Deliverable Report 6.2

Project Title:

Solar-Biomass Reversible energy system for covering a large share of energy needs in buildings

Project Acronym:

SolBio-Rev

Work Package 6: Social acceptance, potential for uptake and engagement

Deliverable 6.2

"Definition of user and installer needs and their introduction in the design process "

Responsible for Deliverable:

University of Sussex (UOS)

Dr Donal Brown, Dr Mari Martiskainen

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Contents

1 Introduction

This document outlines Deliverable 6.2 (D6.2) of the SolBio-Rev project, Work Package 6 (WP6) 'Definition of user and installer needs and their introduction in the design process'. D6.2 summarises results of Task 6.1 'Social Acceptance of SolBio-Rev' and discusses their implications for Task 6.2 'User and installer needs', through a series of interactive interventions with the SolBio-Rev design team.

D6.2 introduces the background research and empirical findings from WP6 into the design process of the SolBio-Rev system - helping to understand how user needs implicate the optimal design and operation of the system. Because of the early Technology Readiness Level (TRL) of SolBio-Rev, it was not possible to test these factors during a field trial. Instead, we have sought the views of key stakeholder groups: the SolBio-Rev system developers; prospective household users; prospective office users and installer bodies who represent the key technologies contained within the SolBio-Rev[1] system. This included both qualitative and quantitative methods: 40 qualitative user interviews; a 3-country representative quantitative survey; 3 qualitative interviews with installer bodies and 2 qualitative workshops with the SolBio-Rev team.

These data yielded findings across four sub-themes relevant to user and installer needs:

1) Indoor comfort, user preferences and social acceptance;
2) System friendliness and ease of use;
3) Chosen business model (hardware based, or service based);
4) Costs, affordability, and financing.

We subsequently interpreted these data regarding their implications for the present and future iterations of the SolBio-Rev system. Following this analysis, we also provide key recommendations for the design team and the future development of the SolBio-Rev system.

This deliverable report is structured as follows. Section 2 reviews the data collection and analysis methodology. Section 3 outlines the findings surrounding user and installer needs and how they have been introduced into the design process. Section 4 provides conclusions and recommendations.

1.1 Contribution of partners

UOS has developed this deliverable with input from NTUA, DBC, UDL, TECH as the respective Task Leaders across the SolBio-Rev WPs. NTUA provided invaluable support in securing and interpreting the Greek interviews. Techlink were also very supportive in securing interviews with key policy actors and installer bodies.

[1] We were unable to secure interviews with the European biomass heating industry body

2 Methodology

Compiling D6.2 involved a mixed methods data set, including workshops, interviews, and a 3-country survey. This also included a review of background socio-demographic and energy statistics at national level from the Eurostat database. These tasks objectives and data are summarised in Table 1.

Table 1 Tasks, Objectives and Data for D6.2

Task	Key objectives	Data
Task 6.1 Social acceptance	(1) Review background socio-demographic and energy statistics at national level (2) Examine views of existing RE users, installers, and developers (3) Provide input in to the SolBio-Rev design process (Task 4.1), business models (Task 8.4) and policy implications (Task 6.3)	• Eurostat database • 40 Interviews in Greece, Finland, UK with 9 case buildings (2020/2021) • 3 Interviews with installers bodies in EU • National surveys in Greece, Finland, UK (2021)
Task 6.2 User and installer needs	(1) Provide feedback on issues such as indoor comfort, system friendliness, ease-of-use, business model, costs and financing	• Data from Task 6.1: interviews and survey • SolBio-Rev internal stakeholder workshop 1 (2020) • SolBio-Rev internal stakeholder workshop 2 (2021)

2.1 Interviews

40 semi-structured qualitative interviews with users were conducted between October 2020 and June 2021. The interviews were divided by country with the aim of securing three case study buildings for each country (15 interviews in Finland, 12 in Greece, and 13 in the UK). This included two residential buildings, one with some form of renewable heating, ventilation, and air conditioning (HVAC), one without, and the third an office building. A further series of three interviews involved representatives of key installer and trade bodies. This included the European Heat Pump Association (EUHPA), Europe-On – who represent electrical installers in Europe, and Solar Heat Europe, who represent the European solar thermal industry. Although an interview with the European Biomass Industry Association (EUBIA) was sought, they declined to be interviewed. Interviews were analysed with the NVivo 12 qualitative analysis software, using common themes to code the data and structure the analysis.

2.2 Survey

We also undertook a quantitative survey of households (March 2021), with3,478 respondents across the United Kingdom (n=1,231), Greece (n=1,065), and Finland (n=1,182). The survey instrument was designed to take 10-15 minutes to complete and consisted of 46 questions across several theme areas. The first section explored the socioeconomic and demographic attributes of respondents. Subsequently it investigated the attributes of the building's heating and cooling system, followed by a focus on thermal comfort and controls. The questions then focussed on the important features of these systems and who has responsibility for maintaining them. A series of questions then explored the respondent's familiarity with different energy systems and willingness to adopt new systems. Questions were then centred on perceived energy poverty before a final focus on preferences for different finance and business models of a new HVAC system.

To analyse the survey results we used the SPSS statistical analysis package. The survey results were first analysed descriptively and with the help of frequency tables and bar charts. For a large number of the responses, we focussed on differences between the three case study countries. In addition, we also sought to understand variations based on the existing heating system of the user, as well as their current heating and cooling control system. Certain questions were also disaggregated by income, education level and age.

2.3 Internal survey and workshops

To better understand the SolBio-Rev design team's intentions and their views on the key variables for social acceptance and user adoption, WP6 ran two workshops with internal project stakeholders in month 11 and month 31.

2.3.1 Internal Survey and Workshop 1

The first intervention in month 11 sought to better understand the design team's objectives for the SolBio-Rev system, its key advantages and its suitability for different applications and use cases. This involved a questionnaire using the Google Forms™ e-survey instrument which was distributed to the SolBio-Rev design team consisting of 18 questions. These included questions relating to the primary motivation for designing the SolBio-Rev system; comparing the features of SolBio-Rev to traditional HVAC systems; its suitability for different applications; and their perceptions of the needs of different users. The survey was run between 19th June 2020 and 3rd July 2020, and subsequently WP6 ran an engagement workshop with the SolBio-Rev team on 31st July 2020 to discuss the findings of the e-survey.

2.3.2 Presentation of D6.1 and Workshop 2

During the SolBio-Rev general assembly on the 5th of November 2021, WP6 presented the findings of D6.1 to the wider design team. Subsequently, WP6 delivered an interactive workshop using the Mural™ digital whiteboard tool. The workshop involved a recap of the key findings from D6.1 then participants provided written "post-it" responses to four questions:

1. How might users existing HVAC expectations / preferences affect the efficient operation of SolBio-Rev?
2. How might users experience SolBio-Rev differently from their current HVAC system?
3. What are the most suitable business models for SolBio-Rev?
4. How will the capital cost (CAPEX) and running cost (OPEX) of SolBio-rev affect users?

These questions, the sub-questions/prompts used, and the responses are shown in Figure 1.

