

Mukherjee, Sanghamitra Chattopadhyay et al.

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## Renewable energy technology uptake: Public preferences and policy design in early adoption

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Public Preferences and Policy Design in Early Adoption**

Sanghamitra Chattopadhyay Mukherjee, Tensay Hadush Meles and  
Lisa Ryan, University College Dublin  
Séin Healy and Robert Mooney, Amárach Research Dublin  
Lindsay Sharpe and Paul Hayes, ESB Networks Ireland

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**UCD SCHOOL OF ECONOMICS  
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BELFIELD DUBLIN 4**

# Renewable Energy Technology Uptake: Public Preferences and Policy Design in Early Adoption

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Sanghamitra Chattopadhyay Mukherjee<sup>a, b, 1\*</sup>, Séin Healy<sup>c</sup>, Tensay Hadush Meles<sup>a, b, d</sup>, Lisa Ryan<sup>a, b</sup>, Robert Mooney<sup>c</sup>, Lindsay Sharpe<sup>e</sup> and Paul Hayes<sup>e</sup>

<sup>a</sup> UCD School of Economics, Newman building, University College Dublin, Dublin 4, Ireland.

<sup>b</sup> UCD Energy Institute, O'Brien Centre for Science, University College Dublin, Dublin 4, Ireland.

<sup>c</sup> Amárach Research, 11 Kingswood Business Centre, Kingswood Road, Citywest Business Campus, Dublin 24, Ireland.

<sup>d</sup> Department of Economics, Mekelle University, Mekelle, Tigray, Ethiopia.

<sup>e</sup> ESB Networks, 5 Leopardstown Road, Sandyford, Dublin 18, Ireland.

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## Abstract

This paper aims to understand what motivates the adoption of key renewable energy technologies (RET) in early adopter markets. Electrification of heat and transport, through the deployment of heat pumps, electric vehicles and solar photovoltaic panels, combined with renewable sources of electricity is a key strategy for policymakers to combat climate change. Notwithstanding their social benefits, uptake remains low. Thus, targeted policy measures are needed to address this. We conduct a survey of a nationally representative sample of Irish households to better understand the motivations behind RET adoption and find fundamental differences between adopters and non-adopters. Current adopters tend to be younger, highly educated, of higher socio-economic status, and are likely to live in newer buildings of generous size. While non-adopters self-report as being more sustainable, adopters appear to be stronger believers that their own decisions impact climate change. Thus, environmental attitudes are an insufficient predictor of uptake. Instead, poor understanding of new technologies often inhibits uptake. Word-of-mouth recommendation matters greatly in communicating the use and benefits of new technology as evident from the significantly larger social networks that adopters enjoy. With this information, a range of monetary and non-monetary policy incentives can be designed according to public preferences.

*Keywords:* Household survey; technology adoption policy; heat pumps; solar PV; electric vehicles; consumer behaviour.

*JEL Classification:* D1, D9, O3, Q4

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<sup>1</sup> \* *Corresponding author:* Email: [sanghamitra.chattopadhyay@ucdconnect.ie](mailto:sanghamitra.chattopadhyay@ucdconnect.ie), Phone: +353-1-716-2625, Postal Address: UCD School of Economics, Newman Building, University College Dublin, Dublin 4, Ireland.

# 1. Introduction

Tackling climate change is now more urgent than ever. As a result, energy policy today is geared towards more sustainable means of producing and consuming energy services. Electrification of heat and transport forms a central part of many countries' strategies to reduce greenhouse gas emissions. Significant growth in innovations in electricity with a shift to renewable sources in many countries means that electricity-based heat and transport generates significantly lower carbon emissions (IEA, 2019a). There is increasing realisation that individual consumers and businesses play a crucial role in driving technological change through their decisions to invest in and adopt electric technologies. However, better understanding is needed of the human factor in terms of how technology will be adopted in reality and the policies required to incentivise sustainable investment decisions (IEA, 2019b). More evidence and analysis are required specifically on the attitudes of consumers towards RET to consider their likely uptake in the transition towards a low-carbon economy and to design government interventions that embody consumer preferences.

Electric Vehicles (EVs)<sup>2</sup>, heat pumps, and solar photovoltaic (PV) panels are currently the three fastest growing RET in Europe. A range of attributes contribute to the uptake of EVs (Mukherjee and Ryan, 2020; SmartGrid consumer collaborative, 2016), solar PVs (Dharshing, 2017; Islam and Meade, 2013; Nath et al., 2016; Rai and McAndrews, 2012; Robinson and Rai, 2015; Schelly, 2014; Sigrin et al., 2015; SmartGrid consumer collaborative, 2016; Zhai and Williams, 2012) and heat pumps (Burley and Pan, 2010; Hannon, 2015; Michelsen and Madlener, 2012; Owen et al., 2013; Singh et al., 2010; Snape et al., 2015). We classify these into four main categories based on a comprehensive literature survey: (1) economic factors, (2) spatial and technical elements, (3) socio-demographic features, and (4) psychographic and behavioural traits. See Figure 1 for details of the main variables, triggers and personal characteristics that underpin the adoption of EVs, solar PVs and heat pumps.

While there are numerous international studies on the adoption of EVs, solar PVs, heat pumps and other technologies individually, to our knowledge a comprehensive study of all key RET in the current political scenario does not exist. In markets at an early stage of development for these technologies, a lack of understanding of the consumer perspective precludes knowledge

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<sup>2</sup> RET: Renewable energy technology; IEA: International Energy Agency; EV: Electric vehicle; PV: Photovoltaic; DCE: Discrete Choice Experiment; SEAI: Sustainable Energy Authority of Ireland; BER: Building energy rating; ESB: Electricity Supply Board; CRU: Commission for Regulation of Utilities

of the level and timing of likely adoption at scale and hence the design of targeted policies to accelerate uptake. This paper aims to contribute to filling this gap in our understanding of the attitudes, individual willingness to try new technologies, and motivations behind the purchase and general use of RET in the face of rising environmental awareness and need for change.

The approach used in this paper to collect evidence of consumer attitudes to RETs comprises the collection of primary data from three focus groups, an in-depth interview process, and a large-scale survey of a nationally representative sample of the Irish adult population. Ireland, a country with very low uptake of all three technologies to date, serves as a case study for countries in the early stage of market development for RET. The qualitative part of the study provides background information on public perception of EVs, solar PV panels and heat pumps in Ireland which allow us to develop a relevant and salient questionnaire for the survey data collection. The household survey explores detailed behavioural, socio-economic and household characteristics of adopters and non-adopters. It also measures a range of demographic and psychographic features as well as self-reported measures of the likelihood that the participants would purchase these technologies in the future. We ask survey participants directly about their preferences for policy instruments to encourage uptake of each of the RETs. It is unique due to the inclusion of three distinct household energy technologies allowing us to compare attitudes to technologies with different functions, costs and appearances and the most effective related policies. The results from this study will help us understand the perceived and real trade-offs associated with investing in RET and hence support the advancement of targeted strategies and policies that promote private investment in these goods. While the data is for Ireland, we anticipate that the results from this study could be applied to other early adopter countries that need such insights to design the appropriate policy mix for RET adoption.

