UCD CENTRE FOR ECONOMIC RESEARCH

WORKING PAPER SERIES

2026

SRAITH PÁIPÉAR OIBRE AN IONAID

UM THAIGHDE EACNAMAÍOCHTA COBÁC

2026

What moves the needle? A comparative study on adoption preferences of clean energy technologies in Irish households

Pranay Kumar
Na Li
Joseph Wheatley
Lisa Ryan

University College Dublin

WP26/01

January 2026

UCD SCHOOL OF ECONOMICS

UNIVERSITY COLLEGE DUBLIN

SCOIL NA HEACNAMAÍOCHTA COBÁC

COLÁISTE NA HOLLSCOILE BAILE ÁTHA CLIATH

BELFIELD
DUBLIN 4

Title: What moves the needle? A comparative study on adoption preferences of clean energy technologies in Irish households

Authors–Pranay Kumar, Na Li, Joseph Wheatley, Lisa Ryan

Abstract–In this article, we compare adoption preferences for three important clean energy technologies-rooftop solar PV, heat pumps and electric vehicles using primary data from a nationally representative household survey in Ireland. The survey questionnaire explored a wide range of techno-economic, behavioural, socio-demographic and building attributes of 1225 residential energy consumers. In our two-step analysis, we first identify four latent behavioural variables, namely, progressive attitude, behavioural inertia, peer effects and hassle factors using confirmatory factor analysis within a structural equation modelling framework. Next, we compare the role, extent and direction of identified behavioural and socio-demographic factors underlying actual adoption and stated preferences of households towards CETs, while controlling for external attributes using a mix of binomial and ordinal regression models. Our findings suggest that actual adoption of CETs varies widely among households despite their stated preferences and perceptions of potential benefits. It also reveals a significant association between the latent behavioural factors, such as progressive attitude and peer effects with adoption preference for CETs. However, the relationships between the behavioural factors and adoption preferences appear to be moderated by the annual income, education level and age group of respondents in a non-linear manner, requiring further research. Further, the perceptions of hassle and discomfort appear to be acting in opposite direction to the generally favourable progressive attitudes towards adoption preferences for solar PVs and heat pumps. Our study supplements the contemporary literature on CET adoption preferences in residential households and provides useful insights for better informed policy decisions.

Keywords–Adoption, Preference, Clean energy technology (CET), Behaviours, Households

JEL Codes–Q41, Q48, C1, D9

Highlights

- We study three significant emission reduction technologies for households-rooftop solar PV, heat pumps and electric vehicles from nationally representative Irish households.

- Compare actual adoption versus stated preferences of clean energy technologies using original primary survey data.
- Study explores role of techno-economic, behavioural, socio-demographic, building attributes and background settings from multi-disciplinary perspectives.
- The actual adoption of CETs remains low and varies across households, despite their stated preferences and perceptions of potential benefits.
- Suggests a significant association between adoption preference and latent behavioural factors, such as progressive attitude and peer effects.
- Perceptions of discomfort and hassle act in different directions to the generally favourable sustainability concerns towards adoption preferences for solar PVs and heat pumps.
- Intrinsic behavioural factors appear to be moderated by the annual income, education level and age group of respondents in a non-linear manner, requiring further research.

Acknowledgement: We kindly acknowledge the institutional support from UCD School of Economics and gratefully acknowledge funding support by Research Ireland (SFI) and co-funding partners under grant number 21/SPP/3756 through the NexSys Strategic Partnership Programme.

1. Introduction

Clean energy technologies (CETs), such as solar photovoltaic (PV) panels, electric vehicles (EVs) and heat pumps are not only considered essential for sustainable energy transition but also important in promoting economic opportunities and energy security (IEA, 2024; EU Commission Report, 2023). Nations and governments are prioritising investment, production and deployment of CETs across sectoral supply chains through suitable fiscal, financial and behavioural incentives. The global market size for six main clean energy technologies, namely, solar PV, wind, electric vehicles (EVs), batteries, electrolysers and heat pumps has grown nearly fourfold since 2015 to exceed USD 700 billion in 2023 (IEA, 2024). The Climate Action Plan 2024 for Ireland outlines a roadmap to deliver on its climate ambition to achieve 51% reduction in carbon emissions from 2021 to 2030. The plan builds upon the overarching goal of achieving net-zero emissions no later than 2050 in line with European and international agreements as adopted by the Irish government. Some of the key performance indicators of the plan include at least 1 GW of new non-utility solar, installation of up to 215,000 heat pumps in new and existing dwellings and adoption of 845,000 private electric vehicles by 2030 (CAP, 2024). Recognising the important role and contribution of heat, transport and energy related emissions from residential households, a key government objective in the delivery of climate targets focuses on societal behaviours towards environmental sustainability and citizens' engagement in sustainable investments in CETs (SEAI, 2025; DCEE Report, 2024).

Despite the regulatory support, monetary incentives and their potential lifecycle benefits, the uptake of CETs falls short of expectations and varies widely across Irish households, necessitating careful reflection and targeted measures to address the mismatch. In this paper, we study adoption preferences for three important clean energy technologies-rooftop solar PV, heat pumps and electric vehicles using primary survey data from 1225 households in Ireland. We first identify some of the dominant theoretical perspectives and analytical approaches in the contemporary literature on adoption preferences and actual investments in CETs relevant for Ireland using the matrix method of literature review (Garrard, 2011; Klopper, et al., 2007) and applied what theoretical perspective and what approaches. Next, we conduct an empirical analysis to explore the role of relatively under-researched intrinsic behavioural factors, while controlling for the socio-demographic and external factors influencing adoption preferences of such technologies. By studying and comparing these technologies together, we intend to uncover useful policy insights on the common as well as distinct behavioural attributes associated with CET adoption preferences that often get overlooked individually. Our study identifies key behavioural attributes that influence the adoption preferences of Irish households, along with their techno-economic, socio-demographic and life situations. It suggests significant association between the behavioural factors, such as progressive attitude and peer effects and adoption preference for CETs. However, the results also caution that they do not translate on their own for actual adoption, requiring more nuanced and targeted policy measures. It also provides empirical evidence on the role of households' perceptions of discomfort and hassle associated with installation of appliances, such as solar PVs and heat pumps. Additionally, our analysis suggests that intrinsic behavioural factors get moderated by the annual income, education levels and age group of respondents in influencing adoption preferences of CETs that future studies can explore further. We believe that our study will not only supplement the contemporary literature on CET adoption preferences in Irish households but also provide useful insights for better informed policy decisions.

The rest of the paper is organised as follows: with a brief overview of the theoretical and empirical literature on adoption preferences of clean energy technologies in Irish households in section 2, we describe the survey data, analytical methods and explanatory variables used in section 3. Next, we illustrate the results and discuss findings from our two-part empirical analysis in section 4. Section 5 concludes with policy insights and research directions for future studies.

2. Background context, literature overview and research questions

2.1) Background context–In general, the term clean energy technology has been used for a wide range of energy efficient appliances and renewable energy technologies that have a vital role in the sustainable transition of energy systems (IEA, 2024; EU Commission Report, 2023). In this paper, we use the term clean energy technologies (CETs) narrowly for solar PV, battery or plug-in-hybrid electric vehicles and air or ground source heat pumps that are commonly used by residential households. Further, we limit the scope of our study to adoption preferences for CETs at the household level as distinct from their social acceptance at community level public infrastructure projects (Görsch, et al., 2025; Batel, 2020; Stuhm, et al., 2025). Among the three technologies, the role of heat pumps is rather less understood among households in comparison to the high awareness and visibility of solar PV panels that generate electricity from sunlight or electric vehicles that differ from conventional automobiles in terms of their fuel source and use of a storage battery. A heat pump (HP) is essentially an energy efficient device that uses refrigerant to absorb heat from air, ground, or water and transfers it at a higher temperature using principles of thermodynamics, although it has also been considered as part of a wider spectrum of renewable energy technologies (Psarra, et al., 2024; Snape, et al., 2015). A recent study summarised GHG emission mitigation potentials across different consumption domains of food, housing and transport sectors. The authors note that about two-thirds of global GHG emissions are directly/indirectly linked to household consumption and identified household actions, namely shifting to EVs, installing Solar PVs and heat pumps among the top five options with the highest emission reduction potentials (Ivanova, et al., 2020).

Despite being an integral part of the European Union, the ownership and usage of energy appliances have some distinct and unique patterns in the Republic of Ireland (Leahy & Lyons, 2010). A big part of energy-related emissions in Irish homes comes from heating demand met from multiple fuel sources, with electricity consumption accounting for only about one-fourth of the total residential energy mix (SEAI Report, 2020). With the residential sector accounting for about one quarter of total energy consumption and roughly 15% of the consequent carbon emissions, some of the key energy and climate policy priorities include promoting adoption of CETs in Irish homes (SEAI, 2025; CAP, 2024). In line with the EU and national level binding carbon emission targets, policymakers in Ireland are pursuing an ambitious plan for adoption of CETs in Irish homes through a range of grant schemes and monetary incentives. Since 2015, a total of 104,928 solar PVs and 18,441 heat pumps have been installed in households up to December 2025 across Ireland, supported by different government funded programmes[1]. Summary plots showing annual registration/installation trends for the electric vehicles, solar PV panels and heat pumps are displayed as figures A1, A2 and A3, respectively in the Appendix. These plots suggest an encouraging trend in terms of the number of licenses granted for new private cars, including the electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) for August 2025, when compared with the same month in the last ten years (CSO, 2025). However, the provisional installation numbers for solar PVs and HPs indicate a mixed trend over the years across different counties, underlining the need for careful reflection and remedial policy measures.

2.2) Literature overview and Concept matrix–To understand the theoretical perspectives and analytical approaches explaining households' daily choices and long-term investment decisions for adoption of CETs, we browsed contemporary academic literature and publicly available reports following the matrix method of literature review (Garrard, 2011). The matrix method of literature review is considered a simple yet powerful research tool that allows researchers to identify gaps, converging and diverging opinions by organising reviewed literature in a tabular format (Johanning, et al., 2024; Klopper, et al., 2007). It also minimises the scope of researcher's own subjective bias by situating and comparing their research topic with available literature and helps them in ascertaining sufficiency of evidence collected on studied topics. Drawing from the publicly available records on adoption preferences of CETs in Irish homes, we compiled a list of peer-reviewed publications to start with. Although our study focuses on Irish households, we added

[1] Source: SEAI portal https://www.seai.ie/grants/home-energy-grants/home-upgrades. These figures reflect measures installed under National home retrofit programmes, Community energy grants scheme, National home energy upgrade scheme and Solar PV scheme excluding Warmer home scheme.

empirical examples from other countries as well, so long as the subject matter fell within the scope of our study. It should also be noted that the artificial categorisation of reviewed literature in distinct rows and columns based on our subjective judgment is meant for our study only, notwithstanding the possibilities of overlaps and absence of clear boundaries. Next, we organised a concept matrix of reviewed publications by listing citations and their country context against the three CETs separately and in combination by arranging them in separate rows and columns as shown in table 1 below. As the literature on CETs overlaps with several other differently named energy appliances and technologies, we added an extra column named other similar technologies for comparison and additional insights. To make sure that sufficient publications were identified covering our research topic, we kept on adding to the compilation, going back and forth between searching relevant resources and updating the table. Thereafter, we synthesised findings from a final list of 38 peer-reviewed articles to identify some of the dominant and less explored theoretical approaches, analytical frameworks and explanatory factors underlying households' willingness to adopt CETs compared with their revealed preferences in terms of actual adoption. We also distinguished between studies that emphasised the role of techno-economic, external and contextual drivers, barriers and their possible interactions with those focusing on intrinsic behavioural attitudes in influencing adoption preferences of CETs.