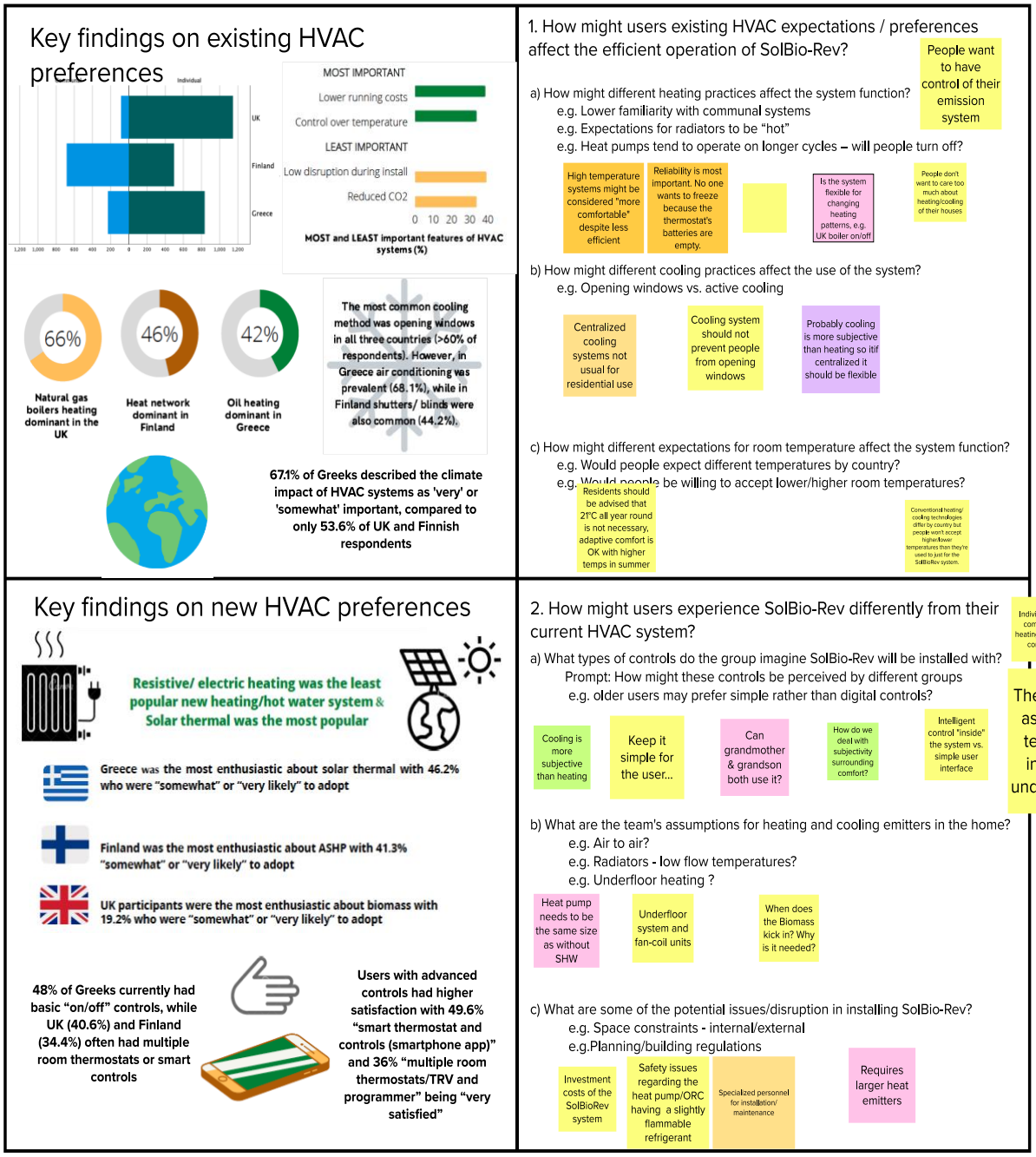

Figure 1 Mural boards from Workshop 2

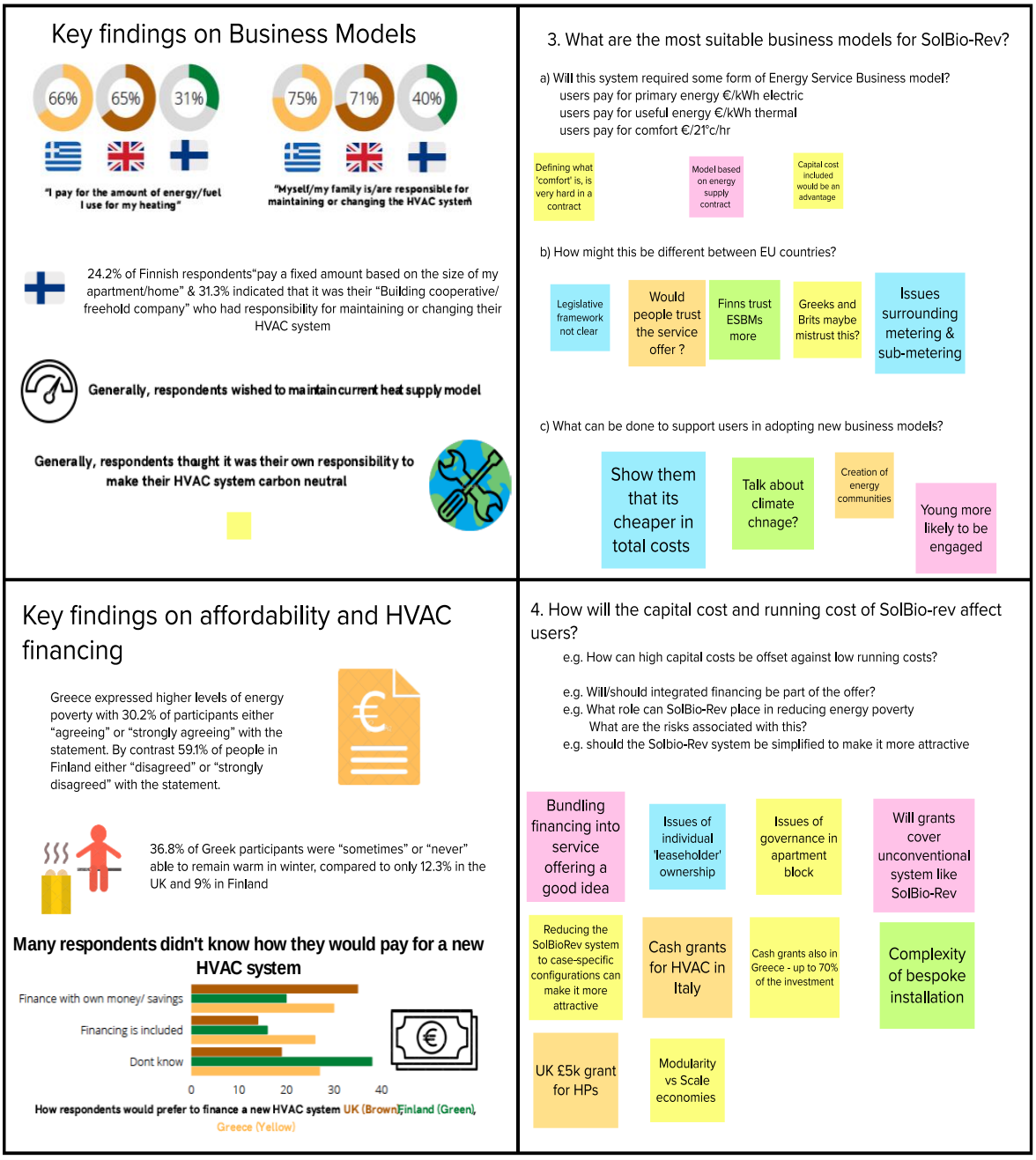

Figure 2 Mural boards from Workshop 2

3 Results: Introduction of user needs into the design process

Prior to the empirical phase of the project, we undertook a literature review to investigate national differences in household demographics, and energy consumption, using the Eurostat database.[2]

[2] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190620-1
https://ec.europa.eu/eurostat/web/products-datasets/product?code=nrg_chdd_a
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We found that Greece's household energy demand is only 66% of the EU average, while the UK's is 104% of the EU average, despite having highly similar (56% and 55%) share of degree days (i.e., equivalent heating/cooling needs). Equally, while Finland's degree days are 318% of the EU average, household energy demand is only 187% of this average – suggesting Finnish homes/households are more efficient than UK.

Single family households tend to use significantly less energy than larger family units. Eurostat data indicates Finland has a higher share of single-family households (44%), due to an increased number of under 65's living alone, whereas Greece has only 25.2% (UK 29%). The UK and Finland have a similar mix of co-habiting couples (52.9% and 51.9% of households respectively). Greece has the highest share of co-habiting adults and due to a much higher share of households with three or more adults (20% of households), suggesting a trend for multiple family generations to co-habit in Greece. Single parent households are more likely to be at risk of energy poverty than co-habiting couples While the UK has a higher share of single parent households (10%) than Finland, (7%), both have a much higher share than Greece (1%).

Therefore, based on this review we expected significant variability in household energy demand, behaviour, and social practices both within and between countries.

3.1 Indoor comfort, user preferences and expectations

The 3-country survey findings in Box 1 highlight large differences between countries in existing household HVAC systems, cooling methods and the sophistication of HVAC controls. These findings suggest that user preferences and expectations for domestic energy services are likely to differ significantly between European countries. Therefore, future applications of the SolBio-Rev system may need to be sensitive to these divergent expectations if the system is to be adopted successfully.