The paper is structured as follows. Section 2 presents our data and methods. Section 3 provides detailed results from the qualitative and quantitative studies. Section 4 concludes with a summary and some policy recommendations.



Figure 1: Common determinants of uptake for EVs, solar PVs and heat pumps

Source: Authors' classification. [Adapted from [Mukherjee & Ryan, 2020](#)]

## 2. Data and methods

This research adopts a mixed-mode approach, utilising both qualitative and quantitative methods. The qualitative element allowed for the initial exploration of the research themes emerging from the literature. These findings informed the questionnaire design for the nationally representative survey. Both these elements are described in subsections 2.1 and 2.2.

## 2.1 Focus groups and interviews

The initial phase of the research involved three exploratory focus groups and four in-depth interviews conducted in March 2018 in partnership with Amárach Research.<sup>3</sup> Each focus group lasted 90 minutes and consisted of eight to ten respondents, who were given an incentive of €50 for their time. The groups were led by trained moderators following a detailed discussion guide (Casey, Mary Anne, Krueger, 2015). The three groups consisted of EV owners, those who had installed solar PVs on their property, and non-adopters of RET, separately. EV owners were sourced from the Irish EV Owners Association Facebook group. Solar PV owners were contacted through Solar Electric's customer database. Since we are interested in exploring the decision-making process involved in technology adoption, those who had bought a property with the technology already installed were excluded. Non-adopters were sourced from a market research panel wherein a market research recruiter selected participants only on the basis of non-adoption of any RET. The groups were not designed to be nationally representative in terms of gender, age, region or social class.

We also explore the experience of heat pump owners – both air source and geothermal. Given the low incidence of heat pump installation generally, instead of focus groups, we conducted four in-depth interviews with those who had installed heat pumps at their property. Participants were selected from Tipperary Energy's database of heat pump owners. Interviews were conducted via telephone calls that lasted between 30 and 45 minutes. See Table 1 for an overview of our qualitative study. All narratives were analysed using descriptive and thematic analyses.

<b>Group</b>	<b>Study type</b>	<b>Group size</b>	<b>Location</b>	<b>Age</b>	<b>Socio-economic status</b>	<b>Profile</b>
<b>Electric vehicle owners</b>	Focus group	10	Dublin	Mixed	High	Electric vehicle owners
<b>Solar PV owners</b>	Focus group	10	Dublin	Mixed	Mixed	Have had solar PV installed
<b>Heat pump owners</b>	In-depth interview	4	Tipperary, Westmeath	Mixed	Mixed	Heat pump owners
<b>RET non-adopters</b>	Focus group	8	Dublin	Mixed	Mixed	Non-adopters of RET

<sup>3</sup> Amárach Research is a market research company based in Ireland that has extensive experience with surveys and focus groups. [www.amarach.com](http://www.amarach.com)

Table 1: Overview of focus groups and interviews

## 2.2 Household survey

The second phase of the research involved granular preference data collection based on the best practice guidelines for primary data collection - the total survey error framework (Bryman, 2012). This was achieved through a nationally representative online survey of the Irish adult population. The survey collected detailed socio-demographic and household data, risk and time preferences, and attitudes, for instance, towards new technology and the environment. A discrete choice experiment (DCE) was also performed for each technology to identify key decision-making criteria in the uptake of EVs, solar PVs and heat pumps (Meles et al., 2019). The DCE is not the subject of this paper and will be the subject of future analysis.

A random sample of three groups of roughly 400 was drawn from one of Amárach Research's market research panels, resulting in a final sample of 1,208 individuals.<sup>4</sup> 203 respondents were RET adopters while 1,005 were non-adopters of RET. A nationally representative sample was ensured via stratification on age, gender, region and social class. Quotas were based on the Central Statistics Office Census 2016 figures. Table 2 provides the demographic profile of respondents compared with national statistics. They are well aligned, ensuring that our findings are generalisable to the national population. The data was analysed using group-level pairwise comparisons as well as regression analysis designed for binary dependent variables [21, 22]. For the regression analysis, multiple five-point Likert scales were converted into single-value indices using factor analysis in statistical software STATA (Stata, 2013).

Sample attributes	% in survey	% in Ireland
Age		
18-24	11	11
25-34	18	18
35-44	21	21
45-54	17	17
55+	32	32
Gender		
Male	49	49
Female	51	51

<sup>4</sup> A sample of 1,200 is statistically robust with a +/- 2.83% margin of error at a 95% confidence interval. Thus, there is a 95% chance that two identical surveys undertaken at the same time and with similar people will vary upwards or downwards by 2.83 points. A sample size of approximately 400 is statistically significant for 1.2 million households and this is why we selected the individual RET groups to be that number.



Socio-economic status		
ABC1F50+	47	46
C2DEF50-	53	54
Region		
Dublin	29	28
Leinster	26	27
Munster	27	27
Connaught/Ulster	18	18

Table 2: Demographic profile: % of Irish adult population

### 3. Results

#### 3.1 Focus groups and interviews

In line with the literature in Section 1, we identified similar themes within our qualitative data. Broadly, four classes of characteristics influenced RET purchase decisions: economic, spatio-technical, socio-demographic and psychographic. We summarise their role in the decision process for heat pump, EV and solar PV purchase, for adopter and non-adopter groups separately.

##### 3.1.1 Adopter groups

###### **a. Heat pump**

The initial purchase decision was driven mainly by renovations borne out of a low level of satisfaction with the existing heating system. The installation was carried out as part of a range of other home improvements undertaken to improve home comfort and energy efficiency. Prior awareness of heat pumps was low and specifications of the technology were almost always decided by contractors with no input from owners. Prior to the home renovations, heating needs were perceived as higher than average due to houses being older with poor insulation.

Overall, the cost of the heat pump was considered good value for money when the €3,500 Sustainable Energy Authority of Ireland (SEAI) grant was accounted for. Cost savings were not a key trigger for installing a heat pump, so neither was the long payback period a concern nor did participants research running costs of heat pump technology vs their old heating system prior to installation. Electricity bills increased for all post-installation, but this was offset by reductions in oil and/or gas costs. High initial outlay and increased electricity bill were considered to be an acceptable trade-off for having a new efficient heating system and comfortable home.

Although personal experiences were positive, some uncertainty remained around use. Real-time feedback and the opportunity to compare heat pump operations and control settings with other users would help consumers understand if they were using the technology most efficiently and effectively. Although respondents considered themselves to be environmentally-minded, sustainability did not emerge as a crucial factor in the decision to install heat pump. All participants believed that there should be more information available on heat pumps and stronger guidance from a national level. Some believed that all new builds should have heat pumps and solar PV panels, and not use any fossil fuels at all. Recent Irish building regulations have indeed moved in this direction by mandating renewables in all new builds through the installation of either a heat pump instead of a boiler or a combination of gas/oil boiler with solar PV panels.<sup>5</sup>

#### b. Solar PV

Solar PVs were mainly installed as part of home renovations such as improved insulation, new boilers and new windows. All were older houses and if the house was newer and did not need improvements, the owner was most unlikely to purchase solar PV panels. Like heat pumps, there was minimal knowledge of the technical aspects of solar PVs prior to installation and specifications were largely dictated by the contractor. There was a desire to increase the building energy rating (BER) for some to make their house more valuable through the impact on the loan to value ratio for mortgage and increased market price if selling. Energy usage was dependent on life stage, working schedule and family composition. Most believed they had low or average energy use as they were employed full time. Those with children at home believed their energy usage was higher than average.

