Exploring attitudes, beliefs, and motives related to energy efficiency for buildings in Ireland and Italy

Abstract

Buildings represent one of the leading energy consumers in the world and one of the largest CO_2 and particulate matter emitters, thus their impact is significant on both the environment and the human health. Heat pumps systems powered by renewable energy have been identified as a valid tool to address such a situation, but the diffusion of these energy efficient systems is still insufficient.
This qualitative research explores beliefs, attitudes, and motives related to specific energy efficiency technologies, based on in-depth interviews with experts of the building sector and focus groups with users, where the latter were also engaged in the assessment of an innovative integrated solar/heat pump system. Results point out the relevance of information sources and personal advantages, in terms of money savings and well-being, in driving the decision, while regulatory frameworks were identified as important contextual factors. Policy actions are suggested to support the creation of local services for technical information and assistance, in addition to financial aid for less advantaged households, in order to foster widespread diffusion of these technologies.

Keywords: Energy efficiency; Sustainable behaviors; Attitude toward new technologies; Information sources; Persuasion

Abbreviations

DOI: Diffusion Of Innovation

GSHP: Ground Source Heat Pump

IDEAS: novel building Integration Designs for increased Efficiencies in Advanced climatically

PV: Photovoltaic

TPB: Theory of Planned Behaviour

1. Introduction

The role of buildings on the worldwide energy balance is important, in fact buildings represent one of the largest CO_2 emitters and a leading energy consumer [1], with respectively the 36% of greenhouse gas emissions, and the requirement of at least 40% of primary energy in industrialized countries [2]. A wider use of renewable energy for heating/cooling systems is required to mitigate the impact of the residential sector on climate change, helping achievement of the European Union targets of at least a 55% of greenhouse gas emissions reduction by 2030, compared to 1990 levels [3], and at least 27% increase of renewable energy. The revised Renewable Energy Directive (REDII) sets a binding target for renewable energy at 42.5%, with the aim to reach 45%. Additionally, with the Fit for 55 packages, the EU has raised its energy efficiency target to a reduction of 11.7% in energy consumption compared to forecasts made in 2020 for 2030.

Innovative heat pumps systems are seen as an effective tool for this objective; however, their diffusion is still too slow to meet the required targets [4].

Given that the shift from fossil fuels to more sustainable energy systems is often a matter of individual choice (e.g., at the household level), it is pivotal to detect what are the key elements orienting people's decision-making in energy choices. Interest in investigating individuals' willingness to invest in renewable energy has emerged in literature, with findings highlighting a variety of factors that influence such willingness.

The choice to invest in a new heating/cooling system is seen as predominantly driven by economic considerations, since significant upfront, installation, and maintenance costs often deter the investment decision. On the other hand, expected bill savings and a relatively short payback period are critical push factors. Further than purely economic considerations, advantages such as indoor air quality and thermal comfort represent significant elements of the choice [5, 6, 7]. Moreover, although environmental benefits typically have less immediate influence compared to economic factors, they still may play a role in driving people choices, leading to higher willingness to invest in environmentally sustainable solutions [8].

A one-stop shop (OSS) model could support these decisions by consolidating multiple aspects of the renovation process into a single, accessible service, helping homeowners navigate financial and logistical hurdles more effectively. OSSs have the potential to address informational (e.g., lack of trust, unknown co-benefits such as comfort and health, misperception of energy use) and decision-making barriers (e.g., limited attention, social invisibility, cognitive burden, loss aversion) by simplifying the process and offering guidance. Additionally, OSSs may facilitate access to financing, improve homeowner engagement, and provide tailored recommendations that align with personal characteristics (e.g., age) and contextual factors, making sustainable investments more feasible and

appealing. [9, 10]. In sum, previous research has shown that the decision process in this context is conditioned by factors that are not just purely economic, technical, and physical [11, 5]. Key social science concepts could help policymakers to better understand and tackle energy efficiency challenges. Moreover, a social science approach is recognized as a complementary perspective that acknowledges the social construction of problems and encourages a broader view that includes social and collective structures influencing individual behaviors [12]. Therefore, social sciences can provide a significant contribution to better investigate which factors prevent or favor the adoption of sustainable behaviors. In this regard, environmental psychology research provides some answers related to socio-psychological dimensions and models predicting individuals' pro-environmental intentions and (actual or future) actions (e.g., installation of sustainable technologies). This research domain has focused on antecedents of pro-environmental choices such as social norms [13, 14], attitudes, beliefs, emotions [15], and values [16], as well as the arguments and the relevance of the communication sources [17].

This paper focuses on the exploration of beliefs, attitudes, and motives held by potential and actual users of specific technologies applied to energy efficiency. It draws from work carried out to promote public engagement in an EU-funded project, labelled IDEAS[1], aimed at the development of an innovative building-integrated renewable energy system, for achievement of nearly zero energy buildings. A qualitative investigation, based on in-depth interviews with stakeholders in the building sector, has been carried out in two sites of interest for the project: Ferrara in Italy, and County Mayo in Ireland, where two applications of the system were planned within the project. The two locations are characterized by very different climate conditions, with different heating/cooling requirements. The second study is based on two focus groups with intermediate and end-users of home energy systems, and carried out in Ferrara, i.e. the location where the first prototype of the system was implemented. The dimensions of interest will be detected through the analysis of experts' and users' narratives about drivers and barriers to the adoption of the advanced technologies proposed in the two studies.

The paper is organised as follows: after a brief overview of the relevant sociopsychological literature regarding energy innovation by households and the qualitative research methods, the two studies are individually presented and subsequently discussed in the last paragraph with the final conclusions.

[1] IDEAS is the acronym of *"novel building Integration Designs for increased Efficiencies in Advanced climatically tunable renewable energy Systems"*, a research project funded by the Horizon 2020 Program of the European Commission (Grant Agreement n. 815271) that aims to develop an advanced system of control techniques to maximize performance, and electrical and thermal/cooling self-sufficiency in the building.

1.1. Households 'adoption of energy technologies: theoretical models

The decision process leading to the intention to adopt an energy efficient technology has been extensively studied in the socio-psychological literature. It has been observed that information sources play a relevant role in influencing beliefs [17] and attitudes [18], which could represent drivers or barriers to the implementation of sustainable choices. For example, information from mass media seems important for removing uncertainty [19], but a crucial role is played by scientists [20], and by significant others (e.g., friends and relatives, but also neighbours), who may have a considerable influence in orienting people's decisions and actions, consistently with studies that underline the impact of significant others in the activation of social norms [21].

As suggested by Stern [22], behaviours which have an impact on the environment can be influenced by an array of socio-psychological dimensions, such as attitudes, besides personal capabilities (education, social status, financial resources, knowledge, and skills), and contextual factors (regulations, market conditions, information, social norms, available technology).

The construct of attitude has been widely used in social psychology [23], [24], and has been considered as the result of the beliefs concerning the consequences of the behaviour and their assessment. In this regard, the Theory of Planned Behaviour (TPB) [25] is one of the main models addressing the relationship between attitude and behaviour, postulating that the proximal cause of an individual's behaviour is the intention to perform such a behaviour. This theory has been shown to predict a considerable range of behaviours which are under our rational control, including pro-environmental actions [26], especially in cases where actions originate from an accurate reasoned analysis of pros and cons [27]. In line with Stern's claims [22], the inclusion of perceived behavioural control in the TPB allows to take into account both personal capabilities and contextual factors influencing the behaviour. The personal ability to carry out a behaviour refers to a series of conditions and required resources to act [27], e.g. money to invest in an energy-efficient technology, space to install the system, market conditions, such as availability of the product, technical assistance, perceived ability in operating the technology [28].