Box 1 Survey findings, current energy system characteristics

Our survey showed the dominant heating regime varied by country with natural gas boilers dominant in the UK (66%), district heating/ heat networks in Finland (46.4%), and oil/ fuel oil/ LPG in Greece (42%). In Greece the hot water regime was split between resistive/ electric heating (41.9%) and solar thermal/ solar PV (25.1%). The most common cooling method was opening windows in all three countries (>60% of respondents). However, in Greece air conditioning was prevalent (68.1%), while in Finland shutters/ blinds were also common (44.2%). Greece had more basic heating controls with 48% of respondents having only a simple "on/off" control, while the UK (40.6%) and Finland (34.4%) often had multiple room thermostats or smart control.

The 3-country survey findings shown in Box 2 highlight how in general users view their current energy systems as reliable, with natural gas-based systems viewed as particularly reliable. By contrast key renewable HVAC technologies, such as heat pumps and solar thermal, were viewed as less reliable. This suggests that there remains a challenge in convincing users that newer renewable HVAC systems are as reliable as more traditional fossil fuel-based heating systems. There were, however, large variances between reported levels of thermal comfort, with people in Greece reporting lower levels of thermal comfort than the other two nations. Promisingly, heat pump users expressed the highest levels of thermal comfort, suggesting that the constant flow temperatures provided by heat pumps could be a key advantage that could be promoted in future applications of the SolBio-Rev developers.

Box 2 Survey findings: Reliability and control

Energy system reliability varied slightly between countries, with UK (85.1%), Greek (79.1%) Finland (78.2%) stating it was either very or somewhat reliable. In general, 81% of users described their energy systems are either "very" or "somewhat" reliable. Natural gas boilers had the highest share of "very reliable" answers (61.4%) followed by biomass boilers (52.3%), wood burner/ fireplace (46.2%) and oil/ fuel oil / LPG (46.1%). Heat pumps and solar thermal/ solar PV had a much lower share of "very reliable" answers at 39.3% and 29.2% respectively, solar thermal/ solar PV also had the highest share of "don't know" at 25%. Greece expressed lower winter thermal comfort with 36.8% of participants either only "sometimes" or "never" able to remain warm whilst at home, compared to only 12.3% in the UK and 9% in Finland. Greece also expressed lower summer thermal comfort with 38.1% of participants either only "often" or "always" unable to remain cool, compared to only 16.8% in the UK and 28.2% in Finland. Heat pumps and GSHPs were shown to have the highest share of people "always" able to remain warm at 53.6% and 47.9% respectively, with Oil/ fuel oil/ LPG users having the lowest share at 20.5%.

As shown by Figure 3 most of the SolBio-Rev project team viewed reduced CO_2 emissions as the main reason for designing the system. However as shown in Box 3 the survey data showed that few respondents ranked this issue as the most important factor when choosing

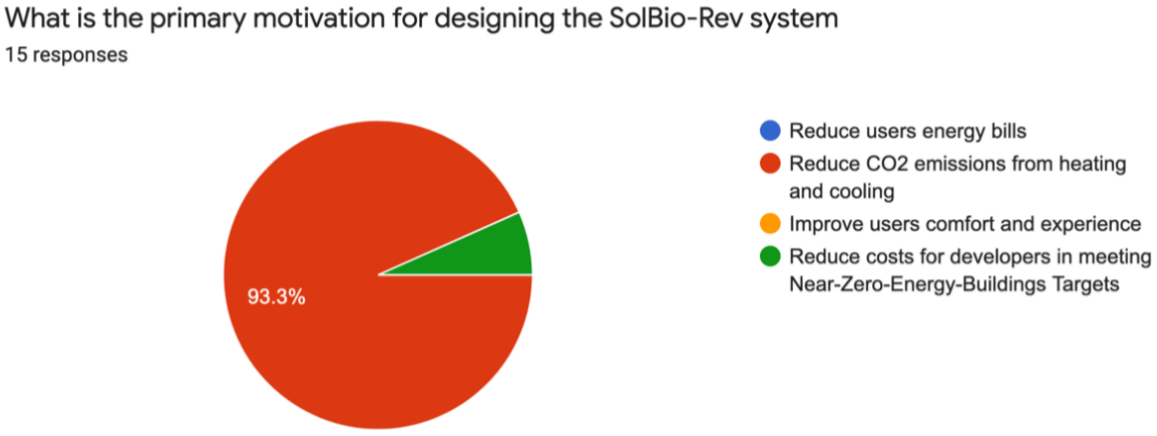

Figure 3 Internal survey findings: primary motivation for SolBio-Rev

an HVAC system. However, respondents in Greece bucked this trend and were more willing to pay extra for HVAC if the energy is carbon free.

Box 3 Survey Results: Environmental concern

Survey respondents ranked "reduced CO2 emissions/ climate change impact" as the second least important factor for a new HVAC system with 33.6% of the sample viewing it as the least important factor. Greek respondents expressed greatest concern for the climate impact of HVAC, with 67.1% of participants describing it as "somewhat" or "very" important, compared to only 53.6% in the UK and 53.6% in Finland, also expressing greater willingness to pay for carbon free energy, with 21.7% of Greek participants willing to pay 30% or more, compared to only 10.1% in the UK and 6.5% in Finland. 39.8% of Finnish respondents and 31.3% in the UK were not willing to accept any increase in their energy bills.

3.1.1 How might users existing HVAC expectations / preferences affect the efficient operation of SolBio-Rev?

Following on from the results of the 3-country survey and interviews, in Workshop 2 we first sought to understand from the design team how the existing expectations of users would affect the efficient operation of SolBio-Rev (Figure 4). Participants discussed how different heating practices, such as the expectation for radiators to be hot, or for shorter heating cycles, would need to be overcome for the SolBio-Rev to operate efficiently. The participants also emphasised the importance of user control in this process. We also discussed how centralised cooling systems – such as SolBio-Rev - were uncommon in residential buildings, and that many would still use more traditional methods such as opening windows or portable fans. Participants also felt that cooling was more subjective than heating and that different residents may have different perceptions of comfort when using space cooling. We further discussed how expectations surrounding room temperatures and the provision of active cooling could differ between countries, leading to cooling systems such as SolBio-Rev being used more or less often depending on the national context.