The upfront cost was not given as a barrier to uptake as it was somewhat lost in larger renovation work. None had availed of a public grant to fund the installation due to a lack of awareness of grants available. Cost savings through reduced electricity bills was considered a key benefit and there was a prior impression that solar PVs would instantly save money. However, most participants had not realised that in reality savings and payback are much longer term, as calculating the payback period was difficult. Most were also unaware that solar PVs would require maintenance and this was not factored into their perceptions of the costs versus savings trade off.

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<sup>5</sup> Recent ESB blog post [here](#).

Similar to heat pumps, there was general consensus that real-time feedback on usage and savings would assist consumers in understanding the functioning of PVs better. Most respondents claimed to be energy-conscious; however, the move towards energy sustainability would have to make sense in terms of cost and feasibility first. Peer effects such as word-of-mouth recommendation or seeing PVs in the neighbourhood were a bigger influence in the purchase decision. Participants believed a national advertisement campaign was needed to help increase awareness of the technology. Linking installation to tangible property benefits such as improved BER, reduced property tax and increased sell-on home value was likely to make them more appealing. Incentivising potential consumers through more salient messages compared to sustainability would be key to encouraging uptake. Participants in the heat pump group were also asked what policy measures could help solar PV uptake in their view. They suggested that increased grants and incentives for giving electricity back to the grid could prove to be beneficial for encouraging uptake.

#### c. EV

The initial purchase decision was driven mainly by lifetime cost savings, with detailed savings analysis done by most. Not only was EV ownership considered rational in terms of cost savings, there was also an emotional element to it. Unlike heat pump and solar PV adopters, EV owners were passionate about EVs and highly engaged with all aspects surrounding them, including technical characteristics and past, current and potential future policies. All had availed of the €5,000 SEAI grant and had home charge points installed through either the free home charger scheme (previous) or the home charger grant scheme (current). Only those living with no garage or driveway had had difficulties in obtaining the required permission from councils and management companies to install a home charger. All had a great sense of pride in owning an EV, with those owning higher-end EVs energised by the high performance and acceleration of their cars compared to petrol or diesel cars. Most participants were long-term EV owners and primarily long-distance drivers who drove more than the average motorist. Driving habits had neither changed nor influenced purchase decisions for the majority.

Participants were not concerned about any increase in electricity bills due to home charging. None had any concerns about paying for charging at public facilities either and considered this necessary. Initial concerns about battery life, driving range and availability of public charge points were overcome by extensive online research and advance planning for longer journeys. All had built up a good knowledge of the location of charging infrastructure along most-

frequented routes. Although there were some negative personal experiences, they were not compelling enough to deter uptake. For example, there were numerous instances of broken charge points throughout the country with most being out-of-service indefinitely. Most respondents logged faulty charging points with the Electricity Supply Board (ESB) or through online EV forums, yet the general perception was that maintenance was slow and overall, the charging network was behind other countries in terms of technology, geographical spread, numbers and density. There was general consensus that increasing the scale and reliability of public chargers would be key to encouraging uptake.

Most viewed themselves as environmentally-minded; however, minimal ownership of other RET suggests that sustainability may have been less of a driving force than claimed. Furthermore, social groups and family members had had little influence on initial purchase decisions as respondents were all early adopters of EVs. Most considered an increased grant to be an effective measure to help drive uptake even though the upfront cost for EVs was not as much of a barrier for EV owners when compared to solar PV or heat pump technology. Personal recommendation will evidently play an important role in enhancing future uptake as current adopters are all extremely vocal about communicating the benefits of EVs to others.

### 3.1.2 Non-adopter group

There was spontaneous awareness of EVs and solar PVs but not of heat pumps. The initial upfront cost for any RET was given as the primary barrier to uptake. While the nominal cost was considered too high for some, others felt that savings were too long term and not worthwhile considering their family size (two-person family) and/or their lifestyle (working 9-5 during the week). In general, high energy users were typically more interested in RET uptake.

The ‘hassle’ factor was a potential barrier to the uptake of solar PVs, with a fear that installation would require additional building changes. Those in terraced houses in particular did not believe that their houses were compatible with solar PV technology. For EVs, driving range, charging time and charge points were barriers. All respondents considered them suitable for city driving only. Barriers to uptake were further enhanced by the perceived complexity of the information relating to installers and grants. Most would use an internet search if looking for information but preferred it to be accessible on the one website as the time commitment of researching all options would be an added burden. Overall, cost was more important than

sustainability when choosing a technology or an energy provider. There was a general belief that a move towards RET was a macro issue and, therefore, should be government-led.

### 3.2 Household survey

The following sections report the findings from the household survey. Section 3.2.1 presents summary statistics for our survey sample followed by insights from pairwise comparisons between adopters and non-adopters of RET and a regression-based analysis of overall RET uptake in Section 3.2.2.

#### 3.2.1 Respondent characteristics

Table 3 provides a summary of the respondent characteristics for our sample of 1208 Irish households. Just under half (46.6%) of the respondents are male. 27% of them are between 18 and 34 years old, 38% are between 35 and 54 years and the remaining are 55 years and above. With respect to the highest education obtained, 42% of the respondents are secondary or primary school educated, 41% have a third level degree and 17% obtained a master's degree or above. As for marital status, a majority (64%) of the respondents are either married or living together with a partner, about 25% are single and 11% are either divorced, widowed or separated. Of those who report the range of their household's average annual income, about 19% reported it as €29,999 or below, 29% as between €30,000 and €59,999 and the remaining as above €60,000. In terms of socio-economic class, about half (49.5%) belongs to the high category (that is, ABC1F50+). When we look at the geographical distributions, 31% of the survey respondents are from Dublin, 26% from Leinster, 26% from Munster and the rest from Connaught or Ulster. A majority (67%) of the respondents live in urban areas with at least 1,500 people.

In terms of property ownership, a higher proportion (38%) of respondents live in a property that they themselves or their family own. 32% are renters and about 30% own the property with a mortgage. 31% of respondents live in a semi-detached house, 34% in a detached house, 18% in a terraced house and 16% in a flat or apartment. A typical residence has three bedrooms.

The sources of home heating vary across households and it is not uncommon for households to use different sources within a household. About 33% of respondents stated that oil is their main source of home heating and 35% reported that gas is their primary household heating source. The proportion of respondents that stated electricity and solid fuels as their primary home heating sources are 16% and 15% respectively. Overall, the incidence of RET as a primary or supplementary source of heating is low. The share of RETs, such as solar thermal, air source

and geothermal source heat pumps, as the primary source of heating is insignificant (1%). Further, the incidence of renewable energy being used as a supplementary source of home heating is very low compared to other sources. Respondents were also asked their satisfaction with their existing home heating systems. Just under half stated they were satisfied, 20% reported that they were not satisfied and 34% stated that they were neither satisfied nor dissatisfied. Thus, the use of traditional forms of heating does not seem to impact on households' heating system satisfaction as the incidence of dissatisfaction can be considered low. This is in part driven by the minority feeling that their household was cold last winter. The least satisfied households were those with electricity as their primary heating source and these households were also the most likely to have felt cold during the previous winter. Similarly, dissatisfaction with current household electricity source is very low (17%).

