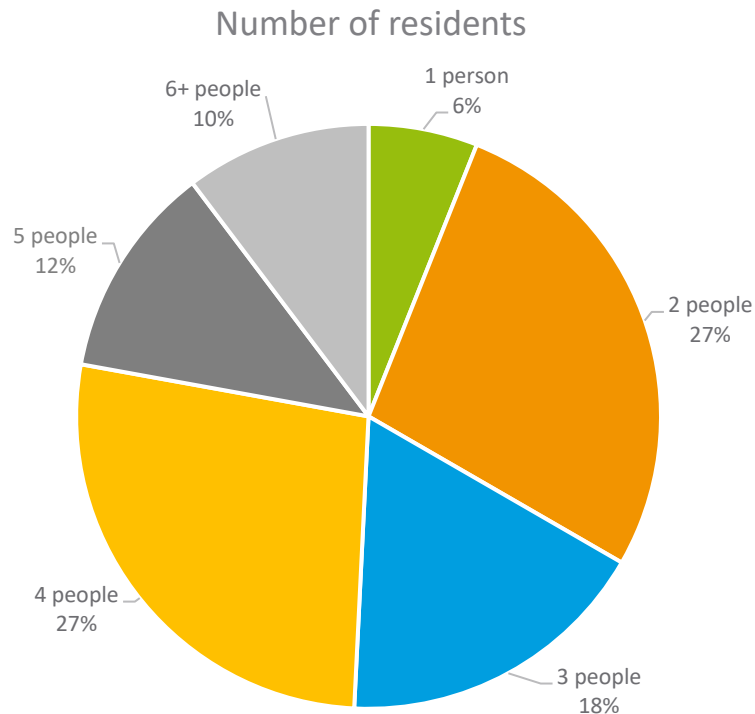
SOLIDpower units that have been installed by Bosch are included in Bosch figures.

*Other includes: Czech Republic, Denmark, Italy, Luxembourg, Netherlands, Poland, Slovakia, Slovenia and Switzerland

Responses by country

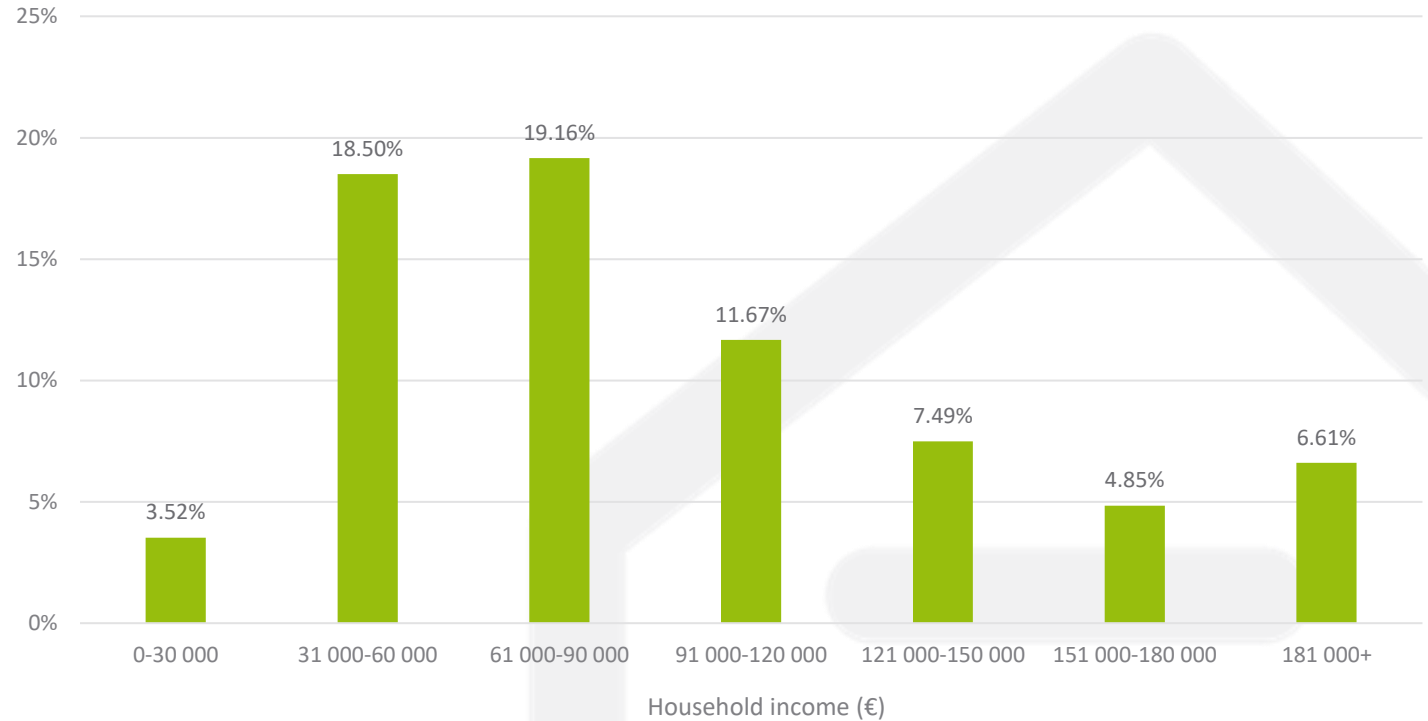


The majority of customers are likely to be couples and families, as 94% of respondents in residential buildings had more than 2 people in their household.



Customer characteristics

Total annual household income



At least 95% of the respondents have an income above the European average income and generally above the average income of their respective countries (median income for Belgium, France, Germany and the UK range from € 31,800 – € 37,000).

Customer characteristics

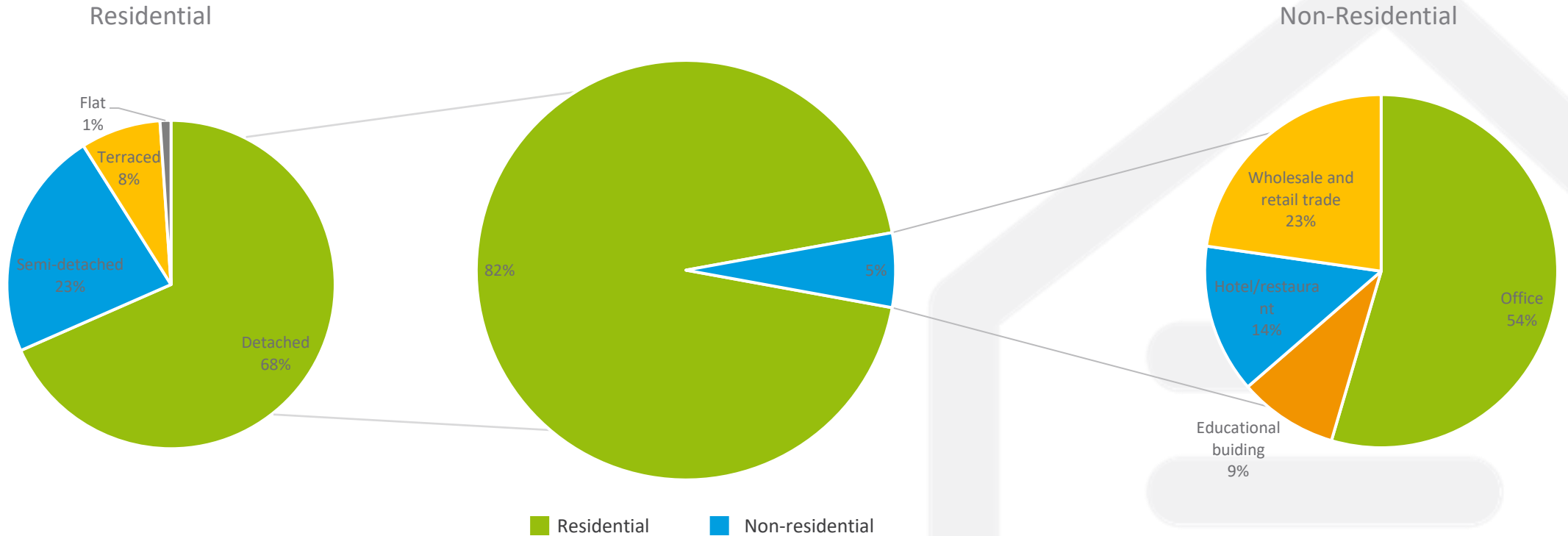
Summary

- The vast majority of respondents are based in Germany (54%) and Belgium (39%).
- Respondents generally have higher than the national average household income. 96% of respondents have a household income (before tax and social security) greater than € 30,000 (in Belgium the national average is € 33,000). 30% of respondents have a household income greater than € 90,000.
- The majority of customers are therefore likely to be couples and families with relatively high disposable income. Indeed, 96% of respondents in residential buildings had more than 2 people in their household.
- The high proportion of affluent customers could reflect their ability to take the financial risk, where high initial costs of the infrastructure may be prohibitive for those with less disposable income. Additionally, this may also be influenced by the characteristics of the building enabling the technology.
- This profile would be expected for a trial of this nature, with a novel technology that is not yet widely used. The process of adoption over time of new technologies generally follows the rules of the technology adoption life cycle, in which the first group of people to use a new product are the “innovators”, followed by “early adopters”. In the early stages of a new technology such as FC mCHP it is therefore expected that the primary customers at this point will be affluent early adopters.

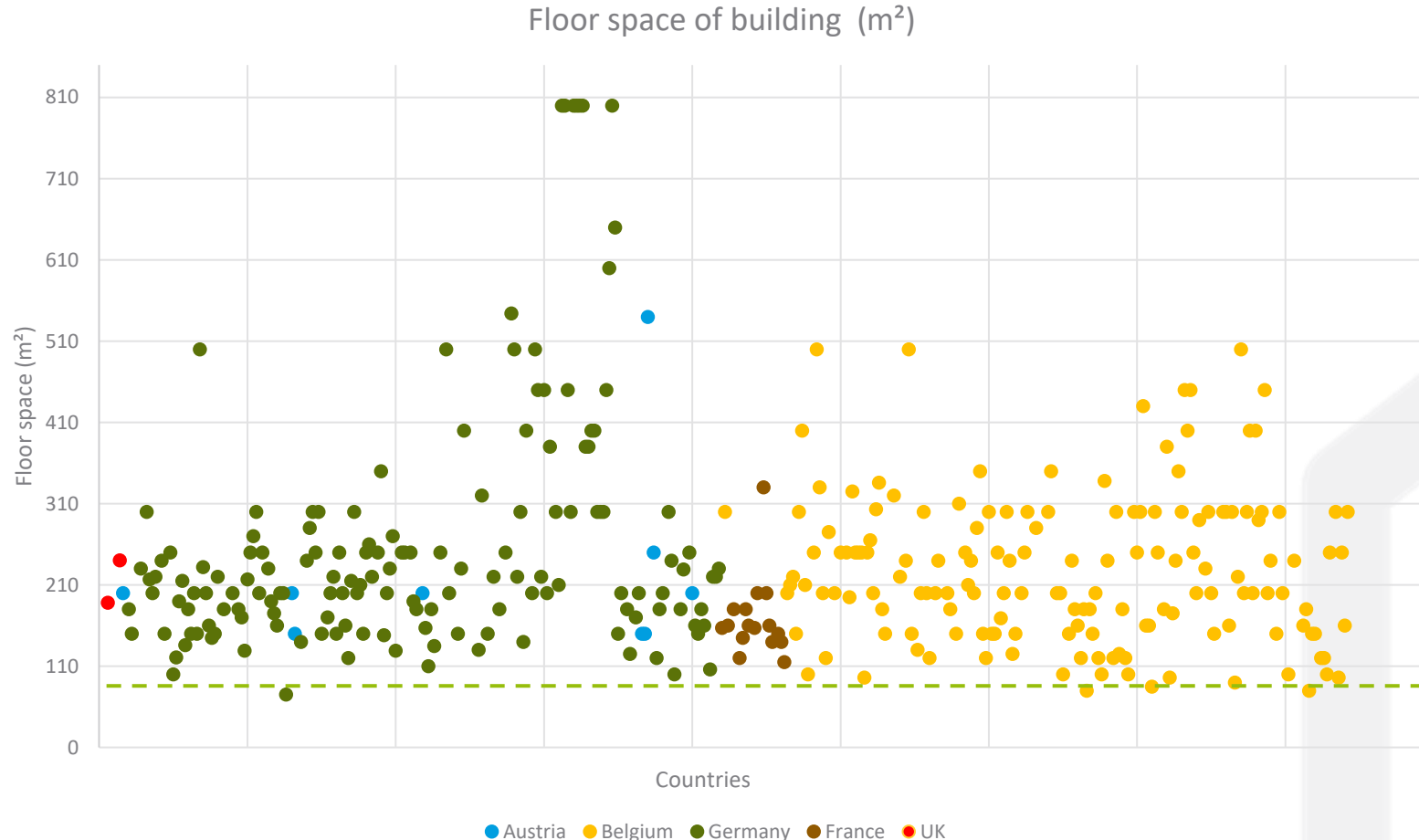
Building characteristics

FC mCHPs have in majority been installed in residential buildings (82%)

- Detached housing is the most common residential building type selected by respondents (68%)
- Office buildings are the most common non-residential building type selected by respondents (54%)



Building Characteristics



The average floor space supplied energy by respondents' FC mCHP is 257m².

The national average house size are:

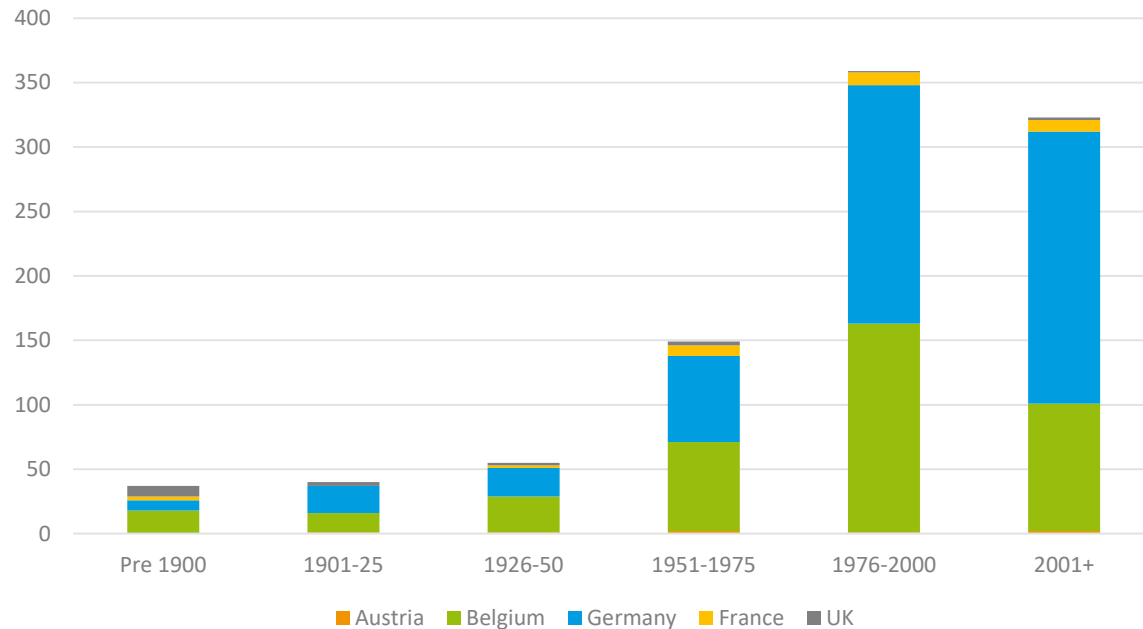
- Austria: 91m²
- Belgium: 86m²
- Germany: 87m²
- France: 88m²
- UK: 76m²

FC mCHP units are best suited to larger buildings, with a high demand for electricity. This, alongside the relatively high costs of the product has led to the average floor space of buildings with PACE units to be significantly larger than average.

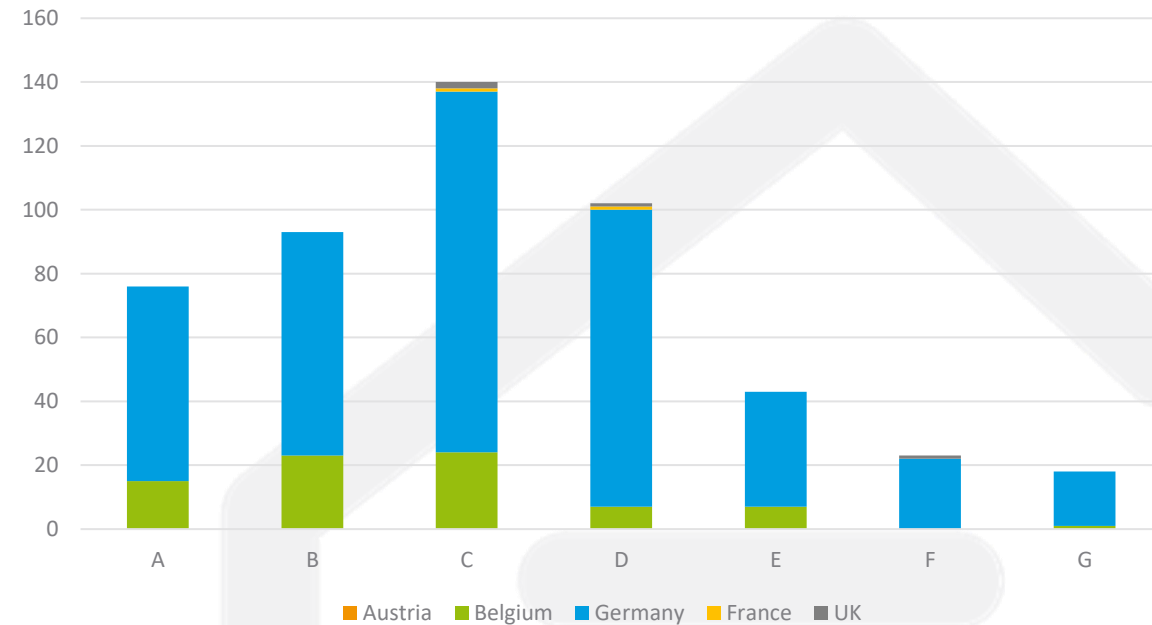
Average house size
in PACE target
countries (85m²)

Building characteristics

Age of building



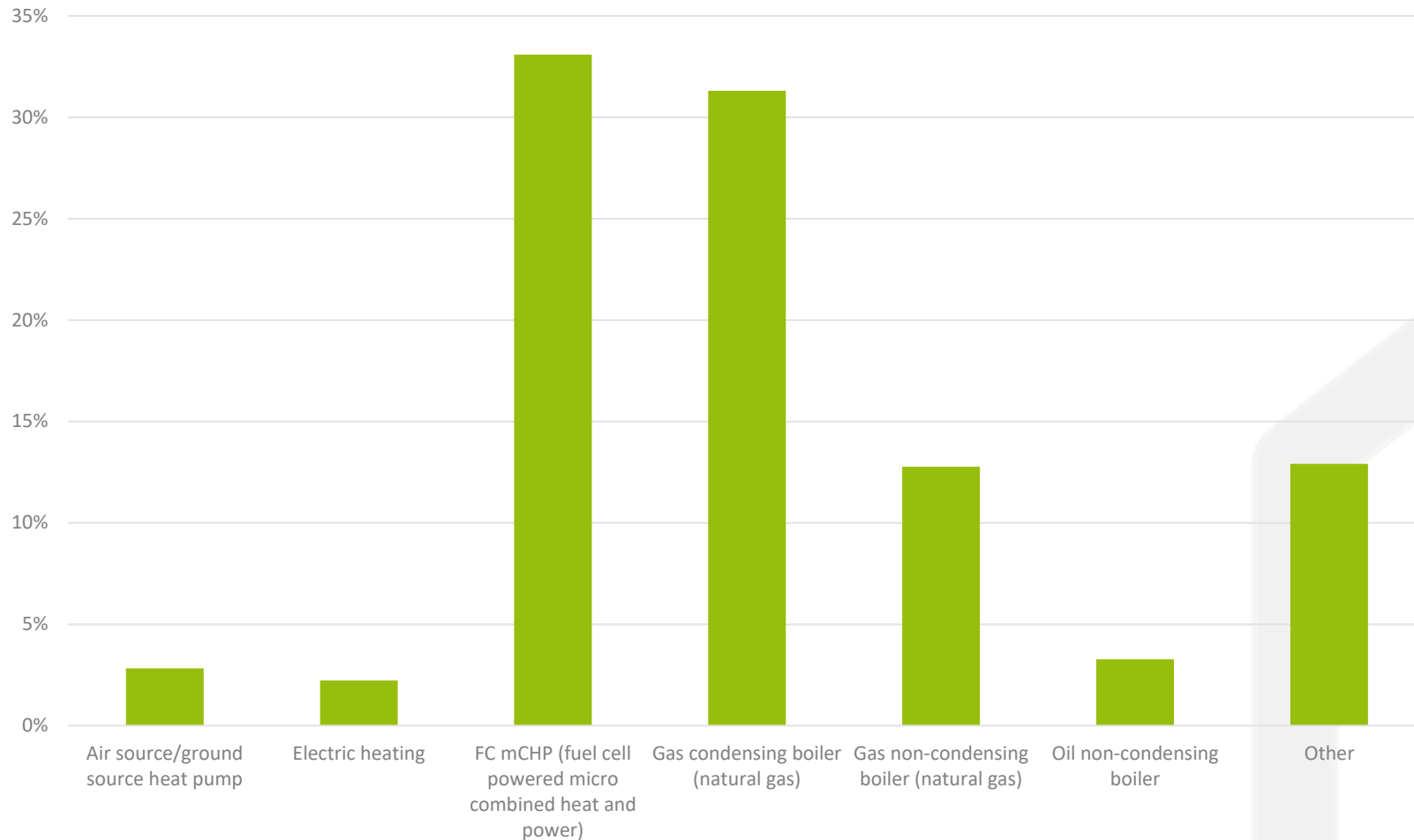
Energy Performance Certificate (EPC) rating of building



- Most FC mCHP units are being commissioned in relatively modern buildings built within the last 50 years. However, this varies with country – for example, the majority of units in the UK are in buildings built pre-1900.
- Most FC mCHP units are being commissioned in buildings with a relatively high Energy Performance Certificate (EPC) ratings, and therefore likely in well-insulated buildings with high levels of energy efficiency. This fits with the profile of an affluent customer who considers themselves to care about “being green”. For example, the average EPC rating for residential buildings in France and the UK is D.