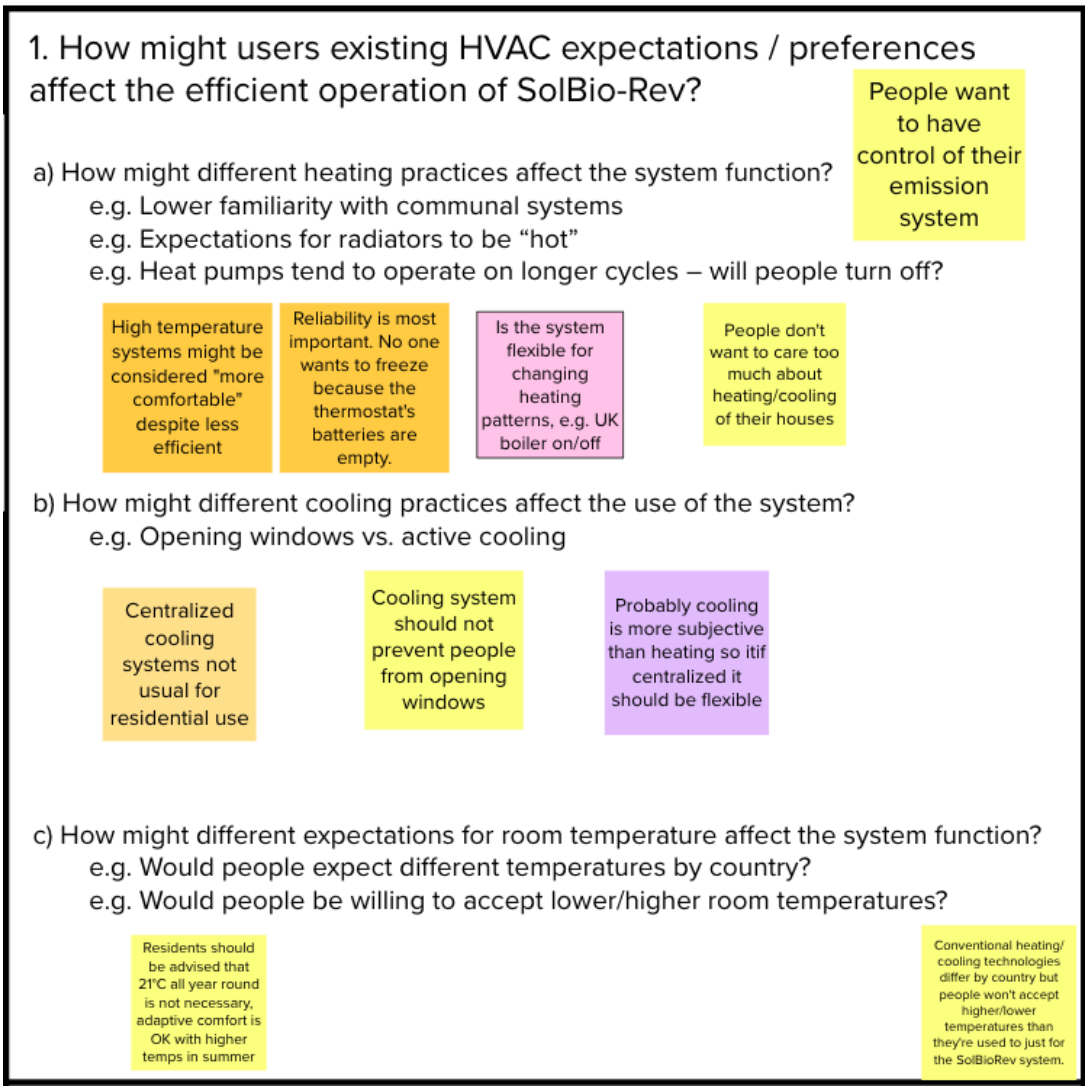

Figure 4 Workshop 2 findings: How might users existing HVAC expectations / preferences affect the efficient operation of SolBio-Rev?

3.2 System friendliness & ease of use

Our 3-country survey respondents ranked "control over temperature" as of second most (30.8%) important feature for a new HVAC system. By contrast 39% of respondents viewed "low disruption during the install" as the least important factor. These findings suggest that prospective users are likely to tolerate significant disruption during HVAC installation, especially if they can maintain effective control over room temperatures. Indeed, as shown in Box 4 many respondents viewed advanced controls very favourably. This suggests that reticence towards new forms of renewable HVAC such as SolBio-Rev may be partly overcome through advanced controls and an effective user interface.

Box 4 Control satisfaction

Users with these more advanced controls had higher control satisfaction with 49.6% "smart thermostat and controls (smartphone app)" and 36% "multiple room thermostats/ thermostatic radiator valves and programmer" "very satisfied". By contrast 33.3% of those with "none" of which were either "very" or "somewhat" unsatisfied.

In general, survey respondents had relatively low familiarity with the core technologies of SolBio-Rev, although there was some variation between countries (Box 5). However, this familiarity mapped well onto the market share of these technologies in the respective countries (Box 1).

Box 5 Familiarity with renewable HVAC

56.5% of Greek respondents were "very familiar" with solar thermal, compared to only 8.4% in the UK and 6% in Finland. Indeed 42.7% of UK respondents and 43.5% of those in Finland were "not familiar" or had "never heard of" the technology. Familiarity with ASHP was generally lower with 60.9% of Finnish respondents "very familiar" or "quite familiar" compared to only 20.7% in the UK and 22.5% in Greece. 57.4% of UK respondents and 53.6% of Greek respondents were "not familiar" or had "never heard" of ASHP. Familiarity with biomass was generally low with 19.1% of UK respondents "very familiar" or "quite familiar" with the technology, compared to only 10% in Greece and 9.3% in Finland. 58.3% of UK respondents, 73.9% of those in Greece and 76.8% of those in Finland were "not familiar" or had "never heard" of the technology. Generally, there was very low familiarity with the other component technologies of SolBio-Rev.

When combining these findings with the data on willingness to adopt these technologies (Box 6), we see a clear correlation. This suggests that users are more likely to adopt technologies with which they are more familiar. This has important implications for the commercialisation of the SolBio-Rev system, as those marketing the system may wish to emphasise different component's features depending on the target market.

Box 6 Willingness to adopt core SolBio-Rev technologies

Resistive/ electric heating was the least popular new heating/hot water system with 50.1% "somewhat" or "very" unlikely to adopt these systems. Solar thermal was the most popular with 35.7% of people either "somewhat" or "very" likely to. Respondents in Greece were the most enthusiastic with 46.2% who were "somewhat" or "very likely" to adopt compared to only 18.1% who were either "unlikely" or "very unlikely". UK and Finnish participants were less enthusiastic about solar thermal with 30.8% and 29% either "unlikely" or "very unlikely" to adopt them respectively.

ASHP's were also not popular with 49.6% "somewhat" or "very" unlikely to adopt these systems. Finnish respondents were the most enthusiastic with 41.3% who were "somewhat" or "very likely" to adopt ASHP compared to only 19.6% who were either "unlikely" or "very unlikely". UK and Greek participants were less enthusiastic about these systems with 34.8% and 47.4% either "unlikely" or "very unlikely" to adopt them respectively.

Willingness to adopt biomass was low with Greeks the least enthusiastic about these systems with 58% either "unlikely" or "very unlikely" to adopt compared to only 12% who were "somewhat" or "very likely". UK participants were the most enthusiastic with 19.2% who were "somewhat" or "very likely" to adopt them and 39.8% either "unlikely" or "very unlikely" to adopt them, 17.3% of responses "don't know".

The findings from our internal survey and workshops also provide important nuance to this picture. For example, the SolBio-Rev team expected the system to have higher maintenance requirements than conventional HVAC systems Figure 5.

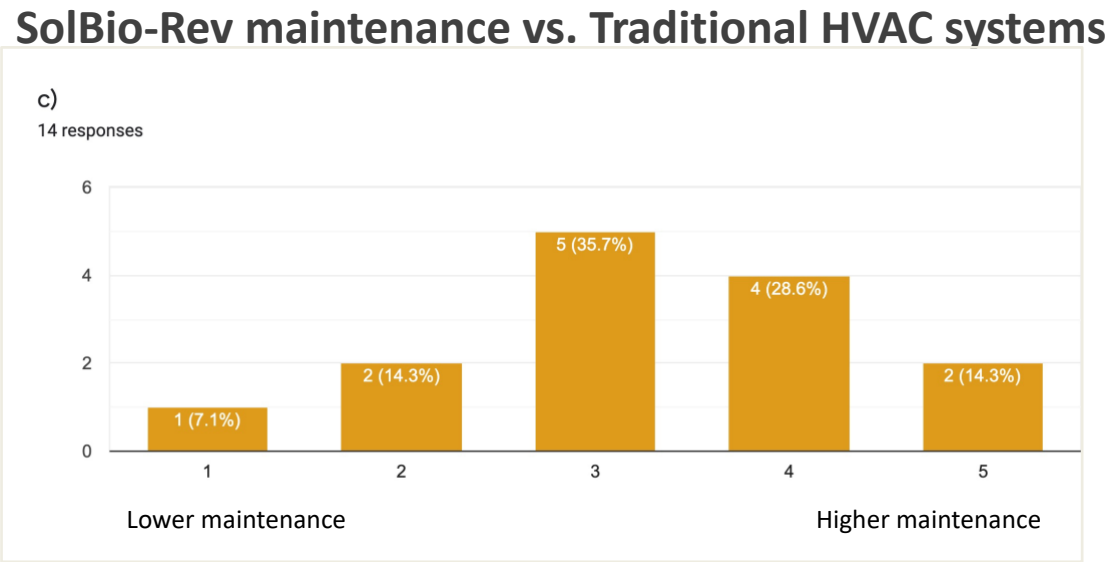

Figure 5 Maintenance requirements of SolBio-Rev

Respondents of the internal survey also expected the system to require more plant space than conventional HVAC systems (Figure 6). Regarding the suitability of the system in different applications, the design team expected the system to be suitable in locations where heating demand was dominant vs. hot water (Figure 7), and where there is a higher demand for heating than for electricity. Finally, the SolBio-Rev team also indicated that the system would not be suitable for locations with limited roof space, due to the space requirements of the solar thermal system (Figure 9).