With regard to RET awareness, 95% of the respondents stated that they were aware of at least one type of RET (that is, EVs, solar panels – PV or thermal, or heat pumps) and 56% reported that they knew at least one household (mostly solar panel users) who had installed or purchased an RET. However, only 17% of the households owned at least one RET themselves. Thus, in line with our focus group findings, although awareness can be considered high, notably for EVs and solar panels, uptake is extremely low. A friend or family member who had purchased or installed an RET and advertising were the primary channels for hearing about RET.

In addition to the above, several other observations stand out. The BER measures the energy efficiency of residential buildings; most participants (76%) were not aware of the BER scheme although it has been in operation in Ireland since 2009. Furthermore, households are most likely to perceive their energy usage and heating costs as being in line with the average; however, it might warrant further investigation as to what they are basing these assertions on. Research for the Commission for Regulation of Utilities (CRU) found that most people pay little attention to their energy bills, thus making a full and accurate assumption of energy usage and costs difficult for most.<sup>6</sup> Similarly, almost 37% believed that their heating costs would remain similar into the future. In the context of the gas and electricity price increase announced recently<sup>7</sup>, this suggests that consumers are lacking full awareness of energy costs and perhaps view the market myopically.

Variables	Obs.	mean	Std. Dev.
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<sup>6</sup> CRU Annual Consumer Report 2017 [here](#).

<sup>7</sup> Energy price increases [here](#).

1 if respondent is male	1208	0.466	0.499
Respondent's age:			
1 if age between 18 and 34 years	1208	0.296	0.457
1 if age between 35 and 54 years	1208	0.383	0.486
1 if age is above 55 years	1208	0.321	0.467
Respondent's highest education obtained:			
1 if secondary or primary	1208	0.418	0.493
1 if third level degree	1208	0.408	0.492
1 if master's degree or doctorate	1208	0.168	0.374
Respondent's marital status:			
1 if married or living together	1208	0.639	0.481
if single - never married	1208	0.254	0.436
1 if divorced, widowed or separated	1208	0.107	0.309
Household annual income:			
1 if less than or equal €29,999	1208	0.190	0.393
1 if between €30,000 and €59,999	1208	0.292	0.455
1 if above €60,000	1208	0.196	0.397
1 if high socio-economic class (ABC1F50+)	1208	0.495	0.500
Region categories:			
1 if from Dublin region	1208	0.311	0.463
1 if from Leinster region	1208	0.256	0.437
1 if from Munster region	1208	0.258	0.437
1 if from Connaught or Ulster region	1208	0.176	0.381
1 if lives in rural areas (< 1,500 people)	1208	0.335	0.472
Property type:			
1 if flat or apartment	1208	0.157	0.363
1 if Terraced House	1208	0.181	0.385
1 if Detached	1208	0.338	0.473
1 if Semi-detached	1208	0.311	0.463
Home ownership:			
1 if own outright	1208	0.383	0.486
1 if own with mortgage	1208	0.299	0.458
1 if rented	1208	0.315	0.465
Number of bedrooms	1208	3.247	1.205
Main home heating system:			
1 if Oil	1208	0.330	0.471
1 if Gas	1208	0.349	0.477
1 if Electricity	1208	0.155	0.362
1 if solid fuels: wood, coal, peat	1208	0.150	0.357
1 if renewables: solar thermal or heat pumps	1208	0.010	0.099

Satisfaction with existing home heating system:			
1 if dissatisfied	1208	0.196	0.397
1 if neutral	1208	0.339	0.474
1 if satisfied	1208	0.464	0.499
Satisfaction with existing electricity source:			
1 if dissatisfied	1208	0.166	0.372
1 if neutral	1208	0.421	0.494
1 if satisfied	1208	0.414	0.493
1 if aware of at least one RET	1208	0.947	0.224
1 if knows at least one other RET user	1208	0.560	0.497
1 if adopted at least one RET themselves	1208	0.168	0.374

Table 3: Respondent characteristics

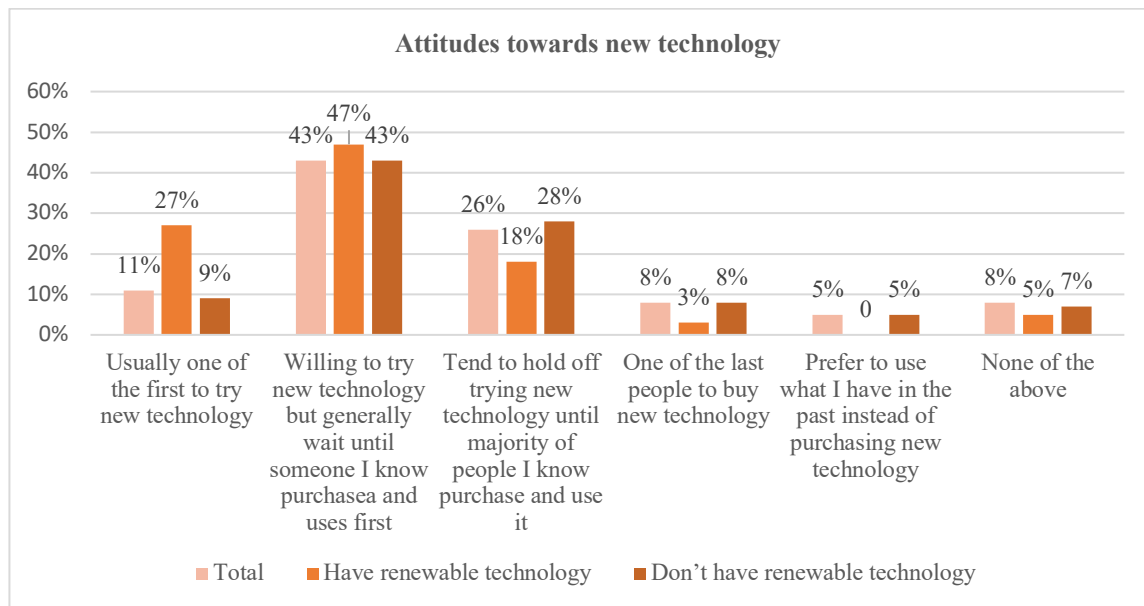
Figure 2 illustrates survey participants' attitudes to new technology, the environment, risk and time preference. Most participants prefer to wait to try new technology until someone they know has purchased and used it first, highlighting the influence of social circles, endorsements and user feedback on purchase decisions. However, there is evidence of attitudinal differences between adopters and non-adopters as adopters were significantly more likely than non-adopters to be one of the first to try new technology.