Building Characteristics

Primary Heating System



33% of all respondents use their FC mCHP as their primary heating system.

The second most used primary heating system from respondents is a gas condensing boiler (31%).

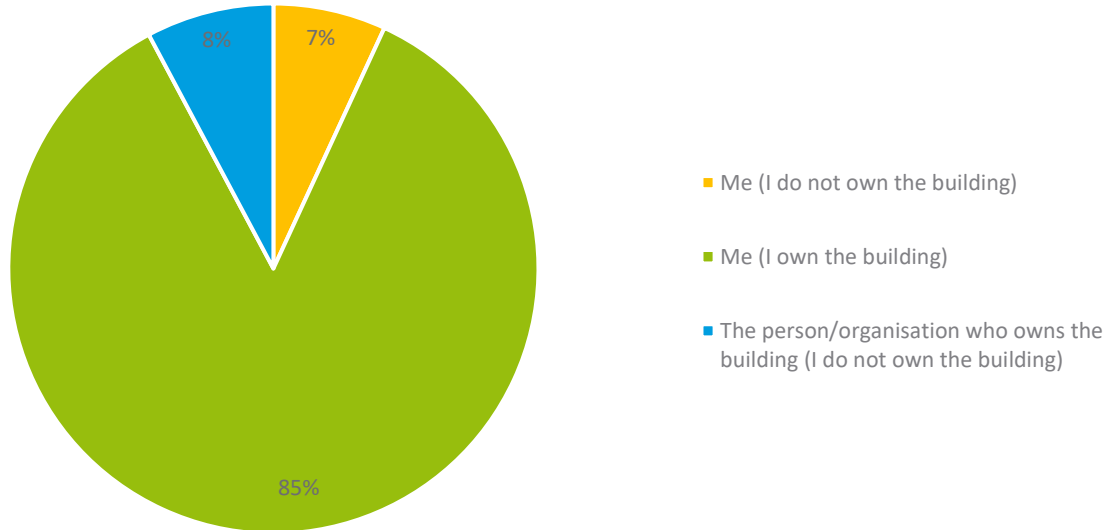
*Other includes gas boiler, oil condensing burner and biomass

Building characteristics

Summary

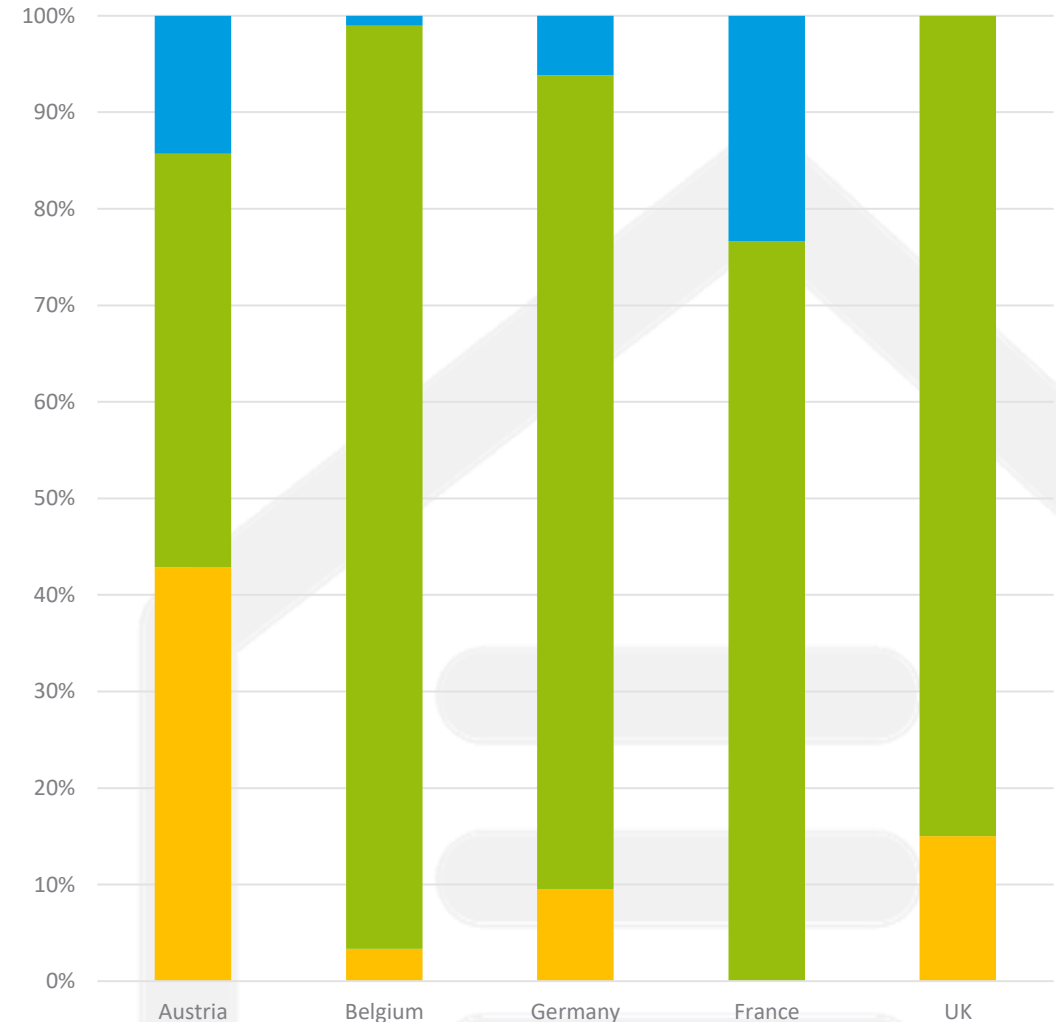
- 82% of the respondents have had their FC mCHP unit installed in a residential building. The building type for residential customers is predominantly detached, which in most cases fits with the profile of an affluent customer with a large house and a higher-than-average disposable income. 68% of respondents live in detached houses, compared to only 38% of houses in Belgium, 26% in Germany, 25% in the UK, and 67% in France. Of the 5% of respondents whose FC mCHP is located in a non-residential building, the most common building type was an office building (54%).
- The average size of the building (measured as the total floor space of the area the FC mCHP supplies energy to) is 257m². For context, the national average house size in Belgium is 86m². The large number of offices being supplied by the units is likely to have impacted this and increased the average area. The size of the units in this trial make them more appropriate for larger homes or multifamily buildings with relatively high energy demand, which will also have impacted the average area.
- The affluent profile and large house size may influence several factors such as energy usage (i.e. a larger house may need more energy to heat the space), and energy efficiency (i.e. quality of insulation, number of appliances).
- A larger house may improve the financial benefits (payback period) of FC mCHP, due to the higher energy usage.
- The EPC rating for customers is predominately C or above, which is a relatively high rating and therefore reflects a well-insulated energy-efficient building. For context, the average EPC rating for residential buildings in France and the UK is D. This therefore fits the profile of a customer who considers themselves to be “green”.

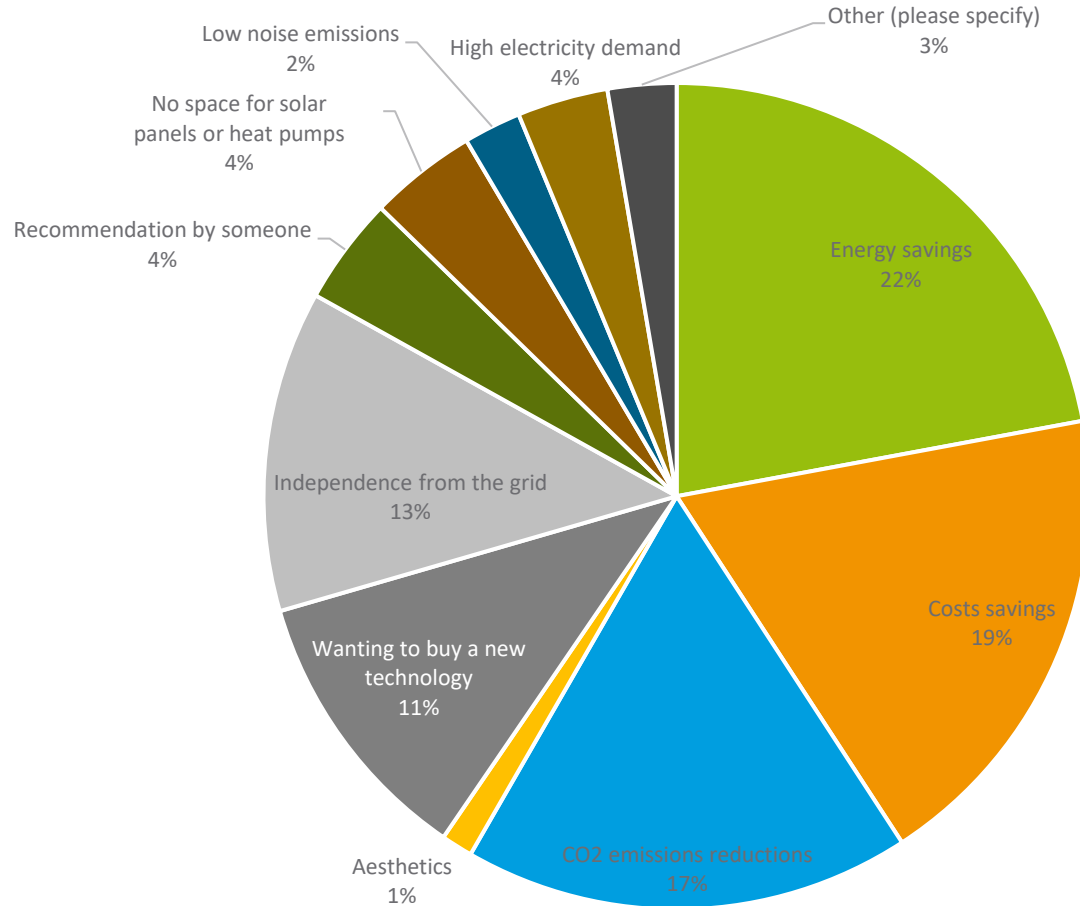
Motivations for purchasing FC mCHP



- 92% of all customers who responded chose to purchase the FC mCHP themselves.
- 8% of all customers who responded have a FC mCHP installed in their building due to the choice of someone other than themselves, who owns the building.

Who decided to purchase the FC mCHP?

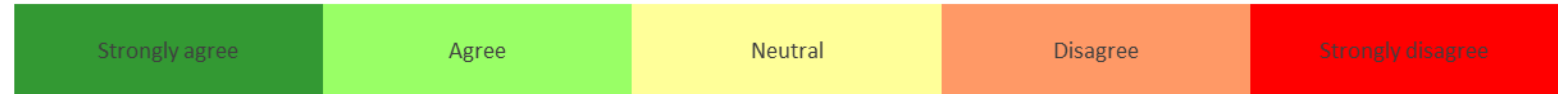




Motivations for purchasing FC mCHP

- Overall energy savings is the main motivation for buying of FC mCHP (22%), followed by cost savings (19%) and CO₂ emissions reduction (17%). This fits with the profile of an affluent customer who considers themselves to care their impact on the environment.
- A desire for independence from the grid and wanting to buy a new technology are also strong motivating factors. This also fits with the profile of an early adopter, and also reflects customers' concerns.
- Motivation varies slightly depending on the application:
 - Customers in both residential and non-residential applications are mostly concerned by energy savings.
 - Customers in residential applications are more concerned with the aesthetics of their FC mCHP than non-residential.

Customer attitudes



I am the type of person to worry about being 'green'



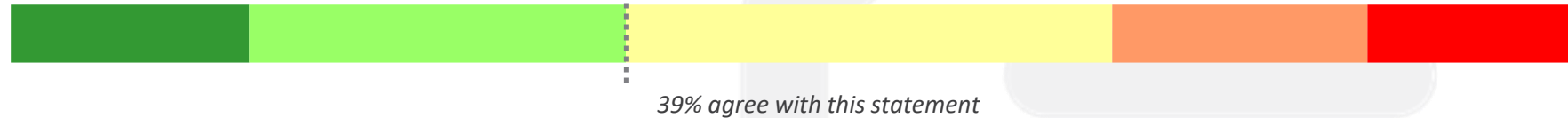
I am the type of person who likes to try new products



I feel a moral obligation to reduce my emission of greenhouse gases



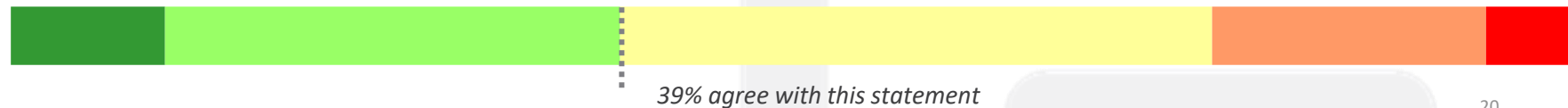
I am the type of person who needs a reputable brand to be willing to invest in a new product



I would be willing to pay a little more for an energy system if I knew it was less harmful to the environment



I would be willing to pay significantly more for an energy system if I knew it was less harmful to the environment



Motivations for purchasing FC mCHP

- The motivations for purchasing FC mCHP are similar for both residential and non-residential customers, with energy savings, cost savings and CO₂ emissions reductions the most-cited reasons for purchasing FC mCHP.
- Energy and cost savings appear to be a greater priority for residential customers. The reason for this greater importance could be that the individual has to bear the cost for energy bills and for the mCHP system, rather than an organisation for non-residential customers which may have greater financial flexibility.
- Most respondents display positive attitudes towards 'green' climate change agendas as well as towards new technologies, products and brands. This may indicate the general profile of these customers as 'early adopters' of the technology, keen to advance the technology and less averse to the financial and operational risks involved. The generally high income of respondents also reduces the consequences of financial and operational risks.
- Almost 80% of respondents would be willing to be a little more for an energy system that was less harmful to the environment, which falls to just 39% willing to pay significantly more. There is, however, a high percentage (38%) of "neutral" responses to paying significantly more. This is likely to indicate a willingness to pay significantly more with the right conditions and other benefits, such as cost savings or independence from the grid.



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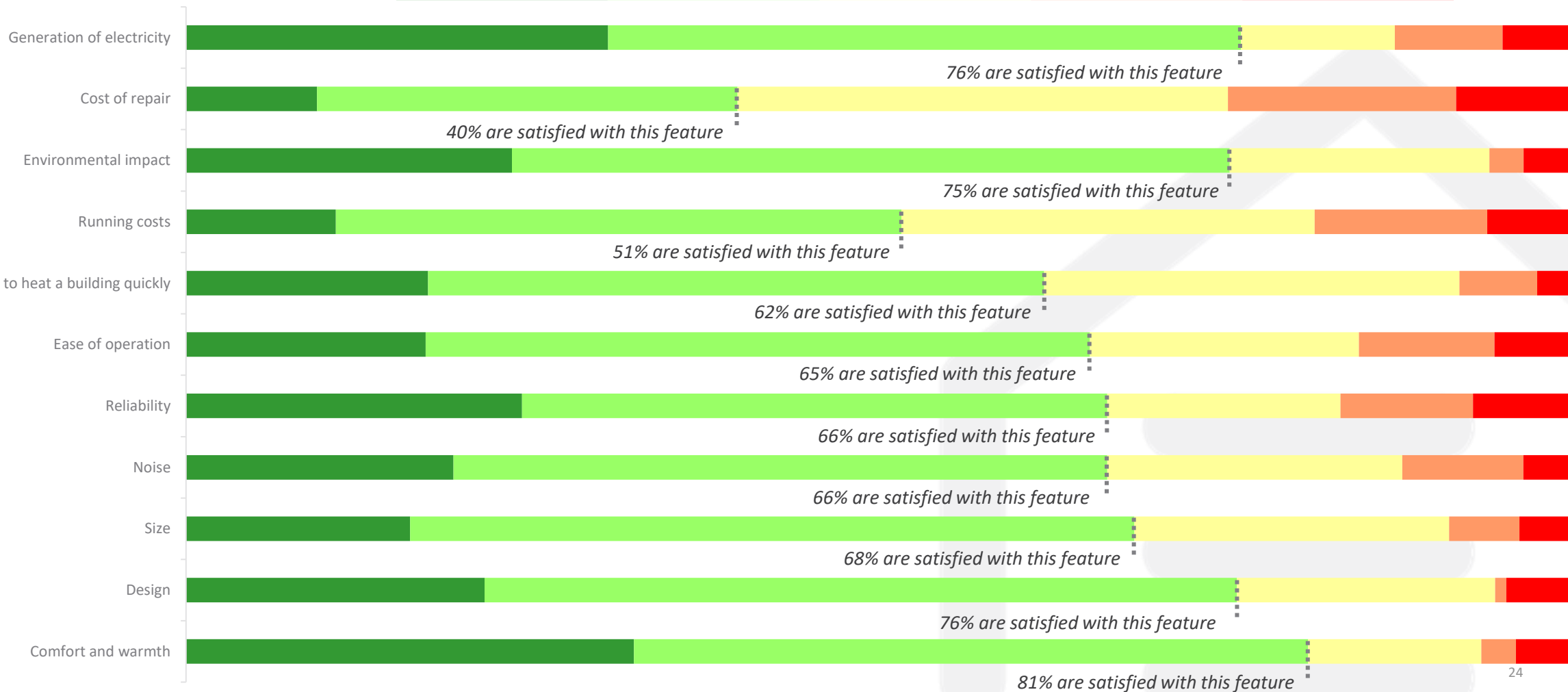
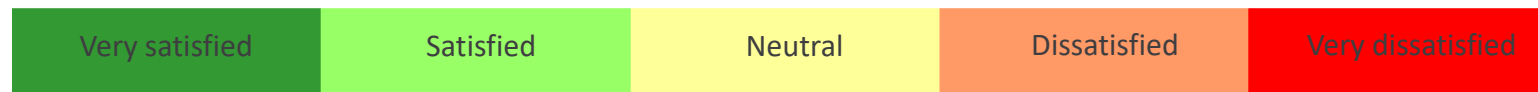
Benefits of FC mCHP

This section seeks to understand the user experience with their FC mCHP unit, including the general operational performance, benefits and payback of the units. This section will cover the following:

- Unit satisfaction
- Improvements to the technology
- Favourite and least favourite aspects of the unit
- Expectations vs experience
- Impact on electricity and gas/oil bills
- Willingness to pay for FC mCHP technology
- Experience conclusions

Operational Performance

How satisfied are you with the following?