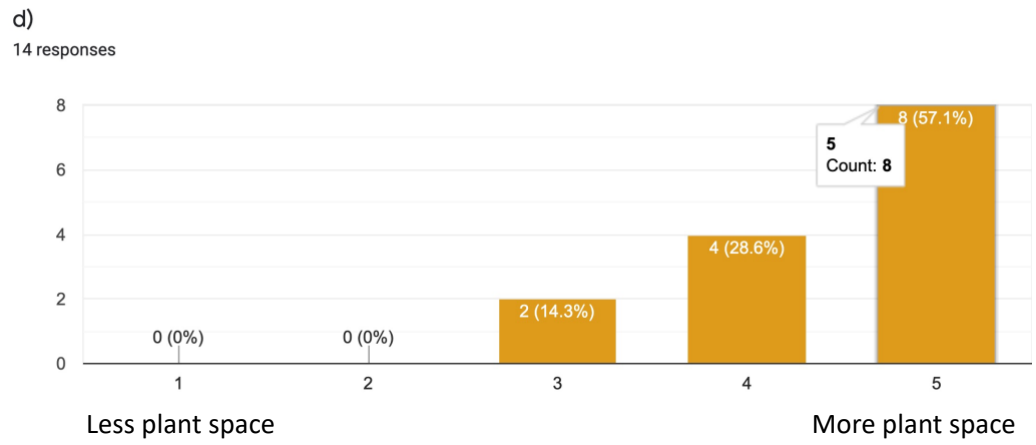

Figure 6 Plant space requirements of SolBio-Rev

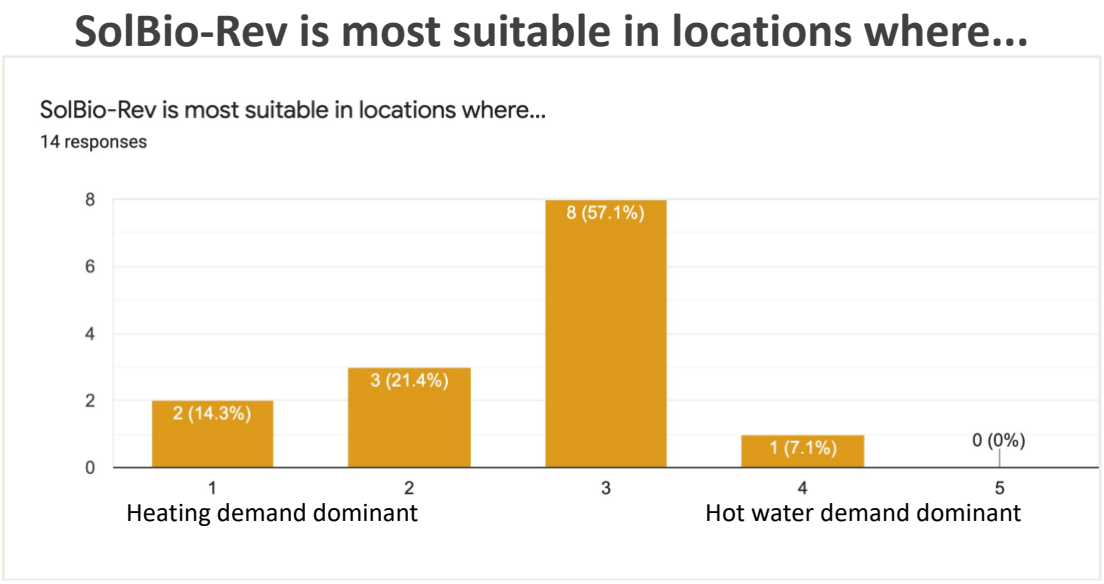

Figure 7 Heating and hot water production

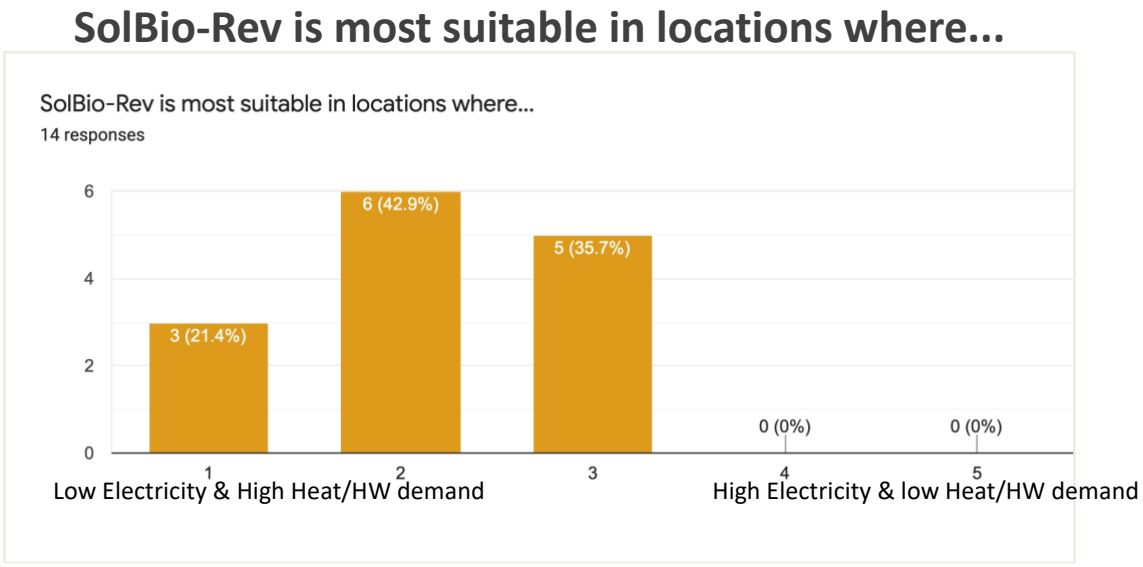

Figure 8 Heating vs electricity demand

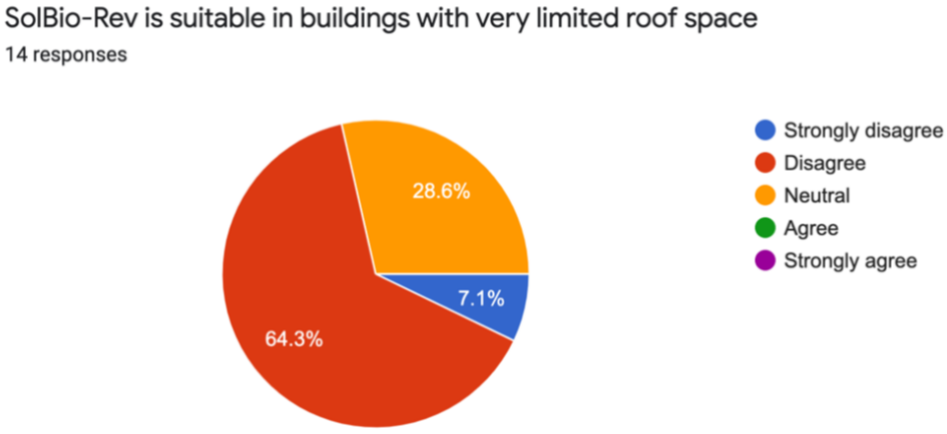

Figure 9 SolBio-Rev roof space requirements

In summary these findings suggest that the SolBio-Rev system will be most suitable in applications where there is a large amount of plant and roof space, and where heating demand is dominant above electricity and hot water consumption. In addition, the high maintenance requirements may necessitate a professional energy manager. These findings confirm that the SolBio-Rev system is likely to be suitable for medium density multifamily residential accommodation, perhaps where the system has sufficient scale to allow professional energy management to be economic.

3.2.1 How users experience SolBio-Rev differently from current HVAC system?

Following on from the discussion on existing HVAC systems, in Workshop 2 we then asked the internal design team to contemplate how users might experience SolBio-Rev differently and the implications of this. A key first focus was controls, with a consensus that controls must be kept simple to ensure both “grandma and grandson” can use them. There was therefore a view that sophistication and intelligence in control of the system was best kept “inside the system” and not in the user interface. The discussion then centred on the nature of the heat emitters, with an expectation that in some settings both heating and cooling would be delivered through underfloor heating while in hotter climates cooling would also be provided through fan coil units. Questions of the disruption of installing the system in a retrofit scenario also centred on changing heat emitters as a key site of disruption. In addition, the need for specialist installers and the potential safety risks of the refrigerants used were also cited as potential issues.