Table 1. Concept matrix based on reviewed literature

CET type/Country/Citation			
Solar PV	EV	HP	Other similar technologies
Germany (Jacksohn et al., 2019); Ireland-(Wheatley et al., 2022), (Claudy et al., 2013), (La Monaca & Ryan, 2017);US-(Alipour, et al.,2022;Schelly, 2014;Graziano & Gillingham 2015).	Australia-(Higgins et al., 2012); Denmark,Finland, Iceland,Norway, Sweden-(Noel, et al., 2019);Germany-(Plötz, et al., 2014); Ireland-(Mukherjee & Ryan, 2020),(MacUidhir et al., 2022), (Charly, et al., 2024);California,US-(Robbennolt et al., 2025;Coffman et al., 2016); (Egbue & Long, 2012).	Portugal-(Domingues & Silva,2025); The Netherlands- (Psarra et al., 2024); Ireland-(Meles & Ryan, 2022); (Snape, et al., 2015).	Renewable and sustainable energy technologies (Milani et al., 2024); Denmark-Smart home technologies (Hansen et al., 2024); Canada & US-Green technologies (Caggiano, et al., 2021); Ireland-Microgeneration technologies (Claudy, et al., 2010), Wind farm (Brennan & Rensburg, 2016); Portugal-Smart home technologies (SHTs) (Domingues & Silva,2025), Eleven energy sources and mitigation technologies (Görsch et al., 2025); Information technology

<table>
<tr><td></td><td></td><td></td><td>acceptance (Venkatesh et al., 2003).</td></tr>
<tr><td colspan="4">Comparison across regions and technologies</td></tr>
<tr><td colspan="3">Four EU countries (Belgium, Germany, Latvia, and Spain)-Solar PVs and HPs (Penaloza, et al., 2022); Germany-Solar PV & thermal systems (Jacksohn, et al., 2019);Ireland-Solar PVs, HP and EVs(Wheatley et al., 2022); Ireland and Italy-HP (Strazzera, et al., 2024);US-(Bull et al., 2025;Dong et al., 2025).</td><td>Green technology preferences across US & Canada-(Caggiano, et al., 2021); Energy efficient appliances, residential clean energy technologies and fuel efficint vehicles across 33 countries (Ang et al., 2020); South Asia-Renewable energy technologies, (Rana, et al., 2025), Home energy technologies- (Antonopoulos, et al., 2024).</td></tr>
<tr><td colspan="4">Major theoretical approaches</td></tr>
<tr><td>Theory of planned behaviour (TPB) & extensions- (Rana et al.,2025); (Schulte, et al., 2022); Behavioral reasoning theory (BRT)- (Claudy, et al., 2013); Theory of consumption values for co-adoption of Solar PVs and EVs, a consumer choice theory that combines elements of economics, sociology, and psychology (Bull, et al., 2025; Sheth, et al., 1991).</td><td>Theory of planned behaviour (TPB), Technology acceptance model (TAM) and theory of consumption values (Robbennolt et al., 2025 (Egbue & Long, 2012); Combination of economic and psychological factors (Plötz et al.,2014); Rogers' theory of diffusion (Mukherjee & Ryan, 2020); Theory of conspicuous diffusion (Noel, et al., 2019); Bass diffusion model & Low Emissions Analysis Platform (LEAP) model (MacUidhir et al., 2022);Innovative diffusion model linked to multi-criteria analysis and choice modelling (Higgins, et al., 2012).</td><td>Theory of planned behaviour (TPB) & Agent based modelling (ABM) (Meles & Ryan, 2022); Q-methodology to identify three distinct but interrelated and shared viewpoints: realistic users, hesitant neighbors and enthusiastic advocates (Psarra, et al., 2024).</td><td>Value belief norm theory-(Caggiano, et al., 2021; Stern, 2000); Technology diffusion model and adopter categories-(Bass, 1969; Rogers, 1962; Ang, et al., 2020); Theory of planned behaviour (TPB)-(Rana, et al., 2025); Extended technology acceptance model (TAM) (Domingues & Silva, 2025).</td></tr>
<tr><td colspan="4">Drivers, barriers, co-adoption & interactions-Economic, environmental, social, personal, demographic, technical, regulatory and market-related factors (Eppe, et al., 2025; Kumar, et al., 2025; Milani, et al., 2024; Shakeel, et al., 2023; Schulte, et al., 2022; Coffman, et al., 2017; Claudy, et al., 2013); co-adoption of solar, solar PVs and EVs-(Bull et al., 2025;Dong et al., 2025).</td></tr>
<tr><td colspan="2">Techno-economic, social contextual, external & socio-demographic-techno-economic factors with sociodemographic and housing characteristics, environmental concern, personality traits (Jacksohn, et al., 2019; Mukherjee & Ryan, 2020), policy & regulatory framework affecting lifetime costs and savings (La Monaca & Ryan, 2017), total cost of ownership (Plötz, et al., 2014), travel characteristics and home charging infrastructure (Charly, et al., 2024; Coffman, et al., 2017); investment costs, socio-demographic factors, limited awareness & legal issues (Penaloza, et al., 2022); financial aspects, and social networks, life situation, capital</td><td colspan="2">Intrinsic behavioural/attitudinal-Environmental concern, novelty seeking, perceived benefits & subjective norm- (Schulte, et al., 2022; Mukherjee & Ryan, 2020), psychological factors (Wheatley, et al., 2022; Meles & Ryan, 2022),hassle factor (Snape, et al., 2015), Knowledge, interests, perceptions, attitudes and views on sustainability (Egbue & Long, 2012), values, environmental concern, and lifestyle orientation (Caggiano, et al., 2021), appeal/status, risk, attitude, demographics (Higgins, et al., 2012); social-economic characteristics and attitudinal factors (Plötz, et al., 2014).</td></tr>
</table>

costs, installation and functional concerns (Bull, et al., 2025), utility rates, EV versus conventional vehicle price ratios and local wealth indicators (Dong, et al., 2025), invidious comparison and pecuniary emulation (Noel, et al., 2019), economic and social utility (Meles & Ryan, 2022); willingness to pay (Strazzera, et al., 2024); tangible costs/benefits, performance and physical limitations, peer effects (Graziano & Gillingham, 2015; Coffman, et al., 2017); socio-demographic & attitudinal (Plötz, et al., 2014; Dong, et al., 2025; Mukherjee & Ryan, 2020);age, income and education (Schulte, et al., 2022); national environment & energy policy indicators (Spandagos, et al., 2022).	

A comparison of reviewed literature across technologies and country examples also helped us in mapping the drivers, barriers and their interactions for CET adoption preferences from different theoretical perspectives and identifying research gaps in the contemporary literature as brought out below:

2.2.1) Plurality in theoretical perspectives–Despite the rich and growing volume of literature in the past two decades, the field of clean energy technology adoption remains fragmented and difficult to navigate systematically due to conceptual pluralities, multiple explanations and inconsistent taxonomies. In the absence of any standard theoretical framework, the actions, outcomes and processes underlying CET adoption have overlapping explanations from techno-economic disciplines, behavioural and other social sciences that vary with technologies and background contexts. Based on a systematic study of peer-reviewed literature, Shakeel et al., (2023) identified 127 unique factors that influence adoption of solar PV technologies at the household level and grouped them into eight categories: economic, environmental, personal, social, demographic, technical, market-related and regulatory factors. They note wide variation in theoretical explanations for solar PV adoption decisions by households with innovation diffusion theory (Rogers, 1962), theory of reasoned action (Fishbein & Ajzen, 1975), theory of planned behaviour (TPB) (Ajzen, 1991), unified theory of acceptance (Venkatesh, et al., 2003), technology acceptance model (Davis, 1993) and the Bass diffusion theory (Bass, 1969) being some of the prominent ones cited. According to TPB, the main determining factors of behavioural intention are attitudes, which are influenced by knowledge and experience, subjective norms that the consumer believes are acceptable by society, and the perceived impact of the behaviour (Egbue & Long, 2012). By including additional behavioural factors, such as environmental concern, novelty seeking and general personal motivations, Schulte et al., (2022) extended the TPB model to conduct a meta-analysis of primary studies on residential solar PV adoption intention. The authors found medium to large correlations between environmental concern, perceived economic and environmental benefits, subjective norm and intention to adopt, whereas socio-demographic variables were largely uncorrelated with intention. Similarly, Claudy et. al., (2013) studied solar PV panels adoption in Irish homes using behavioural reasoning theory by extending TPB to include context-specific reasons for and against adoption decisions. In an effort to combine multiple explanations, Venkatesh, et al., (2003) identified eight prominent theoretical models to develop a unified theory of individual technology acceptance using common insights and by incorporating moderators to account for dynamic influences, including organisational context, user experience, and demographic characteristics. In comparison to the frequent citation of TPB, our review did not find many instances of Stern's value, belief, norm (VBN) theory in CET adoption literature, except for the analysis of biospheric and altruistic values as influencing factors in a comparative study by Caggiano et al., (2021). Separately, a recent study investigated households' co-adoption decisions of solar panels and plug-in electric vehicles in the US employing consumer choice theory using five different types of consumption values in its analysis by combining elements of economics, sociology, and psychology (Bull, et al., 2025; Sheth, et al., 1991). Building on the role of perceived usefulness and ease of use in technology acceptance theory, Rogers' theory of technology innovation adds visibility, complexity and relative advantage as reliable predictors of technology diffusion (Galster, et al., 2025; Rogers, 1962). Drawing from Rogers's diffusion theory and Veblen's theory of conspicuous consumption, Noel et al., (2019) analysed how perceptions of luxury and status impact adoption of new technologies, such as electric vehicles by relying on a mix of empirical approaches and theoretical perspectives in Nordic countries (Rogers, 1962; Veblen, 1900). Terming it as the theory of conspicuous diffusion, the authors identify two salient motives for the adoption of niche technologies: i) invidious comparison, where leisure classes conspicuously consume to distinguish themselves from comparatively lower classes, and ii) pecuniary emulation, where the subsequent lower classes conspicuously consume to imitate the higher classes and garner similar status (Noel, et al., 2019). However, our brief review did not come across any other empirical study that tested for EV diffusion distinguished by conspicuous consumption values. We also note that many empirical studies did not specifically mention background theories while explaining CET adoption preferences using intrinsic behavioural variables.

2.2.2) Adoption preference versus actual investment–It is generally agreed that there is a difference between what people intend to do or think and what they actually do in practice. This discrepancy between professed values, knowledge, attitudes, and actual pro-environmental actions has been variously described in the literature as value-action gap (Blake, 1999; Kowalska-Pyzalska, et al., 2014), knowledge-action gap (Frederiks, et al., 2015; Courtenay-Hall & Rogers, 2002), attitude-behaviour gap (Byrka, 2009; Kollmuss & Agyeman, 2002; Rajecki, 1982; Coffman, et al., 2017), and so on. In the context of residential households, it is often seen that energy consumers do not invest in efficient products and technologies in their daily lives despite apparent benefits (Kumar, et al., 2025; Abrardi, 2019). This disconnect between theoretically available cost-effective potential and actual realised savings for investment in efficient appliances has been described as "efficiency gap" (Jaffe & Stavins, 1994) or "efficiency paradox" (Gerarden, et al., 2017). A rich and diverse literature explains these observations in terms of barriers at the individual level that prevent people from purchasing efficient appliances due to behavioural anomalies explained by *Prospect theory* or at the market level when demand and supply of efficient appliances are impacted due to market imperfections (Moezzi & Lutzenhiser, 2019; Jaffe, et al., 2009; Kahneman & Tversky, 1979). However, studies relying primarily on hypothetical survey questions and traditional models like the theory of planned behaviour may not capture the attitude-behaviour gap, raising critical questions about their findings on actual adoption (Claudy, et al., 2013; Coffman, et al., 2017). A recent quantitative study based on a survey of U. S. households compared behaviours and preferences influencing home energy technologies and their actual uptake. It found a large gap between expressed willingness to adopt and actual adoption rates (Antonopoulos, et al., 2024). Separately, Robbennolt et al., (2025) examined individual-level motivation to choose EVs and their adoption decision using revealed preference for California residents. They found a significant role of income, vehicle functionality, charging infrastructure and improved visibility through social mechanisms in EV adoption, highlighting the need for a multifaceted approach in promoting EVs for a diverse population. Plötz et al., (2014) studied socio-economic attributes and attitudinal factors of German consumers who actually purchased EVs or reported that they are very likely to purchase one in the near future. Noting that the decision-making process is not determined by economic factors alone, they found that users for whom EVs make economic sense may not necessarily be those who are actually interested in EVs (Plötz, et al., 2014). Based on a representative study of Danish households, Hansen, et al., (2024) investigated actual uptake of smart home technologies and their relationship with total energy consumption. While noting that different types of efficient technologies also imply changing norms of comfort, the study suggests that sometimes higher levels of comfort can be prioritised over possible monetary savings. Barring a few instances, however, we find that a majority of reviewed studies either used adoption preferences as a proxy for actual adoption of CETs or conflated them with actual adoption in empirical analysis.