Legend

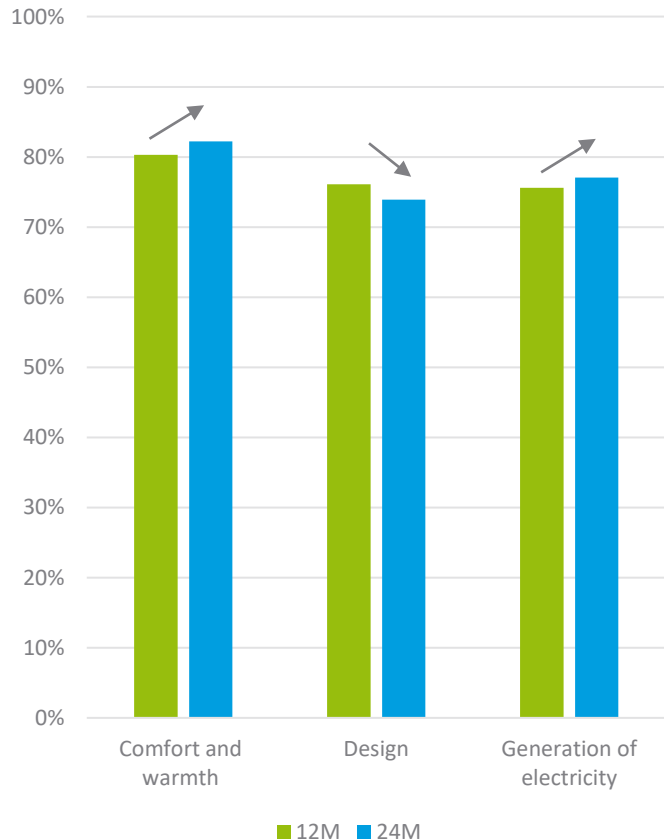
12M = 12 month during operation survey

24M = 24 month during operation survey

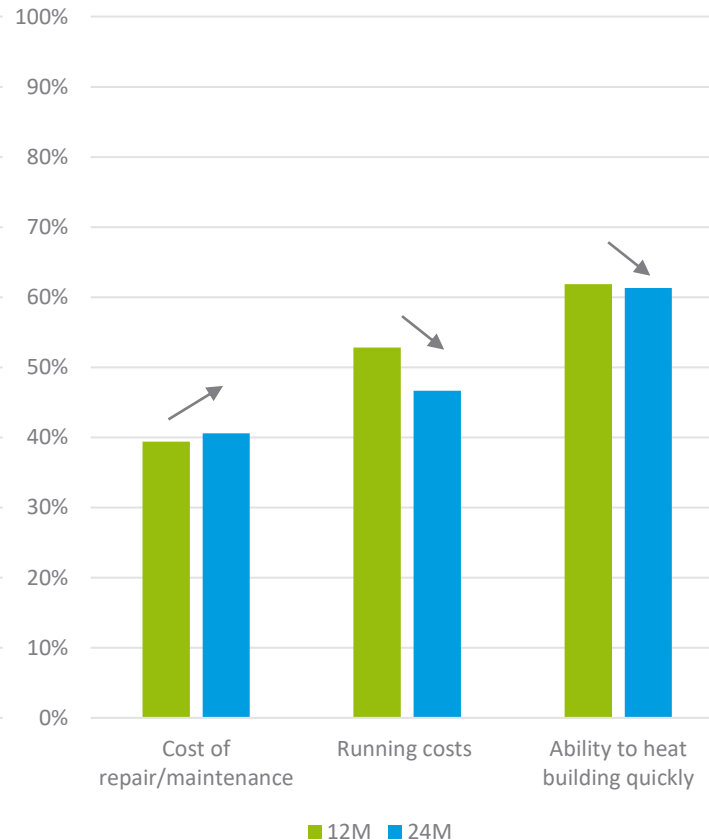
Operational Performance

How satisfied are you with the following?

Parameters with the highest satisfaction



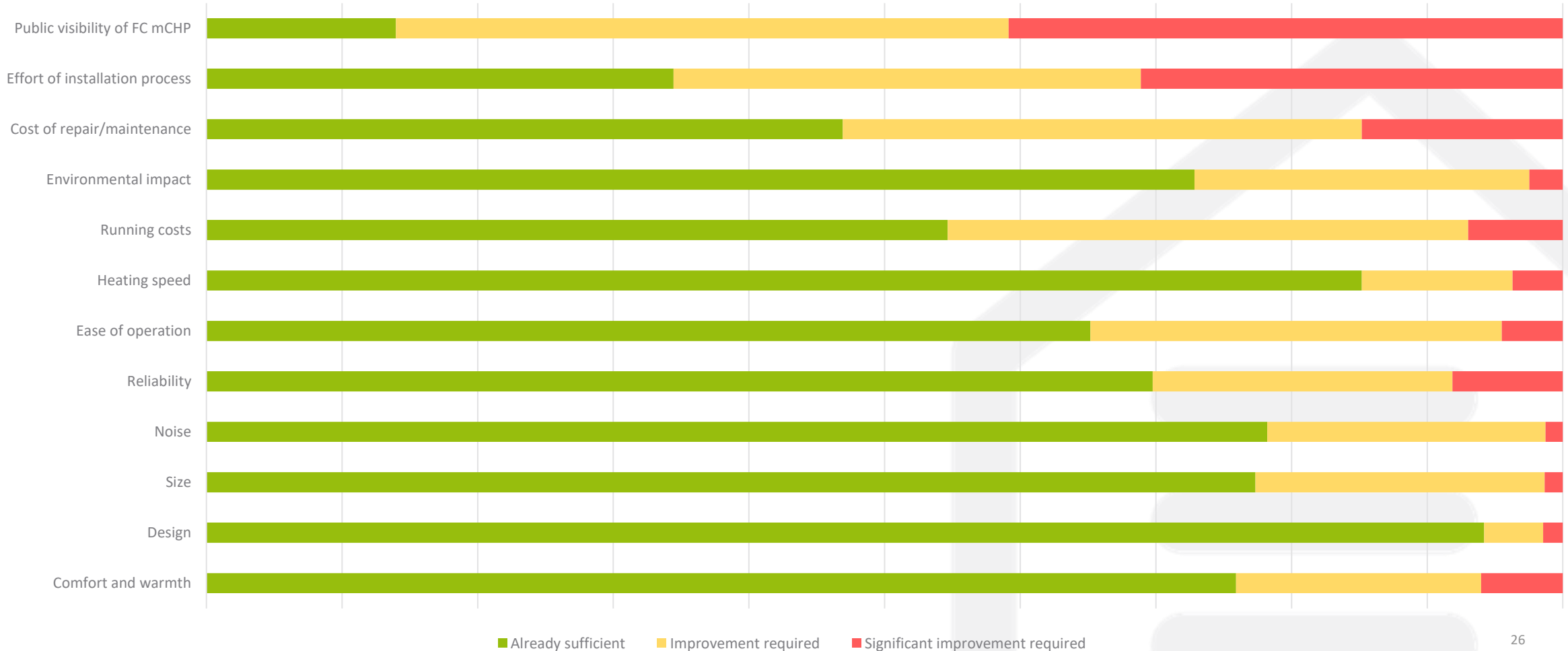
Parameters with the lowest satisfaction



- Respondents were generally satisfied with the operational performance of their unit. For every parameter, at least 75% of responses were either neutral, satisfied or very satisfied.
- The following three parameters had the lowest satisfaction ratings:
 - Cost of repair and maintenance
 - Running costs
 - Ability to heat building quickly
- Of the top and bottom three highest rated, three, there were no significant changes between the 12M and 24M surveys.
- The biggest change between the two surveys was a reduction in satisfaction of 6% for running costs. This has likely been impacted by factors external to the PACE trial, including the energy crisis and rising energy costs.
- It is clear that respondents views are not significantly changing between 12 and 24 months of operation with their unit.

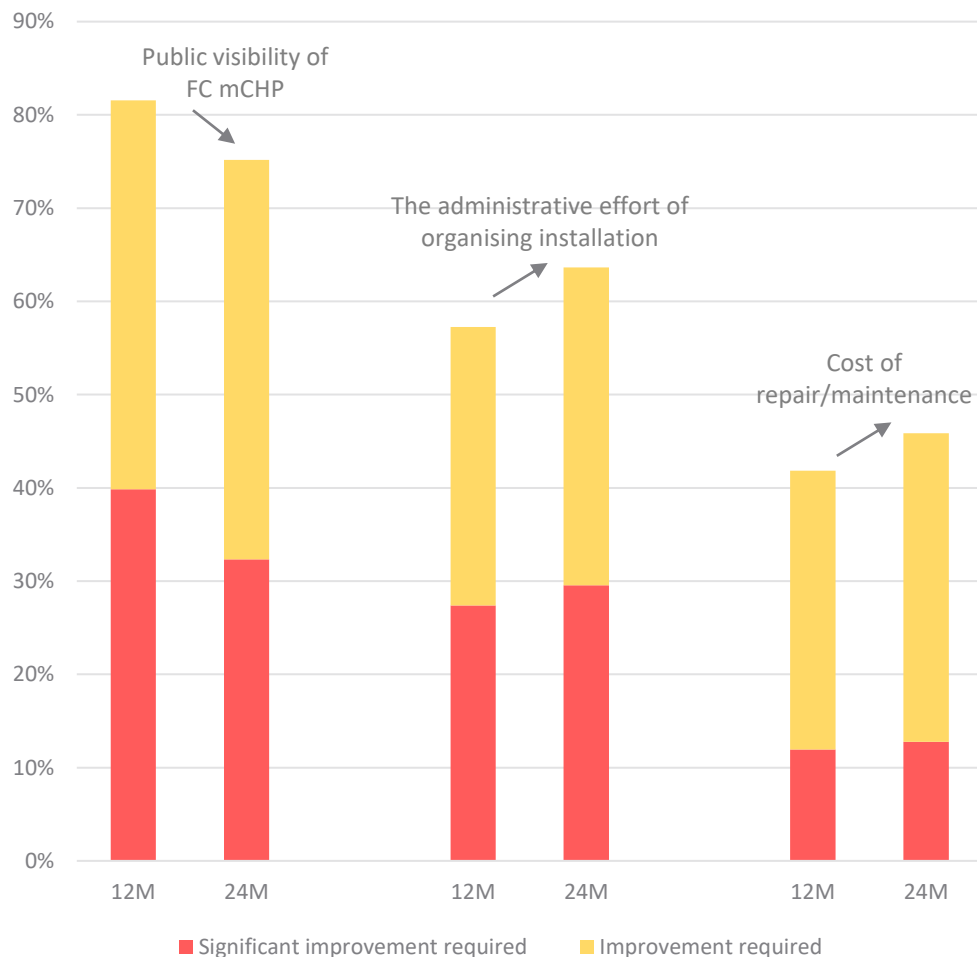
Operational Performance

Based on your experience with a FC mCHP, which of the following do you think have to be improved?



Operational Performance

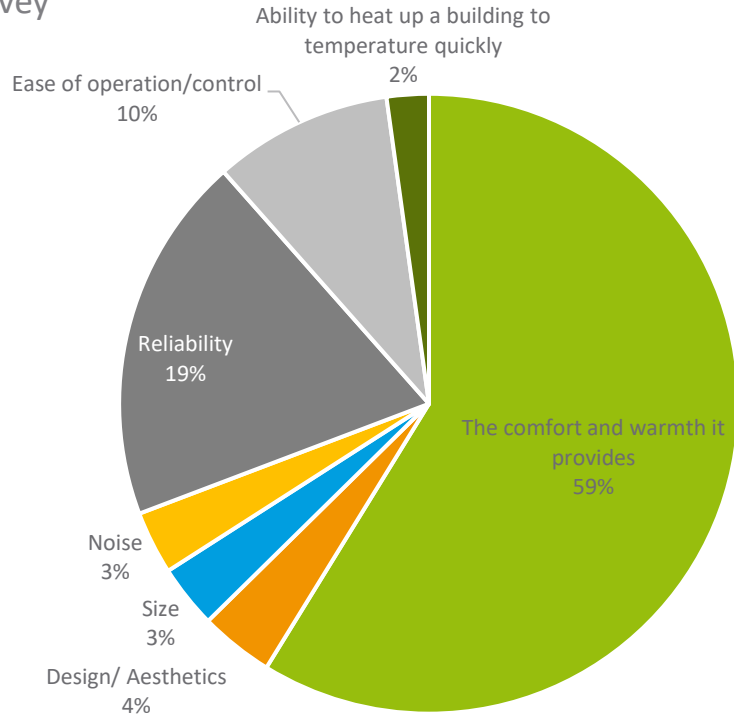
Based on your experience with a FC mCHP, which of the following do you think have to be improved?



- Respondents were generally positive regarding the improvements needed to FC mCHP units. Most parameters were consistently found to be “already sufficient” by the majority of respondents
- The following three parameters were considered most in need of improvements:
 - Cost of repair and maintenance
 - Effort of the installation process
 - Public visibility of FC mCHP
- Of these three, there were no significant changes between the 12M and 24M surveys. For public visibility and cost of repair and maintenance, slightly fewer respondents identified a need for an improvement after 24 months than after 12. The opposite is observed for the effort of the installation process.
- These parameters are all common problems related to new and emerging technologies, as OEMs and installers develop the technical competencies to install and maintain FC mCHP. As a new technology, FC mCHP has additional requirements for specialised training (e.g. electrician know-how, IT skills), and as such only trained and qualified installers can sell and install the technology.

The PACE D1.11 Report on Regulatory Barriers Working Group also identified that the lack of public visibility of FC mCHP is one of the key factors preventing the technology from widespread uptake.

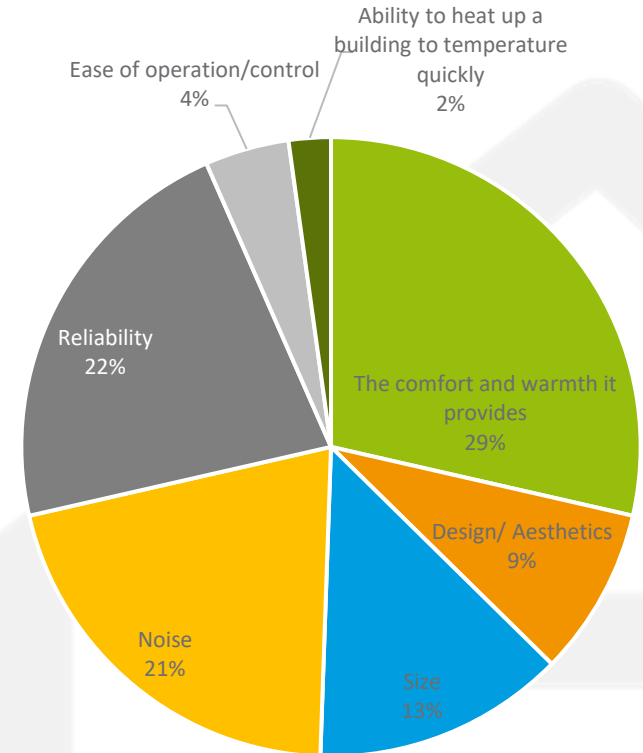
12M Survey



Operational Performance

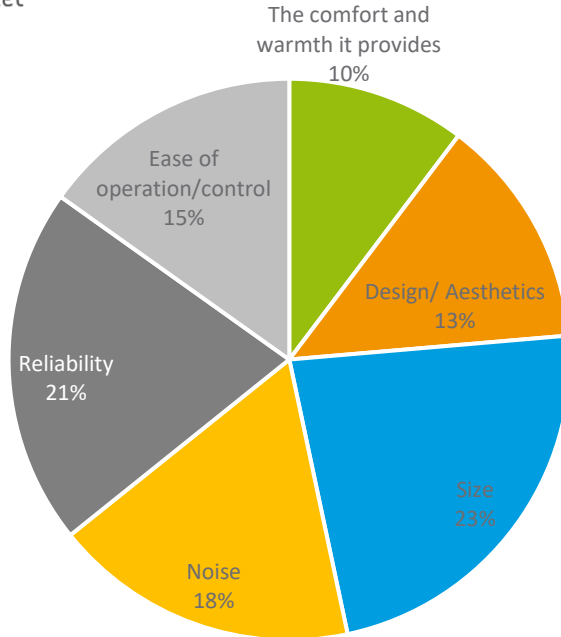
What do you most like about your FC mCHP with regards to the following aspects?

24M Survey



The most liked feature across both the 12M and 24M surveys was the comfort and warmth it provides, which makes up 59% of the responses for the 12M and 29% for the 24M. Reliability had a similar response rate across both surveys (19% and 22%), but noise, size and aesthetics increased in popularity between the two surveys, while the comfort and warmth and ease of operation decreased.

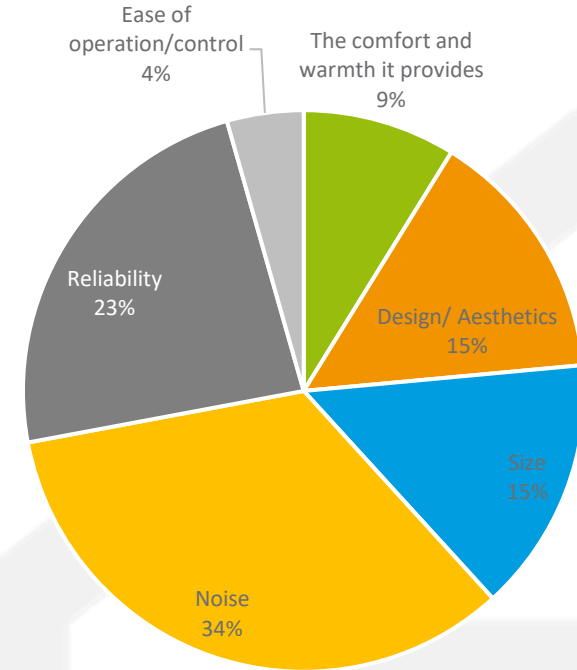
12M Survey



Operational Performance

What do you most dislike about your FC mCHP with regards to the following aspects?

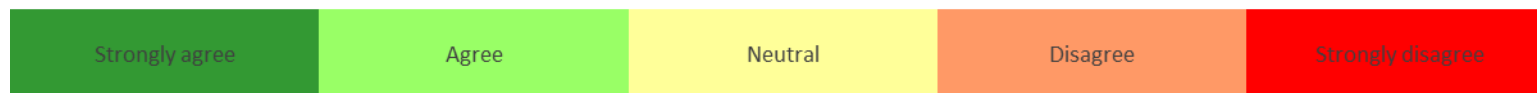
24M Survey



- From the 12M survey, the responses for least favourite features were quite evenly distributed, with the least liked feature being the size of the unit, followed by the reliability. However, when asked if these features needed improvement, just 17% selected that the size could be improved upon and 26% reported that reliability could be improved. Therefore, although these features were selected as a least favourite, respondents were overall happy with them. This question did not provide an option to select “no least favourite” so we can conclude that respondents are generally happy with all features.
- Results differed slightly from the 24M survey, in which noise was consistently identified as the most disliked feature (34%). Once again, just 17% selected that this could be improved upon when asked, suggested that respondents are not overly unhappy with this feature.
- There is a significantly smaller pool of data from the 24M survey, as fewer customers have had their unit for >24 months and were eligible to complete this survey. This may impact the distribution and skew of results.