While there were high levels of environmental awareness and general agreement that fossil fuels cause climate change, the findings point to the minor role these attitudes may have in driving RET uptake as non-adopters were more likely than adopters to report concern for the environment. This is further highlighted by a third of adopters believing that their decisions do not impact the climate, compared to a fifth for non-adopters. This reflects an action-behaviour gap prevalent in energy decisions as well as a potential disconnect between micro and macro impacts regarding environmental and climate change issues.

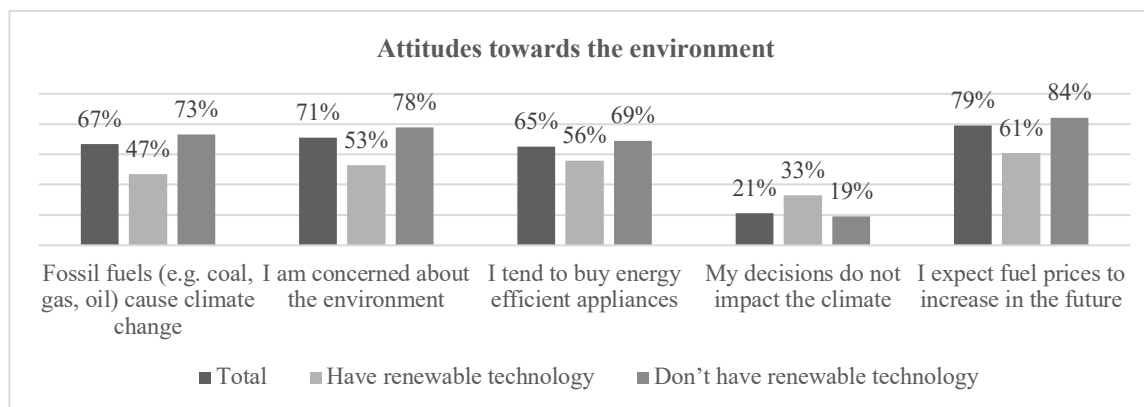
Attitudes to risk seemed to be a stronger differential in the willingness to take up new technology as adopters reported a higher willingness to take risks compared to non-adopters. However, in line with the 'wait and see' approach identified earlier most participants fell into the neutral category for risk preference. This suggests a strong status quo bias. In terms of time preference, roughly half of those surveyed claimed to be willing to give up something in the present to receive some benefit in the future. However, behavioural economic research shows that people are not time consistent in the sense given by standard economic models of decision-making and often over-estimate their behaviours. This highlights another key barrier to the



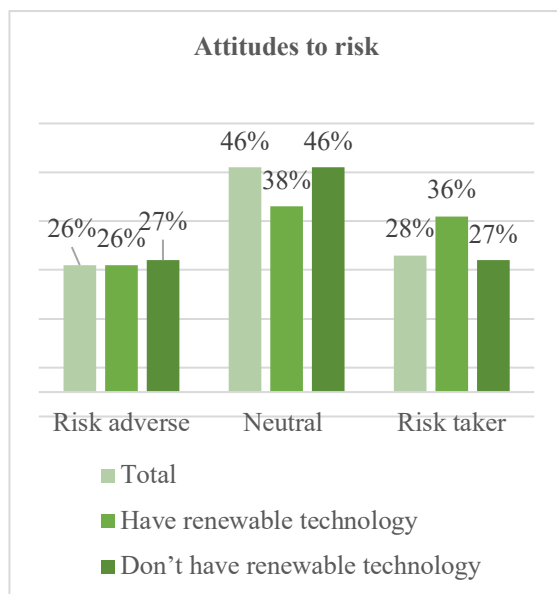
uptake of RET: while consumers may believe that they are future looking, in practice, the long-term nature of cost savings may deter current adoption.



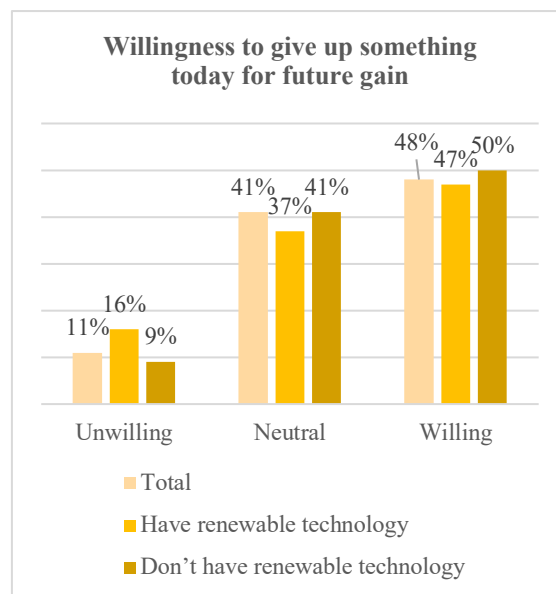
**Figure 2(a): Attitudes towards new technology**