2.2.3) Drivers, barriers & comparisons- The Sustainable Energy Authority of Ireland (SEAI) conducts a monthly online survey called the *behavioural energy and travel tracker* (BETT) that gathers granular data about energy behaviours of Irish citizens over time. Using the *"day reconstruction method",* it asks people to think back over their behaviour the previous day, before responding to detailed questions about their travel behaviour and energy use in the home. It has identified theories of climate-related behaviour under three major categories: (i) agency of the individual, (ii) external and social contextual factors beyond the individual's control, and (ii) interactions of both types of factors (SEAI Report, 2020). For electric vehicles, Coffman et al., (2016) broadly classify factors influencing adoption as internal (vehicle ownership costs, driving range, and charging time) and external (relative fuel prices, consumer characteristics, availability of charging stations, and public visibility/social norms) based on their meta-analytic review of literature. For EVs, another study identified the role of economic, non-financial, behavioural, psychographic, technical, spatial characteristics and socio-demographic profile of households as potential determinants in influencing adoption decisions in an early adopter market context (Mukherjee & Ryan, 2020). For residential solar systems, a review of literature on predictors revealed 333 factors grouped under three overarching categories–individual, social and information with positive and negative influences (Alipour, et al., 2020). Using data from a large-scale representative household survey in Germany, Jacksohn et al., (2019) assessed the relative importance of sociodemographic profile, housing characteristics, environmental concern, and personality traits compared with the role of expected revenue returns as possible factors influencing households' investment decisions in solar systems. They found that the expected economic cost and revenue return had the highest influence on adoption decisions followed by a marginal role of socio-demographic and housing attributes, while environmental concern and personality traits were found to be insignificant. In comparison, Eppe et al., (2025) conducted a global meta-analysis of psychological factors that can either accelerate or hinder uptake of sustainable energy-technology adoption. The authors found that personal norms, attitudes, and perceived behavioural control had the strongest positive associations with sustainable energy-technology adoption, while perceived monetary costs and risk were identified as relevant barriers. Using a mix of survey and historical data from Irish homes, Meles & Ryan, (2022) developed an agent-based model to understand the adoption decision mechanism of heat pumps. The model recognised possible factors under four broad categories as economic, socio-demographic, psychological, and social network to simulate different adoption scenarios based on extant policies up to the year 2030. Based on a comprehensive review of technology adoption decisions in sixteen energy system models, Galster et al., (2025) found that in comparison to the predominant focus on financial aspects in terms of benefit and costs, there is limited consideration and a weaker empirical foundation for non-economic behavioural and social drivers. Using homeowners' data in Ireland to investigate solar panel adoption, Claudy et al., (2013) included factors for and against adoption in their psychological model. Their findings suggest including mediating constructs (i) for adoption, (ii) against adoption, and (iii) attitudes toward a technology, when explaining how consumers' think about adoption intentions. It should be noted, however, that the role and significance of these predictors can also vary across different regions and countries. For example, Penaloza et al., (2022) found differential role and significance of investment costs, legal, economic and organisational challenges generally studied together as common barriers in sustainable technology adoption literature across Belgium, Germany, Latvia, and Spain. Separately, a comparative study of nationally representative US and Canadian households analysed the role of behavioural antecedents using a common lens to discover similar and unique factors influencing purchase decisions of green technologies–lightbulbs, energy efficient appliances, and electric vehicles. It found a significant role of altruistic values, environmental concern, and lifestyle orientation on green technology purchase intention for both countries (Caggiano, et al., 2021). A recent study examined the possible existence of interactions or synergies between socio-demographic, external, and attitudinal factors in influencing adoption of EVs and solar panels, both separately and jointly. Their models identified factors that influence homeowners' decisions across four adoption choice outcomes: no adoption, adoption of only EVs, adoption of only solar panels, or adoption of both technologies (Dong, et al., 2025). A related study compared motivations and challenges associated with co-adoption and single technology adoption of solar PV technologies and EVs in seven US states. It found the decision-making processes for each technology to be independent and sequential rather than being viewed together by households as part of a singular whole (Bull, et al., 2025).

2.3) Research gap & questions– From our thematic review, we note that the literature on CET adoption has expanded in its scope and depth from multi-disciplinary perspectives. Some of the recent publications uncover novel insights on attitude behaviour gaps, co-adoption and comparison across technologies and contexts, with a range of interacting intrinsic and external factors influencing the adoption decisions. Whereas the abundant literature explores reasons underlying adoption and adoption preferences of CETs in terms of their economic utility or pro-environmental attributes, a section of literature also recognises the role of biospheric and materialist values (Werff, et al., 2013; Caggiano, et al., 2021), novelties (Thollander, et al., 2010), risk-taking and enjoyment of technical innovations associated with ownership of solar PV and electric vehicles (Schelly, 2014). Based on a comprehensive review of the literature, Galster et al., (2025) note that a big part of academic literature on energy systems is based on utility maximisation and cost minimisation models despite the potential role of behavioural factors such as loss aversion or status quo bias guided by concepts of bounded rationality (Zeckhauser & Samuelson, 1988; Kahneman & Tversky, 1979). Despite the high frequency of studies on the monetary factors in terms of the willingness to invest to match upfront and maintenance costs, extant literature remains inconsistent on the potential role of behavioural factors that cause them in the first place (Eppe, et al., 2025). It also emerges that in comparison to rich literature that examines the favourable role of pro-environmental concerns and perception of economic benefits associated with installation of CETs, the nature and extent of respondents' perception of mental burden and discomfort associated with installation, operation and maintenance of CETs, especially solar PVs and heat pumps remain understudied (Snape, et al., 2015; Kowalska-Pyzalska, et al., 2014). Barring a few recent examples by (Hansen, et al., 2024; Caggiano, et al., 2021; Wheatley, et al., 2022; Strazzera, et al., 2024; Bull, et al., 2025; Dong, et al., 2025) comparing across regions, technologies and adoption preferences, relatively fewer studies have compared CET adoption in the Irish context. Drawing from the literature above, we explore the following questions in our two-part study using structural equation modelling and multinomial logit regression:

(i) What are the key intrinsic behavioural factors underlying adoption preferences of rooftop solar PV, heat pumps and electric vehicles in Irish households?

(ii) How do the stated preferences for different clean energy technologies adoption compare with actual ownership across Irish households?

3. Analytical approach, research methods, survey data and variables

The idea of comparing like with like is not new and has been fundamental to experimental enquiry for a long time, as part of quantitative research methods for causal explanation by testing data against a hypothetical counterfactual between treatment and control groups (Mill, 1843; Ragin, 1987). It has also been used for comparing like with unlikes or comparison across dissimilar cases in concept development and theoretical practice as part of comparative case studies. Comparative policy analysis is catching up as a research method for assessing benefits and trade-offs in dissimilar settings across different social science disciplines (Wenzelburger & Jensen, 2022; Schriewer, 2021; Krause, 2016; Przeworski & Teune, 1970). In this study, we use a comparative analytical framework to explore the distinctions between actual adoption and stated adoption preferences of CETs. We also compare the role and significance of common factors influencing adoption preferences for the three technologies individually. In line with our research objectives concerning the role of relatively understudied behavioural factors, we limited the scope of our study by controlling for the influence of external factors, such as market cost benefits (CSO, 2021), tariff structure, policy incentives and availability of necessary infrastructure for CET adoption, assuming they will be common across Irish households. Our study also excluded distributive impacts and class alliances arising out of CET adoption dealt with earlier by (Ó Maonaigh, 2023) and (Farrell & Lyons, 2015) in the Irish context.

3.1) Empirical methods–In a recent targeted review of ten European studies on social acceptance of renewable technologies, Stuhm et al., (2025) highlight the need for a comparative analytical framework that combines traditional econometric methods with advanced tools that include structural equation modelling (SEM), machine learning and agent-based modelling approaches. In line with the research objectives and available data, our comparative empirical analysis for the three technologies is in two parts: first, we identify latent behavioural variables (a) progressive attitude towards technology and risk taking, (b) behavioural inertia, (c) peer effects, and (d) hassle factor using confirmatory factor analysis. Next, we conduct binomial and ordinal logit regressions for actual adoption of all three technologies together (Model I) followed by stated adoption preferences of individual technologies separately (Model II, III, IV) using the four factors identified from the first part as explanatory variables with socio-demographic, physical, and techno-economic factors as control variables. Our choice of regression model is based on a hypothesised nonlinear relationship between chosen outcomes and potential predictors measured on continuous and categorical scales.

Assuming that fewer underlying latent factors can explain a large number of observed variables sharing a common variance in proportion to their factor loadings, we conducted confirmatory factor analysis as part of the structural equation modelling framework. Based on our literature review, we looked for potential intrinsic behavioural factors that influence the willingness to invest in CETs by Irish households. Drawing from the responses to the national survey, we identified four latent variables: peer effects, progressive views, hassle factor and behavioural inertia, whose role, extent and significance have been relatively under-researched in empirical studies. Our choice of SEM framework is guided by its ability to represent relationships between observed and latent variables with the help of path diagrams (Schumacker & Lomax, 2016). SEMs also allow for capturing simultaneous multiple regression relationships between endogenous variables with measurement errors subject to multivariate normality assumptions (Hoyle, 1995; UCLA, 2021). The general mathematical formulation for the measurement and structural regression models 1&2 used is as follows:

$$\mathbf{X}_i = \Lambda_x \mathbf{Y}_{i.} + \delta_i \quad -(1)$$

$$\mathbf{Y}_i = \alpha + \beta \mathbf{Y}_i + \Gamma \mathbf{X}_i + \zeta_i \quad -(2)$$

Where, $\mathbf{Y}_i$ represents the set of latent endogenous variables for the i^{th} item, $\mathbf{X}_i$ denotes the set of observed exogenous variables, β and Γ are the coefficient vectors for the observed endogenous and exogenous variables respectively, α represents the set of constant terms, Λ_x is the factor loading vectors and ζ_i is the error term (Bollen & Noble, 2011; Mueller, 1996).

3.2) *Binomial and ordinal logit regression*– With the outcome variable coded on a "*yes*" and "*no*" scale for Model I and on a five-point Likert scale for Models II, III and IV, our natural choice for the regression models were binomial and ordinal logit regression models, respectively. Assuming that an underlying linear latent variable $\mathbf{Y}_i$* can correspond to the observed non-linear outcome variable $\mathbf{Y}_i$. Defining $\mathbf{Y}_i$*as a latent variable ranging from $-\infty$ to ∞, the mathematical equation of structural and measurement models (3) & (4) respectively can be shown as below:

$\mathbf{Y}_i^* = \alpha_i + \beta X_{i,k} + \varepsilon_i$ – (3) with the following conditions:

$\mathbf{Y}_i = 1$ (Strongly disagree) if $-\infty \leq \mathbf{Y}_i^* < \tau_1$ – (4)

$\mathbf{Y}_i = 2$ (Disagree) if $\tau_1 \leq \mathbf{Y}_i^* < \tau_2$

$\mathbf{Y}_i = 3$ (Neutral) if $\tau_2 \leq \mathbf{Y}_i^* < \tau_3$

$\mathbf{Y}_i = 4$ (Agree) if $\tau_3 \leq \mathbf{Y}_i^* < \tau_4$

$\mathbf{Y}_i = 5$ (Strongly agree) if $\tau_4 \leq \mathbf{Y}_i^* < \infty$

where the cut points or thresholds τ_1, τ_2, τ_3, τ_4 are estimated assuming $\tau_0 = -\infty$ and $\tau_5 = \infty$ and intercepts are parameterized as 0 (Long, 1997). Further, the odds ratio for a unit change in $\mathbf{X}_{i,k}$ equals $[\mathbf{\Omega}_m (\mathbf{X}, \mathbf{X}_{k+1}) / \mathbf{\Omega}_m (\mathbf{X}, \mathbf{X}_k)] = \exp(-\boldsymbol{\beta}_k)$ – (5), assuming the parallel regression assumption holds true.

3.3 Data–The empirical data for our study comes from a nationally representative survey administered in September 2024 by a professional market research company across all regions in Ireland. The survey questionnaire was built upon a previous research study conducted six years earlier based on focus groups and in-depth interviews from representative Irish households (fig.1). The survey was conducted after institutional ethics clearance and the data collected were anonymised and secured to protect privacy of the respondents. To correct for unit non-responses and minimise the sampling errors, we applied balancing weights on age, gender, region, social class, and educational levels based on Irish Central Statistics Office census figures (Groves, et al., 2009). A 5% margin of error for the total population in Ireland provided a statistically robust sample size. While the survey data comes from Irish households, we expect that our findings would be relevant for other countries that need such insights to design their policy mix for CET adoption.

Figure 1: Survey timeline

With an adult population forming a total of 1225 respondents, who either owned a house or paid electricity bills of their own, our survey returned a fairly balanced sample with the number of female respondents slightly higher than their male counterparts. The questionnaire had three parts: (i) socio-demographic questions for general respondents, (ii) building, retrofitting, energy sources, and energy bill information, (iii) households' attitude towards solar PVs, EVs, HPs and dynamic tariffs. A summary table showing descriptive statistics of the primary and derived variables is shown in the table below:

Table 1: Summary of descriptive statistics

Variables	**Code**	**Category**	**Frequency**
A. Dependent variables			
Adoption			
Model-I: Installed/own solar photovoltaic (PV) panel or electric vehicle (EV) or heat pump (HP) (CETA)	0	No	818
	1	Yes	192
Adoption preferences			
Model-II: Will install solar PV panels at my house in future	1	Strongly disagree	98
	2	Disagree	127
	3	Neutral	373
	4	Agree	229
	5	Strongly agree	112
Model- III: Will install a heat pump at my house	1	Strongly disagree	181

	2	Disagree	175
	3	Neutral	509
	4	Agree	96
	5	Strongly agree	39
Model-IV: Likelihood that next car bought will be a battery electric vehicle	1	Strongly disagree	328
	2	Disagree	189
	3	Neutral	191
	4	Agree	119
	5	Strongly agree	82
B. Explanatory variables			
Progressive views			
Technology views(P1)	1	I generally prefer to use what I have in the past instead of purchasing a new technology	122
	2	I am generally one of the last people to buy a new technology	177
	3	I tend to hold off trying a new technology until the majority of the people I know purchase and use it	297
	4	I am willing to try a new technology but generally wait until someone that I know first purchases and uses it	461
	5	I am usually one of the first people to try out a new technology	142
Willingness to take risks (P2)	1	Completely unwilling	74
	2	Unwilling	315
	3	Undecided	343
	4	Willing	448
	5	Completely willing	45
Future preference-willingness to give something up today to receive greater benefit in future(P3)	1	Completely unwilling	17
	2	Unwilling	82
	3	Undecided	414
	4	Willing	616
	5	Completely willing	96
Awareness/Peer effects–Number of friends, work colleagues, neighbours, and relatives who one discusses /shares info about technologies with (Model-I); Know people who own or have installed (Model-II, III, IV).	1	One	33
	2	Two	103
	3	Three	104
	4	Four	87
	5	Five	88
	6	Six	75
	7	Seven	71
	8	Eight	22