Operational Performance – Expectation vs Experience

Responses to the question “My FC mCHP has...” from during-operation surveys, compared to customer expectations of what their FC mCHP would provide from the pre-operation survey.



Produced all the electricity we use



27% agree with this statement (32% decrease compared to expectation)

Produced all the heat we need



55% agree with this statement (1% decrease compared to expectation)

Provided hot water when we needed



76% agree with this statement (7% increase compared to expectation)

Kept us warmer than our previous heating system



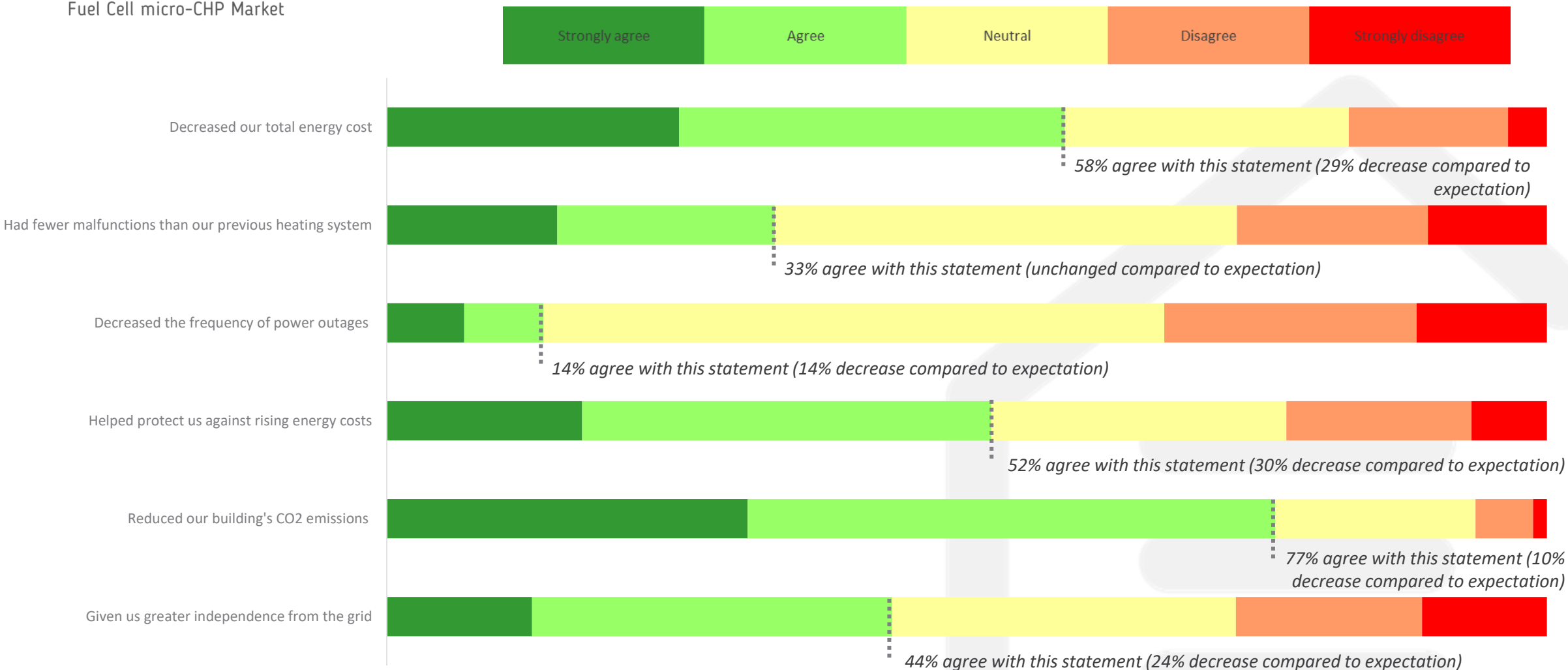
38% agree with this statement (2% increase compared to expectation)

Decreased our total energy consumption



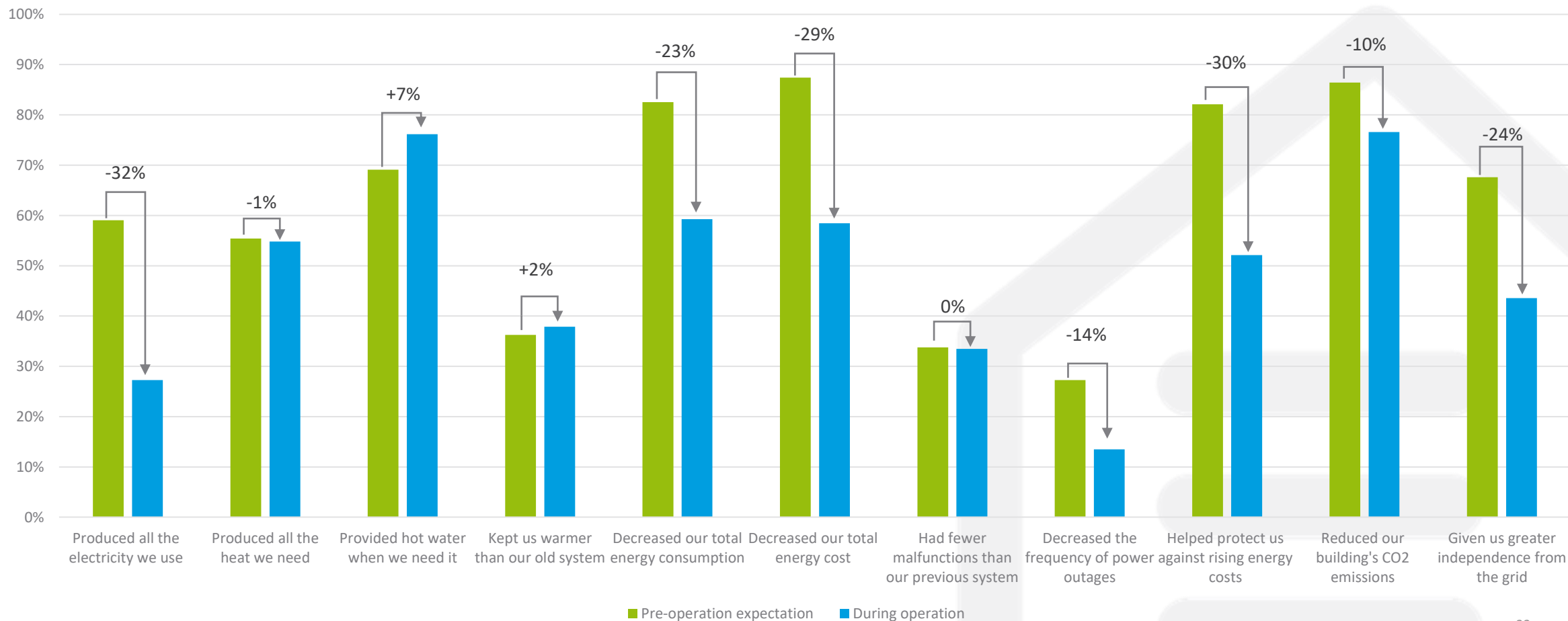
59% agree with this statement (23% decrease compared to expectation)

Operational Performance - Expectation vs Experience



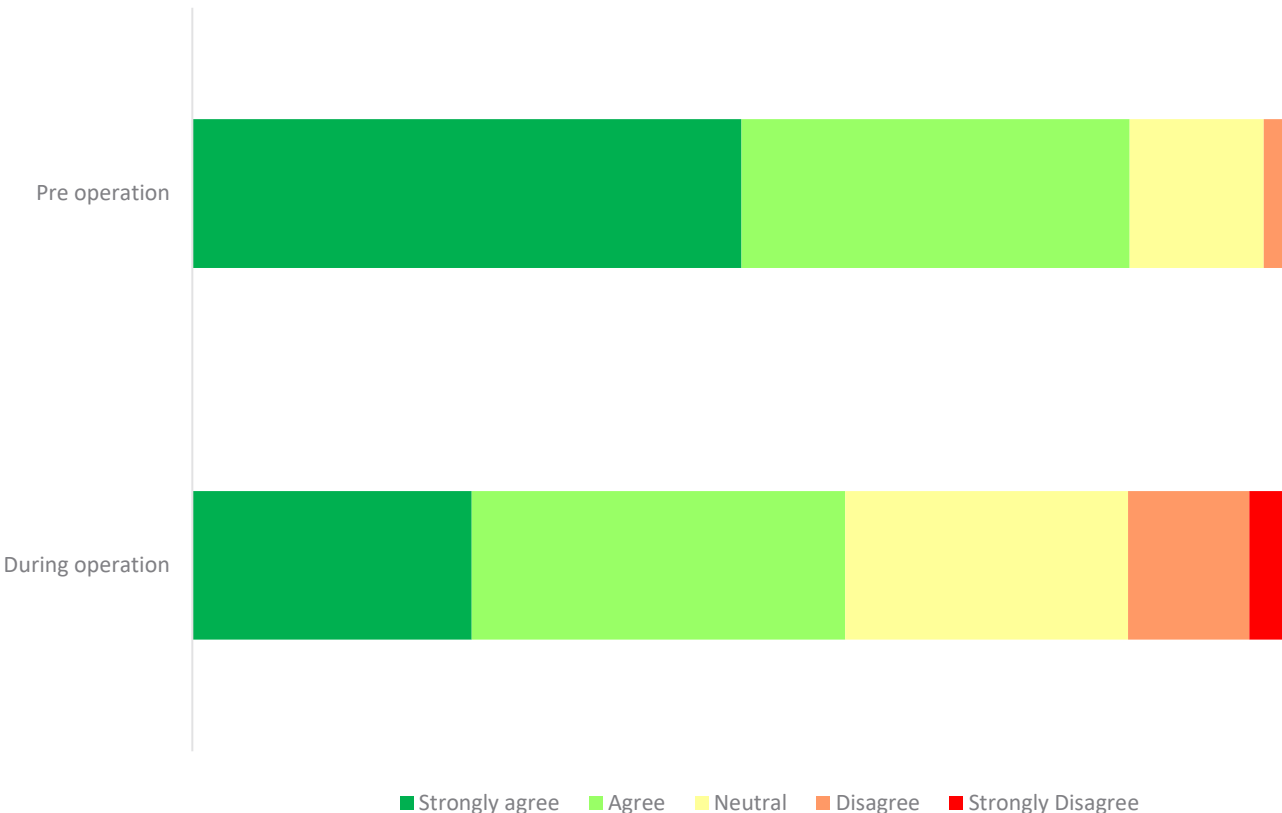
Operational Performance – Expectations vs Experience

Percentage of respondents that agree or strongly agree with the following: "my FC mCHP has / will..."



Operational Performance – Expectations vs Experience

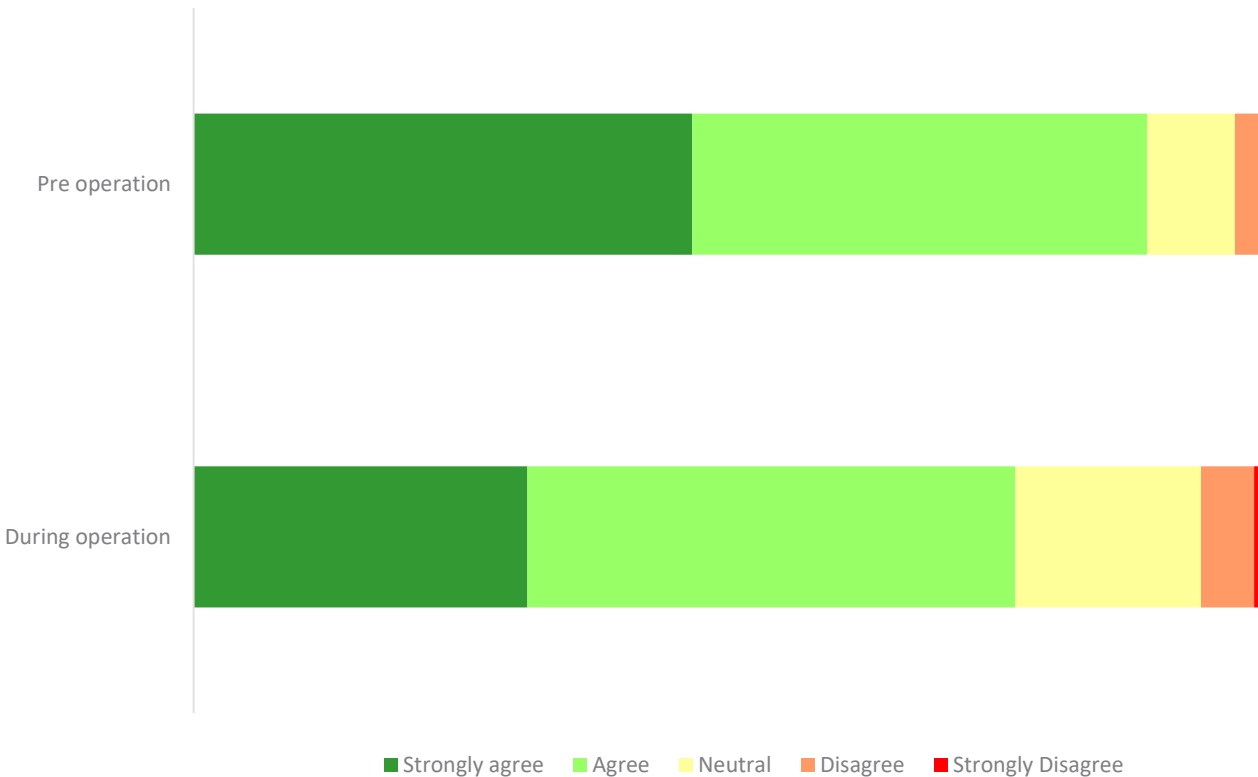
How far do you agree with the following statement: “My FC mCHP has / will decreased our total energy consumption”



- Primary energy savings was the highest motivating factor for PACE customers buying of FC mCHP.
- 85% of respondents anticipated that their consumption would decrease and the unit would provide energy savings, compared to 59% of respondents who reported experiencing this. This is a significant decrease between expectations and experience.
- In the report D2.3 ‘overall Performance in a system perspective’, PACE hypothesises that, in a best case scenario, PACE FC mCHP units can make a 25% primary energy saving for appropriate European homes. Current data suggests that there has been an average energy consumption saving of 6% across PACE units.
- This aligns with the findings from participant surveys that fewer savings have been experienced than expected. These surveys do not, however, assess the extent of the savings and rather test whether any savings have been made.
- A further iteration of the report D2.3 will be developed with a wider data pool to test this hypothesis.

Operational Performance – Expectations vs Experience

How far do you agree with the following statement: “My FC mCHP has / will reduce our building's CO₂”



- CO₂ savings were also a significant motivating factor for PACE customers buying of FC mCHP.
- 88% of respondents anticipated that their CO₂ emissions would decrease, compared to a slightly lower figure of 76% of respondents who reported experiencing this.
- In the report D2.3 ‘overall Performance in a system perspective’, PACE hypothesises that PACE FC mCHP units can make a 30% CO₂ saving for appropriate European homes. Current data suggests that there has been an average CO₂ consumption saving of 16.6% across PACE units.
- This aligns with the findings from participant surveys that slightly fewer reductions in CO₂ emissions have been experienced than expected, although a less significant drop and more positive perspective is shown from the participant surveys. These surveys do not, however, assess the extent of the reduction and rather test whether any reduction has been experienced.
- It is also noted that the survey results are subjective and based on participants’ own perception of whether their emissions have reduced. Participants may measure this in different ways.
- A further iteration of the report D2.3 will be developed with a wider data pool to test this hypothesis.

Operational Performance – Expectations vs Experience

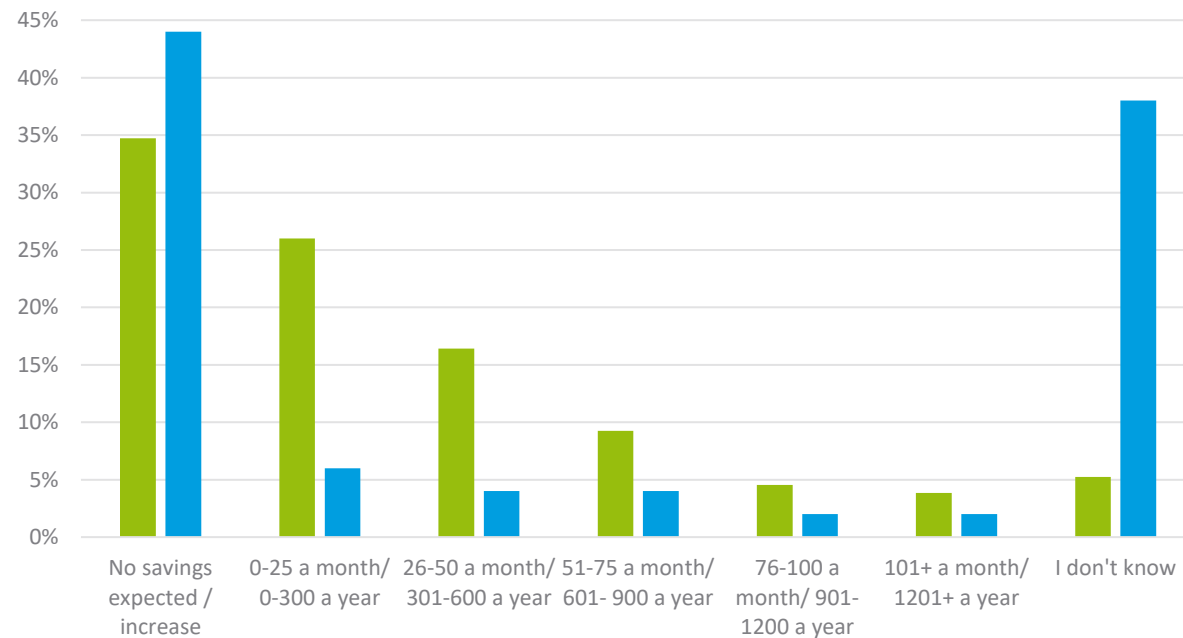


- Expectations of FC mCHP were generally high, particularly regarding the reduction of CO₂ emissions, energy consumption and energy cost.
- In all but three cases, the expectations of FC mCHP were higher than the reality recorded in the during operation surveys.
- For parameters related to heating performance (“provided hot water when we needed it” and “kept us warmer than our old system”), the actual experiences scored higher than customer expectations.
- Many parameters are likely interlinked. For example, with fewer respondents than expected having their FC mCHP decrease their total energy consumption, this may also affect the expectation vs experience of energy costs, CO₂ emissions and independence from the grid.
- The greatest percentage divergence between expectation and actual experience was seen for “helped protect us against rising energy costs”, where a large proportion of respondents (82%) had agreed with the statement prior to operation, whereas approximately half agreed with the statement after their experience with using FC mCHP. However, this may reflect wider energy market issues over the trial period (for example the emergence of the COVID-19 pandemic and the rise in natural gas prices).