Regarding the choice to adopt or reject new technologies, an interdisciplinary theoretical framework, the Diffusion of Innovation (DOI) theory, has been developed by Rogers [29], who defined diffusion as a process by which an innovation is communicated through given channels over time among the members of a social system. Hence, diffusion is considered as a communication process, which may or may not result in adopting the technology. It is not important that the idea is effectively new, what matters is that the target becomes acquainted with the idea and evaluates it for adoption. The timing and rate of innovations diffusion and adoption depend both on characteristics of the decision makers, and on perceived features of the innovation. Previous studies on renewable heating systems based on

129 the DOI theory include those carried out by Franceschinis and colleagues [30], Wolske and colleagues
130 [27], Alam and colleagues [31], Faiers and Neame [32]; in the context of the current study, Strazzera
131 and colleagues [5] find evidence of the relevance of trialability and feasibility, besides economic
132 advantage, as factors associated with different choice behaviour.
133 The DOI theory highlights the importance of the individual's knowledge about a new technology as
134 a driver for accepting and adopting it, also in line with the view of Stern [22], who considered
135 knowledge as a personal resource for making pro-environmental choices. A positive correlation has
136 been found between knowledge of a new technology and acceptance of it, even though the causal link
137 between knowledge and acceptance has not been tested: it is not surprising that the higher the
138 knowledge, the more likely the acceptance, nevertheless a high level of acceptance may also influence
139 information uptake and, thus, knowledge [33].
140 A further model, combining theories from social and environmental psychology, and particularly
141 tailored for predicting the acceptance and adoption of innovative technologies, is represented by the
142 Sustainable Energy Technology Acceptance Model [34] and its derivates (such as the integrated
143 Sustainable Energy Technology Acceptance), used for explaining the acceptance of respectively a
144 hydrogen fuel station and biofuels. Also in these models, which include the TPB dimensions,
145 knowledge is a crucial dimension, together with perceived risks, costs and benefits, perceived
146 fairness, values, emotional reactions to the technology, and trust in relevant communication channels,
147 market agents, and policy institutions.
148 In sum, people's intention to adopt energy efficiency devices at the household seems related to
149 features such as knowledge about energy efficiency issues, trust in information sources for household
150 heating choices, structural factors (e.g., economic motives, laws and rules, incentives) orienting such
151 choices, and attitudes toward the installation of energy efficiency technologies. These features have
152 been considered as a framework for the present research.
153
154
155 **1.2. Qualitative research methods**
156 The theoretical framework described in the previous section provided the benchmark for the structure
157 of the qualitative research presented in this paper, with a first study based on a set of in-depth
158 interviews with experts of the building sector, and a second study based on focus groups run with
159 building users, including both laypeople and experts of energy systems. Qualitative techniques allow
160 a better grasp of the underlying motivations and beliefs that are associated with people's decision-
161 making about environment-related actions (e.g., see [35, 36, 37]) and are relevant in understanding
162 the specific socio-cultural dimensions of renewable energy adoption. Within the wide literature

concerning qualitative studies on renewable energy adoption, research has increasingly recognized focus groups as an important tool to explore themes and dilemmas [38, 39].

Several studies have focused on the identification of drivers and barriers influencing the acceptance of renewable energy technologies (see [40]). The use of interviews and focus groups in these investigations promoted the exploration of diverse perspectives and experiences, allowing researchers to uncover not only individual attitudes, but also collective social norms guiding energy-related decisions [41]. These studies explore the interplay between technological innovation and human behaviour, providing insights into the complex decision-making processes underlying the adoption of sustainable energy systems. Scheller and colleagues [42], for instance, found in the content of four focus groups the important role of influential stakeholders (i.e., people in the same social network of the decision maker, like family, friends, neighbours; but also PV providers, and civil society groups that are deemed trustful and reliable) in the adoption of residential photovoltaic systems. In sum, qualitative research is considered as appropriate in exploring "why" there are differences in individual attitudes and intentions quantitatively detected [43] and, moreover, it can help to "overcome self-presentation biases and reveal the complexity of motivational structures", e.g., social desirability, social norms ([44], p. 188).

A qualitative approach allows deeper insight, enabling to explore opinions, obstacles, acceptability, and motivations of end users regarding a new energy efficiency technological package such as the one proposed in the IDEAS project. Despite the extensive literature on renewable energies and their acceptance by users, the novelty and originality of this research lie in evaluating not just a specific type of technology, but rather a complex and integrated system.

2. Case study

2.1. Objectives

In order to gather information on the factors that could drive or hinder the adoption of an innovative energy system such as the one proposed in the IDEAS project, we first conducted a study based on in-depth interviews with stakeholders involved in the building sector. Afterward, a second study based on focus groups was conducted with intermediate and potential end users. The aim of these studies was to explore beliefs, attitudes, and motives concerning specific technologies applied to energy efficiency. In particular, the objective was to identify drivers and barriers related to the adoption of such technologies as they directly emerge from the users' narratives. Given both the qualitative methodology and the exploratory nature of these studies, there are no operational hypotheses to test.

Despite the extensive literature on renewable energies and their acceptance by users, the novelty and originality of this research lie in evaluating not just a specific type of renewable energy, such as photovoltaic or solar panels, but an integrated system prototype. Additionally, being a qualitative research, it will provide a different kind of insight, enabling us to explore in greater depth opinions, obstacles, acceptability, and motivations of end users regarding a new energy efficiency package.

For easiness of reading, we chose to organize the results section of both studies around the same thematic issues, that is: a) knowledge about energy efficiency issues, b) information sources for household heating choices, c) factors influencing the choice of heating systems, and d) attitudes toward the installation of different energy technologies (i.e., photovoltaics and solar thermal panels, heat pumps, smart control systems). The only difference is an added final paragraph for the second study, concerning the e) attitudes toward the specific energy system here focused, i.e. the IDEAS system (see Figure 1).

2.2. Contexts

The two countries selected for the study, Italy and Ireland, are representative of climate conditions respectively in southern and northern Europe. In the period 2001-2020 Italy has experienced decreasing trends for Heating Degree Days (on average, from 1500 to 1300 days/year requiring heating) and increasing trends for Cooling Degree Days (on average, from 244 to 305 days/year requiring cooling); in the same period Ireland had stable trends of about 2000 Heating Degree Days, and near zero Cooling Degree Days[2]. Ireland mostly relies on oil and petroleum products (52.4%) for space heating, followed by natural gas (23.9%); solid fuels still account for 17.6% of heating energy needs, electricity for 3,8% and renewables only for 2.3%. In Italy, space heating accounted for 66.3% of household energy consumption, water heating for 12% and space cooling for 0.8%; the primary energy source in the residential sector was by far natural gas (51.8%), while electricity ranked third (18.1%).

3. Study 1

3.1. Method

In-depth interviews are a qualitative social research method which allows to gather comprehensive information from stakeholders. Specifically, this is a useful method for getting into the interviewees' social and personal worlds [45] and for exploring their experiences, feelings, and motivations, also in relation to energy system choices.

The interviews were conducted between July and October 2019 in the Irish and Italian specific areas where the IDEAS pilot projects had to be implemented. All interviews were realised face-to-face (except one, conducted by phone with an Italian architect), respectively in County Mayo and Ferrara (except for two interviews, one in Dublin and one in Modena). Prior consent from the interviewees, each interview has been digitally recorded and then fully transcribed.

2 Data from International Energy Agency: https://www.iea.org/data-and-statistics/charts

234 **Participants**

235 The sample included a total of 13 stakeholders (7 from Italy and 6 from Ireland[3]), who were
236 representatives of the following categories: builders, architects, engineers, house owners, real estate
237 agencies, credit sector, municipal administration.

238

239 **Procedure**

240 Semi-structured interviews were prepared in Italian and then translated into English with amendments
241 to suit the local context for the Irish study. The interview content aimed at gathering information on
242 a range of topics, such as the technologies to be used for achieving higher energy efficiency in
243 buildings, the relevant attributes of the dwelling taken into account by house buyers and owners, the
244 role of banks in the promotion of energy efficiency, the current situation of the property market, the
245 bureaucratic procedures related to energy efficiency in new constructions and renovations in County
246 Mayo and Ferrara.

247

248 **Data analysis**

249 The interviews were transcribed and subsequently analysed using a qualitative content analysis. In
250 order to ensure inter-rater reliability, two independent judges carried out the categorization process.
251 Convergence points were sought in case of differences between raters in the analysis, and the final
252 categories were redefined accordingly.

253

254 **3.2. Results**

255 The results section is organized according to specific issues such as knowledge about energy
256 efficiency issues, information sources for household heating choices, structural factors influencing
257 the choice of heating systems, and attitudes toward the installation of specific energy technologies.