**Figure 2(b)1: Attitudes towards the environment**



**Figure 2(c)2: Attitudes towards risk**

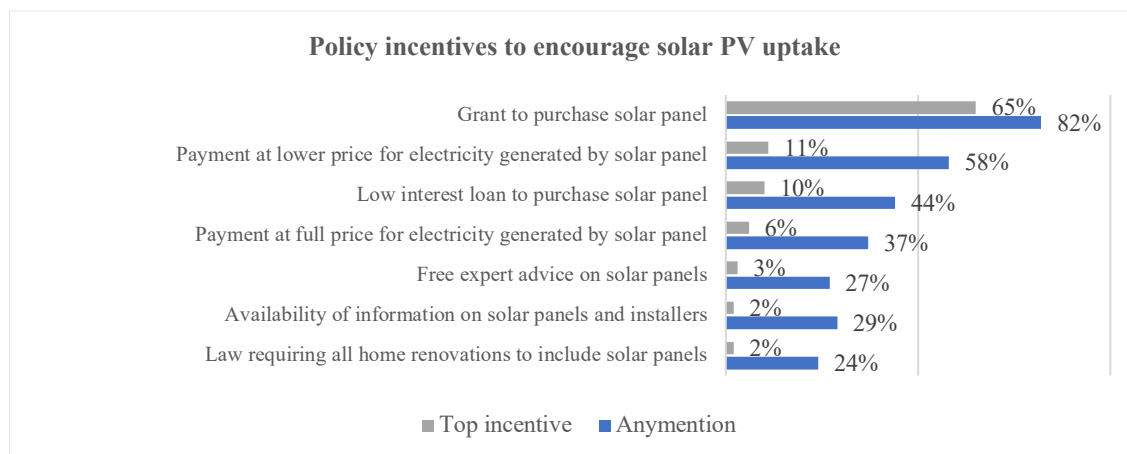


**Figure 3(d): Time preference**

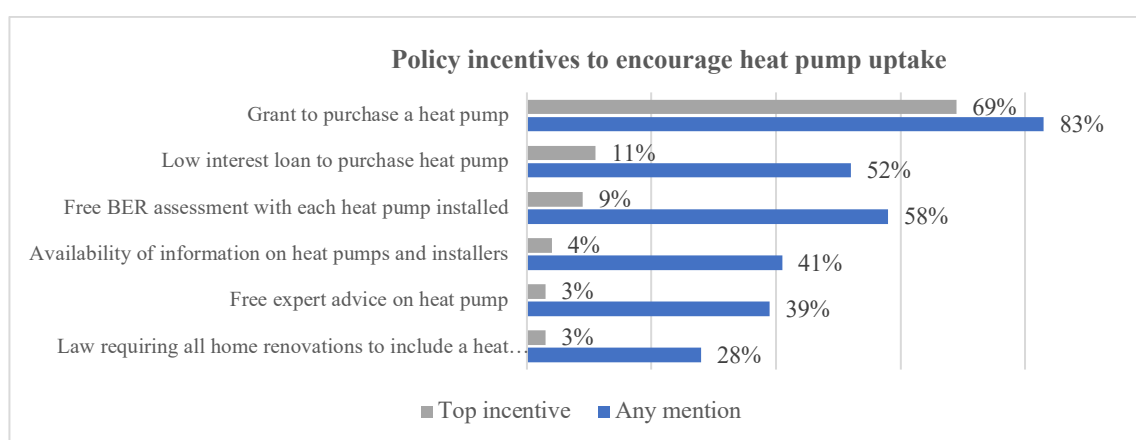
Figure 2: Attitudes towards new technology, the environment, risk and time preference

*Source: Authors' illustrations using household survey data*

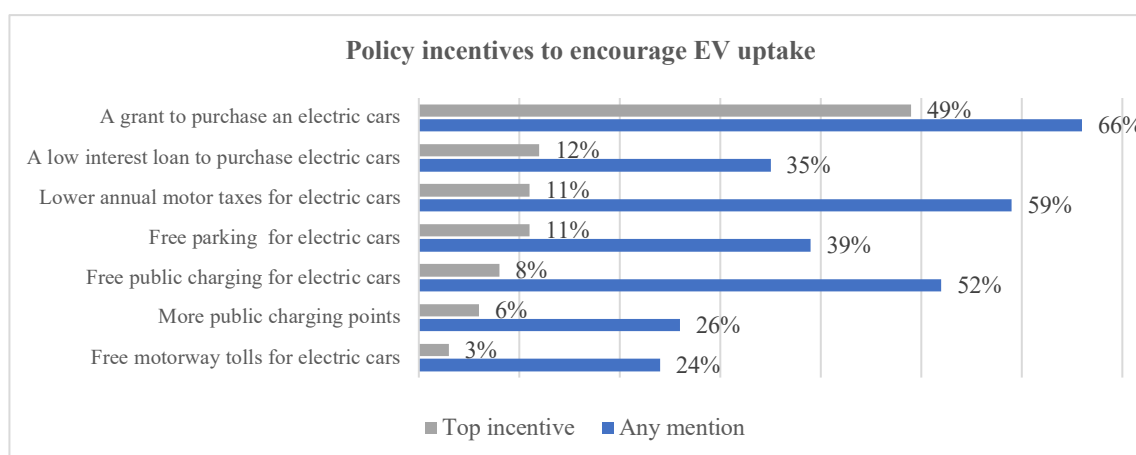
Figure 3 illustrates survey participants' views on potential policy incentives relating to the individual technologies. The top three policy measures for any RET were financial incentives that either lessen the initial cost burden or offset running costs during use. Reducing energy consumption and making savings on energy bills were the biggest drivers when considering the purchase of any RET. Participants had positive perceptions of solar PVs, heat pumps and EVs regarding their potential to save money and reduced impact on the environment. The environmental benefits were most clearly understood for EVs. However, environmental awareness had minimal impact on any potential purchase decision and costs, especially high upfront costs associated with these technologies, were a significantly bigger obstacle than the next biggest barrier, notably for solar PVs and heat pumps, where lack of awareness was somewhat high as a barrier to uptake. For these technologies, uncertainty about performance and reliability was another key barrier. Thus, it is not surprising that grants were overwhelmingly considered the strongest measure to encourage any RET uptake. Solar PV different in one aspect of the preferred policy options, namely the preference for a tariff for electricity generated by the panel over a low interest loan.



**Figure 3(a): Policy incentives to drive solar PV uptake**



**Figure 3(b): Policy incentives to drive heat pump uptake**



**Figure 3(c): Policy incentives to drive electric vehicle uptake**

**Figure 3: Policy incentives to drive solar PV, heat pump and EV uptake**

*Source: Authors' illustrations using household survey data*

### 3.2.2 Adopter vs. non-adopter profiles

Table 4 presents detailed group comparisons between adopters (n=203) and non-adopters (n=1005) of RET in our sample, where adopters are defined as respondents who purchased or installed at least one technology. Since our data is mostly categorical, that is, ordinal but not interval-scaled, we ran a series of non-parametric tests, the Wilcoxon-Mann-Whitney test<sup>8</sup>, to compare adopters and non-adopters based on our sample attributes. We replaced the Wilcoxon-Mann-Whitney test with a parametric test, the Student's t-test, for variables that are continuous. Profiling of adopters in this manner helps us identify the type of consumer that is most likely to take up RET and hence benefit from policy instruments that encourage RET uptake. There is one limitation to this analysis, however. The findings from the focus groups showed that the three technologies under study have different owners and attributes. Since our survey did not provide sufficient data to analyse adopters and non-adopters of each technology separately, we chose to pool all adopters and analyse RET adoption as a whole instead. Nonetheless, our approach ensures that we arrive at more reliable results than those that would have arisen from poor sample sizes. Specifically, out of a total of 1208 respondents, our adopter sample includes 63 EV owners, 58 solar PV owners, 99 solar thermal owners and 43 heat pump owners of which few participants own more than one technology.<sup>9</sup>

Sample attribute	More likely to adopt if:	P value
Socio-demographics:		
1. Age	Younger	0.000
2. Gender	Male	0.056
3. Socio-economic status	Higher	0.004
4. Education level	Higher	0.000
5. Employment status	Full-time employed	0.000
6. Occupation	High managerial, professional	0.000
7. Marital status	Single-never married	0.011
8. Number of children under 17	More	0.000
9. Number of children over 17	Fewer	0.000

<sup>8</sup> The Wilcoxon-Mann-Whitney test tests the null hypothesis that it is equally likely that a randomly selected value from one group will be equal to a randomly selected value from a second group. The p-value gives the probability that the null hypothesis is true.

<sup>9</sup> The probability of combinations,  $nCr$ , denotes the number of ways in which  $r$  objects can be chosen from a set of  $n$  objects. Mathematically,  $nCr = n! / r! * (n-r)!$  where  $n$  represents the number of objects and  $r$  represents the number of objects being chosen at a time. Thus, there are ten possible combinations of pairs, ten possible combinations of triads, five possible combinations of quartets and one possible combination of quintets, given that we have five objects (EV, solar PV, solar thermal, air-source and geothermal heat pump) to choose from. As an extension, the number of respondents who own various combinations of technologies can be easily calculated. For instance, the number of respondents who own an EV *and* a solar PV system (a pair) is ten and the number of respondents who own all five technologies (a quintet) is three.