	9	Nine	467
Solar PV(Model-II)	1	None	599
	2	Yes, one	264
	3	Yes, two	145
	4	Yes, more than two	217
Heat pump (Model-III)	1	None	733
	2	Yes, one	286
	3	Yes, two	94
	4	Yes, more than two	112
EV(Model-IV)	1	None	526
	2	Yes, one	356
	3	Yes, two	167
	4	Yes, more than two	
Behavioural inertia			
Loss aversion-I feel very bad if I lose something, even when it's not that important(I1)	1	Strongly disagree	37
	2	Disagree	152
	3	Neither	272
	4	Agree	581
	5	Strongly agree	183
Inertia-I tend to keep old energy appliances around even after they are replaced or obsolete (I2)	1	Strongly disagree	318
	2	Disagree	468
	3	Neither	191
	4	Agree	214
	5	Strongly agree	34
Materialist values-I get easily attached to material things(I3)	1	Strongly disagree	93
	2	Disagree	311
	3	Neither	370
	4	Agree	375
	5	Strongly agree	76
Hassle factors			
Solar PV panels are too much trouble to install(H1)	1	Strongly disagree	159
	2	Disagree	361
	3	Neutral	250
	4	Agree	193
	5	Strongly agree	73
A heat pump is too much trouble to install(H2)	1	Strongly disagree	70
	2	Disagree	149
	3	Neutral	282
	4	Agree	237
	5	Strongly agree	130
Electric cars have low range and are unreliable(H3)	1	Strongly disagree	55

	2	Disagree	198
	3	Neutral	222
	4	Agree	363
	5	Strongly agree	223
Sustainability concern–about environment/climate change	1	Strongly disagree	84
	2	Disagree	110
	3	Neither	210
	4	Agree	536
	5	Strongly agree	285
Pro-environmental identity–acting environmentally friendly is an important part of who I am	1	Strongly disagree	58
	2	Disagree	107
	3	Neither	373
	4	Agree	541
	5	Strongly agree	146
C. Control variables (Socio-demographic & external attributes)			
Age group	1	Young (18-34)	224
	2	Medium (35-54)	518
	3	Old (above 55)	483
Annual household income (€)	1	Very low (below 25,999)	251
	2	Low (26,000-50,999)	393
	3	Medium (51,000-104,999)	379
	4	High (above 105,000)	83
Family size	1	One	205
	2	Two	155
	3	Three	182
	4	Four	83
	5	Five	430
	6	Six	64
	7	Seven	44
Property type	1	Terraced house	206
	2	Semi-detached house	452
	3	Detached house	408
Education	1	Primary	136
	2	Secondary	676
	3	Higher	412
Building vintage (Year built)	1	Before 1976	272
	2	1976-1991	202
	3	1992-2004	252
	4	After 2005	284

Work from home	0	No	900
	1	Yes	325
Primary heat source	0	Others	1006
	1	Electricity	207
Region	1	Dublin	361
	2	Rest of Leinster	314
	3	Munster	353
	4	Ulster/Connacht	197

In terms of educational background, more than half of the respondents had secondary level qualifications followed by respondents having a third level or professional degree, with primary level degree holders forming less than one tenth of the sample. Similarly, medium and older age groups together accounted for most of the sample, with younger groups representing roughly one-fifth of the sample. In terms of the family size, five-member households were in majority accounting for more than a third of the sample size. Single-family households stood next, forming 17 percent of the total respondents, followed by three and two-member households, respectively. About a quarter of the total respondents mentioned that at least one of their family members worked from home. In terms of the annual household income, the households with annual income of less than € 51,000 together represented more than half of the sample followed by medium and higher income categories accounting for nearly one third and less than one tenth of the sample size, respectively. In terms of the fuel choices, less than one-fifth of the respondents mentioned electricity as their primary source of heating services, with the rest using multiple other energy sources. The survey also collected detailed information on what and why questions surrounding households' perceptions towards clean energy technologies (CETs) from a range of behavioural, socio-demographic, techno-economic and building attributes.

3.4) Explanatory variables–Instead of relying on any specific theoretical model, our choice of analytical methods and explanatory variables is guided by an interdisciplinary approach that includes insights from traditional and behavioural economics, environmental psychology and social practice theories (Egmond & Bruel, 2007; Bryman, 2016; Little, 2023). Following the literature suggesting inclusion of factors for and against adoption preferences (Claudy, et al., 2010), we identified survey questions that explored behavioural attributes measured on a bidirectional scale. In line with our research questions on the comparative role of intrinsic behavioural and contextual factors across technologies, we identified variables that could either drive or hinder the willingness to adopt CETs. We also tried to assess the role of daily lifestyles in terms of work from home situation or family size of households in their investment choices, while controlling for the gender, age, education level, annual household income of respondents and building attributes. We note that our choice, classification and assumptions about the nature of behavioural variables are limited by available data and despite the distinct classifications, it may not always be possible to have a clean distinction between them in real life. A brief description of the rationale and choice of explanatory variables used in our study is provided below:

(iii) Progressive views–Based on their perceptions and attitudes towards handling uncertainties surrounding technologies, prospective adopters of innovative technologies have been distinguished from innovators, early adopters to laggard categories (Rogers, 1962). Individual choices also differ based on differential valuation of future risks and uncertainties associated with technology choices, energy prices and expected returns (Volland, 2017; Alipour, et al., 2020; Plötz, et al., 2014). To capture the progressive views of the respondents based on their perception of technology and future risk preferences, we classified the respondents based on their responses to the following questions: I generally prefer to use what I have in the past instead of purchasing a new technology, I am generally one of the last people to buy a new technology, I tend to hold off trying a new technology until the majority of the people I know purchase and use it, I am willing to try a new technology but generally wait until someone that I know first purchases and uses it, and I am usually one of the first people to try out a new technology; willingness to take risks and to give something up today in order to receive greater benefit from it in the future measured on a five point Likert scale.

(i) Peer effects–In addition to the phenomenon of technology adoption over time, some studies have also found evidence of neighbour effects or influence of word of mouth in spatial diffusion of CET adoption(Alipour, et al., 2022; Graziano & Gillingham, 2015; Schelly, 2014). To assess the role of peer effects in our study, we recorded responses on the number of friends, work colleagues, neighbours, and relatives with whom one discusses and shares information about technologies or knows people who own or have installed these CETs on a numerical scale for the three technologies separately.

(ii) *Behavioural inertia*–A useful theoretical explanation for the so-called energy efficiency gap, where individuals are biased towards maintaining the status quo instead of investing in efficient technologies despite their potential benefits comes from Prospect theory (Kahneman, et al., 1991;

Zeckhauser & Samuelson, 1988). Such behavioural anomalies have been explained in part by the status quo-bias or behavioural inertia of individuals, who tend to keep their current stock of appliances or current level of home insulation in their households (Blasch & Daminato, 2020; Li, et al., 2016). In our analysis, we tested for the empirical significance of the behavioural inertia using the following survey questions measured on a five point Likert scale ranging from strongly disagree to strongly agree options: I feel very bad if I lose something even when it's not that important, I tend to keep old energy appliances around even after they are replaced or obsolete, and I get easily attached to material things.

(iv) Hassle factor–Previous studies have identified the role of mental barriers, such as increased hassle or discomfort associated with installation and maintenance of solar PVs and heat pumps as a potential reason for lower-than-expected uptake beyond a certain tipping point (Mogensen & Thøgersen, 2024; Snape, et al., 2015). In the case of electric vehicles, consumers have expressed concerns regarding battery range and reliability as barriers to adoption, when compared with conventional automobiles (Egbue & Long, 2012). To assess the role of these non-financial barriers, we hypothesised hassle factor as a composite latent variable constructed from the following survey questions measured on a five-point Likert scale: solar PV panels are too much trouble to install, a heat pump is too much trouble to install, and electric cars have low range and are unreliable.

(v)Pro-environmental identity & sustainability concern–In addition, we also tested for the potential role of environmental concern and pro-environmental identity of the respondents in influencing their CET adoption and preference decisions by using survey questions on how concerned they were about environment/climate change and whether acting environmentally friendly was an important part of who they are, measured on a five-point Likert scale (Dermody, et al., 2018; Steg, et al., 2018; Whitmarsh & O'Neill, 2010; Jacksohn, et al., 2019).

(v) *Other variables*–Finally, we controlled for socio-demographic profiles and external factors, namely, work from home situation, age profiles, education level of respondents, grant received, annual family income, building vintage, house attributes and region in the regression models to situate and compare the role of explanatory variables identified above.

4. Results and discussion

Using the *lavaan* package in R software (R Core Team, 2023; Rosseel, Y., 2012; Venables, W. N., & Ripley, B. D., 2002), we proceeded first with confirmatory factor analysis under the SEM framework of our empirical analysis. Based on the literature review, we identified relevant survey questions for the four latent variables, namely, progressive attitudes, peer effects, behavioural inertia and hassle factors in the model. We checked for the strength and robustness of the SEM using standard model fitness indices as brought out in table 2 below.

Table 2: Fitness test results

Number of observations	1225	
Model chi-square (Chisq)= 122.617,	p-value 0.00	Degrees of freedom (df) 48
Comparative Fit Index (CFI>0.9)	0.909	
Tucker-Lewis Index (TLI>0.9)	0.867	
Standardized Root Mean Square Residual (SRMR<0.05)	0.042	
Root Mean Square Error of Approximation (0.05<RMSEA<0.08-Reasonable fit)	0.052	

With 1225 observations included in the computation, the overall model fitness indices used in assessing the measurement and structural models, including the model versus saturated likelihood ratio chi-squared test value of 122.617 and p-value less than 0.001, the comparative fit index (CFI) value of 0.909 and the Tucker-Lewis index (TLI) value of 0.867 were found to be reasonably good fit. Further, the root-mean square error of approximation (RMSEA) and the standardised root mean square of residuals (SRMR) values below 0.08 are indicative of good model fit. From the analysis, we find that the questions used in our survey are significant predictors of the latent variables, supporting our choice of questions for the latent variables. The standardised path coefficients and covariances between latent variables following the confirmatory factor analysis using the SEM approach are shown in table 3 below.

Table 3: Standardised covariance estimates

<table>
<tr><th>Peer effect</th><th>Covariable</th><th>Estimate</th><th>Std. Err</th><th>z-value</th><th>P(>|z|)</th></tr>
<tr><td>~~</td><td>Inertia</td><td>0.026</td><td>0.02</td><td>0.576</td><td>0.565</td></tr>
<tr><td>~~</td><td>Progressive</td><td>0.407***</td><td>0.025</td><td>6.439</td><td>0.000</td></tr>
<tr><td>~~</td><td>Hassle</td><td>-0.381***</td><td>0.031</td><td>-7.478</td><td>0.000</td></tr>
<tr><td>Inertia</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>~~</td><td>Progressive</td><td>-0.02</td><td>0.013</td><td>-.405</td><td>0.685</td></tr>
<tr><td>~~</td><td>Hassle</td><td>0.105*</td><td>0.020</td><td>2.196</td><td>0.028</td></tr>
<tr><td>Progressive</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>~~</td><td>Hassle</td><td>-0.353***</td><td>0.023</td><td>-5.789</td><td>0.000</td></tr>
</table>

Note: significance codes for p value less than 0.001'***',0.01 '**', 0.05 '*'

For better visibility, the path diagrams showing latent variables in ellipses and measured survey responses on ordinal scales are also shown in figure 2 below. The estimated path coefficients were considered significant if the p-value was found to be less than 0.05.

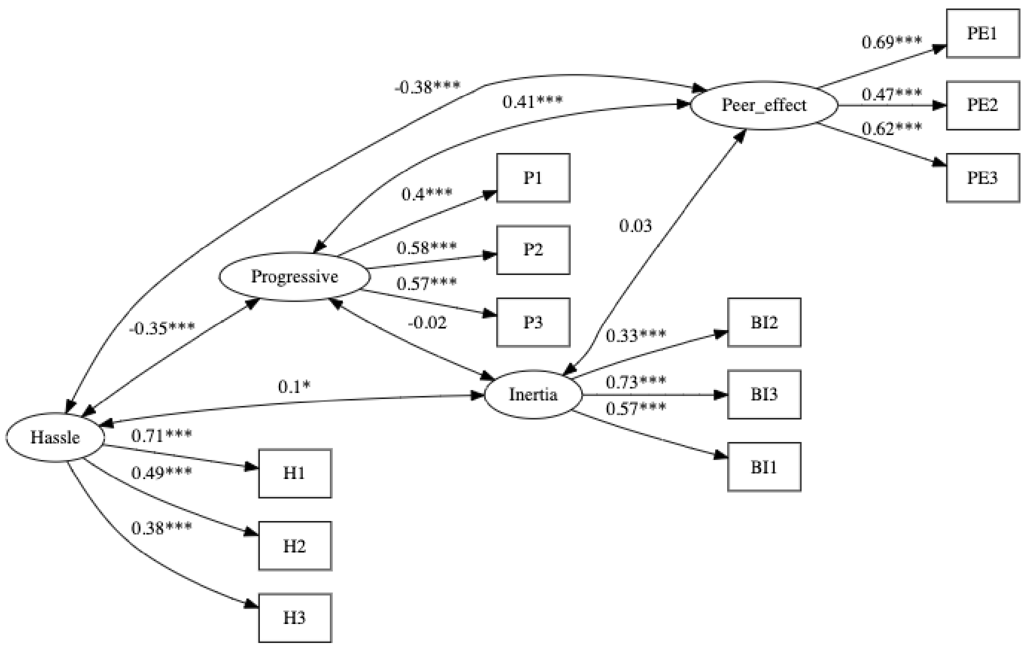

Figure 2: Path diagram showing confirmatory factor analysis results using SEM

We note that all observed variables recorded in response to survey questions shown in rectangular boxes are found to be significant, supporting their inclusion in the model. Further, there appears to be a significant covariance between peer effects representing respondents' communication frequencies with their social network and progressive attitudes towards CET uptake. However, the hassle factor as a latent variable representing the discomfort and inconvenience levels, appears to be significantly and negatively associated with peer effects and progressive attitudes. Additionally, the role and relationship between behavioural inertia and other variables do not appear consistent and statistically significant, requiring more research.