258

259 **Knowledge about energy efficiency issues**

260 In general, the stakeholders involved in the study seem to share the view that homeowners do not
261 perceive the importance of investing in energy efficiency nor seem to be fully informed of the
262 advantages it implies. In their opinion, potential buyers could be interested in energy efficiency, but
263 they do not really know what to do to achieve certain results. It is argued that if people were aware,
264 they would ask for specific energy-efficient technologies, and the supply side in the housing market
265 would respond.

[3] The interviews in Italy have been conducted by the fourth author, while in Ireland they have been carried out by local partners of the project, with assistance by the third author.

"They are [interested] but, like I say, you know, when you mention the insulation, they glaze over. […] I mean, it's like the whole climate changing, energy efficiency, and so on. People are saying 'Yes, of course, we must do something', but they do not know what. You know, they do not know what to do." [Architect, Ireland]. "*The client not always is aware. If nobody asks for certain things, nobody is going to make them.*" [Real Estate Agent, Italy]. "*If the final user is not aware, energy efficiency cannot be a trigger for the housing market.*" [Builder, Italy].

Information sources for household heating choices

Not surprisingly, the intermediaries can play an important role in driving homeowners' investment decisions related to energy efficiency. In this regard, a first issue highlighted by some stakeholders is the lack of independent advice and sources of information on which people could rely on. The same experts who are supposed to provide useful indication to select the most suitable technology for the specific individual situation are often not impartial, and merely propose the technology they have to sell. As one Irish stakeholder explains, talking about clients and builders' awareness about energy efficiency: *"They know about it and they know what products are on the market, they know which ones they like using and so on. But we have a huge problem in that. There's an awful lot of 'snake oil salesmen' out there. […] And every solar panel, a double glazing, insulation, they're all tied into manufacturers. So, you're not getting impartial advice, you're getting a salesman. And a salesman can only say what he is commissioned to sell you."* [Architect, Ireland].

In some other cases, technicians do not really take into account all the technologies available in the market potentially suitable for the specific case, but simply tend to suggest to the client the technologies they are more knowledgeable on, that is to say, more likely traditional systems than new and innovative systems. Some stakeholders also indicate that homeowners – especially elderly people – are often sceptical towards new technologies and are more willing to choose traditional (and already known) systems.

Structural factors influencing the choice of heating systems

Among structural factors, economic factors play a pivotal role in influencing homeowners' decisions related to energy efficiency, often still considered as a luxury good. Cost concerns prevail even on potential concerns about the environmental impacts of personal energy consumption behaviours, to the point that reductions in utility bills and fixed costs could drive part of the demand for investments in energy efficiency. *"I think that a lot of people are more aware of energy savings… You know, their responsibilities to [...] the environment. So, all of these things could be factors [...] but of course, as always, money concerns are number one, I suppose, for most people."* [Builder, Ireland].

"They want assurances that their home is energy efficient, and their utility bills will be decreased." [Real Estate Agent, Ireland]. A substantial difference emerges when considering the building potential uses, such as exploiting it as a personal residence or renting it out. In this latter case, in fact, the lack of interest for energy efficiency is even more emphasised. According to the Italian interviewees, the current rental market conditions are such that there is no interest in investing in energy efficiency "*because there is no return on the investment*" [House Owners Association, Italy]. Moreover, unless we are dealing with new, high-quality buildings, investments on energy efficiency are thought not to be worth the cost, and in fact, in renovations, people are not so keen on investing money to achieve a high level of energy efficiency. "*Over 100 apartment renovations, 90 are only space restructuring, and 10 also include energy efficiency interventions. The numbers are not high.*" [Architect, Italy]. *"...There is always a huge difference in the requirements between those who look at new rather than existing dwellings; ... the customer who looks at new houses expects that the energy rating is high... let's say that if they look at new buildings it's because they give importance to this aspect."* [Real Estate Agent, Italy]. Location is also a determinant on homeowners' decisions related to energy efficiency: according to the Irish stakeholders, a difference exists between urban and rural areas. Some believe that energy efficiency receives more attention in the latter, others argue that *"urban dwellers are much more concerned with it versus the rural dweller."* [Real Estate Agent, Ireland]. Findings from a large-scale survey [5] confirm the result for Ireland.

A key influencing role is certainly played by new regulations, which however are not really changing people's awareness and sensitivity on this topic. Indeed, what emerges from the interviews is that often energy efficiency is pursued exclusively for being a condition imposed by the law - because *'it's the thing to do'* [Architect, Ireland] - leading people to do just the minimum requirement to comply with the regulations, i.e. installing just what is strictly necessary, which often result in just a token gesture.

"In Emilia Romagna PV is now mandatory in deep renovated and new buildings, so... there are people who say 'okay, since I have to install some PV, I do not care, let's only put the minimal that I would need', and this can be done." [Engineer, Italy]. **"***Well, now because if you're building a new house, […] the regulations say you have to put in some class of an energy saving device, energy creating device. […] The regulations say you have to do something, but it's not thought through, you know."* [Architect, Ireland]. However, some stakeholders recognize the essential role played by regulations in promoting energy efficiency. *"Fortunately, there are rules that oblige people to respect some construction criteria related to energy efficiency, because the private citizen who has to make a choice on his/her own is not sufficiently knowledgeable as yet."* [Real Estate Agent, Italy].

Since contractors must comply with the regulations that require the achievement of specific energy classes, the new buildings have to get a high energy class. As a stakeholder explains: *"Every new build […] would be hitting a B anyway. And that's driven by the Local Authority."* [Builder, Ireland]. *"And, legally, we are obliged now when we put a property on the websites… it is not saying everyone is complying – they're probably 90% compliant – […] unless it's not applicable in some cases of very old building or a Georgian property - it wouldn't be applicable to those - but yes, people are very, very concerned about. […] So, yes, it's very important for people. It's the first question they'll ask you when they go into the house: 'What rating has the house'."* [Real Estate Agent, Ireland].

Some stakeholders reported that finding efficient policy tools to support homeowners' investments on energy efficiency is not a simple task. They emphasize the need to increase people's awareness, clearly explaining the advantages linked to energy efficiency, not only from an environmental point of view, but from an economic one as well. "*There has to be some incentive there, but if you can demonstrate through policy, through education, awareness, the benefits locally even here to the climate, to the householders how the energy utility bills would be reduced and looking at payback periods, then those are the policy tools that should be employing […] to encourage homeowners to invest in their properties"* [House Owners Association, Ireland].

An important issue highlighted by the Italian stakeholders concerns the lack of certainty about the rules and the incentives system. They emphasise the importance of clarity in regulations and in the design of subsidies, also in terms of duration of the policy measures. Consequently, the Government intervention should be aimed at reducing uncertainty – which "*makes initiatives complicated"* [Real Estate Agent, Italy] - and increasing clarity, by means of long-term programs, while avoiding the continuous introduction of new rules, since *"every day, every week, there's something new. You can't never come full circle"* [Engineer, Italy]. Moreover, the administrations should play a more important role in increasing people's awareness and informing the various stakeholders and the general public on regulation regarding energy efficiency. As an interviewee argues: "*It should be the Public Sector [...] to inform on the specific requirements of the laws, it must give indications on the limits that the law imposes*. […] *Why does not the Public Sector conduct a sample survey, so that it can raise awareness in the private sector?*" [Real Estate Agent, Italy].

Attitudes toward the installation of different energy technologies

In both countries the stakeholders from the building sector see photovoltaic panels as more promising than solar thermal systems. This seems to be mostly due to the combined effect of new regulations, on one hand, and lower prices, on the other: *"Photovoltaics is now a must, especially in renovations and in new buildings."* [Engineer, Italy].