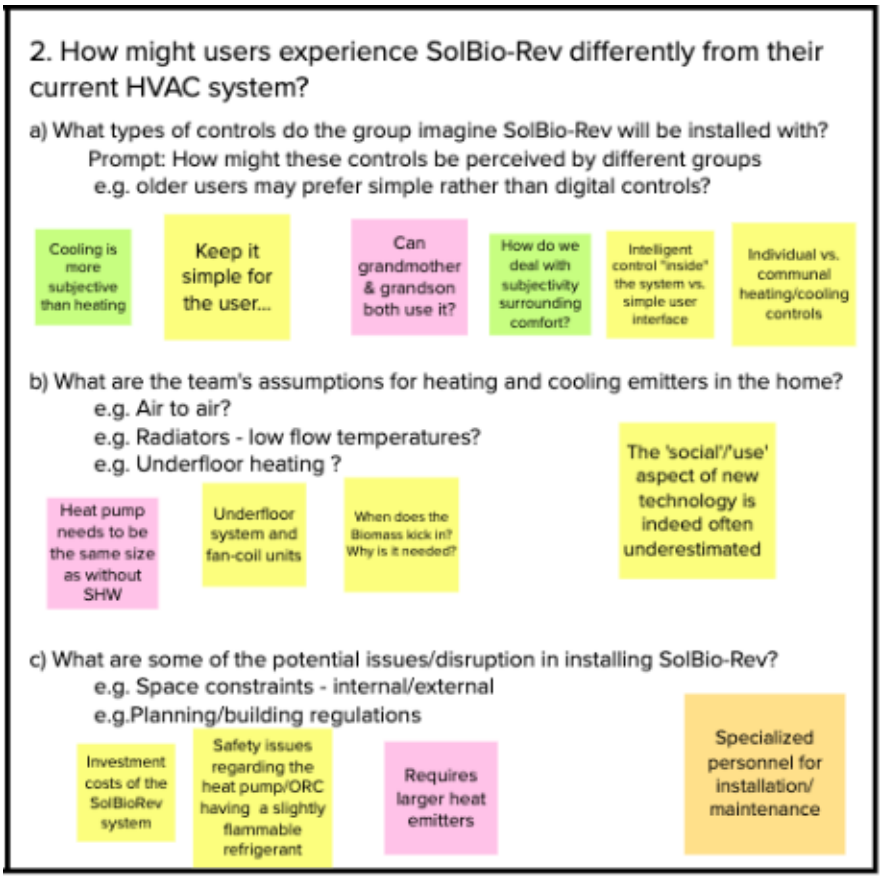

Figure 10 Workshop Findings: How might users experience SolBio-Rev differently from their current HVAC system

3.3 Chosen business model (hardware based, or service based)

Our interviews and survey also provided insights regarding the typical business model for heating. As shown below, most respondents in the 3-country survey pay for the kWh of energy they consume. However, a large share of Finnish respondents pay for a fixed amount, through a service contract, typically provided by their building cooperative. Much like the differences in main heating system, these findings suggest that user expectations around business models, may differ substantially between different European national markets.

Box 7 Existing business models

Most respondents currently "pay for the amount of energy/fuel I use for my heating", with 64.4% of UK and 65.6% of Greek respondents providing this answer, compared to only 30.5% in Finland. Instead, 24.2% of Finnish respondents indicated that they "pay a fixed amount based on the size of my apartment/home". Most respondents stated that "myself/my family" is/are responsible for maintaining or changing the HVAC system, with 70.9% of UK and 75.3% of Greek respondents providing this answer, compared to only 39.7% in Finland. Instead, 31.3% of Finnish respondents indicated that it was their "Building cooperative/ freehold company".

When asked about their preferences for the future heat business model, many respondents opted to maintain the *status quo*. This further suggests that there remain challenges in enticing users to adopt new business models, especially those which provide useful or final energy services.

Box 8 Future business models

Most respondents would prefer to "pay for the amount of energy/fuel I use for my heating" in a future HVAC system, with 48.5% of UK and 40.8% of Greek respondents providing this answer, with 12.8% and 12.1% stating "no change" respectively. 17.5% of those in Finland indicated that they would prefer to "pay for the amount of useful hot water / heat/ cooling I use", with 22.5% requesting no change.

3.3.1 What are the most suitable business models for SolBio-Rev?

In Workshop 2 we subsequently asked the SolBio-Rev design team their views on appropriate business models for SolBio-Rev (Figure 11). The group agreed that some form of energy service business model as shown in Figure 12 would likely be necessary. Here users would pay for the useful energy services of hot water, heating and cooling rather than units of primary energy. Further respondents also suggested that the inclusion of system financing would be an advantage – under energy supply financing (ESF) (Figure 12). However, there were some concerns that these "bundled" models may be distrusted by some groups, as was borne out in the interviews with Greek households. Concerns also related to the lack of a legislative framework for these business models, as well as issues surrounding metering. The design team was then asked to consider what steps should be taken to support users in adopting new

business models. Responses centred around reduced costs, increased convenience, and the leveraging of energy communities and young people as early adopters.

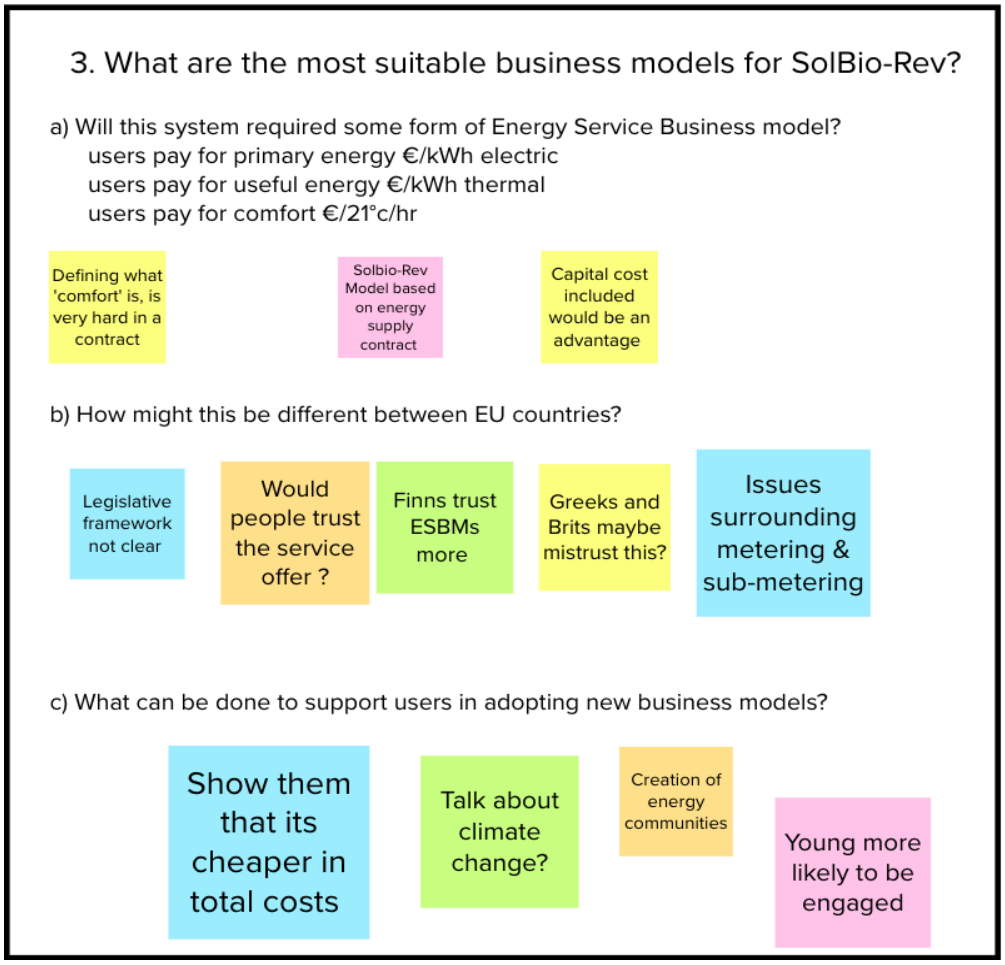

Figure 11 Workshop findings: What are the most suitable business models for SolBio-Rev