Following SEM analysis, the factor scores of latent behavioural variables were appended to the original dataset for use in later regression analysis. To explore possible interaction of the intrinsic behavioural variables with the socio-demographic profile of the respondents, we compared their factor scores for different income, education and age groups of respondents. Figures 2, 3 and 4 below show the distribution of these four latent variable factor scores plotted as bar charts on a bidirectional numerical scale for different age, income and education groups, respectively. We observe a distinct heterogeneity in progressive attitudes, peer effects, behavioural inertia and perception of discomfort associated with installation, operation and maintenance of CETs for respondents from different socio-demographic profiles.

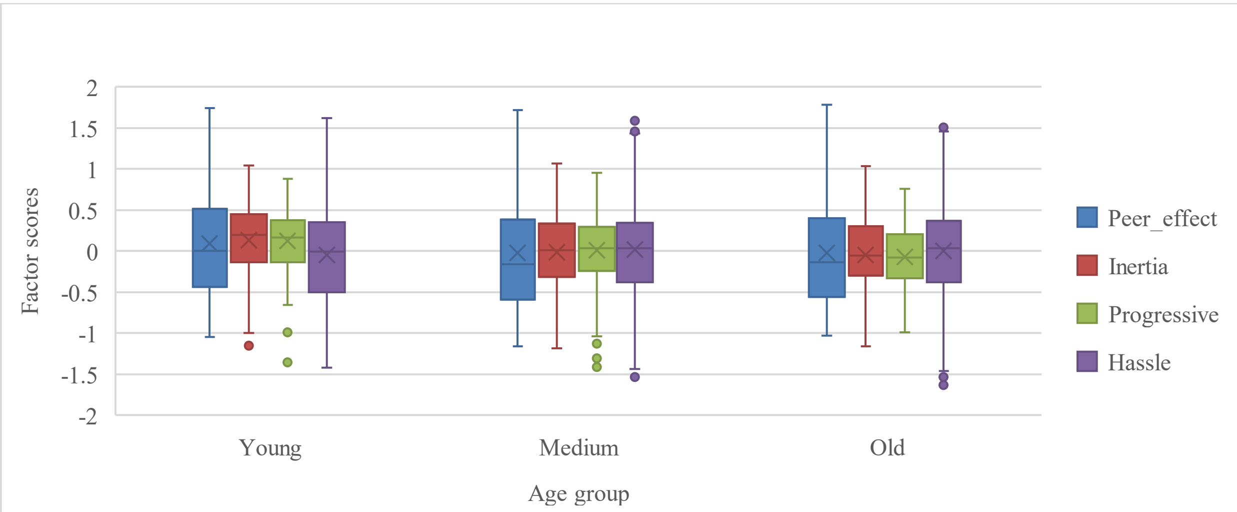

Figure 2: Bar chart showing factor scores of latent variables across different age groups

The respondents from three age groups appear to have distinct views towards the latent behaviours concerning peer effects, behavioural inertia and perception of risks, future preferences, hassles and discomfort towards adoption of CETs. Whereas the younger population appears to score higher on progressive attitudes and peer effects, the older cohorts have higher perceptions of discomfort and inertia scores. Similarly, respondents with higher or professional education appear to be more inclined towards CETs with a positive median score of progressive attitudes and peer effects. In comparison, respondents with primary and secondary education appear to have higher scores on the perception of discomfort and hassle scores.

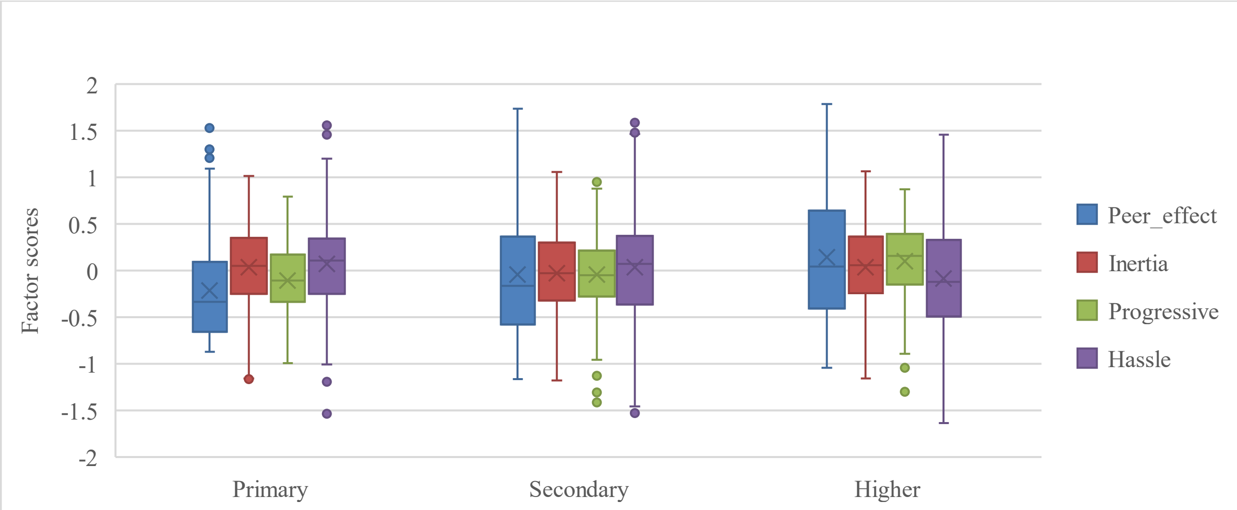

Figure 4: Bar chart showing factor scores of latent variables across different education groups

Interestingly, the perception of behavioural inertia appears to be higher for households with respondents having primary and higher education in comparison to those with secondary education, having small but negative median values.

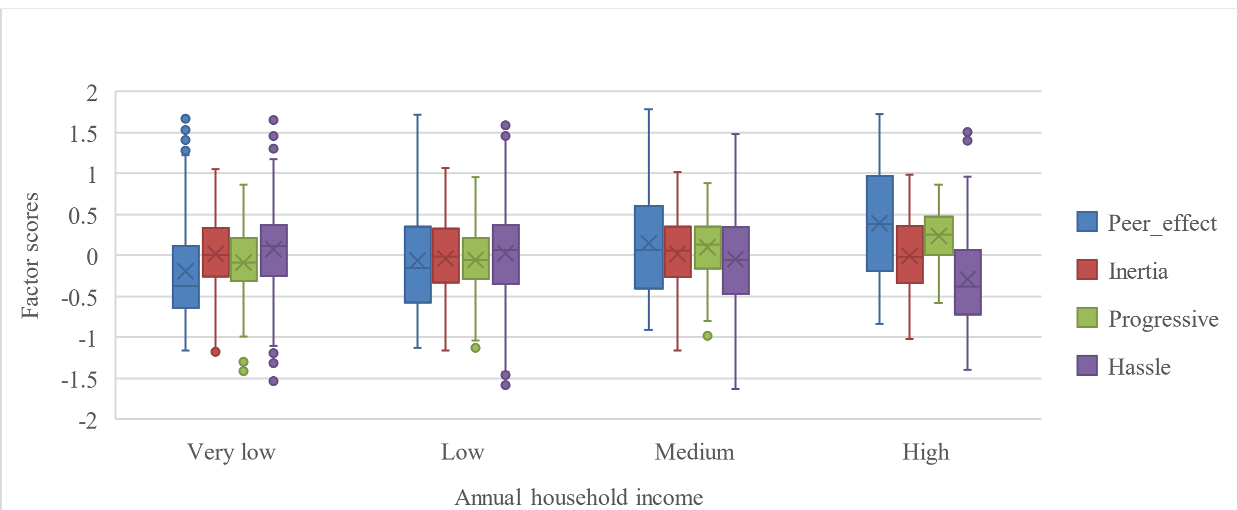

Figure 3: Bar chart showing factor scores of latent variables across different income groups

Among the three different income groups, median scores for progressive attitudes and peer effects are highest for the high-income group followed by the medium-income group, with the low and very low groups having slightly negative values. Further, the median value for the hassle factor score is negative for high-income groups in comparison to positive values for very low and low-income groups, with a negligible negative median score for the medium-income group.

Next, we used the IBM SPSS statistical software version 29.0.2.0 (20) to conduct binomial and ordinal logit regressions (Walker and Duncan, 1967) to compare the actual adoption and adoption preferences for CETs using a mix of key socio-demographic and behavioural characteristics (Models I, II, III and IV). With an original sample size of 1225, the valid number of observations decreased somewhat after taking out the missing values. However, the sample size ranging between 1010 to 774 across different models remained way higher to meet the robustness criteria in terms of its explanatory statistical power. The overall goodness of fit metrics, including tests of parallel slope assumptions for the ordinal logit models are brought out in table 4 below. For the binomial model, the overall model was found to be a good fit with Hosmer–Lemeshow test results failing to reject the null hypothesis and model explaining 18 to 29 percent of the variance. Similarly, the overall models were found to be significant with Pseudo R-squared values ranging from 0.19 to 0.26.

Table 5: Model fitness test results

Model I (All)	Omnibus Tests	Chi-Square	df	Sig.
		206.16	25	<.001
Pseudo R-Square	Cox and Snell	.185	Nagelkerke	.297
Goodness of fit test	(Hosmer and Lemeshow test)	Chi-square	df	Sig.
Step 1		7.227	8	.512
Model II (PV)	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2296.65			
Final	2069.73	226.92	24	<.001
Test of Parallel Lines				
Null Hypothesis	2069.73			
General	1984.28	85.448	72	.133
Pseudo R-Square	Cox and Snell	.254	Nagelkerke	.268
Model III (HP)	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2172.143			
Final	1997.995	174.148	24	<.001
Test of Parallel Lines				
Null Hypothesis	1997.995			

General	1967.096	1.855c	72	1.000
Goodness-of-Fit		Model chi-square	Degrees of freedom (df)	Sig. (p-value)
Pseudo R-Square	Cox and Snell	.192	Nagelkerke	.206
Model IV (EV)	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2351.83			
Final	2142.25	209.57	25	<.001
Test of Parallel Lines				
Null Hypothesis	2142.253			
General	2065.246	77.01	75	.414
Pseudo R-Square	Cox and Snell	.236	Nagelkerke	.248

The odds ratio estimates, standard errors and significance from the regression results for the four models are shown in table 5 below. In Column (1), current adopters were defined as participants who owned at least one of the CETs. Whereas results from ordinal regression on adoption preferences mention respondents who demonstrated that they were likely to purchase a solar PV, heat pumps and electric vehicles are described in Columns (2), (3), and (4), respectively.