As regards solar thermal, conflicting opinions emerge from the Italian interviews, since some respondents believe that a demand still exist, whereas others consider the solar thermal as outdated. Regulations can act both as drivers and barriers of the diffusion of energy-efficient technologies. An example is given by Italian restrictions on the application of specific technologies in historic city centres. In downtown Ferrara, for instance, neither the solar thermal nor photovoltaic panels can be installed on the roof, "*because of their high visual impact"* [Municipal Administrator, Italy]. In contrast, it is however noticed that the air conditioner splits are widespread (also on the roofs), "*because for an installation below 5 kW no building permit is required, and therefore there is no communication to be made to anyone."* [Engineer, Italy]. In both countries some stakeholders talked about a decreased interest towards PV panels. In Italy, most interviewees claim that this is due to the decrease in financial support from the Government. Also in Ireland "*there has been a very important increase in the demand for panels until 4 or 5 years ago, as long as there were government subsidies of a certain level, but as the subsidies have plunged, so the demand has plunged […] The photovoltaic… we do not hear any longer about it. There was no decrease in costs, perhaps a little, and then the subsidies have gone down, so it is no longer of interest"* [House Owners Association, Italy]. *"The PV panels, some of the ones we're encountered now are not brilliant, and so people are not inclined towards them. For some of them for the outlay, for what you get back is… [not much payback]"* [Builder, Ireland].

As about heating/cooling technologies, an opinion was solicited regarding one of the devices included in the IDEAS project, namely Ground Source Heat Pumps (GSHP). Most interviewees had little direct experience with this technology and *'do not know enough about it in detail.*' [Architect, Ireland]. Application of GSHPs seems very sparse, and the stakeholders highlight some factors that could justify such a scarce diffusion. From a technical point of view, the space needed - especially for the horizontal probes - plays a pivotal role. As two interviewees argue: "*Oh, yes, 'tennis courts' […] No, people do not have the room. It's like the electric car problem, where are you going to plug it in, you know."* [Architect, Ireland]. *"I prefer the vertical [system]… For the horizontal [system] you need to have spaces of a certain type... Then even if I have spaces of a certain type, I can no longer put plants... it's a problem, there are constraints... I can do it on a football pitch, just to say..."* [Engineer, Italy].

Conversely, another potential issue concerns the effects of cooling accumulation in the soil, especially in case of vertical systems. As one Irish architect tells: "*I was in one house that had it. They were very pleased with it. I do not know that she wouldn't end up cooling down your half acre. And the efficiency…. the efficiency would go down. I'm not sure.*" [Architect, Ireland]. However, the greatest barrier turns out to be the investment cost. GSHPs are indeed considered as too expensive yet,

especially if compared to other available technologies, as clearly emerged from interviewees' statements, in both Italy and Ireland: *"I've had only experience of two and I felt that were very, very expen*sive." [Real Estate Agent, Ireland]. "*Houseowners could be interested, if the price were lower."* [House Owners Association, Ireland]. *"...heat pumps or at least geothermal [heat pumps] are a mirage, at least to me... I do not believe it from the point of view of market possibilities."* [Engineer, Italy]. *"It makes sense in new properties or in high-quality properties, or renovations of a certain type, meant for those who can afford spending of a certain type. Everyone else is not interested."* [House Owners Association, Italy]. Future savings for heating/cooling purposes are mentioned by some interviewees as pros related to GSHPs, especially if these are included in integrated systems along with solar thermal and/or photovoltaic panels. However, increased efficiency of other types of heat pumps may conflict with the diffusion of the GSHP option: *"geothermal, they're not that common, you know, since air-to-water has come in. Nearly every house we do now is air-to-water. Geothermal was popular maybe seven or eight years ago, but not anymore… […] The air-to-water units seem to be very efficient, you know. So, I'd say they are a simpler system, and they are efficient enough, you know."* [Builder, Ireland]. Irish interviewees agree on the fact that heat pump systems are increasingly applied inside buildings, although the opinions in terms of efficiency are somewhat divergent, as shown by the following two excerpts: *"There's a good number of heat pumps right now, yes. It's a lot more common than it was. […] They're relatively common around this part of the world where there is plenty of money, as the capital cost is high. I do not think they are very good a lot of them. Some of them are good, but an air-to-water heat pump can't really be up to much in Ireland, you know."* [Architect, Ireland].

About smart control systems, interviewees have rather positive attitudes them, particularly appreciated for simplifying people's life and allowing savings.

In Ireland, smart control systems are deemed to be a *"huge opportunity"* [Architect, Ireland] and all stakeholders strongly believe that homeowners are interested in such a technology and are already making use of it. Their importance is foreseen to be even greater in the future, especially for younger people, whereas older people – taking the return of the investment into account - might be less willing to invest in such technologies. As two stakeholders argue: *"It makes life easier for people and I think it's not even an interest now, there's expectations that everyone is able to turn on their heat remotely through the mobile phone or through the laptop or whatever it might be, control the temperature etc. So, it's everyday practice."* [House Owners Association, Ireland].

"I think it's going to become very important in the future. So, I think if somebody came to me in the morning and said '[Name], we have a site in [Place Name] or whatever, and we are going building 20 houses', I would say I probably call them 'smart homes' and I would be kind of say 'Yes, I would

go down that route', because it's likely going to be younger people that are buying them, and they are very, very smart on those things, and they are looking at their investment over 25 or 30 years, where an older couple might say 'Ah, it doesn't need to be that.'" [Real Estate Agent, Ireland].

In Italy, a partially different picture emerges, since it looks like such systems are almost a niche in the market, potentially interesting for a wider audience (mainly influenced by advertising), but now actually doable only by wealthy people. As one interviewee argues: *"Someone shows interest, before renovating or buying, because they talk about it a lot, but then they do not realize it. It is most of all advertising, susceptibility to advertising. Maybe over time it will develop more… It has considerable costs."* [House Owners Association, Italy].

The importance of being able to exert control over these systems is also mentioned by stakeholders, as well as the fact that often homeowners experience some difficulties in understanding how to use smart control systems, even after the intermediary's explanation. As two interviewees report: *"All these technologies allow to improve our lives and save energy, but you must also be able to control them and be able to accept them. I do not exclude that one can control the house with smart systems"* [Municipal Administrator, Italy]. "*But after it will be necessary […] to spend two days explaining to people how it works... But that's not enough, because once you've explained it […]* [it works if users are] *quick in learning and therefore they know the technology, they are young, etc. etc., but the elderly people…"* [Engineer, Italy]. Thus, buyers' age and capabilities are seen as key factors in acceptance and diffusion of these advanced technologies.

4. Study 2

4.1. Method

The technique of focus group was used for data collection. Such a technique consists in a group interview based on the communication among participants [46], who focus on a specific issue under the guidance of one or more interviewers/moderators. The assumption was that the participants' responses and exchange of opinions reproduced the views about the topic which are usually socially constructed within a given cultural context or social group [47].

Participants

Two focus groups were realized with a total of N = 16 participants (gender: 10 = 62.5% males; age range = 19-68, mean = 44.6) living in the city of Ferrara (Italy). The focus groups showed the following differences: the first one (N = 8, gender: 62,5 % males; age range = 27-66, M = 41) involved homeowners as potential end users having low knowledge about energy efficiency systems; the second one (N = 8, gender: 62,5 % males; age range = 19-68; M = 48,2) included intermediate users,

such as consultants, technicians, managers, with different levels of expertise in the sector of energy efficient technologies (see Table 1).

Procedure

The focus groups were held by two expert moderators (namely, the first and the second author of this study) in a proper setting, i.e. a lecture room located in the Department of Architecture at the University of Ferrara equipped with chairs to seat a circle of up to 8 people.

An overview of the topic was given by the moderator, who also explained the rules. Participants were encouraged into spontaneous conversation, without pressure, and follow-up questions were used to facilitate further discussion. The assistant moderator had the role to take notes and to support the moderator.

Two slideshows have been set up for presentation during the focus groups, in order to provide appropriate stimuli for the discussion: the first one, which contained pictures and short descriptions of the functioning of some energy technologies already present on the market (photovoltaics, heat pumps, fan coil units, radiant systems, thermal storage, and smart control systems), was displayed at an early stage of the interview, i.e. immediately after the moderators' introduction; the second one, focusing on the IDEAS innovations, in the final part of the focus group. In the case of the experts' focus group, only the second presentation was given (since the first was supposed to be redundant for the target participants). In both cases a leaflet was handed-out to participants, containing a brief description of the standard technologies, which could be used by participants as a quick reference during the discussion.