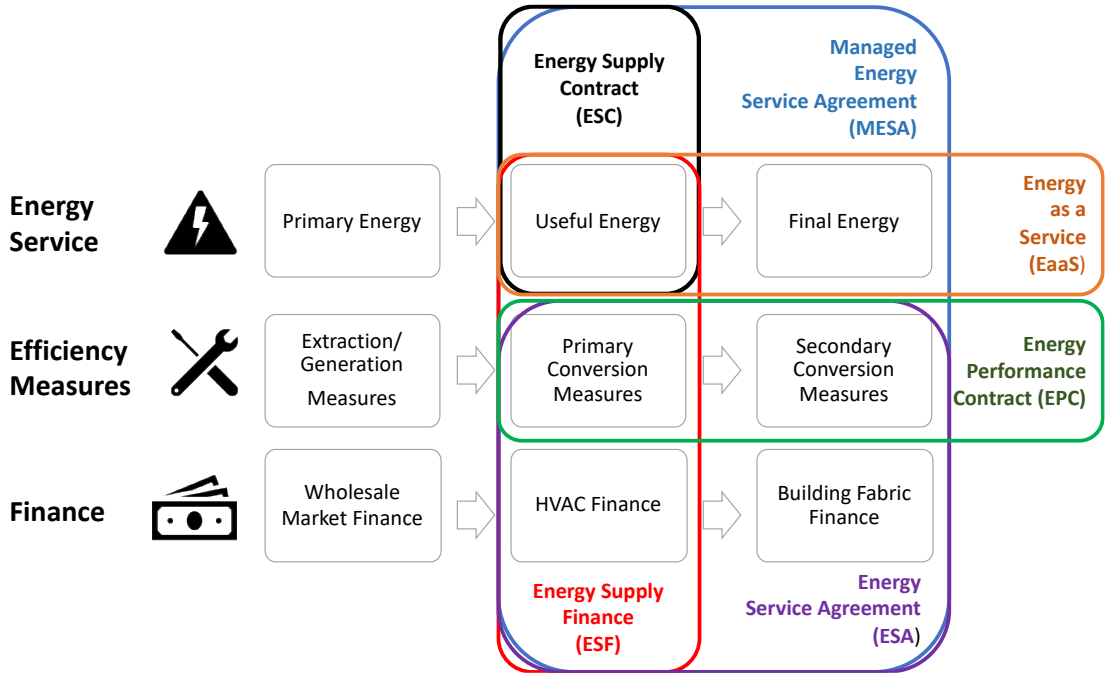

Figure 12 Typology of energy service business models. Source: (Brown et al 2021)[3]

3.4 Costs, affordability, and financing

The 3-country Survey respondents viewed operational or running costs as the most important feature of HVAC systems. Energy bills were highest in Finland and lowest in the UK, although the UK has many fewer degree days. We also observed large variances in energy bills depending on heating system type, although the effect of dwelling size could not be factored in. Finally, we observed the highest levels of self-reported energy poverty in Greece.

When comparing these figures to the reported income levels, we can infer that a large factor for Greek energy poverty is the relatively low-income status of Greek households. We can also infer that in general people in Finland live in much more energy efficient housing than in the UK or Greece, as their much higher degree days would likely push their energy bills much higher, all things being equal.

Box 9 Energy bills

38.4% of participants ranked "lower running costs" as the most important feature of a new HVAC system. Mean energy bills were €96.22 for the UK, €119.56 for Finland and €117.56 for Greece, and by heating system: Natural Gas boiler €96; Biomass Boiler €164; Wood burner/ fireplace €142; GSHP €133; ASHP €159; District heating/ heat network €78; Fuel cell €295; Oil/ fuel oil / LPG €129; Solar Thermal/ PV €181; Resistive/ electric heating €125; Other €141; Don't know €55. However, these figures did not account for differences in building or household size. Greeks expressed higher energy poverty with 30.2% of participants either "agreeing" or "strongly agreeing" with "I find it difficult to afford my energy bills". By contrast 59.1% of people in Finland either "disagreed" or "strongly disagreed" with the statement.

[3] https://www.sciencedirect.com/science/article/pii/S0301421521005693

These findings bode well for a system like SolBio-Rev, which the project developers expect to have much lower operating costs than conventional HVAC systems (Figure 13). When combined with the previous section's insights regarding the suitability of the system in different applications, a potential important first market could be medium density low-income housing, such as social or municipal housing. Indeed, the suitability of the system for this application was confirmed during interviews with the technical design team for the Lancaster West UK case study.

However, while the OPEX of the SolBio-Rev system is lower (Figure 13), the project team expected the CAPEX to be much higher (Figure 14).

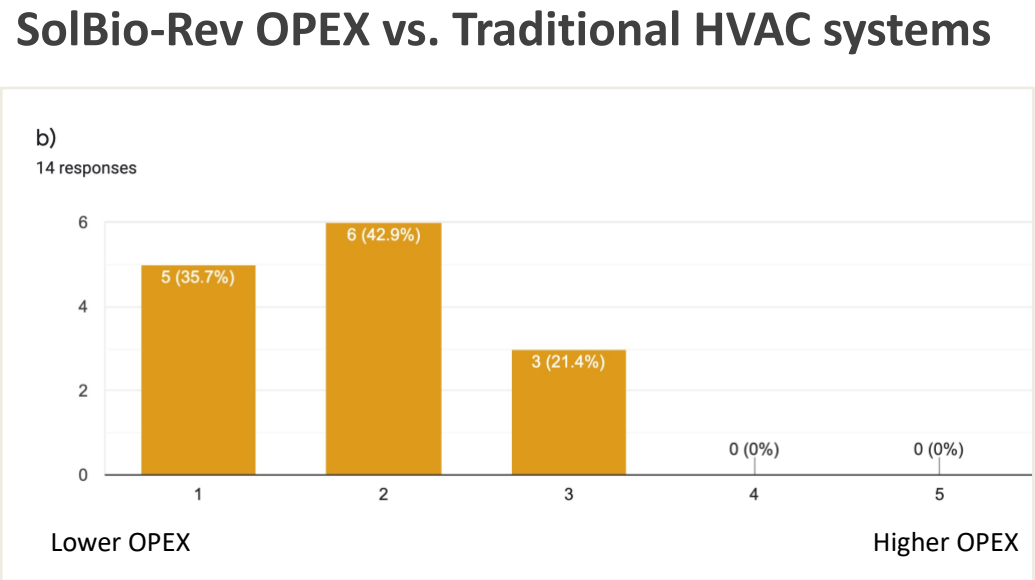

Figure 13 OPEX of SolBio-Rev

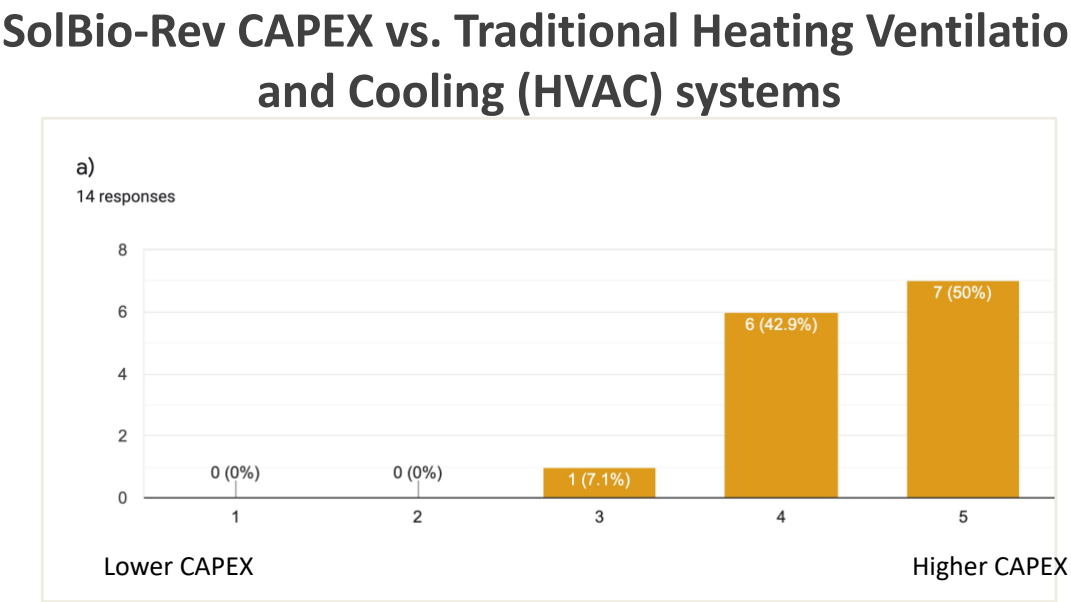

Figure 14 CAPEX of SolBio-Rev

These low OPEX high CAPEX characteristics suggest finance will play an important role in the adoption of SolBio-Rev, allowing users to spread the costs of installation and recover it via bill savings. However, as shown in Box 10 many respondents did not know how they would pay for a new system. Further, as shown in the box, many felt they would finance the system with their own money and or savings. Less than a third suggested they would like integrated financing. Indeed, many saw the decarbonisation of HVAC as their own responsibility, particularly in the UK. These findings suggest there are challenges in getting acceptance of the type of integrated business model where heat supply and system financing are bundled into a single service charge, as described in Section 3.3.