10. Social network	Larger, by 6 members on average	0.000
Spatio-technical & building characteristics:		
1. Region	Dublin	0.001
2. Property type	Flat (apartment)	0.005
	Not semi-detached	0.007
3. Property size	Larger, in terms of number of rooms	0.013
4. Building era	2006-18	0.000
	Not pre-1976	0.000
5. BER of property	Higher, i.e. A-C	0.014
6. Residence period	Lower, by 67 months on average	0.000
7. Primary heating system	Electric	0.000
	Not solid fuel	0.008
	Renewable (solar thermal, heat pump)	0.000
8. Bi-monthly heating bill	Higher, by €12.96 on average	0.035
9. Bi-monthly electricity bill	Higher, by €5.84 on average	0.018
Behavioural & psychographic features:		
1. BER awareness	Higher	0.000
2. Perceived household energy usage	Higher	0.013
	Known	0.003
3. Perceived current heating costs	Cheap	0.000
4. Perceived future heating costs	Will not increase	0.003
	Will remain similar	0.000
5. Satisfaction with current home heating system	Higher	0.012
6. Will change heating system	Yes	0.000
7. Awareness of RET	Aware of at least one type	0.000
8. Awareness of other RET owners	Higher	0.000
9. Willingness to try new technology	One of the first people to try (i.e. innovators)	0.000
10. Environmental attitudes	Believes that fossil fuels do not impact climate change	0.000
	Believes that fuel prices will not rise in the future	0.000
	Not concerned about the environment	0.000
	Does not buy energy efficient appliances	0.003
	Believes that own decisions impact climate change	0.000
11. Happiness levels	Very happy	0.000

Table 4: Significant differences in sample attributes between adopters (n=203) and non-adopters (n=1005) of RET.

Table 4 reveals several statistically significant differences between adopter and non-adopter profiles. Adopters tend to be younger, of higher socio-economic status and employed full time

in high managerial or professional posts. Their higher educational attainment possibly leads to higher lifetime incomes. They are more likely to be single and never married, and have more children under 17 and fewer children over 17. They have significantly larger social networks, by six members on average, whom they share technical information with. These socio-economic characteristics may point to the stage of life most current adopters are at.

Adopters are more likely to be located in Dublin, the most populous region in Ireland and the commercial hub of the country. They are more likely to live in flats (apartments), have larger houses in terms of number of rooms and live in newer properties constructed after 2006. Adopters have lived in their current property for significantly lesser time than non-adopters; their residence period is 67 months lower on average. These spatial and built environment features may indicate that newer apartment-style homes are more likely to have the infrastructure in place to install RET. Additionally, adopters are more likely to be satisfied with their current home heating system, more likely to have higher perceived household energy usage than most and less likely to not know this information. Both bi-monthly heating bill and electricity bill are higher for adopters than non-adopters, the differences being on average €12.96 for heating and €5.84 for electricity for those who reported their bills.

Adopters are more likely to be aware of BER and have properties that are BER-rated. Moreover, their awareness of RET and other RET users is higher than for non-adopters. Adopters are more likely to be one of the first people to try new technology, that is, they are innovators. Although they are less likely than non-adopters to believe that fossil fuels impact climate change or that fuel prices will rise in the future, are less concerned about the environment, and are less likely to buy energy efficient appliances, they are significantly more likely to believe that their own decisions impact climate change. These psychographic traits suggest that adopters tend to engage in more proactive behaviour and may have a stronger sense of personal responsibility.

Table 5 presents regression results on the influence of key attributes identified from our pairwise comparisons on the likelihood of RET take up. We ran a logit model to predict uptake (0 refers to non-adopter and 1 refers to adopter) for different definitions of who an ‘adopter’ is. Column (1) defines adopters as participants who own at least one RET. Column (2) redefines adopters as those who either already own an RET (and are thus likely to purchase more RET in the future) or demonstrate a strong interest in purchasing one (by self-proclaiming that they are likely to purchase one in the future). We use a mix of socio-demographic variables (age,

marital status, education level, home ownership), spatial and building characteristics (location, number of bedrooms, property type, household energy usage, building era) and attitudinal and behavioural variables (BER awareness, awareness of other RET users, risk behaviour, time preference, and indices for sustainability, positive perception of EVs, social network approval, household infrastructure compatibility and own heating and electricity system satisfaction).

Dependent variable (0/1)	Current RET adopter (1)	Potential RET adopter (2)
<b>Socio-demographics:</b>		
1. 25-34 years old	1.094** (0.440)	0.028 (0.422)
2. 35-44 years old	-0.992** (0.486)	-0.950** (0.426)
3. 45-54 years old	-0.831 (0.533)	-1.439*** (0.459)
4. 55+ years old	-0.559 (0.567)	-1.218** (0.490)
5. Single – never married	0.976** (0.476)	-0.349 (0.417)
6. Education (years)	0.086 (0.053)	0.102** (0.047)
<b>Spatio-technical &amp; building characteristics:</b>		
1. Urban location	-0.743** (0.289)	-0.081 (0.245)
2. Number of bedrooms	0.345** (0.139)	-0.042 (0.123)
3. Average household energy usage	-1.139*** (0.373)	-0.098 (0.328)
4. Semi-detached property	-1.201*** (0.420)	-0.302 (0.363)
5. Detached property	-1.147** (0.464)	-0.251 (0.413)
6. Rented property	-0.919** (0.367)	-0.639** (0.307)
7. Building era: 1992-2001	1.131*** (0.410)	-0.236 (0.309)
8. Building era: 2006-2008	1.340*** (0.451)	-0.125 (0.420)
9. Building era: 2009-2014	2.680***	0.033

	(0.564)	(0.534)
Behavioural & psychographic features:		
1. Not aware of BER	-1.771*** (0.257)	-0.487* (0.252)
2. Knows other RET users	0.139*** (0.279)	0.334* (0.199)
3. Environmentally sustainable	-0.083*** (0.014)	-0.031 (0.011)
4. Believes EVs are worth considering	0.008 (0.009)	0.075*** (0.009)
5. Social network approves new technology	-0.001 (0.009)	0.016** (0.008)
6. Household infrastructure is RET compatible	0.059*** (0.011)	0.085*** (0.009)
7. Satisfied with heating & electricity systems	0.039*** (0.009)	-0.003 (0.007)
8. Risk taker (risk preference)	-0.004 (0.007)	0.013** (0.006)
9. Forward looking (time preference)	-0.009 (0.007)	0.020*** (0.006)
Intercept	-0.913 (1.597)	-9.080*** (1.629)
Observations	985	985

Note: standard errors in parentheses. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.10$ .