A tailored interview trace was set up for the two different targets of participants. It covered an array of questions (see Appendix) related to specific issues such as information sources and relevant structural factors for household heating choices, attitudes toward specific technologies, and possible motivations for installing the IDEAS system. The extent to which each issue was explored was dependent upon its importance for the participants.

Each focus group lasted about 2 hours; it was digitally recorded and then fully transcribed.

Data analysis

A content analysis was performed on the two focus group transcripts. Two independent judges were recruited to code each focus group discussion following a theory-driven approach, on the basis of pre-defined conceptual categories [48], for identifying the relevant sentences and issues related to each topic. The use of two coders has allowed to assess the reliability of the coding process. For those few cases where the inter-rater agreement was not optimal, the two judges exchanged their opinions

in order to find convergence points.

4.2. Results

The following paragraphs give an account of the content analysis results (including examples of pieces of narratives emerged in the focus groups) for each conceptual category considered. The section has the same structure used for the results of Study 1, including the subsections addressing knowledge about energy efficiency issues, information sources for household heating choices, structural factors influencing the choice of heating systems, and attitudes toward the installation of specific energy technologies. In addition, there is here a paragraph on attitudes toward the IDEAS system.

Knowledge about energy efficiency issues

This topic emerges only in the focus group of potential end users having low knowledge about energy efficiency systems. Focusing on their own role in the CO_2 reduction, participants recognize the need of mass media campaigns to increase awareness on this theme through the promotion of an *"energy culture"* because *"our behaviours sometimes derive from education"* and *"there is no mass communication on this topic"* [Woman, User, aged 52]. Basically, they think that CO_2 emissions are more frequently linked with vehicles than with domestic consumption *("just afterward people think about the house, even on television, on the news, they mainly tell us "to solve the issue, stop the car"* [Woman, User, aged 32]). Anyway, the commitment "*should be global"* and it should be declined in several sustainable behaviours such as the reduction of home heating temperature (*"[it does not make sense] you save on and then he sets 25° at home: or everybody or nobody"* [Man, User, aged 66], an implementation of energy efficiency measures (e.g., window fixtures replacement, double-glazed windows) and "easy" behaviours due to the technological progress (*"we are very spoiled…because, in the past, if there were no air conditioner, low-cost methods were used (…), now it is simpler, it is more comfortable, you turn on the air conditioner, set it to the maximum and in a few moments you cool everything (…) we are a bit guilty because it is also progress that leads us to behave more simply"* [Woman, User, 52]; even when people have some awareness of the impacts that their energy consumption behaviour has on the environment. In fact, it is affirmed that the intention to invest in energy efficiency is also driven by economic arguments *("if you have to buy a house, if you have to renovate a house, you think about it. However, when people already have a house, a little less (…) first of all, people think of money, (…) the priorities are savings but also the investment for obtaining such savings…it's important to know the laws: if there are tax reliefs, because the input must arrive from the Government"* [Man, User, aged 50]).

Information sources for household heating choices

On the whole, householders are well-informed, as a consequence of both their own interest and experiences, such as home renovation because *"anyway, those who have to renovate their home, ask more for information"* [Woman, Expert, aged 48]. The search for information is *"autonomous"*, mainly supported by the experts and the web *("I use it a lot...I did a lot of research on the Internet but I found conflicting results, good and bad issues...for those that were bad for me, I sought clarifications from experts"* [Man, User, aged 66]).

An opposite point of view is provided by the experts who believe that web search is usually superficial (*"In my opinion, young people rarely get information […] they do it when they need it and, however, news arrive in a very generic way, mainly derived from the first item found"* [Man, Expert, aged 19] and occurs after an initial input from an expert, even though, among the experts, there is often a lack of both technological skills and desire to change. In general, experts share the idea of information as negatively perceived because of ads phone calls by companies that create mistrust *("because they are assailed by companies who want to sell them batteries, rather than the plant, so this constant bombing leads to a pessimism regarding these new technologies (…), it leads to closure"* [Man, Expert, aged 55]; *"then the trust that people have in the person who proposes [new technologies] also comes into play…that's very important…"* [Man, Expert, aged 62]).

As information source, mass media are described as *"too generic"* and the scarce attention for this topic emerges as well with also a perception of an imposition by the law (*"there is a lot of mistrust and they perceive it as an obligation, meaning that the law requires me to do it, but they do not raise awareness of the reason for which it is done (…), thus it is experienced (…) as an imposition"* [Woman, Expert, aged 37]).

Finally, relatives, friends, and acquaintances play a minor role, but word of mouth is suggested as the best practice *("word of mouth from acquaintance to acquaintance would be better (…), whoever used it, her/his proof is certainly the best driver for those who potentially could use it"* [Man, Expert, aged 68], also because *"it's not just advertising"* [Man, Expert, aged 53]).

Structural factors influencing the choice of heating systems

Among the structural factors that may play a role in the choice of a heating system, the economic issues take the undisputed first place. This aspect involves both the availability of incentives – especially subsidies that bring "*a fairly immediate benefit*" [Man, Expert, aged 53], and potential future savings and relatively short payback periods that may encourage the purchase. On the contrary "*the brake becomes the investment cost*" [Man, Expert, aged 62], "*the cost-effectiveness of*

installation, because budgets are never unlimited, and grants are also always a bit complex to use" [Man, Expert, aged 68]. Furthermore, people also cite the potential increase in property value and the evaluation of potential future costs to replace a specific system (e.g., "*boilers, right?... which have to be changed as they get older*" [Man, Expert, aged 53]).

Improvement of indoor air quality, personal comfort, and well-being are important factors. Obviously, subjective aspects are taken into account: for example, the presence of children or elderly people could require the necessity to satisfy specific needs related to the home environment ("*Then it depends if you live alone, if you have a family, if you are an elderly person [...] if there were children and elderly people it would certainly be different*" [Man, User, aged 50]). Also, the building characteristics could influence the technical feasibility of the intervention ("*… '50s houses have very thin floors... So when you have to load them with 10 cm, sometimes it's just not physically possible"* [Woman, User, aged 52]) or, yet, the size of the intervention that is undertaken, since "*one thing is to intervene on a whole building, another is to intervene on a small portion. If you have to renovate your flat, at the most you can get a heat pump, but you certainly do not get geothermal or photovoltaics because you do not have the space, because... they always concern the whole building*" [Man, Expert, aged 68].

External factors, such as bureaucratic constraints and potential restrictions imposed by the legislation, according to the building location (e.g., for photovoltaic panels in the historical city centre), do not seem less important.

Lastly, "*the trend of the moment*" [Man, User, aged 66] and the direct experience of other people have an influence, too, "*because, through word of mouth, one begins to realize that it is not just advertising... that they promise you savings... but one also wants to be sure that there is a result*" [Man, Expert, aged 53].

Attitudes toward the installation of different energy technologies

The following paragraphs give an overview of the participants' attitudes toward several technologies available on the market, and benefits and limits related to them.

About photovoltaics, they are mostly described as advantageous for savings in consumption and the return of energy, as well as environmental-friendly, enabling a lower use of fossil fuels (*"In the last 3 years we have not burn 150 quintals of diesel"* [Man, Expert, aged 55]). However, some doubts arise about the reliability of this technology, e.g. "*it is not so clear as a system, […] at environmental and global level*" since it is necessary to take into account the entire product life cycle, and specifically the costs related to its production and disposal: "*if you run an environmental study, you should do it on a complete cycle, which is never done because obviously they have to sell them a bit...*

You do not know that there is an enormous energy consumption to dispose of or produce these products... So, I do not know if I'm so favourable" [Woman, User, aged 52]. A common concern about the PV panels disposal is reported also by some experts, who state that although "*many people see it as a problem*", it is actually a "*resource*", as *"[PV panels] contain a lot of materials - precious minerals - that can be recycled and reused*" [Man, Expert, aged 19].