Box 10 Financing new HVAC

Many respondents "don't know" how they would pay for a new HVAC system, with 38.3% in Finland, 26.6% in the UK and 19.2% in Greece. 26.1% of Greek respondents indicated that they would prefer "financing is included with the new system" compared to only 13.7% of UK respondents and 15.8% in Finland. 35% of UK respondents, 19.6% of those in Finland and 29.7% in Greece stated they would prefer to "finance the new system with their own money/ savings". Most respondents stated that "myself/my family" should have responsibility for making their HVAC system carbon neutral with 53.3% of UK and 47.4% of Greek respondents providing this answer, compared to only 25.6% in Finland. Instead, 21.2% of Finnish respondents indicated that it should be their "Building cooperative/ freehold company" with 15.2% arguing it should be an ESCO.

3.4.1 How will the capital cost and running cost of SolBio-rev affect users?

Finally, we asked the SolBio-Rev design team to comment on how the cost characteristics of SolBio-Rev would affect users (Figure 15). Respondents reiterated the importance of financing to resolve the high CAPEX – low OPEX characteristics of the system. However, they also raised a series of issues relating to the freehold and leasehold arrangements, and their governance, in multifamily buildings. Respondents also commented that the system was perhaps too complex and could be simplified for different markets depending on their needs. This led into a discussion on the relative merits of bespoke installations vs. modularisation. The final discussion point centred on the nature of the grant funding landscape in different European countries and the extent to which grants would be available for hybrid systems such as SolBio-Rev.

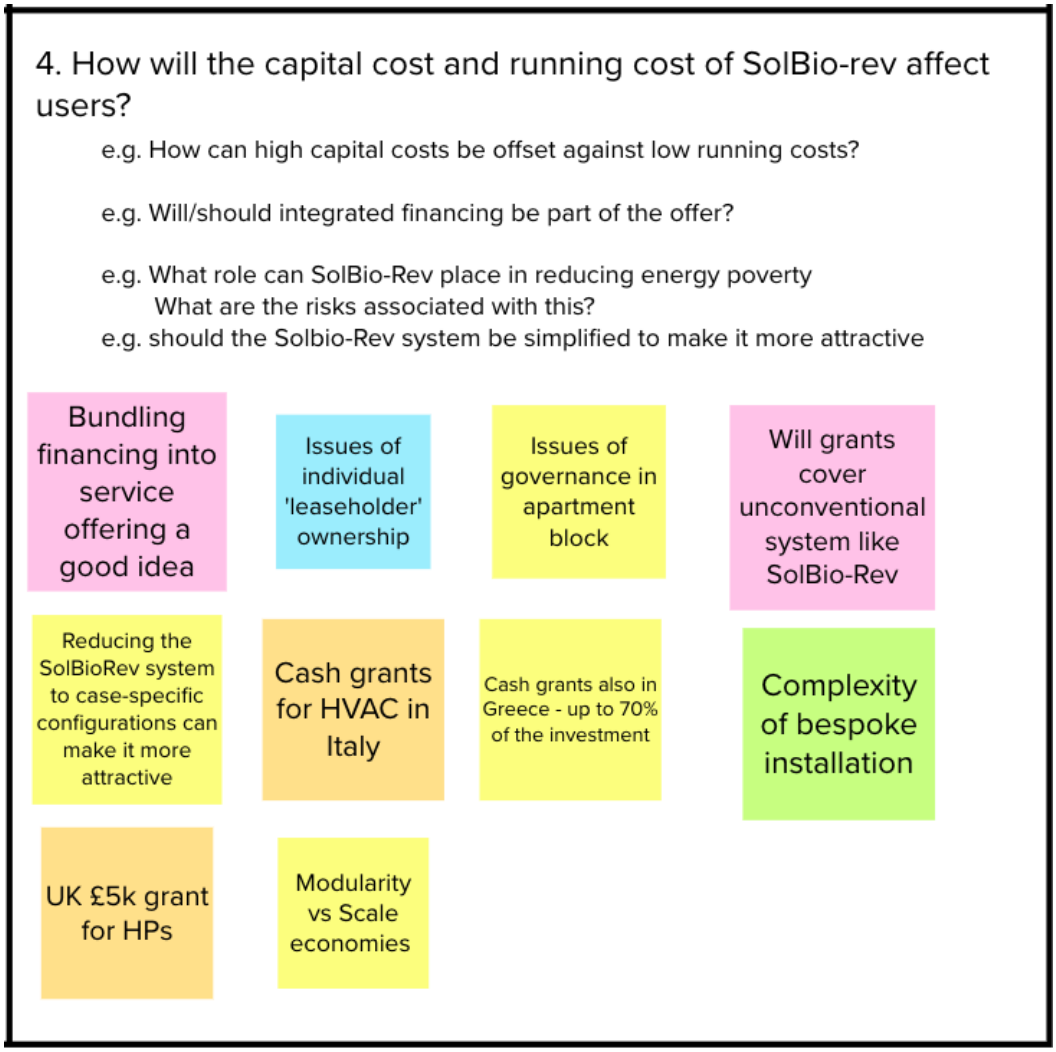

Figure 15 Workshop findings: How will the capital cost of SolBio-Rev affect users?

4 Conclusion: Implications for social acceptance and user uptake

Following the synthesis of our empirical findings, we present a series of conclusions and recommendations for the future uptake and application of the SolBio-Rev system below.

User expectations and preferences

- Future applications of the SolBio-Rev system should be sensitive to divergent expectations between different users and societal contexts for existing household HVAC systems, cooling methods and the sophistication of HVAC controls, if the system is to be adopted successfully.
- There remains a challenge in convincing users that renewable HVAC systems are as reliable as more traditional fossil systems.
- However, the constant flow temperatures provided by heat pumps could be a key advantage that could be promoted in future applications of SolBio-Rev.
- Reduced CO_2 emissions are unlikely to be a major motivation for most people, however this may be different for certain groups of early adopters.

System friendliness and ease of use

- Our findings suggest prospective users may tolerate significant disruption during HVAC installation.
- Reticence towards SolBio-Rev may be partly overcome through advanced controls and an effective user interface.
- Users are more likely to adopt technologies with which they are more familiar. Therefore, those marketing the system may wish to emphasise different component features which are more common in the target market e.g., solar thermal in Greece.
- SolBio-Rev is most suitable in applications with plenty of plant and roof space, where heating demand is dominant above electricity and hot water consumption. In addition, the high maintenance requirements may necessitate a professional energy manager.
- These findings confirm that the SolBio-Rev system is likely to be suitable for medium density multifamily residential accommodation, perhaps where the system has sufficient scale to allow professional energy management to be economic. When factoring the low running costs, social housing would thus seem an important first market.

Business models

- We expect that SolBio-Rev will require some form of energy service business model where users would pay for the useful energy services of hot water, heating and cooling rather than units of primary energy.
- However, these “bundled” models may be distrusted by some groups, suggesting there remain challenges in enticing users to adopt new business models, especially those which provide useful or final energy services.

- Much like the differences in main heating systems, these findings suggest that user expectations around business models may also differ substantially between different European national markets.

Costs and financing

- 3-country survey respondents viewed operational or running costs as the most important feature of HVAC systems. Therefore, as energy poverty remains an important factor, SolBio-Rev's much lower operating costs than conventional HVAC systems may be a clear advantage, especially for disadvantaged groups.
- These low OPEX high CAPEX characteristics suggest finance will play an important role in the adoption of SolBio-Rev, allowing users to spread the costs of installation and recover it via bill savings.
- Respondents also suggested that the inclusion of system financing as part of the energy delivery business model would be an advantage – under energy supply financing (ESF).
- However, there are challenges in getting user acceptance of the type of integrated business model where heat and cooling supply, and system financing are bundled into a single service charge.