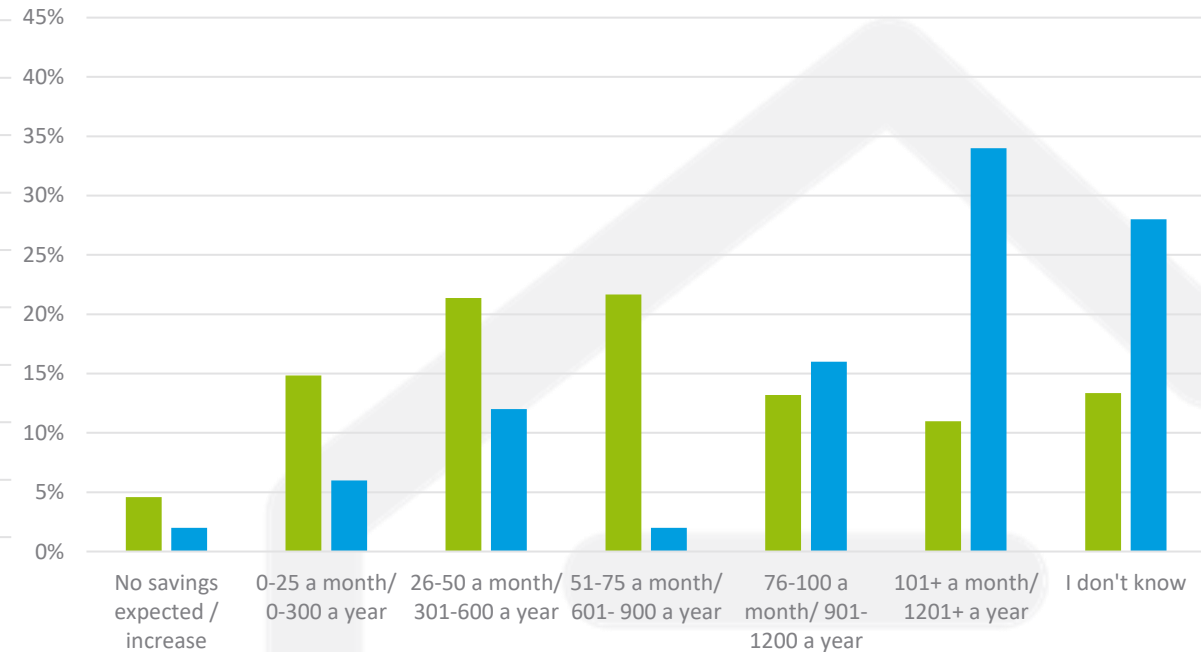
It is clear that the expectations that end users had for their FC mCHP units were very high and that, despite the divergence between these expectations and their experiences, overall appraisal of the system remains very high.

Expected financial benefits of FC mCHP compared to actual benefits

Decrease in gas and oil bills



Decrease in electricity bills



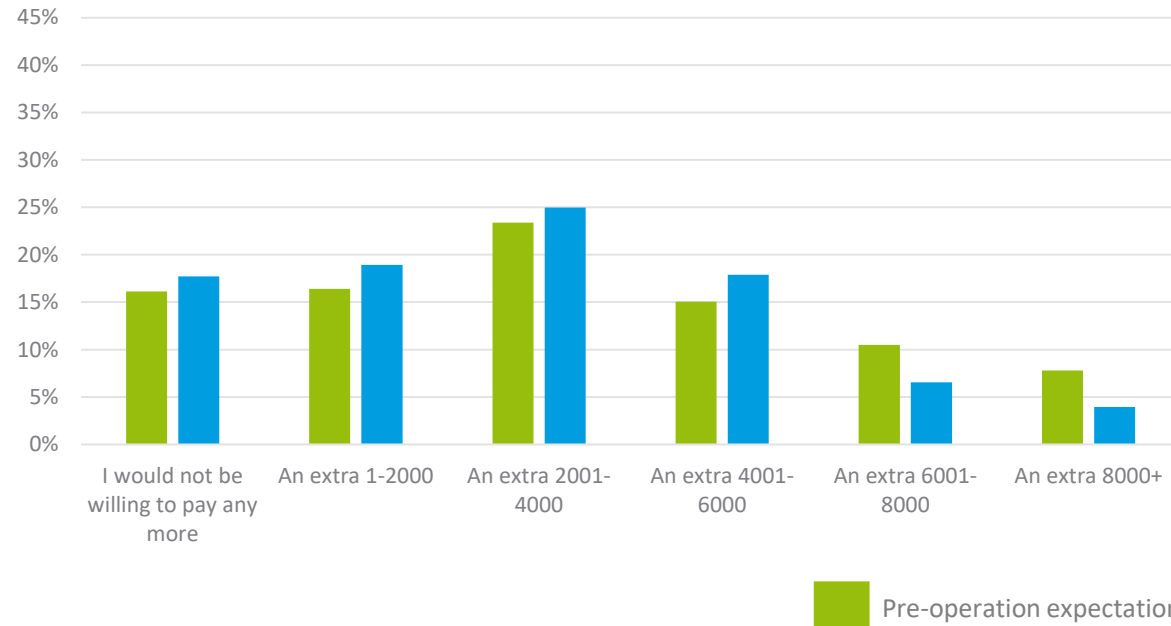
Pre-operation expectations During operation

- 60% of respondents anticipated a decrease in their gas and oil bills after installation, compared to just 16% who actually experienced a decrease. This may reflect wider energy market issues over the trial period (for example the emergence of the COVID-19 pandemic and the rise in natural gas prices). Conversely, 82% of respondents expected to see a decrease in their electricity bills and 70% did. It can be seen that FC mCHP helped to protect users from volatile power prices, delivering savings despite significant spikes in energy prices between 2021-2023.
- There were also, however, a significantly higher percentage of respondents that selected "I don't know" in the during operation questionnaires (38% for gas and oil bills and 28% for electricity bills) compared to the pre-operation questionnaire (5% for gas and oil bills and 13% for electricity bills).

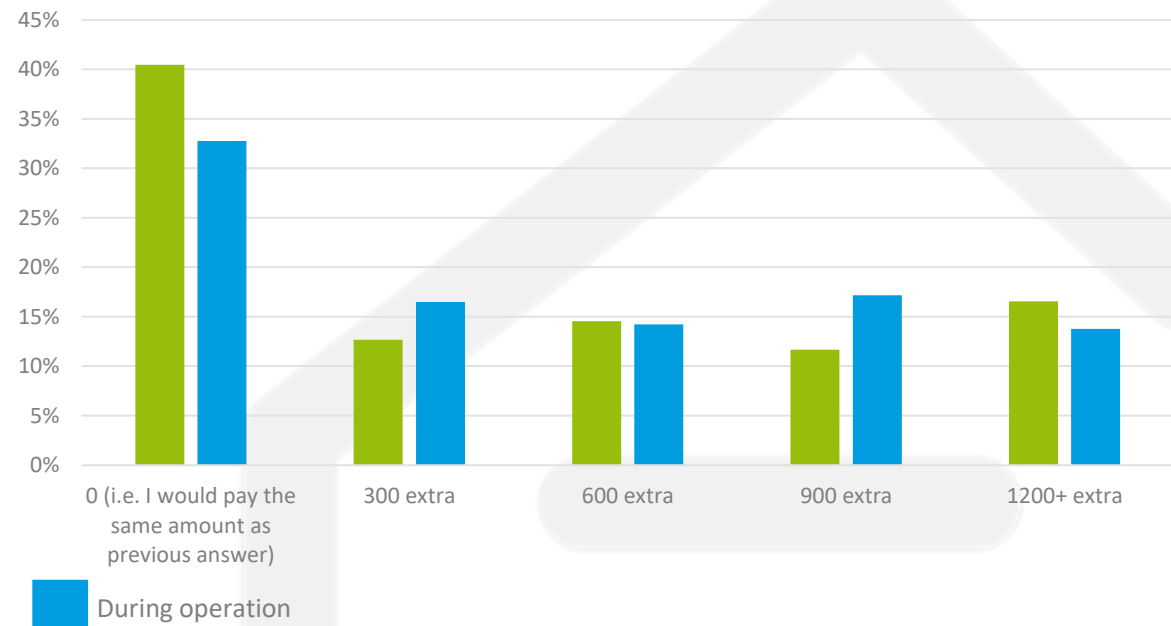
Financial Benefits

Willingness to pay for FC mCHP

How much would you be willing to pay for a FC mCHP, assuming you made a saving of £125/month and reduced your CO₂ emissions by 20%?



How much more would you be willing to pay for a FC mCHP that reduced your household CO₂ emissions by 40% rather than 20%?

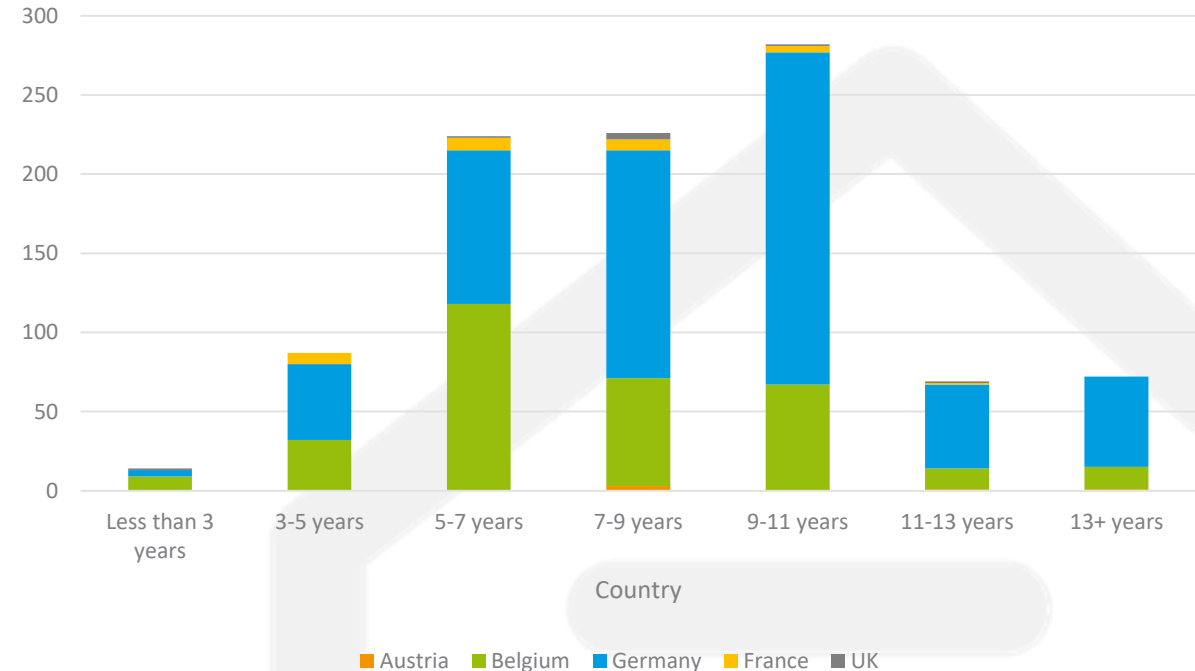
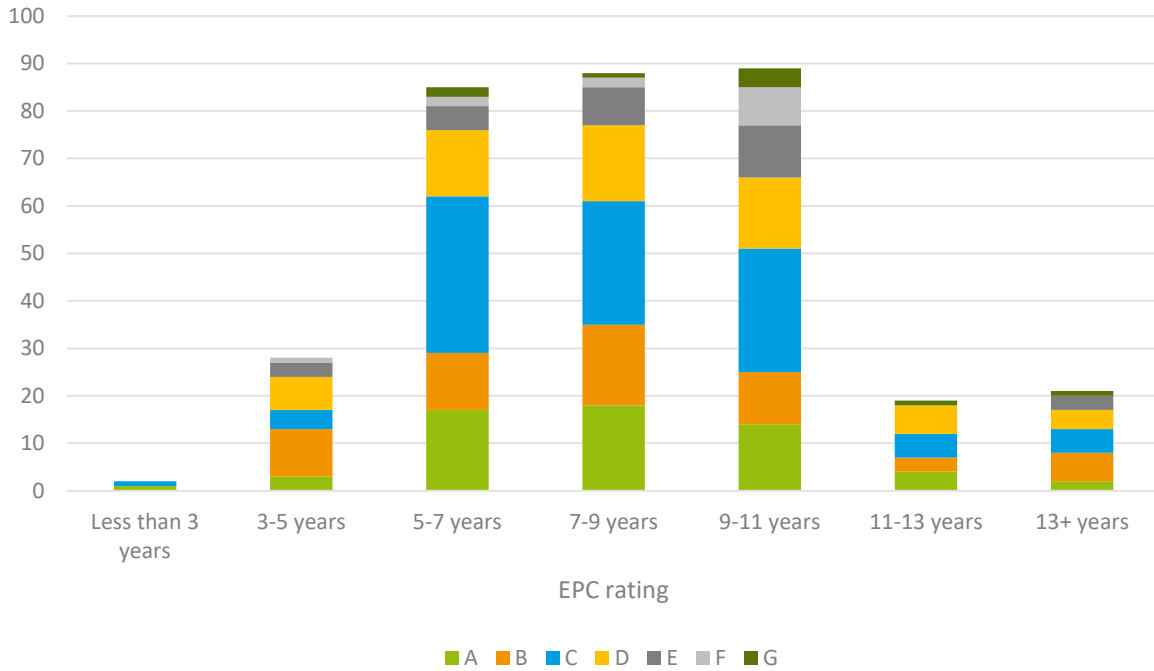


- Over 80% of respondents would be willing to spend more money on a FC mCHP compared to a conventional boiler, assuming cost savings of €30 per month and carbon emissions reductions of 20%. A further 60% of customers would be willing to pay an additional amount to reduce household carbon emissions by 40% rather than 20%. This shows that while reduction of carbon emissions are a key motivation for many customers, the cost of the technology still remains a large factor in the buying decision.
- Customer attitudes remained fairly constant between the pre-operation and during-operation surveys. There has been a slight increase from the pre-operation survey in the amount customers would be willing to pay if their household carbon emissions were reduced by 40%, while a small decrease in the amount for a reduction of 20%.

Financial Benefits

Payback on investment compared to building EPC rating and country

How long would you be willing to wait for payback on your FC mCHP investment?



- 68% of all respondents in the pre-operation and during operation surveys would be willing to wait for more than 7 years for payback on the money spent on a FC mCHP through energy savings.
- Respondents from Germany would be prepared to wait slightly longer for payback than those from other countries.
- Respondents with a lower EPC rating would be prepared to wait slightly longer than those with a higher rating.

Benefits of FC mCHP – Expectations vs experience

Summary

- Expectations of FC mCHP were generally high, particularly regarding the reduction of CO₂ emissions, energy consumption and energy cost. In all but three cases (“provided hot water when needed”, “had fewer malfunctions than previous system” and “kept us warmer than our old system”), the expectations of FC mCHP were higher than the reality recorded in the during operation surveys.
- The greatest difference between expected and experienced benefits was regarding protection against rising energy costs. 82% of respondents anticipated that their FC mCHP unit would help protect them from rising costs, whereas 52% of respondents reported actually experiencing this. It is important to consider the impact of external market and living conditions on these responses, given the (up to) 2-year gap between respondent’s pre-operation and during operation questionnaires. The impact of COVID-19, the war in Ukraine and the subsequent, ongoing energy crisis across Europe has raised energy costs beyond any foreseen expectations. This is likely to have had an impact on the rising costs experienced by respondents.
- The actual financial benefits of FC mCHP were lower than the expected, particularly regarding gas and oil bills. 60% of respondents anticipated a decrease in their gas and oil bills after the installation of their FC mCHP, whereas only 16% actually experienced a decrease. Conversely, of the 82% of respondents who expected to see a decrease in their electricity bills, 70% did. This data suggests that switching to a FC mCHP unit has indeed helped to lower bills and protect against rising costs in many cases, even if less than was expected.
- The responses regarding overall experiences with FC mCHP units have highlighted some concerns, despite the customers being generally supportive of the technology and being ‘early adopters’. These concerns could therefore be exacerbated in a wider market where customers may be less accepting of issues with the technology. It is also worth noting, however, that as these respondents are largely ‘early adopters’ trying out new technologies, this may have led to inflated initial expectations.
- Despite these concerns, the overall response of the surveys has been a strong overall satisfaction with the systems.



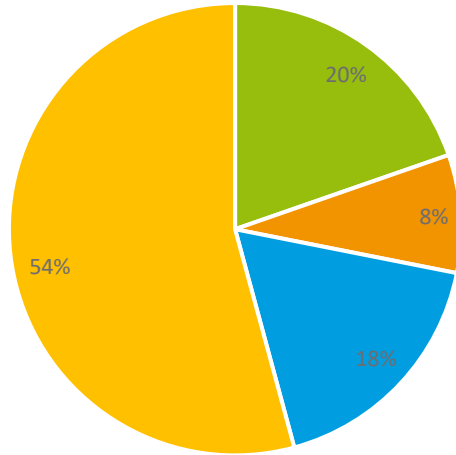
Pathway to a Competitive European
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Problems and Breakdowns

Problems and breakdowns

In the past year, have you experienced any problems or breakdowns with your mCHP?

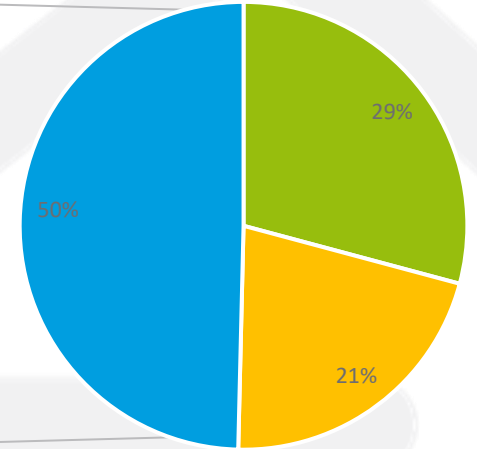
If your problem required emergency repair, how long did it take between reporting the issue and someone coming to visit?



■ A few hours ■ Less than 1 day ■ 1-2 days ■ More than 2 days

■ No ■ Yes, emergency repair ■ Yes, non-emergency repair

If your problem required non-emergency repair, how long did it take between reporting the issue and someone coming to visit?



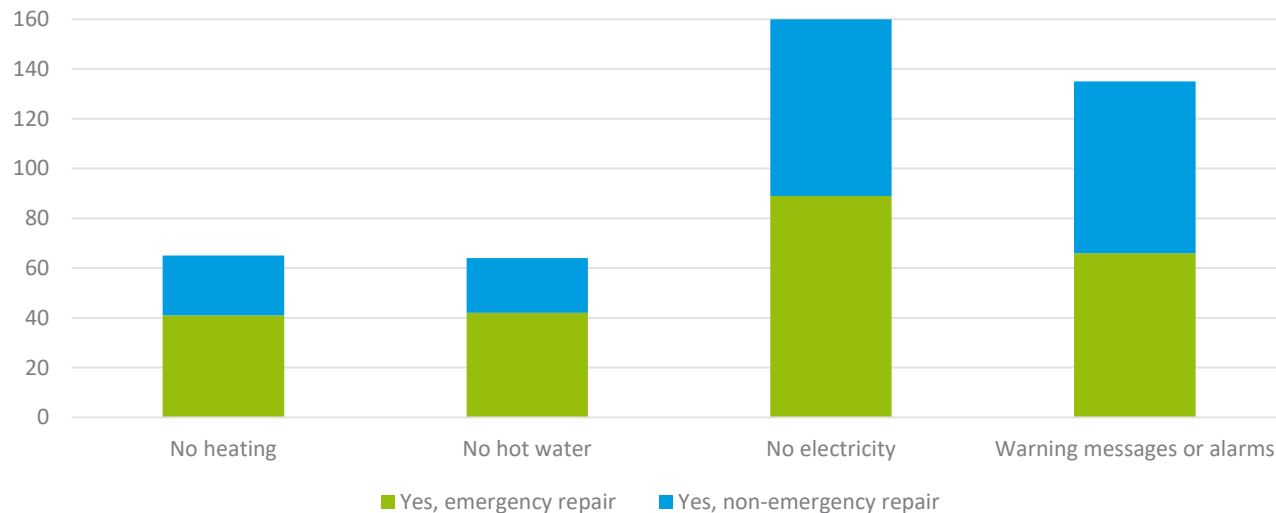
■ 2 days or less ■ 3-7 days ■ More than 1 week

- The majority of respondents required repairs during operation of their FC mCHP. Non-emergency problems were slightly more common than emergencies.
- This high rate of problems reflects the nature of new technologies, and it would be expected that this will decrease over time.
- Wait times for service providers to be able to visit the issue have been largely impacted by COVID-19 throughout the trial, resulting in the availability of service people being lower than usual, and wait times being longer. This is something that has begun to improve in 2022 as COVID-19 restrictions were eased across Europe.