PV is seen as an "*extraordinary instrument*", which nevertheless "*makes sense if you put it in a shed of an electromechanical workshop...a lathe shop, where there are machines working all day long, and electricity is produced to make them work...in that sense it would be 100% exploited*", whereas "*in a house, if you take into account that we use electricity more in the evening than during the day…in the evening it doesn't produce electricity, so it is penalised*" [Man, Expert, aged 62]. That's why "*it is essential that it is connected to […] a system that can allow you to make the most of photovoltaic energy"* [Man, Expert, aged 55], i.e. a storage. In fact, if the only alternative consists in sending the excess of energy back to the grid, "*it's not worth the effort*", considering also the lower return obtainable by the utility company, that "*pays it to you…a pittance, but when it sells it to you it costs much more"* [Man, Expert, aged 62]. The impossibility to exploit it directly is perceived as a "*loss of control…because you do not know what you're going to get from the other side, what they're going to decide"* [Man, Expert, aged 53]: so, the consequent uncertainty, along with an instability at a bureaucratic-political level, "*creates mistrust, with good reason*" [Man, Expert, aged 55].

The fact that consumption in residential building is not as high as in offices or the tertiary sector makes more complicated to convince the client of its usefulness in case of second level or less important renovations, whereas it appears to be an almost automatic choice in new buildings or major renovations, due to the obligation to use a system with a renewable source, to power themselves.

Some landscape issues arise as well ("*At the private level, or at the centralisation level, it becomes complicated, in landscape terms, the effect on private roofs rather than on lawns, fields, that sort of thing*" [Man, Expert, aged 68]), but they could be partly solved thanks to vertical PV.

Other aspects to consider are the building exposure, that could make PV not feasible or useful ("*because if there are trees, […] it's shady…even if you can put it and it does not work, you can't do it"* [Woman, User, aged 52]) and, even more, the location, which plays an essential role for all types of PV panels: local regulations limit their use in historical city centres and participants would disapprove a potential use of vertical or coloured PV panels in those areas. Vice versa, they would be acceptable in modern districts. Some doubts about the performance emerge for both façade ("*It does not give the same output it could give on the rooftops*" [Man, User, aged 66]) and coloured PV panels, along with some aesthetic issues for the latter. Nevertheless, according to one participant - who would also be willing to install them "*if they were integrated in the building, that is, if there were a project*

that would allow me […] to improve the building aesthetically, as well as at the energy level..." - "*...if [coloured panels] work, it can actually be quite a challenge for designers to make appealing, to make pleasant something that now, seen like this, maybe it's not so pleasant to see"* [Woman, User, aged 27]. As regards solar thermal, participants mentioned such technology if connected with thermal storage, which they recognize the excellent performance in terms of both a non-stop and immediate hot water availability. "*Very comfortable, even in summer...there is always hot water"* [Woman, User, aged 27].

As concerns heat pumps, air-to-air heat pumps represent the most common technology among participants. Such heating system is mostly described as "*technologically, […] quite straightforward*" (Man, Expert, aged 68), easily accepted by people, handy and advantageous ("*As a layman, I think it is cheaper to heat with electricity than with gas*" [Man, User, aged 66]). They are fast in both heating and cooling, considered useful in the mid-seasons, during which "*you can dehumidify, and you can heat up a little, without turning on the boiler*" (Woman, User, aged 52), and even essential for summer conditioning: "*I couldn't do without it... In summer, absolutely...it's vital*" [Man, User, aged 66]). Nevertheless, heat pumps "*do not have the efficiency of a normal boiler*" [Man, User, aged 66] and also can cause annoying air and dust movement: "*Personally, I do not like the things that move air...I find them not healthy, [but] harmful...you breathe hell*" [Woman, User, aged 52].

As regards air-to-water heat pumps, since "*they work best when working at low temperatures*", they are described as excellent if combined with radiant diffusion systems. On the contrary, if working at higher temperatures, the outdoor air temperature can play a key role: indeed, if at average temperatures (i.e., at the beginning and the end of winter) the heat pump can easily operate with radiators, in case of lower temperatures a boiler associated to air-to-water heat pumps would be necessary to guarantee the performance. In fact, they could find problems with low temperatures: "*When it's very cold outside, the heat pump stops working […] the battery freezes, it takes longer to "de-ice", and to restore its operation*" [Man, Expert, aged 62]. However, they also argue that the most recent technological solutions would be able to work even under cold weather conditions.

Ground Source Heat Pumps (GSHP) are less known than the air-source ones by participants, who indeed are more familiar with the different concept of "geothermal power". As regards the horizontal probes, the main concern is related to the large space required ("*you need an integrated football field"* [Man, User, aged 66]), which, among other things, would make easier to install them in single-detached dwellings than in multifamily ones [Woman, User, 32]. Looking at the vertical heat pumps, the structural characteristics of the soil play a key role, given the need to dig very deep. However, the GSHP is seen as a technology with a very low visual impact ("*no external unit that could spoil the landscape*" [Woman, Expert, 37]) and that "*could become very interesting in the application*"

[Woman, User, 27], taking advantage of the fact that underground temperatures are more stable than air temperatures through the year. More generally, it is deemed that GSHPs installations are more easily evaluated *"when working on new constructions rather than in retrofitting existing buildings"* [Woman, Expert, aged 48]. Bureaucratic constraints – e.g., authorizations to be required – have to be taken into account, "*so it's not so easy to do it privately*" [Woman, User, 52], but the main barrier - in both private and public cases - seems to be its investment cost, which is deemed to be very high, especially in case of vertical boreholes.

Regarding smart control systems, they are associated with the *"automatism"*, and the possibility of a remote management through mobile phones *"because when you have set it up well, you do not even have to worry (...), you can schedule with a smartphone, whenever you want (...), it's convenience"* [Man, User, aged 66], as well as "*the fact of being able to do everything from the mobile phone – complete control – start to simplify a lot (...), remote control tempts the user towards home automation, to use systems"* [Man, Expert, aged 68]. Nevertheless, smart control is seen as an expensive system, which requires that all connections work well because *"technology helps a lot but [in case of] electrical failure, dead battery, cell out of power, [it failed]"* [Man, User, aged 66]. Furthermore, smart control systems could face a possible refusal by some people, especially elders, with consequent difficulties in using a complex system: *"there is a refractory mentality, particularly people of a certain age"* (Man, User, aged 66); *"there is a preventive refusal, that is, they start defeated"* (Man, User, aged 50); *"in my opinion, we really lack technological culture (...) you have to be a computer or a technological maniac to get to say "home automation"...in my opinion most people may not even know what it is, so"* [Woman, Expert, aged 48]; *"people struggle to use a complex system...if the access was easier and more immediate, their dissemination would probably be easier"* [Man, Expert, aged 68].

Other aspects to be taken into account are the lack of both unified protocols and potential privacy problems that could be connected to such technology (*"in my opinion there is also a privacy problem...that is, Alexa and Google and anything else do not have voice recognition inside the station, but online, so everything I say is sent on...remotely, processed by Google server, which can obviously also memorize everything I say...and having to be always operative (...) it means that they could potentially record all my conversations, because when I say a command, it must respond...it's also a system that learns my habits, it is recording what I do and what my behaviours are, and if it is remotely connected…"* [Woman, Expert, aged 43], *"Yes, this is quite fearsome"* [Man, Expert, aged 55].

Attitudes toward the IDEAS System

The IDEAS system earns the approval of all participants, who appears particularly interested in its characteristics of independence and convenience. It is described as a modular and *"perfect system"* [Man, User, aged 66], which does not require further integration, because of an innovative switch among systems. In fact, its peculiarity is "*that you can manage [it] in a simple way - that solves a number of problems, with an energy efficiency that, in any case, you are able to manage"* [Woman, Expert, aged 48], even though it is seen as more suitable for single-detached dwellings than for multi-family residential dwellings. *"The interesting matter is that (…) it is a system…that is, it uses systems that are already all known and integrated"* [Woman, Expert, aged 48] and its automatism - that allows energy accumulation rather than energy exploitation - is really appreciated, enhancing the motivations in installing it (*"it would be my dream"* [Man, User, aged 66]). In fact, in order to persuade people to install the IDEAS system, the focus should be put on the benefits it offers, so that it would be not perceived as an imposition.