Table 5: Binomial and Multinomial logit regression results

	Model I (All)	**Model II (PV)**	**Model III (HP)**	**Model IV (EV)**
Adopted/Preference	Own/adopted	Preference	Preference	Preference
Scale	Two (0,1)	Five (1,2,3,4,5)	Five (1,2,3,4,5)	Five (1,2,3,4,5)
Estimates	Odds ratio (Std. error)	Odds ratio (Std. error)	Odds ratio (Std. error)	Odds ratio (Std. error)
Age group				
Young	Base	1.44 (0.365)	1.81*(0.233)	1.22(0.222)
Medium	0.83 (0.253)	1.55** (0.436)	1.31(0.167)	1.06(0.175)
Old	1.338 (0.295)	Base	Base	Base
Education level				
Primary (base)	Base	0.66 (0.247)	0.96(0.248)	0.40***(0.283)
Secondary	1.16 (0.365)	0.69*(0.161)	0.95(0.16)	0.56***(0.156)
Higher	1.85 (0.385)	Base	Base	Base
Annual household income				
Very low (base)	Base	0.53* (0.323)	1.43(0.318)	0.67(0.308)
Low	1.02 (0.284)	0.57* (0.294)	2.0*(0.287)	0.97(0.267)
Medium	1.23 (0.301)	0.67 (0.285)	2.04**(0.279)	0.76(0.252)
High	3.81*** (0.393)	Base	Base	Base

Peer effects	1.603** (0.179)	1.11 (0.138)	0.57***(0.14)	0.96(0.132)
Inertia	1.181 (0.215)	2.03*** (0.157)	1.70***(0.153)	0.86((0.158)
Progressive	0.675 (0.331)	1.51* (0.228)	1.60*(0.246)	1.6*(0.235)
Hassle	0.533** (0.203)	0.44** (0.148)	0.37***(0.207)	0.49***(0.142)
Identity	1.09(0.132)	1.27*(0.096)	1.22*(0.096)	1.24*(0.095)
Concern	0.911(0.115)	1.15(0.082)	1.24**(0.082)	1.28**(0.084)
Family profile	1.083 (0.059)	1.14** (0.042)	0.1.01(0.044)	0.99***(0.042)
Heat source	4.748** (0.236)	1.41 (0.266)	1.65(0.267)	0.94(0.197)
Region				
Dublin (base)	Base	Base	Base	2.39***(0.232)
Rest of Leinster	0.792 (0.270)	0.52** (0.23)	0.90(0.226)	1.62*(0.221)
Munster	0.932 (0.256)	0.54** (0.21)	0.91(0.209)	1.32(0.216)
Ulster/Connacht	0.818 (0.321)	0.56** (0.20)	1.01(0.206)	Base
Property type				
Terraced house	Base	0.86 (0.216)	1.02(.204)	1.24(0.217)
Semi-detached house	2.34* (0.380)	1.11 (0.171)	1.07(0.163)	1.16(0.167)
Detached house	2.749** (0.443)	Base	Base	Base
Vintage				
Before 1976	Base	0.99 (0.204)	0.52**(0.822)	0.65*(0.199)
1976-1991	0.743 (0.326)	1.14 (0.212)	0.63**(0.823)	0.76(0.211)
1992-2004	1.373 (0.281)	1.33 (0.201)	0.66*(0.822)	1.19(0.186)
After 2005	2.714*** (0.270)	Base	Base	Base
Work from home	1.17 (0.236)	1.13 (0.171)	1.0(0.17)	1.09 (0.157)
Constant/Cutoff	0.018*** (0.710)	0.15***(0.519)	0.80(0.547)	2.37(0.521)
Level 2		0.47(0.515)	2.38(0.548)	6.69***(0.525)
Level 3		3.36*(0.518)	35.77***(0.561)	20.45***(0.531)
Level 4		19.36***(0.525)	163.04***(0.582)	68.44***(0.541)
N	1010	774	817	777

Note: significance codes for p value less than 0.001 '***', 0.01'**', 0.05 '*'

From the binomial regression results in column I, we find a significant contribution by peer effects and hassle factor for households that actually adopted CETs. However, we find that the perceived role of hassle and discomfort reduces the odds of CET adoption in comparison to the favourable role of peer effects. Parenthetically, households that had electricity as the primary source of heating were found to be significant adopters of CETs. Among the socio-demographic factors, higher income groups have a distinct and significant role in CET adoption in comparison to the low-income groups. However, the households distinguished by education levels and age groups of the respondents do not show a significant influence on the actual CET adoption on their own. In terms of the role and significance of the individual behavioural attributes for individual CETs, we find the role of progressive attitudes and pro-environmental identities to be significant in influencing favourable adoption preferences consistent across all CETs. While the role of peer effects is not significantly brought out in adoption preferences of solar PVs and EVs, it appears to be significant in an reverse way. This might be because residents might share and observe favourable and adverse opinions across their social groups, especially for HPs. In comparison, we find the role of hassle and inconvenience as negatively impacting the chances of CET adoption preferences. However, we did not find the role of behavioural inertia as a barrier consistent with previous literature in the context of our study, which future studies might explore further. An important finding from our comparative study is that the intrinsic behavioural factors, such as progressive attitude, environmental concern, and pro-environmental identity are not significant enough on their own to influence actual adoption, although they do play a significant role in the stated preferences to adopt CETs. In comparison, the perception of hassle and discomfort associated with installation or operation for CETs appears to be a barrier reflected consistently across adoption preferences as well as in actual adoption. Further, building attributes like type of building and their vintage appear to have significant association with adoption preference for HPs and EVs. To explore if and how the intrinsic behavioural attributes chosen in our models interact with socio-demographic profiles of the households, we analysed the predicted probabilities of regression outcomes further. For better visibility, we combined the predicted probabilities for the agree and strongly agree outcomes for the adoption preference of individual CETs. Next, we displayed the scatterplots showing changes in model-predicted probabilities for different respondents due to variation in chosen behavioural variables for different subgroups based on age group, annual income and education levels. Figures 5 to 10 below display the scatterplots of cumulative predicted probabilities for behavioural variables found to be significant for adoption preferences separately for individual CETs.

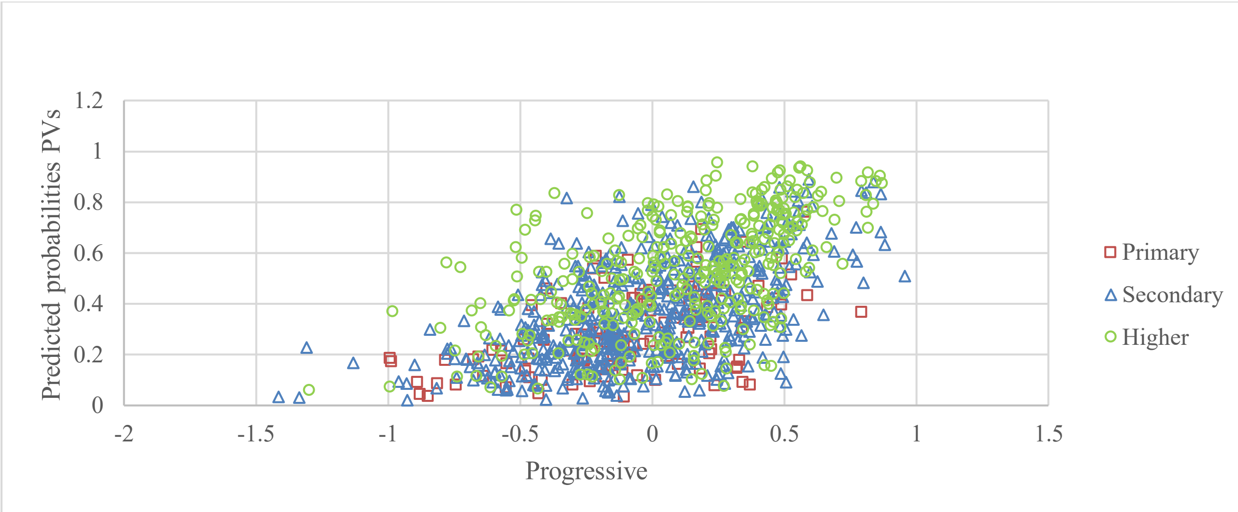

Figure 5: Scatterplot of predicted probabilities of PVs with progressive attitude for different education groups

Education

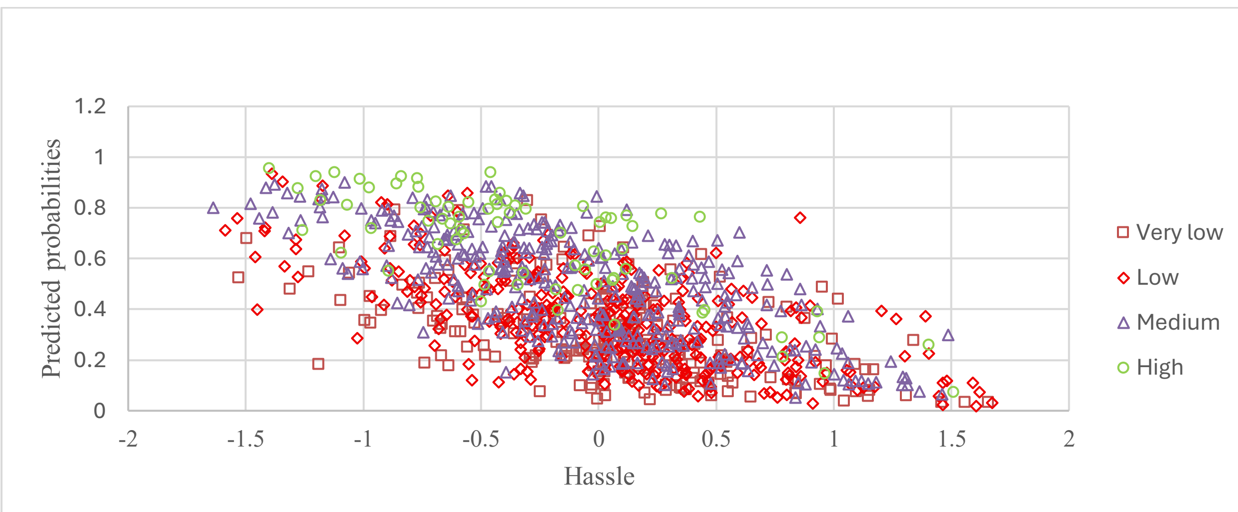

Figure 6: Scatterplot of PV predicted probabilities with hassle factor for different income groups

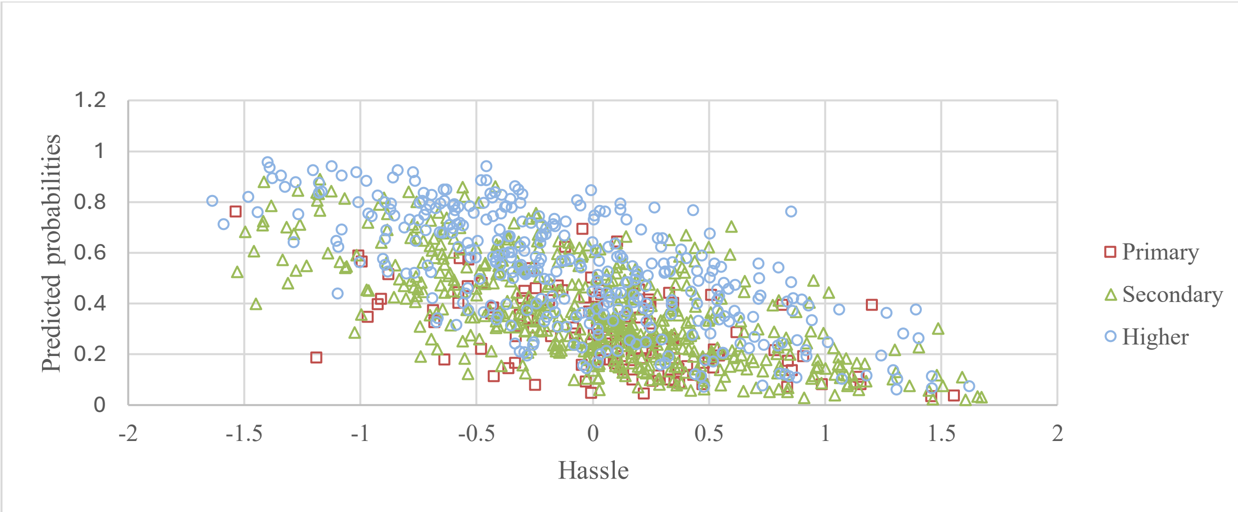

Figure 7: Scatterplot of PV predicted probabilities with hassle factor for different education groups

Ev hassle income below

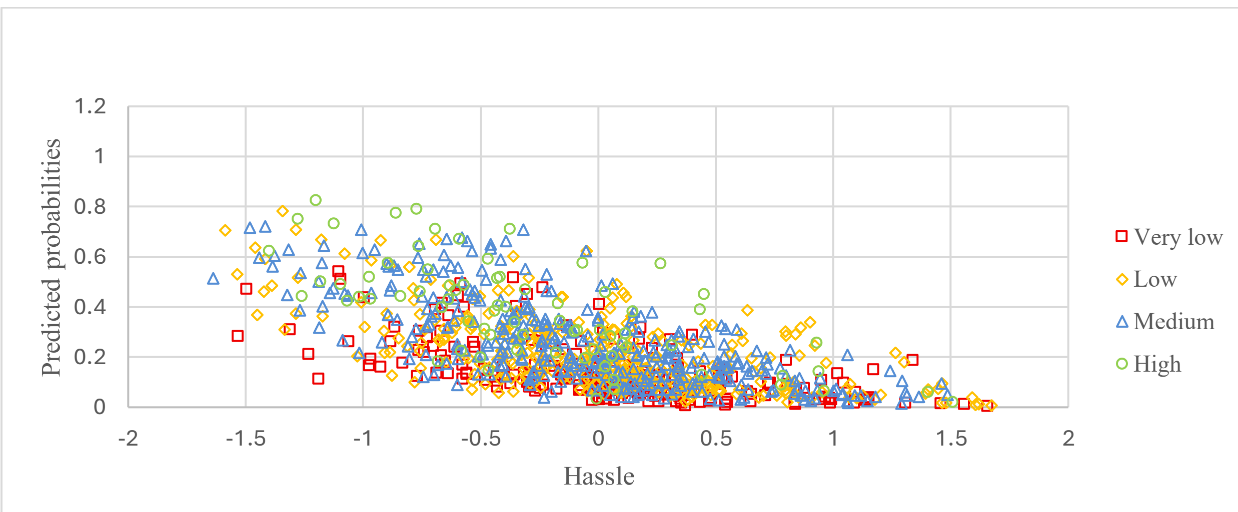

Figure 8: Scatterplot of EV predicted probabilities with hassle factor for different income groups