The most common problem or breakdown experienced by respondents has been “no electricity”. This problem has also been reported to be the slowest to be repaired, whether in an emergency or not.

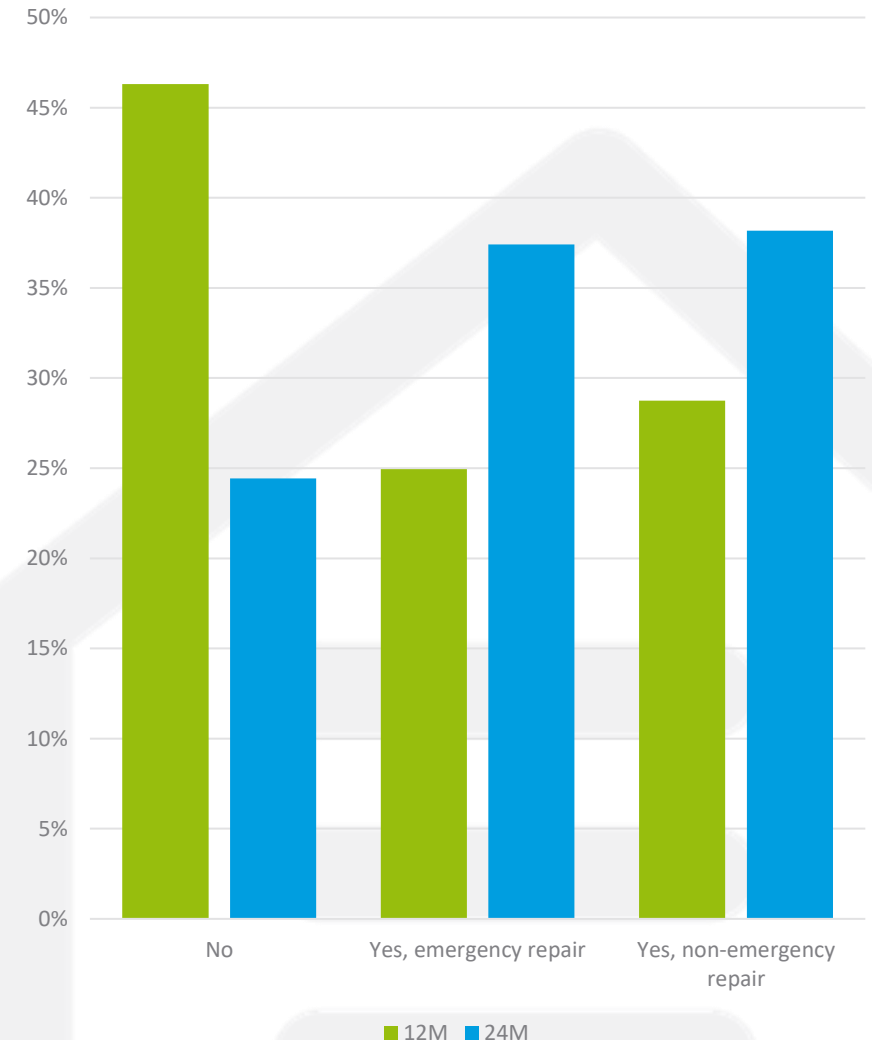
More respondents reported experiencing problems or breakdowns in the second year with their unit, with an increase in breakdowns from 54% to 76% between the two surveys.

Conversely, PACE analysis of the units’ hours in operation has shown a general increase between years. There was, however, a sharp decrease in operating hours in Q2 and Q3 of 2021, before continuing to rise from Q4 2021 onwards. Depending on when respondents had their units installed, this may have coincided with their completion of the 24 month survey and therefore would align with the increase in breakdowns seen in the survey results.



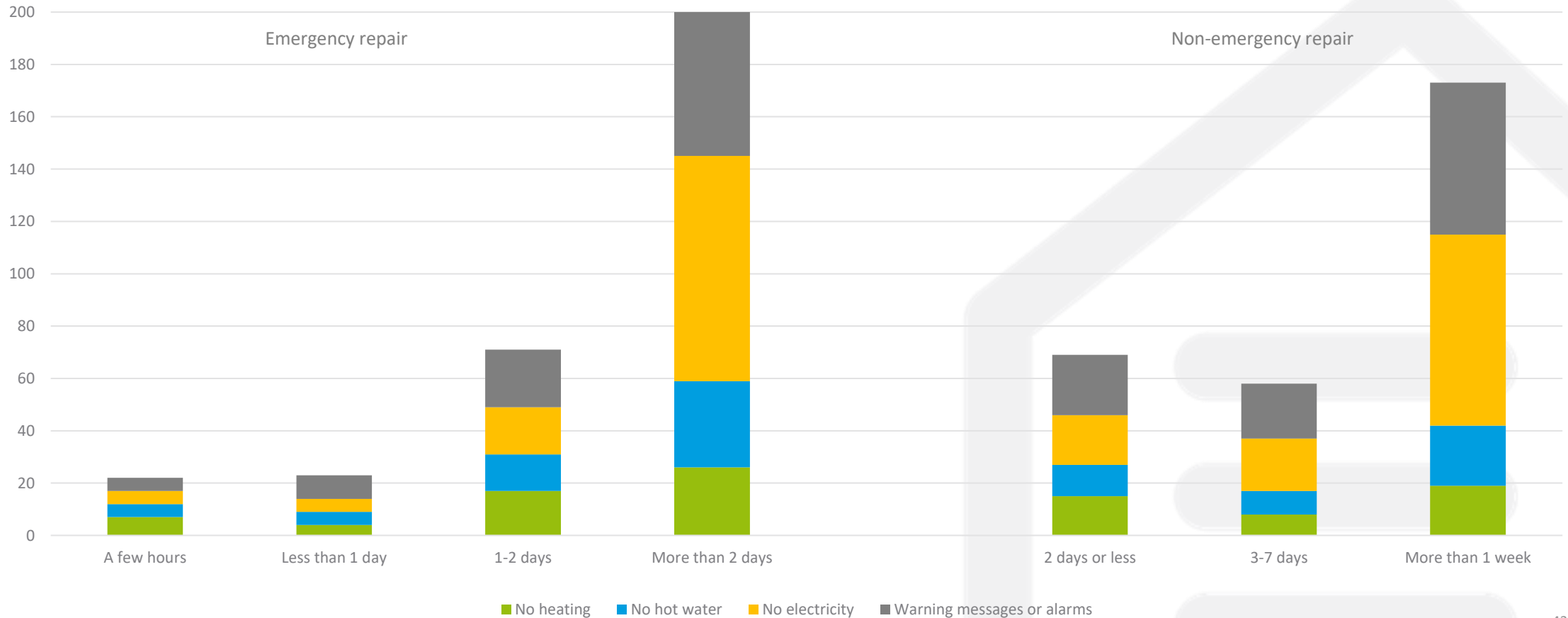
Problems and breakdowns

In the past year, have you experienced any problems or breakdowns with your mCHP?



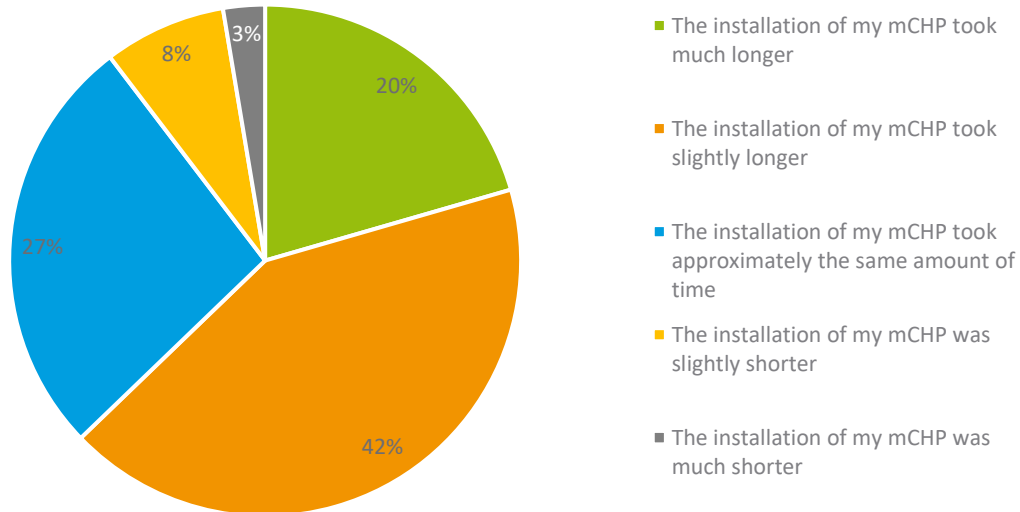
Problems and breakdowns

How long did it take between reporting the issue and someone coming to visit?

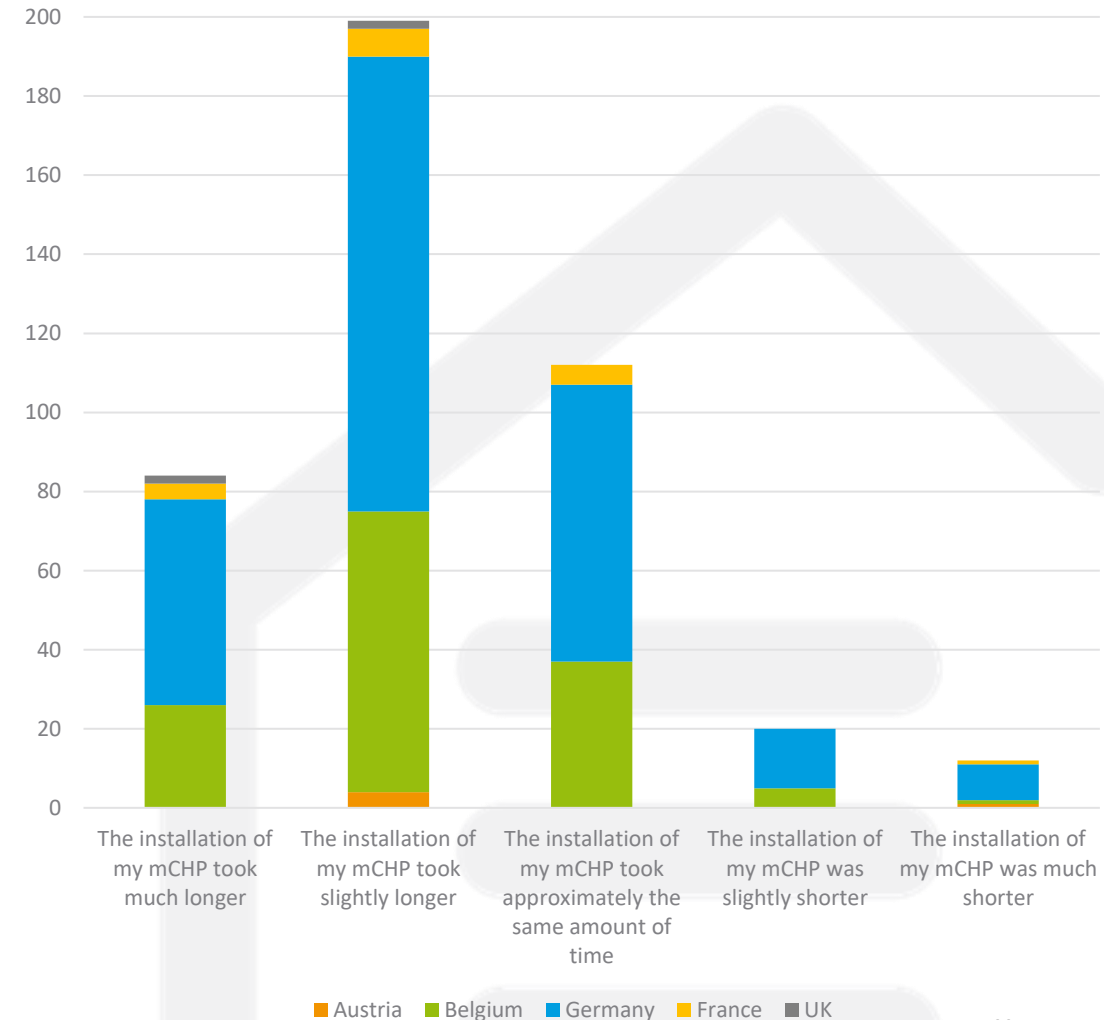


50% of respondents reported that the installation of their mCHP unit took longer than their previous heating system. The length and effort of the installation process was also identified as being a key area of improvement for the technology. This is to be expected, however, as in most cases the unit has been replacing a simpler system.

The average installation time for PACE units is 2-7 days, varying slightly depending on the availability of service providers. The time span between when the order is placed and when the installation takes place, however, is significantly longer. OEMs have reported wait times ranging from 1-7 months.



Length of Installation



Problems and breakdowns

Summary

- 59% of respondents experienced a problem or breakdown in the past year. 31% of these were non-emergency problems and 28% were emergencies. This high rate of problems reflects the nature of new technologies, and it would be expected that this will decrease over time.
- The most commonly reported problem was no electricity (160 responses), followed by warning messages or alarms (135 responses).
- The most common length of time between reporting an issue and someone coming to visit was more than 2 days for emergency problems, and more than 1 week for non-emergency issues. The relatively long time taken to repair these issues may reflect the lack of installers who are able to carry out maintenance on this new technology (See D1.2 report for further information).
- More respondents reported problems or breakdowns in their second year, with an increase in breakdowns from 54% to 68% between the two surveys.
- 50% of respondents also found the installation time of their FC mCHP to be longer than that of their previous systems. This aligns with the effort of installation being identified as a key area of improvement for the technology.
- The average consumer for this technology is currently still an early-adopter, and there is therefore a strong need to improve on these areas when scaling up the technology to larger markets.



Pathway to a Competitive European
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Case Studies and Testimonials

“Very efficient heating system which also covers part of the electricity demand.”

Case study 1

Location: Germany

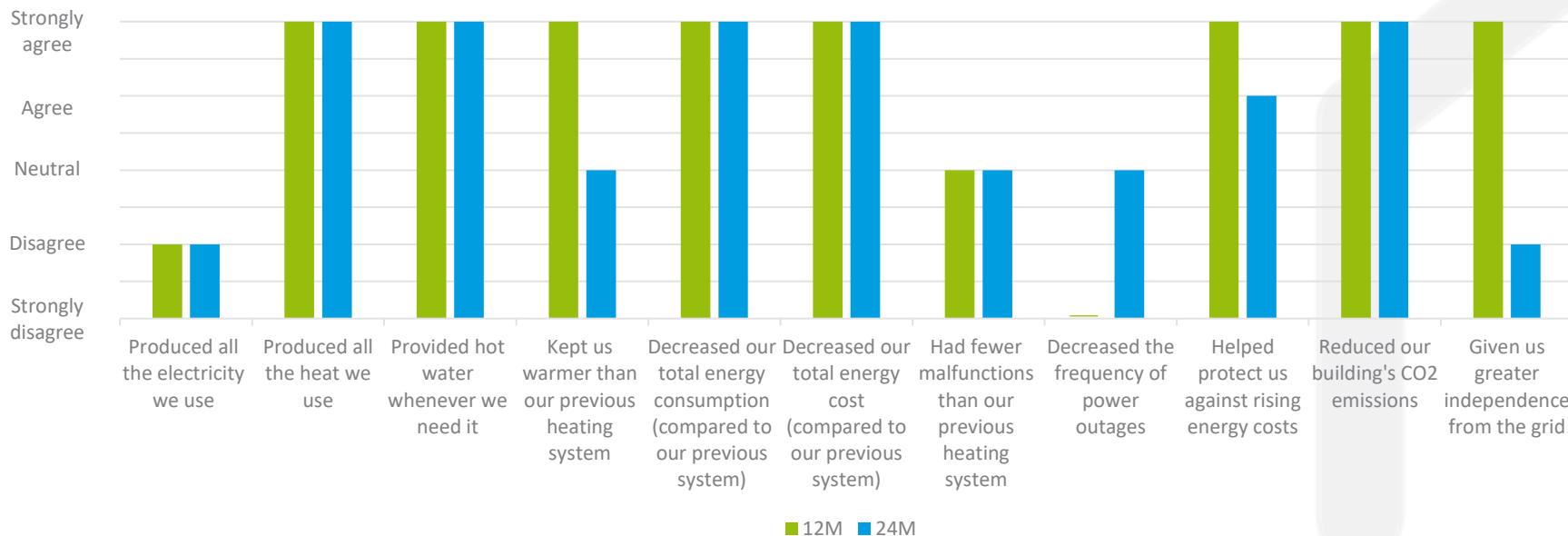
Installation: 2017

Motivation: New technology

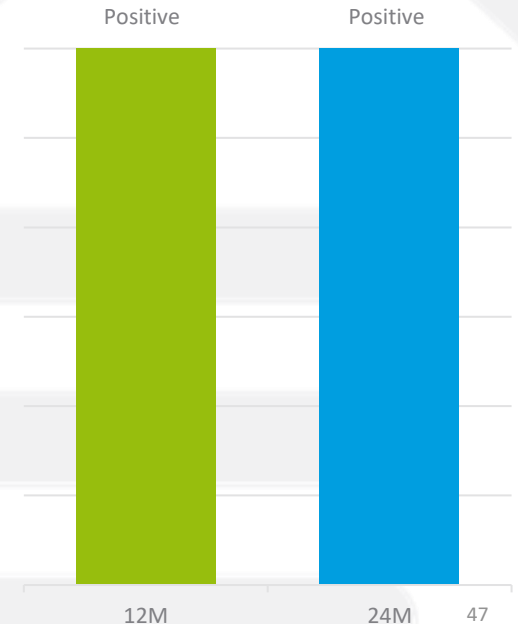
Participant 1 rated their experience with their unit consistently very high between the 12M and 24M surveys

- Their overall satisfaction was “positive” in both surveys
- When asked about different performance factors, they “strongly agreed” in both surveys for 5 of 11 parameters, including that the unit produced hot water and heat when needed and decreased both energy costs and consumption.

Participant 1 described their units as a “very efficient heating system”, but reported that it only covers a portion of the electricity demand rather than producing all electricity that they used.



Overall unit satisfaction



"We find the technology fascinating. We will and have already recommended FC to others. Everything is good! We can only recommend it! Try it out for yourself, it's worth it!"