Key aspects to be taken into account are the possibility to solve many landscape problems, thanks to the aesthetical appreciation of vertical PVs under certain conditions (e.g., the placement in modern buildings or neighbourhoods), the defrosting of the coil, the accumulation of heat in the ground, and the autonomous management of the system ("*It seems an excellent system […] especially that [the systems have a] complete autonomy compared to other systems, it does not need to be integrated […] They are not an accessory of a more complete system but they are perfectly autonomous from an energy point of view [...] This seems the most important and interesting thing ...it solves many landscape problems...not all, but well [...] In general, as a conception, it is very effective"* [Man, Expert, aged 68]), able to memorize habits with the prospect to choose the moment in which to use a certain type of energy rather than another ("*if the system is also able to predict to accumulate energy rather than exploit it and, then, to check the forecast […] if there is the sun or not […], if the system does it automatically it is certainly an advantage"* [Man, Expert, aged 55]). In fact, smart control system is considered as an essential technology, able to simplify both the user's experience and the technician's work *("I think it is a simplification both for the user who [...] must not be too worried about what happens, if he has to go to the plant to turn some valves...anyway, now there is...and also for the maintenance technician, who perhaps […] if there is something...can understand if a system is not working well from his own home"* [Woman, Expert, aged 37]). However, this kind of system elicits worries for its supposed costs and for its supposed need to be adapted to each building.

Despite the numerous advantages, a common concern about the IDEAS system is the initial investment that, *"even though is a little higher than traditional systems…but the idea of having a finished system, that you manage in a simple way, becomes interesting*" [Woman, Expert, aged 48]:

739 *"the interest could be […] to understand what is the best option among the various technologies and*
740 *their integration... and, above all […], what is the economic impact"* [Man, User, aged 28].
741 Finally, as regards future information related to the IDEAS system, participants seemed to be
742 interested in understanding how the system works in different climatic zones and types of housing.
743

5. Discussion and conclusions

This research aimed at exploring, through the analysis of two qualitative studies, the array of factors that may drive or deter people in adopting an innovative energy system, such as the one proposed in the EU funded IDEAS project, in residential buildings.

Both the studies took place in Ireland and Italy, i.e. two countries that are characterized by different climatic conditions and, consequently, by different energy requirements for heating and cooling residential buildings. Table 2 summarizes the main findings from the two studies regarding drivers and barriers in people's acceptance of the new energy technologies.

As concerns awareness, in line with the DOI theory [29] and, more in general, with studies on acceptance and adoption of new technologies (e.g., [33]), knowledge confirmed to play a key role, thus suggesting the importance of making people aware through the promotion of an "energy culture". Many stakeholders emphasised the demand-pull factor of technology change: homeowners may be interested in improving the energy efficiency of their home, but if they do not know how to achieve certain results, they will not; while if people are aware, they may ask for specific energy-efficient technologies. In this regard, the information sources emerged in both studies as an important factor for driving homeowners' choices related to energy efficiency, thus confirming the influence of reliable information sources as postulated by the Heuristic Systematic Model [49] in the persuasion process. The in-depth interviews highlighted the lack of independent sources on which people could rely on, and such point emerged also among the technicians, who reported how the information provided by vendors can create mistrust and scepticism, especially in older people. As suggested by Park and colleagues [50], the worldwide decline of trust in information is the result of an intensification in social media use for accessing news. Even though web and mass media appear to be the first sources of access, previous literature has shown large evidence on how expertise [51, 52, 53] and significant others (for the individual) (e.g., [54, 47, 26) have the greatest influence on people's attitudes, intentions and future actions. In line with this empirical evidence, the findings of this study point out how citizens recognize the most influential source in experts such as technicians, managers, engineers, and architects, especially when dealing with an innovative system such as the integrated renewable energy/heat pump system proposed in the IDEAS project. This result conforms with the DOI theory, which also predicts that the role of significant others, such as relatives, friends, and neighbours, as a source of social influence (e.g., [55]) becomes more important when talking of more standard and widespread technological options.

As postulated by the TPB, the intention to adopt a given behaviour stems from "the motivational factors that influence a behavior; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behavior" [25, p.181].

Nevertheless, behaviours are also influenced by those “non-motivational factors as availability of requisite opportunities and resources (e.g., time, money, skills, cooperation of others)” which “represent people’s actual control over the behavior” [25, p.182]. In this regard, an integrated renewable energy/heat pump system is still perceived to be very expensive and difficult to access in economic terms, especially for the initial investment that seems to cut off many citizens, even though the gap has been reduced over the years [56]. Availability of subsidies, and potential future savings are seen by our stakeholders as factors motivating the decision to innovate. On the other hand, a higher perception of personal benefits, first in terms of savings on energy bills, but also in terms of other personal advantages, can be a trigger for the choice. In fact, the role of environmental aspects such as comfort, indoor air quality (e.g., [57, 58]), and personal well-being [59] was found as emphasised in the respondents’ narratives. In contrast, environmental impact implications are considered less important for the decision to invest than personal benefits, notwithstanding the increasing concern about sustainability issues in the general population [60]. As regards technical issues, the independence and convenience of the systems are advantageous. Nonetheless, they are often complex and expensive, requiring seamless connectivity, and there are concerns about the absence of unified protocols and potential privacy issues. Important contextual factors that reduce the capability to innovate and install renewable energy technologies are lengthy administrative processes and bureaucratic constraints, which emerged as possible barriers to installation in Italy (e.g., restrictions in historical city centres), while not in Ireland.

To summarize, these findings show a general interest toward these innovative energy technologies, with a substantial agreement between technicians and citizens on the need to increase people's awareness, still considered poorly informed. As a first step, a higher awareness can be grounded on providing homeowners with a greater in-depth search for information on innovative technologies, from both technical and economic points of views. The focus group discussion underlined how in the first phase of information collection people use the web as a first source, autonomously, but afterwards they need further insights, confirmations, and clarifications from experts [19]. In fact, the web is chosen for its accessibility features, but it is often described as contradictory, generic and superficial, increasing the general mistrust in the source. In this regard, the literature highlights the "one-stop shops" (OSSs) model as a valuable tool to support homeowners in the renovation process, so accelerating decarbonization efforts in the European buildings stock. The findings indicate that OSSs, which offer centralized services to simplify complex decisions involving multiple stakeholders through a single, customer-centric entry point, can be crucial in overcoming the numerous barriers that prevent homeowners from renovating. This service may be especially relevant in social contexts

where technical knowledge networks are scant, e.g. in rural areas (as emphasised by Irish stakeholders) and in less advantaged households.

As for practical implications, a wider use of these technologies would make it possible to contribute to the achievement of the CO_2 reduction objectives set by the European Union. It would represent a significant milestone for industry and a notable result for research that would have contributed to identify the individual factors involved in the motivation to innovate.

In sum, to comply with this, results suggest that policy makers should pay attention to economic concerns and bureaucratic fulfillment that appear among the main barriers for the activation of better sustainable choices. At the same time, both the citizens and countries would benefit from reduced costs for heating/cooling with clear economic and environmental advantages.

Furthermore, outcomes may have practical applications on the decision to design new strategies and activities based on the promotion of a new energy culture capable of reinforcing both the knowledge and awareness of new technologies.

About limitations of this research, the use of qualitative techniques such as in-depth interviews and focus groups does not allow, by definition, neither to demonstrate the existence of causal connections nor to verify the goodness of multivariate correlational models. Furthermore, this study involved privileged actors who were not representative of the general population, even though the focus group with citizens was balanced in terms of key socio-demographic characteristics. Nevertheless, even though it is not possible to generalise these results to other contexts and situations, the content analysis of the textual material emerged by individual and group situations showed the richness and complexity of narratives used by people for motivating their attitudes, opinions and beliefs concerning the object of analysis. Thus, this kind of qualitative data could be useful for inspiring quantitative studies as well as to explore in more detailed way possible perceived drivers and barriers in making sustainable energy choices, as in Strazzera and colleagues. [5].