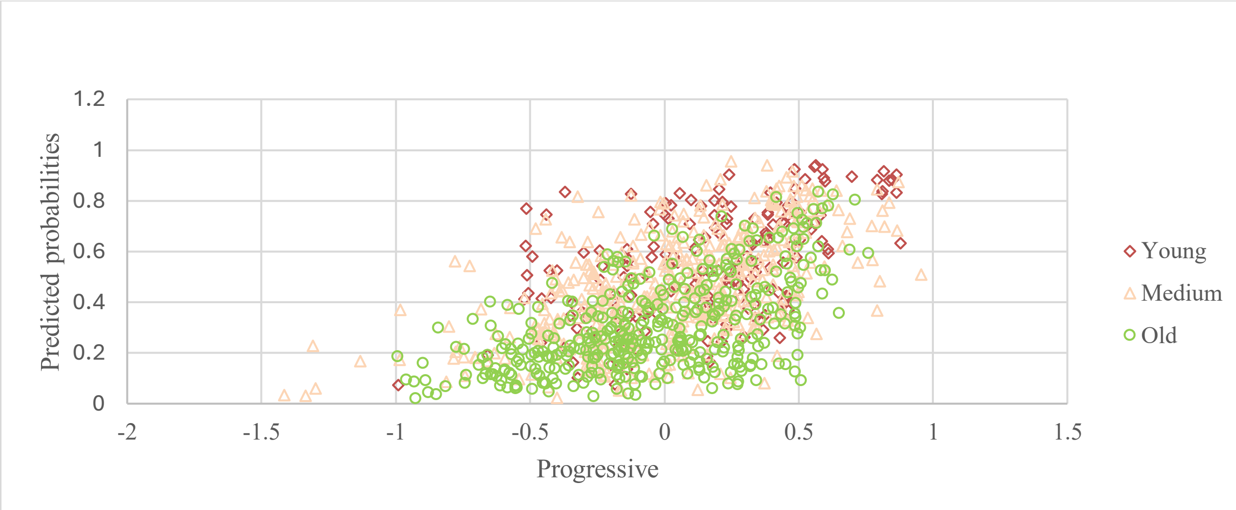

Figure 9: Scatterplot of EV predicted probabilities with progressive attitude for different age groups

Respondents with higher educational levels were found to have a significantly higher likelihood of preference for solar PVs and electric vehicles.

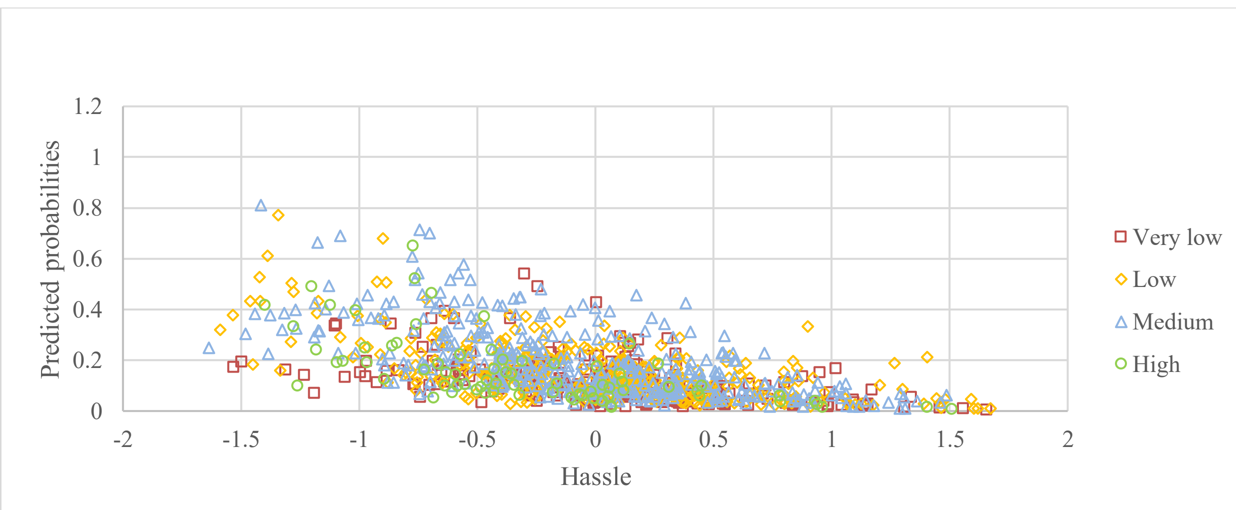

Figure 10: Scatterplot of HP predicted probabilities with hassle factor for different income groups

Together, these plots suggest: (i) predicted probabilities across behavioural variables follow a nonlinear pattern supporting the choice of our regression models, (ii) role of behavioural factors gets moderated by the socio-demographic profiles with younger, high educated respondents with high annual incomes favourably inclines to adopt CETs, and (iii) role of behavioural inertia and annual income on adoption preferences of heat pumps remain inconsistent, requiring future research. An interesting finding with reference to lifestyle and embedded practices was regarding the role of electricity as the primary source of heating, which was found to be a significant factor positively associated with the actual adoption of CETs. Although it was not captured in the survey responses to CET adoption preferences. In comparison, the results from models II, III and IV suggest a consistent but modest association between perception of hassle or discomfort and stated intention to install solar PV and heat pumps. Progressive views towards technology adoption and future preferences are found to be significant for intention to adopt solar PV and electric vehicles, suggesting a higher likelihood of adoption preferences for these technologies by respondents favourably inclined towards novel innovations.

5. Conclusion

A growing body of academic literature and government reports identify the structural barriers in terms of the objects, subjects and actions hindering investments in CETs from multiple disciplinary perspectives (SEAI Report, 2024; MacUidhir, et al., 2022; Mukherjee & Ryan, 2020; SEAI Report, 2020; SEAI Report, 2020; Weber, 1997). Recognising the need for encouraging households to invest in renewable and efficient appliances as well as for switching over to electric heating and public transportation options, these reports also identify topics for more research that influence sustainable energy behaviours. From a climate policy perspective, it is not only important to understand what the observed market and non-market barriers in terms of their willingness to pay or intention for investing in CETs are but also to identify intrinsic factors underlying those barriers in the first place (Sherren, et al., 2021; Claudy, et al., 2010). Recently, Mac Uidhir et al., (2022) studied two key policy targets for rapid diffusion of electric vehicles and significant deep retrofitting of residential buildings by combining the Bass diffusion model and the Low Emissions Analysis Platform (LEAP) modelling program. Their simulation results suggest that unprecedented technology diffusion rates will be required to match Ireland's Climate Action Plan targets (MacUidhir, et al., 2022). Another study on Irish homeowners draws from experiences of solar PV panel deployment across jurisdictions to suggest special and targeted policy measures for different groups, including low-income households (Ryan, et al., 2023). To understand the issues and challenges associated with adoption of CETs in Irish homes, we conducted an empirical study on the nature, role and extent of the intrinsic behavioural factors underlying willingness to purcha CETs based on a comprehensive national survey of Irish households. In our two-step analysis, we first identified four latent behavioural variables, namely, peer effects, progressive attitude, behavioural inertia and hassle factors using confirmatory factor analysis within structural equation modelling framework. Next, we estimated and compared the role, extent and direction of latent behavioural and socio-demographic factors underlying actual adoption versus stated preferences of households towards CETs, while controlling for external attributes using a mix of binomial and ordinal regression models. Our study has several theoretical and analytical limitations. An obvious limitation is regarding the scope of ascertaining adoption preference using hypothetical survey questions, subject to response biases. It is also important to note that our sample with a positively skewed annual income distribution may not be representative at the national scale. Further, behavioural variables used in our study are based on stated responses of respondents to survey questions that are prone to social desirability bias (Vesely & Klöckner, 2020; Volland, 2017). We also assumed that the role of external factors, such as market prices, availability of incentives and infrastructure will either be consistent across studied households or will be captured in terms of their paying capacity linked to annual household income. As such, the results from this study will have to be carefully interpreted. Future studies might also explore the nature and extent of CET adoption based on theory on conspicuous diffusion, which our review identified but could not test empirically for want of sufficient information.

Despite these limitations, our results suggest a clear distinction between factors underlying adoption of technologies and their stated preferences to adopt. It also reveals a distinction between the role, nature and extent of behavioural and socio-demographic factors across three technologies. We find significant relationship between progressive attitudes and adoption preference for solar PV adoption, which also appears to be moderated by the annual income, education level and age group of respondents in a non-linear manner, requiring further research. Further, the behavioural factors such as discomfort and hassle factors appear to be acting in opposite directions to the generally favourable pro-environmental concerns towards sustainable technologies. Our study suggests a significant association between the latent behavioural factors, such as peer effects and progressive attitude, with adoption preference for CET adoption but also cautions that they do not translate on their own for actual adoption, requiring more nuanced and targeted policy measures. In sum, we find that the overall process of CET adoption is more likely to be a result of opposing intrinsic behavioural tendencies that drive or hinder the willingness to pay, depending on their perceived lifecycle benefits over costs after taking into account the external contexts and peer effects for individual technologies. We believe that our study will not only address an important literature gap in Irish residential households' behaviours in terms of their adoption of CETs but also provide useful insights for better informed policy decisions in the future.

References

Ó Maonaigh, C., 2023. Cross-class alliances and the rise of electric vehicles in Dublin. *Human Geography,* 16(3), pp. 260-272.

Abrardi, L., 2019. Behavioral barriers and the energy efficiency gap: a survey of the literature. *Economia e Politica Industriale: Journal of Industrial and Business Economics,* 46(1), pp. 25-43.

Ajzen, I., 1991. The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes,* pp. 179-211.

Alipour, M., Salim, H., Stewart, R. A. & Sahin, O., 2020. Predictors, taxonomy of predictors, and correlations of predictors with the decision behaviour of residential solar photovoltaics adoption: A review. *Renewable and Sustainable Energy Reviews,* Volume 123, p. 109749.

Ang, J. B., Fredriksson, P. G. & Sharma, S., 2020. Individualism and the adoption of clean energy technology. *Resource and Energy Economics,* Volume 61, p. 101180.

Antonopoulos, C. A. et al., 2024. Regional assessment of household energy decision-making and technology adoption in the United States. *Energy Policy,* Volume 185, p. 113940.

Bass, F., 1969. A New Product Growth Model for Consumer Durable. *Management Science,* 15(5), pp. 215-227.

Batel, S., 2020. Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Research & Social Science,* Volume 68, p. 101544.

Blake, J., 1999. Overcoming the 'value-action gap' in environmental policy: Tensions between national policy and local experience. *Local Environment: The International Journal of Justice and Sustainability,* 4(3), pp. 257-278.

Blasch, J. & Daminato, C., 2020. Behavioral Anomalies and Energy-related Individual Choices: The Role of Status-quo Bias. *The Energy Journal,* 9 November.pp. 181-214.

Bollen, K. A. & Noble, M. D., 2011. Structural equation models and the quantification of behavior. *Proceedings of the National Academy of Sciences,* 108(3), pp. 15639-15646.

Brennan, N. & Rensburg, T. M. V., 2016. Wind farm externalities and public preferences for community consultation in Ireland: A discrete choice experiments approach. *Energy Policy,* Volume 94, pp. 355-365.

Brown, M. A. & Sovacool, B. K., 2018. Theorizing the Behavioral Dimension of Energy Consumption: Energy Efficiency and the Value-Action Gap. In: *Oxford Handbook of Energy and Society.* Online: Oxford University Press, pp. 1-29.

Bryman, A., 2016. *Social Research Methods.* New York: Oxford University Press, 5th edition.

Bull, S. et al., 2025. Electric vehicles and rooftop solar energy: Consumption values influencing decisions and barriers to co-adoption in the United States. *Energy Research & Social Science,* Volume 122, p. 103990.

Byrka, K., 2009. *Attitude-behavior consistency : Campbell's paradigm in environmental and health domains.* [Online]
Available at: https://research.tue.nl/nl/publications/attitude-behavior-consistency-campbells-paradigm-in-environmental
[Accessed July 2021].

Caggiano, H. B. et al., 2021. Explaining green technology purchases by US and Canadian households: the role of pro-environmental lifestyles, values, and environmental concern. *Energy Efficiency,* 14(46), pp. 1-16.

CAP, 2024. *Climate Action Plan 2024.* [Online]
Available at: https://assets.gov.ie/296414/7a06bae1-4c1c-4cdc-ac36-978e3119362e.pdf

Charly, A. et al., 2024. Evaluating the readiness for electric vehicle adoption among the urban population using geospatial techniques. *Journal of Transport Geography,* Volume 119, p. 103972.

Claudy, M. C., Michelsen, C., O'Driscoll, A. & Mullen, M. R., 2010. Consumer awareness in the adoption of microgeneration technologies An empirical investigation in the Republic of Ireland. *Renewable and Sustainable Energy Reviews,* Volume 14, pp. 2154-2160.

Claudy, M. C., Peterson, M. & O'Driscoll, A., 2013. Understanding the Attitude-Behavior Gap for Renewable Energy Systems Using Behavioral Reasoning Theory. *Journal of Macromarketing,* 33(4), pp. 273-287.

Coffman, M., Bernstein, P. & Wee, S., 2017. Electric vehicles revisited: a review of factors that affect adoption. 37(1), pp. 79-93.