Case study 2

Location: Germany

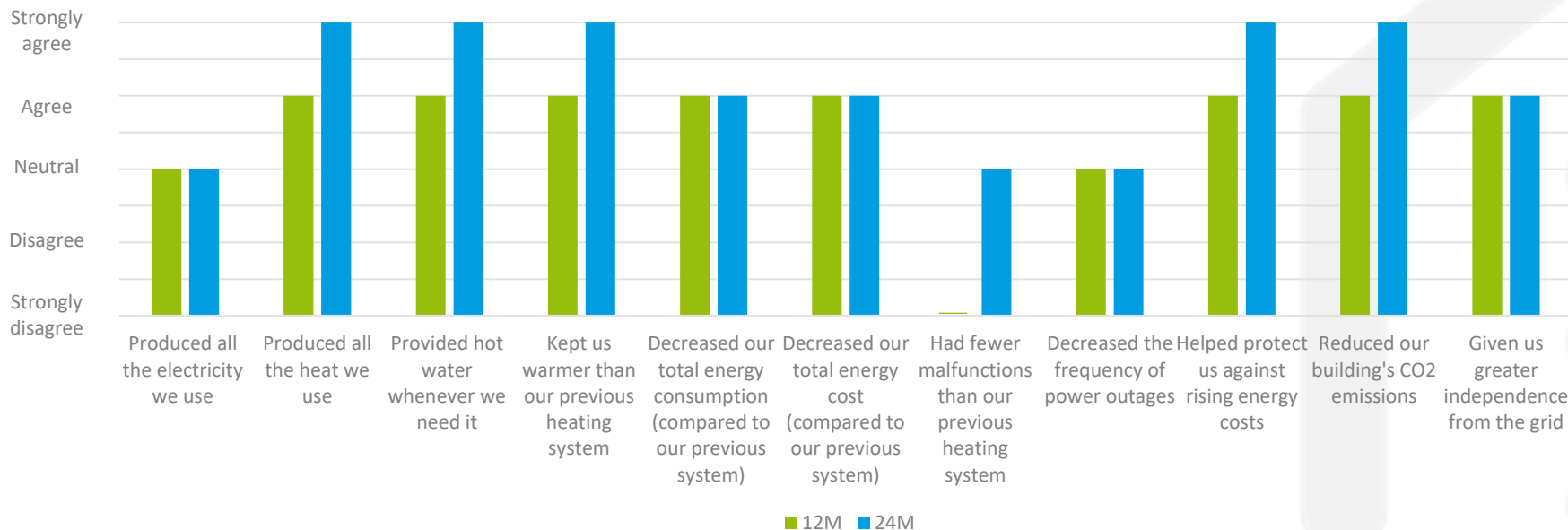
Installation: 2018

Motivation: Energy savings

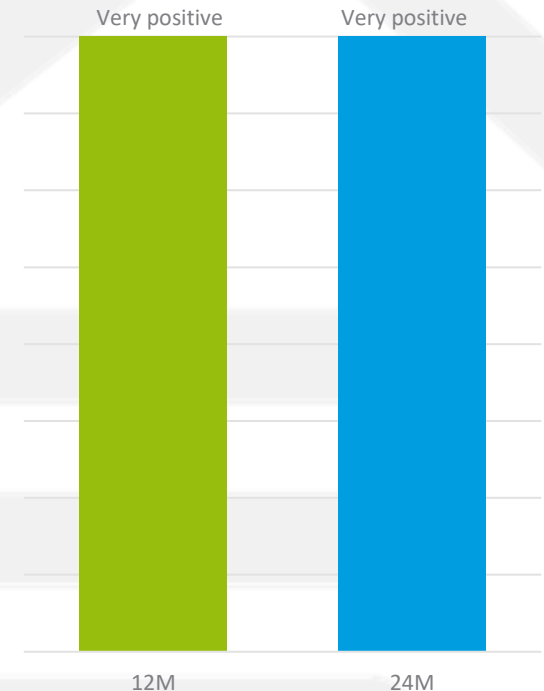
Participant 2 rated their experience with their unit consistently very high between the 12M and 24M surveys

- Their overall satisfaction was "very positive" in both surveys
- When asked about different performance factors, their experience improved in 6 of the 11 factors between the 12M and 24M surveys, and did not decrease in any of them. They "strongly agreed" with 5 parameters across the two surveys.

The testimonials provided by participant 2 were extremely positive, stating that "everything is good" and that they highly recommend the technology.



Overall unit satisfaction





Pathway to a Competitive European
Fuel Cell micro-CHP Market

"The FC mCHP bears our electricity consumption of several large appliances in a household with 7 people. The system is expensive to purchase, hence high operating costs. In combination with a solar system, there is extensive independence from the electricity grid. About 60% of the electricity demand is met by the CHP, especially in winter. However, the system does not operate if the external power grid fails. High reliability of the system, but too few heating engineers to service the system (always 100 km away)."

Case study 3

Location: Germany

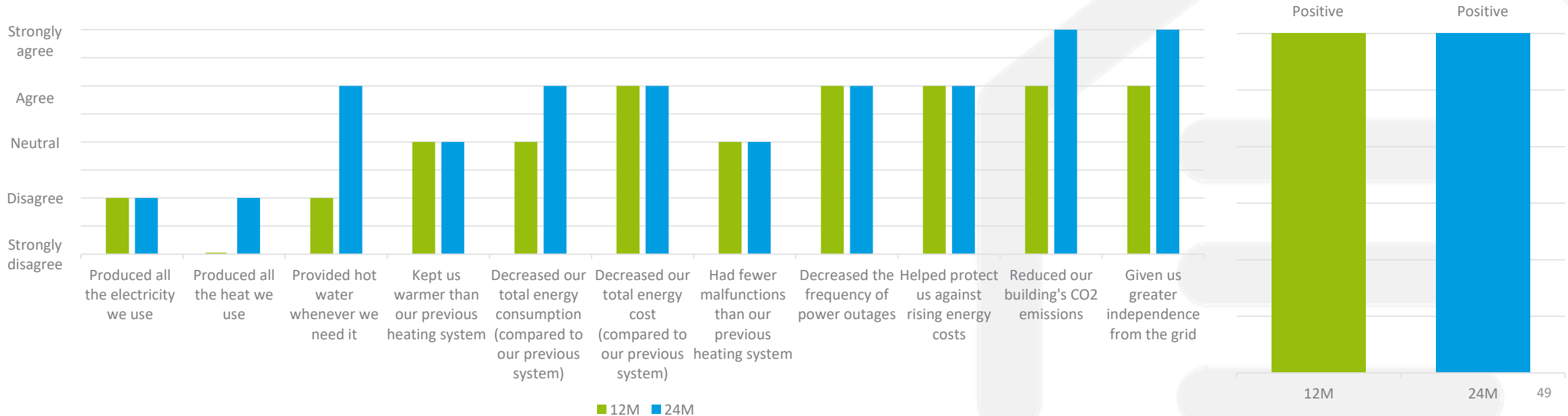
Installation: 2019

Motivation: Energy savings

Participant 3 rated their experience with their unit consistently high between the 12M and 24M surveys

- Their overall satisfaction was "positive" in both surveys
- When asked about different performance factors, their experience improved in 5 of the 11 factors between the 12M and 24M surveys. Their satisfaction did not decrease for any of the factors.

Although reporting an overall positive experience with their FC mCHP, participant 3 did site several areas of improvement needed, including high costs and the need for more engineers to be able to service the system when errors occurred.





Pathway to a Competitive European
Fuel Cell micro-CHP Market

“After very bad experiences with our previous CHP, we were initially very sceptical as to whether this would be similarly error-prone. Compared to its predecessor, however, it is clear that both heat and electricity production function reliably. Another big advantage is the pleasantly low noise emission and the convenient operation via a touch display. A minus are the relatively high maintenance and portal costs. So far, however, we are very pleased with the purchase and hope that the reliability will continue in the future.”

Case study 4

Location: Germany

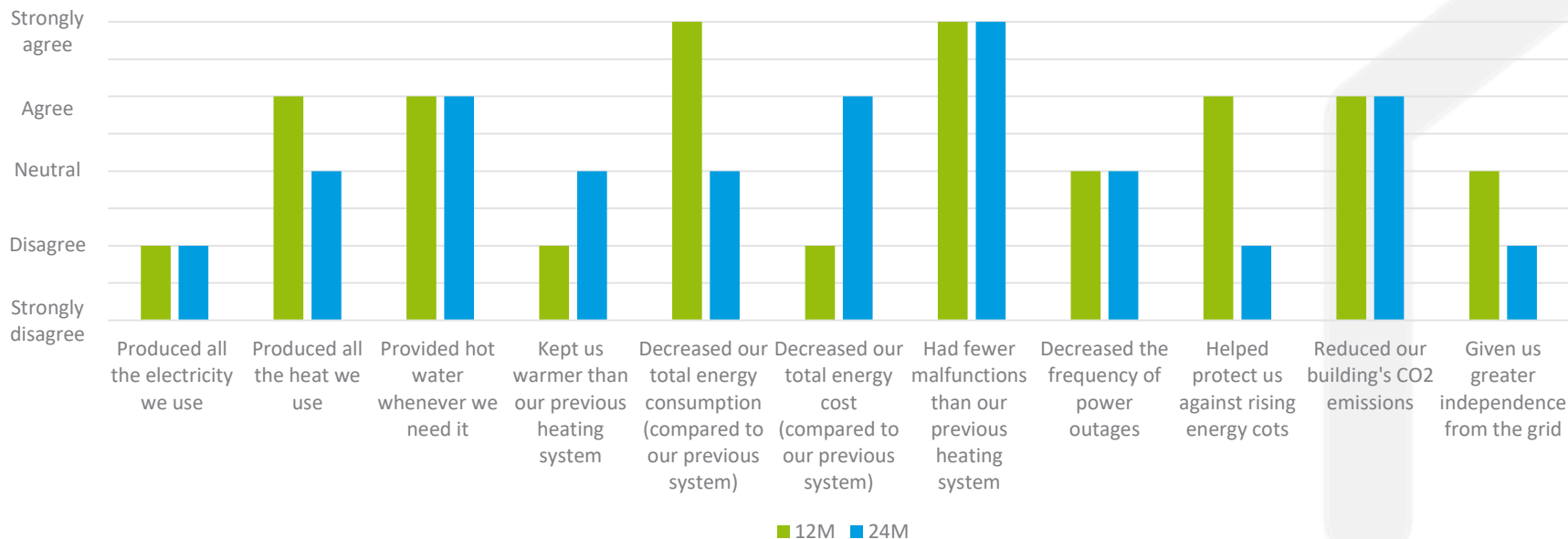
Installation: 2020

Motivation: Energy savings

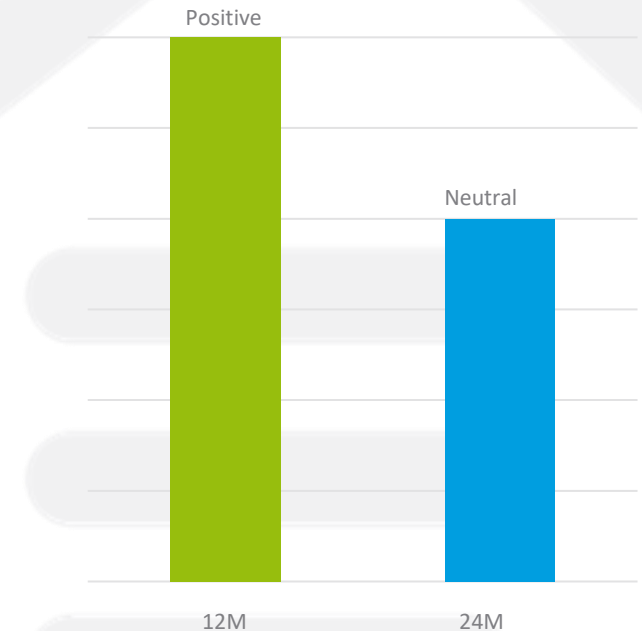
Participant 4 rated their experience with their unit higher in the 12M survey than the 24M

- Their overall satisfaction decreased from “positive” to “neutral”
- When asked about different performance factors, their answer decreased between the 12M and 24M surveys in 4 out of 11 cases. Their opinion improved in 2 cases and remained the same in 5.

Participant 4 was most happy with the consistency of performance and lack of malfunctions, finding the unit to have fewer malfunctions than previous systems.



Overall unit satisfaction





Pathway to a Competitive European
Fuel Cell micro-CHP Market

“When the fuel cell is running, it runs well and inconspicuously. There have been long downtimes (4 months) because the manufacturer did not receive any initial spare parts. It is not known why they do not keep all the spare parts in stock itself. Unfortunately, the fuel cell has been running for a few months (approx. 2 years old) with quite strongly fluctuating electrical output power (770W to 650W) and estimated on average well below the specified nominal power of 750W. But at least it is currently running. I hope that at least it stays that way”

Case study 5

Location: Germany

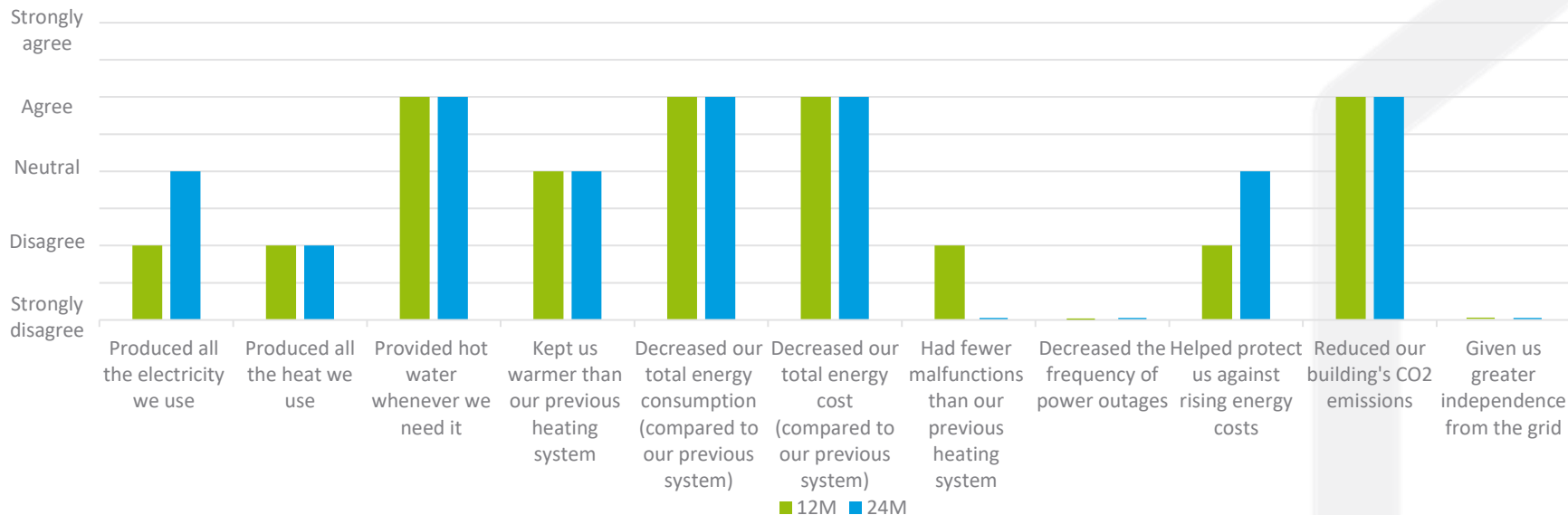
Installation: 2020

Motivation: Energy savings

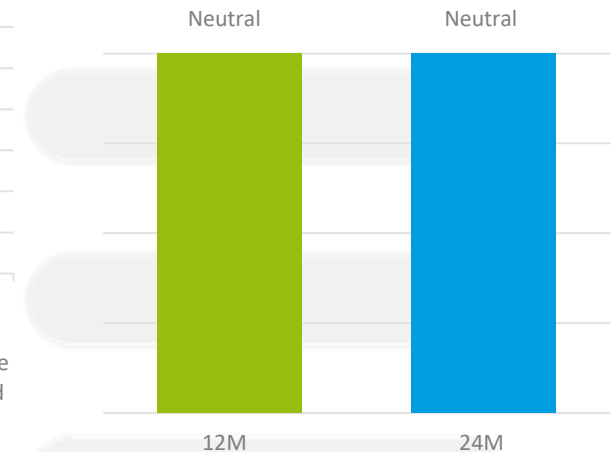
Participant 5 rated their experience with their unit as neutral in both the 12M survey than the 24M

- When asked about different performance factors, their answer remained consistent between the 12M and 24M surveys in 7 out of 11 cases.
- Only 4 parameters were rated as higher than “neutral”, none of which were “strongly agree”

Participant 5 was most happy with the decrease in consumption, cost and CO2 emissions due to their unit, but was not satisfied with its ability to reduce the number of power outages or provide greater independence from the grid.



Overall unit satisfaction



"If it worked as planned I could be satisfied but as it is now I feel like a cheated customer. I am unlucky to have hit a bad installer as a result of which the cell does not work. I have already paid a lot for maintenance and follow-up work resulting in more expenses than revenue. So I can hardly advertise the device. Result: dissatisfied customer.

Case study 6

Location: Belgium

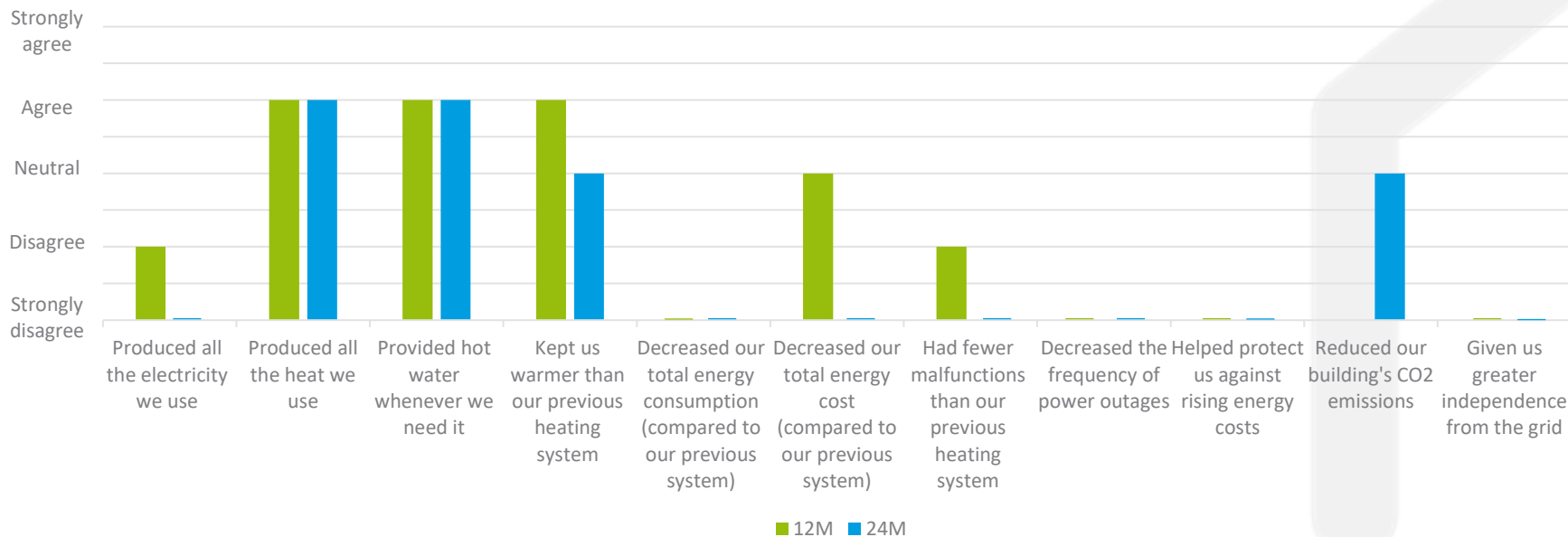
Installation: 2020

Motivation: Energy savings

Participant 6 rated their experience with their unit higher in the 12M survey than the 24M

- Their overall satisfaction decreased from "negative" to "very negative"
- When asked about different performance factors, their answer decreased was "strongly disagree" across both the 12M and 24M survey in 4 categories, and decreased in a further 4 categories.

Participant 6 was most happy with the heat and hot water provided by their unit, but was not satisfied with all other parameters. In their provided testimonial, participant 6 has credited this dissatisfaction to high maintenance costs for a unit which "does not work".



Overall unit satisfaction

Negative

Very negative

12M

24M

Testimonials

Please provide a short testimonial regarding your experience with your FC mCHP:

German

English

French

Dutch

12M

„Fazit: komplett Paket, welches sehr zu empfehlen ist.“

“In conclusion: a complete package, which is highly recommended.”

“In principle, the concept of generating our own electricity while having a highly efficient gas boiler was exciting. Unfortunately, the reality has been disappointing”

« Une solution d'avenir à mettre absolument en avant auprès du grand public.. »

“A solution for the future that absolutely needs to be promoted to the general public.”

“Let wel niet goedkoopste oplossing, wel duurzame oplossing met comfort.”