In conclusion, findings from this qualitative investigation offer a general insight for understanding how to promote the adoption of renewable and sustainable energy technologies at the residential scale, suggesting means to improve communication and awareness. Outcomes bring to light the importance of considering socially contextualized explanations of factors limiting the adoption of sustainable energy technologies, in order to have a complete framework finalised to the pro-environmental action. This potential can be fully realized with a supportive policy framework, the availability of affordable financing solutions, and the sharing of experiences within and between countries [9].

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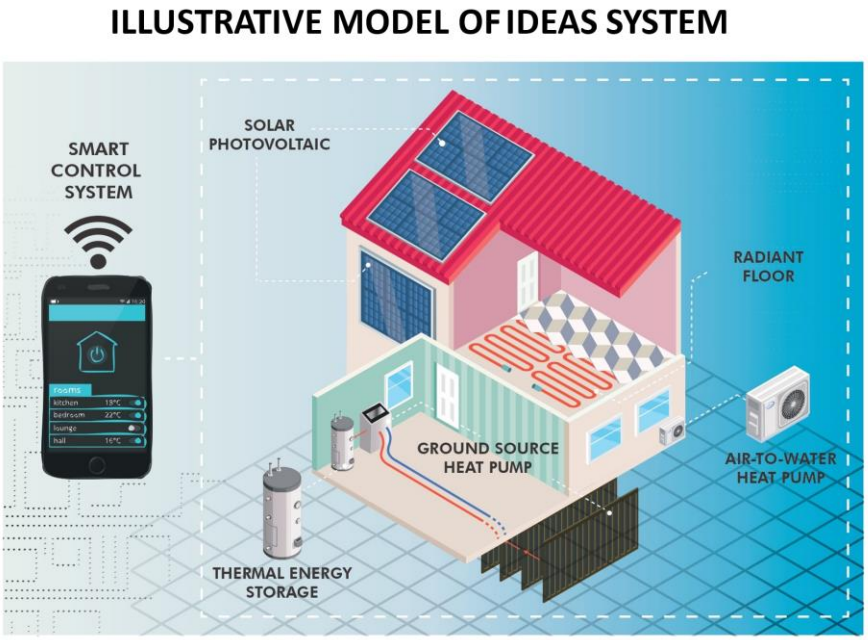

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Figure 1. Simplified illustration of the IDEAS system.

Table 1. Socio-demographics of the focus groups participants.

	Homeowners	Experts
Gender	62,5 % males; 37,5% females	62,5 % males; 37,5% females
Age	age range = 27-66, M = 41	age range = 19-68; M = 48,2
Role	Architects, retired, employees	Consultants, technicians, managers
Types of houses	50% flat; 50% detached house	---

Table 2. Overview of the main drivers and barriers emerged in the two studies.

Drivers	**Barriers**
• Trust in information sources • Knowledge of technology options through the promotion of an "energy culture" • Availability of subsidies and potential future savings • Characteristics of independence and convenience • Comfort, indoor air quality, and personal well-being, with great attention to the environmental impact of people's choices • Household conditions • Building exposure • Life events • Policy measures	• Lack of independent sources on which people could rely on • Reliability of the new technology • Investment cost • Expensive and/or complex system, which requires that all connections work well • Lack of both unified protocols and potential privacy problems • Environmental impact implications not so important for the decision to invest • Bureaucratic constraints • Restrictions in the historical city downtown

Declaration of interests

☐The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Elisabetta Strazzera reports financial support was provided by European Union. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDIX

In-depth interviews

1. How is the real estate market currently doing in (Country/Region/Town)?
2. Which are the main issues, if any, in the real estate market in (Country/Region/Town)? Is there any policy change that can modify in an effective way the real estate market current equilibrium in (Country/Region/Town)?
3. Which are the most relevant characteristics of the dwelling that people seek when buying/renovating a home?
4. How important is the energy certification? In general, do you think that potential buyers are informed about it?
5. In your opinion, is the energy efficiency class of buildings reflected in the market price?
6. Are potential customers interested in specific heating/cooling systems?
7. Are potential customers interested in specific thermal insulation technologies?
8. Do you know if there is a market demand for (dwellings endowed with) geothermal/air to water heat pumps heating/cooling systems?
9. Do you know if there is a market demand for (dwellings endowed with) smart control systems for heating/cooling management?
10. Is there an interest in electric vehicles charging facilities integrated in buildings?
11. In your opinion, current Irish (local) policies (such as...) are effective to improve energy efficiency in buildings in (local area)?
12. Are these policies sufficiently known by citizens?
13. In your opinion, the (local) building companies operating in pay sufficient attention to energy efficiency issues? Are they technically adequate to implement innovative technologies (such as geothermal, hydronic heat pumps etc.)
14. In your opinion, the credit institutions operating in (local area) pay sufficient attention to energy efficiency issues? Do they take into account energy efficiency issues when evaluating projects to be funded?
15. In your opinion, the real estate agencies operating in (local area) pay sufficient attention to energy efficiency issues? Do they have any interest in soliciting customers' attention to the energy requirements of the dwelling?

Focus group (citizens)

1. Do you consider yourself sufficiently informed about domestic energy efficiency? What sources of information have you used, or do you use?
2. What heating system do you currently have in your home?
3. What are the most important factors when choosing a heating system?
4. Have you recently made, or do you plan to make changes to your home?
5. (For those who have recently made or plan to make energy efficiency changes) Why did you do it? Could you briefly list the benefits and limitations of the changes made?
6. (For those who have not recently made or do not plan to make energy efficiency changes) Why haven't you done it? What would lead you to make a change?
7. Regarding photovoltaic panels, what benefits and what limitations or concerns do you think of?
8. What do you think about photovoltaic panels on facades?
9. What do you think about coloured photovoltaic panels?
10. Would you be interested in installing these panels? And what type? (on the roof or on the facade, standard or coloured)
11. Regarding heat pumps in general, what benefits and what limitations or concerns do you think of?
12. Regarding the different heat pump systems (air-to-air, air-to-water, geothermal), which would you prefer and why?
13. Regarding radiant heating systems in general, what benefits and what limitations or concerns do you think of?
14. Regarding the different radiant heating systems (floor, wall, ceiling), which would you prefer and why?
15. Regarding thermal storage systems, what benefits and what limitations or concerns do you think of?
16. Regarding intelligent control systems, what benefits and what limitations or concerns do you think of?
17. What characteristics and functions should energy systems have?
18. How important is it for you to understand in detail how these technologies work?
19. What information would you like to have to evaluate the decision to use these technologies?
20. What do you think about the IDEAS system?
21. What are your main concerns or doubts about it?
22. Which specific elements of the IDEAS system (photovoltaic, heat pumps, radiant heating, intelligent control) convince you the most and which the least? And why?
23. What could convince you to install the technologies developed by the IDEAS system?
24. Do you plan to delve into the topics covered in this meeting in the near future?
25. Do you think you will talk to friends, family, colleagues, and acquaintances about these topics?
26. Do you think that after this meeting something has changed regarding what you think about domestic energy efficiency?

Focus group (experts)

1. Do you think people are sufficiently informed about domestic energy efficiency?
2. What are the main factors influencing your clients' choice of heating system?
3. What aspects could be more effective in changing your clients' choice of heating system?
4. Regarding photovoltaic panels, what motivations and what limitations or concerns do your clients express?
5. On a technical level, what benefits and limitations do you identify?
6. Regarding heat pumps, what motivations and what limitations or concerns do your clients express?
7. On a technical level, what benefits and limitations do you identify?
8. Regarding radiant heating systems, what motivations and what limitations or concerns do your clients express?
9. On a technical level, what benefits and limitations do you identify?
10. Regarding thermal storage systems, what motivations and what limitations or concerns do your clients express?
11. On a technical level, what benefits and limitations do you identify?
12. Regarding intelligent control systems, what motivations and what limitations or concerns do your clients express?
13. On a technical level, what benefits and limitations do you identify?
14. What additional information should be provided to encourage people to use these technologies?
15. What is your opinion on the IDEAS system?
16. What are your main concerns or doubts about it?
17. Which specific elements of the IDEAS system (photovoltaic, heat pumps, radiant heating, smart control) convince you the most and which the least? And why?
18. What could convince people to install the technologies developed by the IDEAS system?
19. Is there any aspect related to these technologies that we have not discussed and that you consider relevant?