Table 5: Regression output: Logit model

The regression results are largely in line with our pairwise comparison results in Table 4. On the one hand, being young adults (under 35 years) and single, having bigger houses (in terms of number of bedrooms), knowing other RET users, residing in houses dating post 1992, and rating highly on household infrastructure compatibility and satisfaction with current home heating and electricity systems are positive predictors for current RET ownership. On the other hand, being aged between 35 and 44 years, living in urban locations, not being aware of own property's BER, living in semi-detached or detached properties (vs. apartments), having average or below average household energy consumption and ranking highly on sustainability are negative predictors of current RET ownership. There are a few dissimilarities, however. Education levels are no longer significant whereas homeownership is as renting accommodation is now a negative predictor of uptake. The regression results further indicate that urban dwellers are less likely to take up RET whereas earlier, location in terms of



rural/urban classification was not significant. Moreover, average household energy use appears to influence adoption in opposite directions now – while the pairwise comparisons suggested that current adopters have higher than average household energy use, the regression output shows that higher energy usage currently lowers propensity to uptake. Furthermore, different variables seem to inform purchase decisions for current and ‘potential’ adopters. Location, property type, building era, property size, household energy usage, satisfaction with heating and electricity systems, sustainability and marital status are no longer significant predictors of uptake for potential adopters. Instead, being highly educated, believing in new technology (such as EVs), having the approval of social networks and being willing to take risks and trade current comforts for future gain now shape the adopter mindset. The greater openness to try new technology amongst potential adopters is an opportunity for policy makers to dispel any ignorance or uncertainty that has hindered uptake in the past.

#### 4. Conclusion and policy implications

This study uncovers insights into RET purchase behaviour and decision-making in an early adopter market, Ireland. The focus groups and interviews highlight the variance of key purchase drivers across three types of RET – heat pump, solar PV and EV technology. Whereas home comfort drove heat pump adoption, home renovations drove solar PV installations. Heat pump and solar PV owners had no prior awareness of technical aspects and were guided solely by their contractor or installer in choosing the type of unit installed. EVs on the other hand were actively sought out and selected for their technical characteristics. These differences have implications for the design of policies to incentivise uptake.

Heat pumps specifically were only chosen through chance as owners did not have an objective to purchase before their initial conversation with a contractor. Solar PV awareness was mainly through word-of-mouth and a visible presence in the neighbourhood. Benefits and grants were poorly understood for both. In contrast, EV ownership was primarily emotive. Owners showed passion and pride in owning an electric car and understood both the technical and economic benefits in terms of performance and lifetime cost savings, which they researched in depth prior to purchase. The type of property was not a barrier to heat pump or solar PV ownership as renovations meant properties were adapted to suit installation. Likewise, EV owners adapted their behaviours to suit driving range, vehicle requirements and infrastructure availability. Non-adopters were most likely to take up RET based on potential and easily understood cost savings,

information on which are generally lacking or inaccessible. Across all technologies, sustainability was a secondary factor and did not trigger a purchase on its own.

The household survey revealed that awareness of some RET overall is quite high, especially for EVs and solar PVs. Awareness of other technologies is, nonetheless, relatively poor, especially for heat pumps, perhaps due to low adopter numbers generally. Overall, social networks, especially friends and family who have already purchased or installed RET, and advertising were key communication channels. Most people, however, adopted a ‘wait and see’ approach wherein they were not willing to try new technology until someone they knew had purchased and used it first. Most people cared about the environment, overwhelmingly stating that they were concerned about the impact of fossil fuels and their own actions on the climate. Most participants were also forward-looking in that they were willing to give up something in the present for future gain. Attitudes to risk were mostly neutral.

Current adopters are presumably different from non-adopters for being innovators, that is, one of the first to try new technology. Splitting the sample into adopter and non-adopter groups thus allowed us to draw deeper insights from the data. Current adopters tend to be younger, homeowners, and of higher socio-economic status. They are more likely to have higher energy use, live in newer buildings with capacity for large families, and have significantly larger social networks. While non-adopters can be quite pro-environment and often come across as more environmentally-minded than adopters, adopters are stronger believers that their own decisions influence climate change, indicating greater personal responsibility for their actions. Potential adopters are, in general, more aware of RET, more willing to take risks and more forward looking. Their openness to try new technology is an opportunity that policy makers should utilise to boost immediate uptake.

### *Policy implications*

Firstly, attitudes towards environmental sustainability are not reliable predictors of uptake. Therefore, for the scale of climate action needed, national level policies will be required to translate attitudes into pro-environmental behaviour. Reductions in energy consumption and energy bills are the strongest drivers of any RET uptake. People are, however, most concerned about the initial outlay which is often prohibitive. Accordingly, low cost finance options such as grants and low interest loans that contribute towards the capital costs of energy upgrades would help reduce the financial burden of purchasing or installing an RET substantially. Some

of these already exist, such as in Ireland a grant to purchase an EV when the list price is greater than €14,000.<sup>10</sup> However, although there is a good level of consideration given to EVs, over half of the survey respondents claimed that their next car budget is under €15,000. Thus, in the case considered, current grant levels are unlikely to trigger an EV purchase for many. It is crucial then that incentives are designed according to public preferences.

Secondly, many non-adopters prefer not to change their existing systems due to the perceived complexity of energy decisions, various cognitive biases, and a genuine lack of understanding of new technologies and potential cost-benefit trade-offs. Trust in contractors is strong for solar PV and heat pump installation and is likely to continue to be a driver. However, awareness-raising through advertising campaigns will be needed to help defuse inertia and uncertainty among those not planning for general home renovations in the near future. Word-of-mouth recommendation is also key as evident from the large social networks that current adopters enjoy. Government-led training and advisory services and household energy audits would further bridge the current knowledge and skills gap by helping households understand technology better and thereby take actions for better home energy management.

Finally, policies must be updated to be more inclusive of diverse user types. Current EV owners in this case study are almost all wealthy home owners with private garages, driveways or parking spaces and mostly charge their vehicles at home. There are opportunities, therefore, to expand the uptake of EVs in rural areas, where people have the capacity to charge at home and have otherwise little public transport alternatives to reduce their carbon footprint. However, as the current incidence of public chargers has not been successful in removing range anxiety amongst non-adopters, a more extensive and reliable charging network would need to be immediately prioritised to attract other customers who may live in rented accommodation or apartment buildings without charging facilities. Further policy measures related to cost savings during use such as lower motor tax, free parking and free public charging, and clear information regarding these are needed to complement subvention programmes. The survey revealed a preference for used cars for those considering a vehicle change and budgets under €15,000, which indicate that a bigger used car market for EVs could play a positive role in increasing uptake. For adoption of solar PV, payments for electricity generated (feed-in-tariffs) may act

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<sup>10</sup> Current SEAI grant levels available [here](#).

as a supplementary incentive to help counteract the lengthy payback periods. They are especially beneficial for consumers who are unable for any reason to use all the energy they generate during the day. Free BER assessments with each heat pump installation may help attract new heat pump customers especially when they are informed about the various benefits of acquiring BER certification.

Overall, as technologies continue to improve and prices plummet, increased uptake will require a societal transformation through public engagement, a suitable regulatory framework and empowerment of individual consumers in their long-term energy decisions. In the context of a national move towards more sustainable forms of energy and energy use, it is crucial that policy measures appeal to the cultural factors that drive people's behaviours. The results from this research show that this can be achieved through widespread dissemination of accurate information on use and necessary behavioural changes, the creation of positive social feedback that often triggers a multiplier effect, and making it generally easier for potential consumers to switch to new technologies through grants and other incentives. In addition, the introduction of options to trial technologies before consumers are required to commit to purchase can increase uptake. Implementing smart policies today will ensure a more efficient energy transition, making it more likely that we meet our environmental targets, sooner.

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## Data Availability

Unfortunately, we do not have permission to make the primary data associated with this research available due to data confidentiality reasons.

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