“Not the cheapest solution, but a sustainable solution with comfort”

24M

„Bis zum starken Anstieg der Gas- und Strompreise waren wir mit der Anlage sehr zufrieden!“

„Until the sharp rise in gas and electricity prices, we were very satisfied with the system!“

“Overall works very well. To give this excellent technology a future, it needs “green” gas. The need for a net zero fuel is my main concern when recommending the system”

« L' économie de consommation électrique ne compense pas le surcoût de ma consommation de gaz. »

“I don’t recommend this installation. Savings in electricity consumption don’t compensate for extra cost of gas.”

“Heel erg tevreden alleen de onderhoudskosten zijn te hoog en dat zeggen velen.”

“Very satisfied, only the maintenance costs are too high and many say so”

There has been a mixture of positive and negative feedback in the testimonials received in both the 12M and 24M surveys. General trends suggest that there is an overall high satisfaction with their unit, but that some key areas require improvement for the technology to succeed. High prices and maintenance issues were regularly mentioned as being less than satisfactory. Rising energy prices are also commonly referenced in the 24M survey responses, highlighting the impact of external factors on customer’s experience with the technology.



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Conclusions

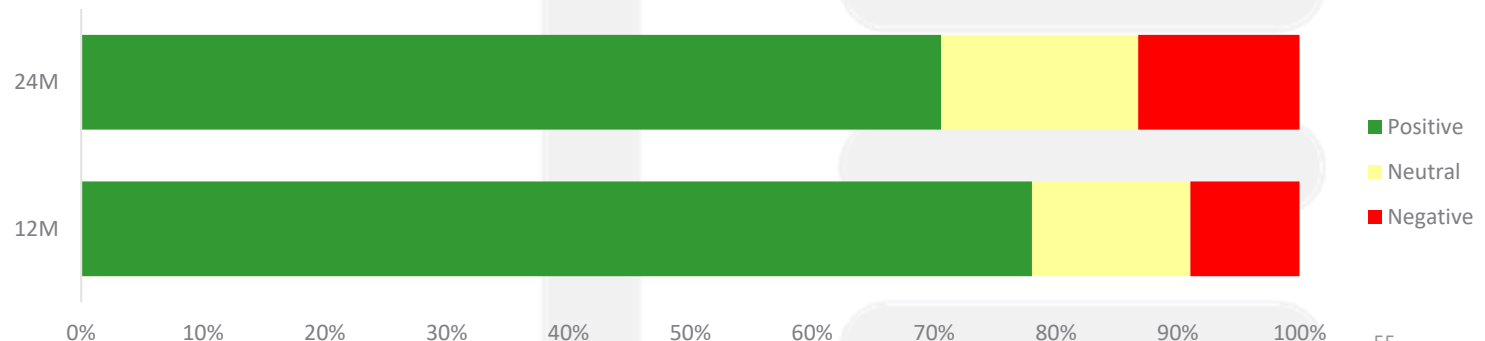
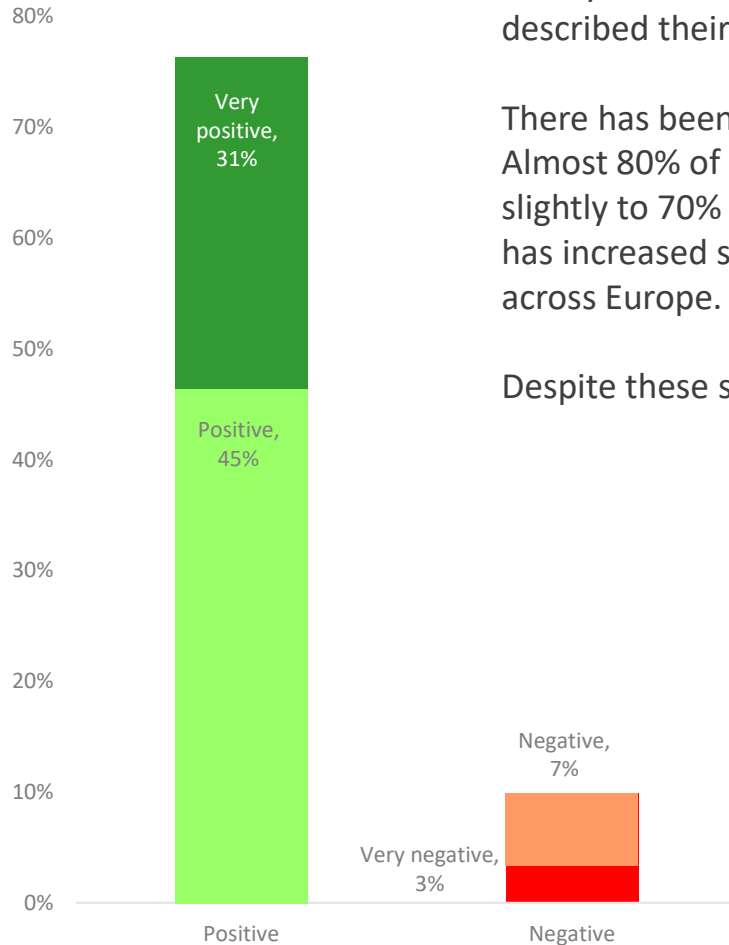
Conclusions

Overall how would you describe your experience with your mCHP?

Nearly 80% of respondents reported having a positive overall experience with their FC mCHP unit and just 10% described their experience as negative or very negative.

There has been a slight shift in respondent's overall satisfaction with their unit between the 12M and 24M surveys. Almost 80% of responses in the 12M survey reported an overall positive experience with their unit, which dropped slightly to 70% in the 24M survey. Meanwhile, the number of respondents rating their overall experience as negative has increased slightly from 9% to 13%. This is likely in part due to the impact of the ongoing energy market crisis across Europe.

Despite these small changes, the overall response has been resoundingly positive across both surveys.

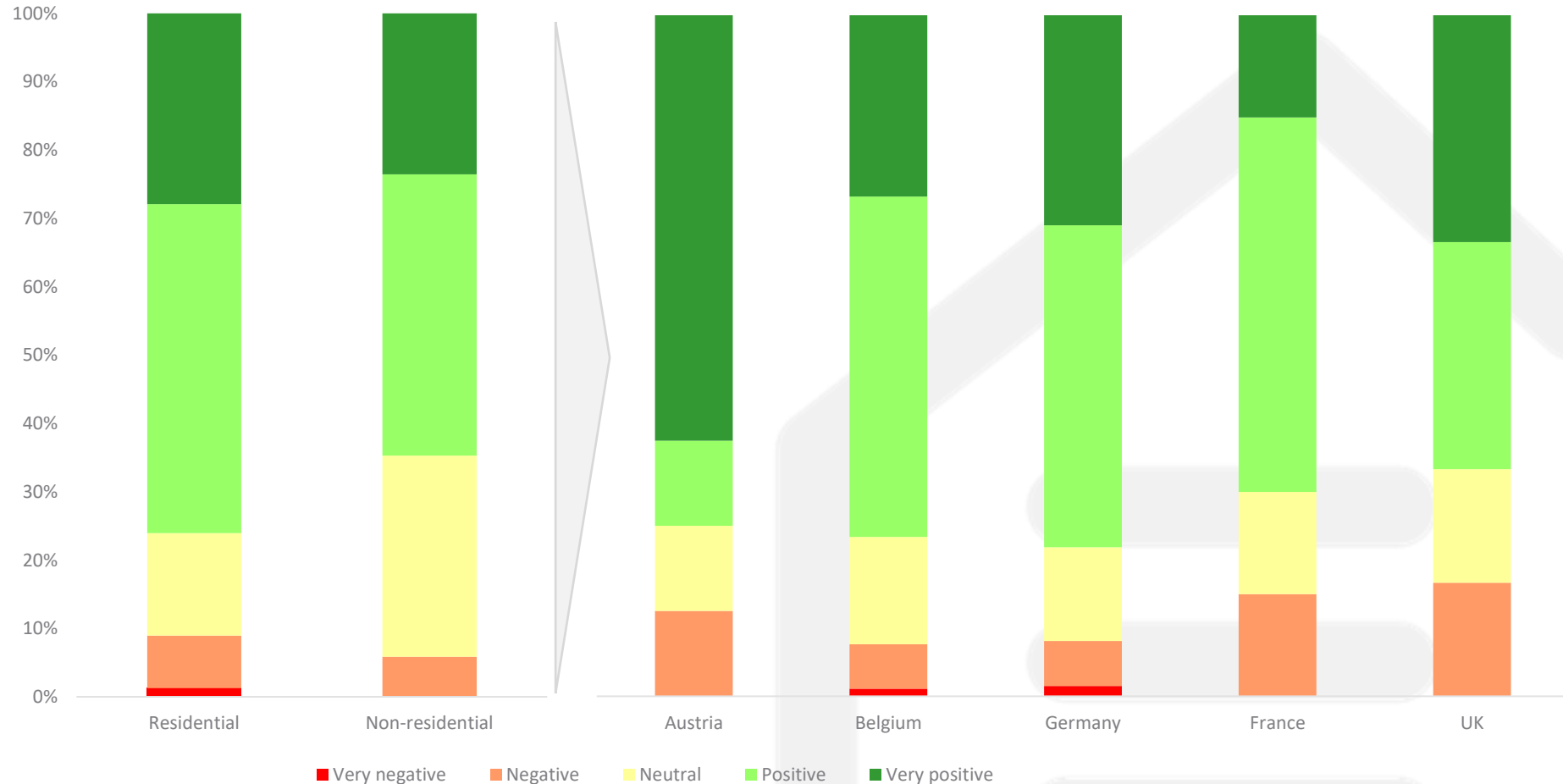


Overall how would you describe your experience with your mCHP?

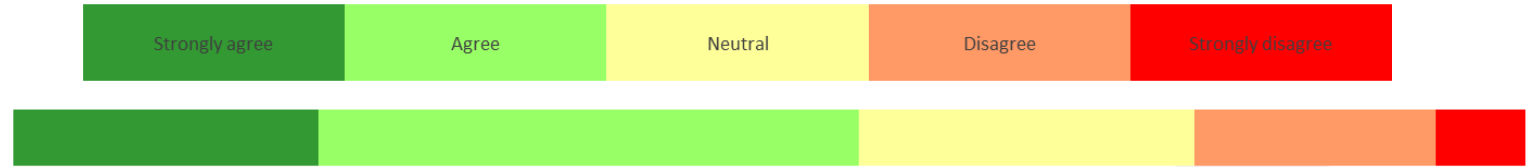
No very negative responses were reported by any non-residential respondents. There were only 20 very negative responses out of 670 respondents within the PACE project

Austria reported the highest number of “very positive” responses, and only Belgium and Germany were the only two countries to report any “very negative” experiences.

As the two countries with the most installations, it would be expected that Germany and Belgium would have a broader range of responses.



I am the type of person to worry about being
'green'



56% agree with this statement

I am the type of person who likes to try new
products



83% agree with this statement

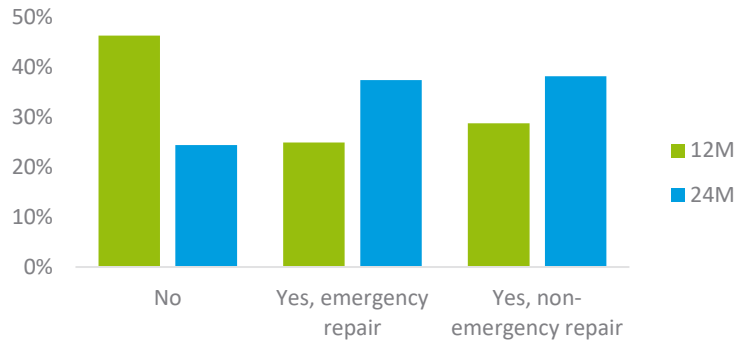
I feel a moral obligation to reduce my emission
of greenhouse gases



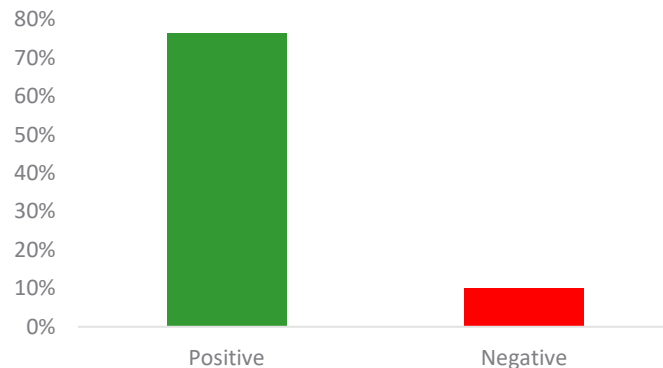
73% agree with this statement

- The general profile of the customer is affluent couples or families living in large detached housing. It appears that these customers are active 'early adopters' who are interested in trialling new technologies in order to reduce carbon emissions.
- Expectations of the FC mCHP units were generally very high, with the majority of customers expecting the system to fully meet their heating and electricity needs while reducing energy consumption and energy costs. These expectations were not always met in the responses to the during operation surveys. It is clear that cost remains a particularly important limiting factor, in addition to installation and maintenance requirements. This could also reflect some difficulties encountered over the last few years related to the COVID-19 pandemic and energy price rises.
- Customers were, on the whole, very satisfied with the performance and features of their FC mCHP unit. The comfort and warmth, design and generation of electricity were considered the most liked features, while the cost of repair and maintenance, effort of the installation process and public visibility of FC mCHP could all use improvements. These parameters are all common problems related to new and emerging technologies, as OEMs and installers develop the technical competencies to install and maintain FC mCHP. As a new technology, FC mCHP has additional requirements for specialised training (e.g. electrician know-how, IT skills), and as such only trained and qualified installers can sell and install the technology.
- The responses regarding overall experiences with FC mCHP units have highlighted some concerns, despite the customers being generally supportive of the technology and being 'early adopters'. These concerns could therefore be exacerbated in a wider market where customers may be less accepting of issues with the technology. It is also worth noting, however, that as these respondents are largely 'early adopters' trying out new technologies, this may have led to inflated initial expectations.

In the past year, have you experienced any problems or breakdowns?



Overall how would you describe your experience with your mCHP?



- The financial benefits of FC mCHP were lower than the expected. 60% of respondents anticipated a decrease in their gas and oil bills, whereas only 16% actually experienced a decrease. Conversely, 82% of respondents expected to see a decrease in their electricity bills and 70% did.
- More respondents reported problems or breakdowns in their second year, with an increase in breakdowns from 54% to 76% between the two surveys. Conversely, PACE analysis of the units' hours in operation has shown a general increase between years. There was, however, a sharp decrease in operating hours in Q2 and Q3 of 2021, before continuing to rise from Q4 2021 onwards. Depending on when respondents had their units installed, this may have coincided with their completion of the 24-month survey and therefore would align with the increase in breakdowns seen in the survey results.
- The most common length of time between reporting an issue and someone coming to visit was more than 2 days for emergency problems, and more than 1 week for non-emergency issues. The relatively long time taken to repair these issues may reflect the lack of installers who are able to carry out maintenance on this new technology (See D1.2 report for further information).
- With regards to overall experience, non-residential respondents were reportedly more neutral. There were no negative experiences, but there were also fewer positive and very positive responses. Customers are perhaps more inclined to feel strongly about technology being used for their own use in a private, home setting.
- There has been a slight shift in respondent's overall satisfaction with their unit between the 12M and 24M surveys. A decrease of approximately 10% for positive ratings is observed, while an increase of 4% for negative can be seen. This is likely in part due to the impact of the ongoing energy market crisis across Europe. Despite these small changes, the overall response has been resoundingly positive across both surveys.
- As found in Report 1, financial considerations are still a major part of customer motivations and expectations. This is likely to be exacerbated through wider industry developments in the energy market.

Callux

The Callux project, a predecessor to Ene.field and PACE, ran from 2008 – 2015 and installed 500 FC mCHP systems in Germany. This was a large scale practical test for FC mCHP systems for domestic use in Germany.

- The Callux project highlighted positive experiences with the technology during operation. This can be explored in future analysis once similar information is collected.
- Many of the participants in the Callux project appear to be early adopters keen to trial the new technology, reflected in the positive attitudes displayed. This is comparable to the general profile and attitudes of respondents so far during the PACE project.

Comparison with preceding projects

Results of the accompanying activities: AP2 market research

Experience with installing and operating the fuel cell heating system



Survey of Callux field test customers in June 2013

ying activities: AP2 market research

Almost all participants would recommend fuel cell heating as the system of the future.

- 8 out of 10 field test customers took part in the field test because they believe that fuel cell heating is the system of the future.
- 9 out of 10 field test customers would recommend fuel cell heating to other people living in a similar situation.
- 8 out of 10 field test customers say the heating system runs quietly.
- 9 out of 10 field test customers say the system has an attractive design.
- 8 out of 10 field test customers say the system was installed by the technicians quickly and with no hassle.
- 9 out of 10 field test customers say the customer service department solves problems quickly and reliably.
- 9 out of 10 field test customers would be happy to take part in a follow-up test with a next-generation heating system.

Comparison with preceding projects

Ene.field

The Ene.field project, a predecessor to PACE, ran from 2012 – 2017 and installed >1,000 FC mCHP systems in 11 European countries. PACE has continued to build on the work of this project to continue large scale demonstration of the technology and contribute to early market uptake.

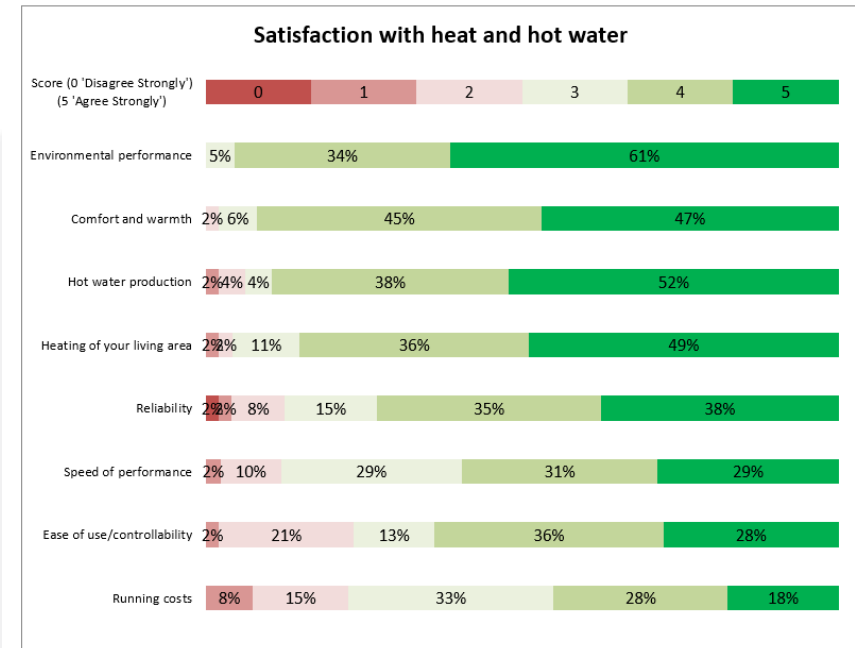
- Ene.field displayed a similar demographic to the general profile of customer displayed in the PACE project, with the majority of respondents having above average household income and living in modern detached houses.
- Experiences with the FC mCHP system in Ene.field were generally positive and customers were generally satisfied. However, customers were least satisfied with running costs. As cost savings are seen to be an important factor for PACE respondents, future iterations of this deliverable could explore the satisfaction in this respect and whether this has progressed over time.

Table 2: Property types

Property type	Proportion of properties
Detached	43%
Non-residential	25%
Semi-detached	17%
Terraced	7%
Flat	5%
Other	4%

Table 6: Household incomes

Income range	Proportion of properties
Up to €30,000	3%
€31,000-€60,000	26%
€61,000-€90,000	31%
€91,000-€120,000	14%
€121,000-€150,000	12%
€151,000-€180,000	3%
Over €180,000	12%





Pathway to a Competitive European
Fuel Cell micro-CHP Market

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