Courtenay-Hall, P. & Rogers, L., 2002. Gaps in Mind: Problems in environmental knowledge-behaviour modelling research. *Environmental Education Research,* 8(3), pp. 283-297.

CSO , 2025. *CSO statistical release online ISSN: 2009-5678.* [Online]
Available at: https://www.cso.ie/en/releasesandpublications/ep/p-vlftm/vehicleslicensedforthefirsttimemarch2025/
[Accessed 14 September 2025].

Davis, F. D., 1993. User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International Journal Man-Machine Studies,* Volume 38, pp. 475-487.

DCEE Report, 2024. *Climate Conversations: Summary Report.* [Online]
Available at: https://assets.gov.ie/static/documents/climate-conversations-2023-summary-report.pdf

Dermody, J., Koenig-Lewis, N., Zhao, A. L. & Hanmer-Lloyd, S., 2018. Appraising the influence of pro-environmental self-identity on sustainable consumption buying and curtailment in emerging markets: Evidence from China and Poland. *Journal of Business Research,* Volume 86, pp. 333-343.

Domingues, J. P. M. & Silva, C. F. d., 2025. *Acceptance and Use of Smart Home Technologies: A Focus on Portugal.* Singapore, Springer Nature Singapore Pte Ltd. , pp. 359-370.

Dong, L., Hardman, S., Firestone, J. & Bunch, D. S., 2025. Clean Technology Adoption Preferences: Integrated Analysis of Co-adoption of Electric Vehicles and Solar Panels. *Transportation Letters,* p. 2537849.

Egbue, O. & Long, S., 2012. Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy,* Volume 48, pp. 717-729.

Egmond, C. & Bruel, R., 2007. *Nothing is as practical as a good theory, Analysis of theories and a tool for developing interventions to influence energy-related behaviour.* [Online]
Available at: http://www.cres.gr/behave/pdf/paper_final_draft_CE1309.pdf

EIA Review, 2022. *Monthly Energy Review.* [Online]
Available at: https://www.eia.gov/totalenergy/data/monthly/pdf/sec2_3.pdf
[Accessed May 2022].

Eppe, P. S., Niehoff, E., Albers, C. & Bouman, T., 2025. Sustainable energy technology adoption for a low-carbon future: A global meta-analysis of psychological determinants. *Energy Research & Social Science,* Volume 126, p. 104152.

EU Commission Report, 2023. *Report from the Commission to the European Parliament and the Council.* [Online]
Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023DC0652
[Accessed September 2025].

Farrell, N. & Lyons, S., 2015. Who should pay for renewable energy? Comparing the household impacts of different policy mechanisms in Ireland. *Energy Research & Social Science,* Volume 7, pp. 31-42.

Fishbein, M. & Ajzen, I., 1975. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.* Reading,MA: Addison-Wesley. .

Frederiks, E. R., Stenner, K. & Hobman, E. V., 2015. Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews,* Volume 41, pp. 1385-1394.

Görsch, R., Perlaviciute, G. & Steg, L., 2025. A systematic review of public acceptability and perceived impacts of eleven energy sources and mitigation technologies. *Global Environmental Change,* Volume 93, p. 103014.

Galster, H. et al., 2025. A comprehensive review of integrating behavioral drivers of technology adoption and energy service use in energy system models. *Renewable and Sustainable Energy Reviews,* Volume 214, p. 115520.

Garrard, J., 2011. *Health sciences literature review made easy: the matrix method.* 3rd edition. ed. Sudbury, MA: Jones and Bartlett Publishers.

Gerarden, T. D., Newell, R. G. & Stavins, N. R., 2017. Assessing the Energy Efficiency Gap. *Journal of Economic Literature,* 55(4), pp. 1486-1525.

Graziano, M. & Gillingham, K., 2015. Spatial patterns of solar photovoltaic system adoption: The influence of neighbors and the built environment. *Journal of Economic Geography,* Volume 15, pp. 815-839.

Groves, R. M. et al., 2009. *Survey Methodology.* 2nd Edition ed. Hoboken, New Jersey: Wiley.

Hansen, A. R., Trotta, G. & Gram-Hanssen, K., 2024. Smart home technology adoption in Denmark: Diffusion, social differences, and energy consumption. *Energy Efficiency,* Volume 17, pp. 1-16.

Higgins, A., Paevere, P., Gardner, J. & Quezada, G., 2012. Combining choice modelling and multi-criteria analysis for technology diffusion: An application to the uptake of electric vehicles. *Technological Forecasting & Social Change,* 79(8), pp. 1399-1412.

Hoyle, R., 1995. *Structural Equation Modeling: Concepts, Issues, and Applications.* London.Delhi: SAGE Publications.

IEA, 2024. *International Energy Agency.* [Online]
Available at: https://www.iea.org/reports/energy-technology-perspectives-2024

Ivanova, D. et al., 2020. Quantifying the potential for climate change mitigation of consumption options. *Environmental Research Letters,* 15(9), p. 093001.

Jacksohn, A., Grösche, P., Rehdanz, K. & Schröder, C., 2019. Drivers of renewable technology adoption in the household sector. *Energy Economics,* Volume 81, pp. 216-226.

Jaffe, A. & Stavins, R., 1994. The energy-efficiency gap. *Energy Policy,* 22(10), pp. 804-810.

Kahneman, D., Knetsch, J. L. & Thaler, R. H., 1991. Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias. *The Journal of Economic Perspectives,* 5(1), pp. 193-206.

Kahneman, D. & Tversky, A., 1979. Prospect Theory: An Analysis of Decision under Risk. *Econometrica, Vol. 47, No. 2,* pp. 263-292.

Klopper, R., Lubbe, S. & Rugbeer, H., 2007. The Matrix Method of Literature Review. *Alternation,* 14(1), pp. 262-276.

Kollmuss, A. & Agyeman, J., 2002. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior?. *Environmental Education Research,* 8(3), pp. 239-260.

Kowalska-Pyzalska, A. et al., 2014. Turning green: Agent-based modeling of the adoption of dynamic electricity tariffs. *Energy Policy,* Volume 72, pp. 164-174.

Krause, M., 2016. Comparative research: beyond linear-casual explanation. In: *Practising Comparison: Logics, Relations, Collaborations.* Manchester, UK: Mattering Press, pp. 45-67.

Kumar, P. et al., 2025. Reflections on Energy Efficiency Policies in Sustainable Transition: Bedrock, Gamechanger, or More of the Same?. *Environmental Policy and Governance,* Volume 0, pp. 1-19.

La Monaca, S. & Ryan, L., 2017. Solar PV where the sun doesn't shine: Estimating the economic impacts of support schemes for residential PV with detailed net demand profiling. *Energy Policy,* Volume 108, pp. 731-741.

La Monaca, S. & Ryan, L., 2022. The state of play in electric vehicle charging services – A review of infrastructure provision, players, and policies. *Renewable and Sustainable Energy Reviews,* Volume 154, p. 111733.

Leahy, E. & Lyons, S., 2010. Energy use and appliance ownership in Ireland. *Energy Policy,* Volume 38, pp. 4265-4279.

Li, J., Liu, M. & Liu, X., 2016. Why do employees resist knowledge management systems? An empirical study from the status quo bias and inertia perspectives. *Computers in Human Behavior,* Volume 65, pp. 189-200.

Little, D., 2023. Causation in the Social Realm:A Pluralist Toolbox. In: A. Damonte & F. Negri, eds. *Causality in Policy Studies.* Cham, Switzerland: Springer, pp. 11-36.

Long, J., 1997. *Regression Models for Categorical and Limited Dependent Variables.* London.New Delhi: SAGE Publications.

Lorenzen, J. A., 2012. Going Green: The Process of Lifestyle Change. *Sociological Forum,* 27(1), pp. 94-116.

MacUidhir, T.´., Gallachoir, B. O., Curtis, J. & Rogan, F., 2022. Achieving the unprecedented: Modelling diffusion pathways for ambitious climate policy targets. *Energy and Climate Change,* Volume 3, p. 100073.

Meles, T. H. & Ryan, L., 2022. Adoption of renewable home heating systems: An agent-based model of heat pumps in Ireland. *Renewable and Sustainable Energy Reviews,* Volume 169, p. 112853.

Milani, A., Dessi, F. & Bonaiuto, M., 2024. A meta-analysis on the drivers and barriers to the social acceptance of renewable and sustainable energy technologies. *Energy Research & Social Science,* Volume 114, p. 103624.

Mill, J. S., 1843. *A System Of Logic, Ratiocinative And Inductive:Being a Connected View of the Principles of Evidence, and the Methods of Scientific Investigation.* Cambridge, UK: Cambridge University Press.

Moezzi, M. & Lutzenhiser, L., 2019. Beyond energy behaviour: A broader way to see people for climate change technology planning. In: *Energy and Behaviour Towards a Low Carbon Future.* s.l.:Academic Press, Elsevier Inc., pp. 89-106.

Mueller, R. O., 1996. *Basic Principles of Structural Equation Modeling: An Introduction to LISREL and EQS.* New York, USA: Springer-Verlag New York, Inc..

Mukherjee, S. C. & Ryan, L., 2020. Factors influencing early battery electric vehicle adoption in Ireland. *Renewable and Sustainable Energy Reviews,* Volume 118, p. 109504.

Noel, L., Sovacool, B. K., Kester, J. & Rubens, G. Z. d., 2019. Conspicuous diffusion: Theorizing how status drives innovation in electric mobility. *Environmental Innovation and Societal Transitions,* Volume 31, pp. 154-169.

O'Donoghue, T. & Rabin, M., 1999. Doing It Now or Later. *The American Economic Review,* 89(1), pp. 103-124.

Ozkaya, B., 2022. *Introduction to a New Journal: Clean Energy Technologies Journal (CETJ).* [Online]
Available at: https://dergipark.org.tr/en/pub/cetj/about-journal

Penaloza, D. et al., 2022. Social and market acceptance of photovoltaic panels and heat pumps in Europe: A literature review and survey. *Renewable and Sustainable Energy Reviews,* Volume 155, p. 111867.

Plötz, P., Schneider, U., Globisch, J. & Dütschke, E., 2014. Who will buy electric vehicles? Identifying early adopters in Germany. *Transportation Research Part A,* Volume 67, pp. 96-109.

Przeworski, A. & Teune, H., 1970. *The Logic of Comparative Social Inquiry.* New York: John Wiley & Sons, Inc..

Psarra, I., Turhan, E. & Ghassemialiabadi, F., 2024. Zero carbon, some nuisance: Exploring the viewpoints of heat pump owners and their neighbors in Groningen, Netherlands. *Energy Sources, Part B: Economics, Planning, and Policy,* 19(1), p. 2421924.

Ragin, C. C., 1987. *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies.* Oakland, California: University of California Press.

Rajecki, D. W., 1982. *Attitudes: themes and advances.* Sunderland, MA. : Sinauer Associates, Inc. .

Rana, M. et al., 2025. Understanding the adoption of renewable energy technologies by households in South Asia: a theory of planned behavior perspective. *Discover Sustainability,* Volume 6, p. 477.

Reguant, M. & Fabra, N., 2022. *Assessing the distributional effects of real-time pricing for electricity.* [Online]
Available at: https://cepr.org/voxeu/columns/assessing-distributional-effects-real-time-pricing-electricity

Robbennolt, D., Hardman, S., Firestone, J. & Bhat, C. R., 2025. A model of electric vehicle adoption and motivating reasons for adoption. *Transportation Research Part D:Transport and Environmen,* Volume 146, p. 104906.

Rogers, E. M., 1962. Classifying adopter categories on the basis of innovativeness. In: *Diffusion of Innovations.* New York, London: The Free Press, pp. 241-263.

Ryan, L., Monaca, S. L., Mastrandrea, L. & Spodniak, P., 2018. *Harnessing Electricity Retail Tariffs to Support Climate Change Policy.* [Online]
Available at: https://www.ucd.ie/economics/t4media/WP18_22.pdf

Ryan, L., Wheatley, J. & Saba, N., 2023. *A Review of Policies for the Rollout of Rooftop Solar PV in Ireland.* [Online]
Available at: https://www.climatecouncil.ie/councilpublications/councilworkingpaperseries/WORKIN~2.PDF

Schelly, C., 2014. Residential solar electricity adoption: What motivates, and what matters? A case study of early adopters. *Energy Research & Social Science,* Volume 2, pp. 183-191.

Schriewer, J., 2021. Comparison and explanation: a long saga. *Comparative Education,* pp. 1-7.

Schulte, E., Scheller, F., Sloot, D. & Bruckner, T., 2022. A meta-analysis of residential PV adoption: the important role of perceived benefits, intentions and antecedents in solar energy acceptance. *Energy Research & Social Science,* Volume 84, p. 102339.

Schumacker, R. E. & Lomax, R. G., 2016. *A Beginner's Guide to Structural Equation Modeling.* New York: Routledge-Taylor & Francis Group.

Schwartz, S. H., 1977. *Normative Influence on Altruism.* Wisconsin: University of Wisconsin Madison.

SEAI Report, 2020. *Driving Purchases of Electric Vehicles in Ireland A Behavioural Economics Perspective.* [Online]
Available at: https://www.seai.ie/sites/default/files/publications/Driving-Purchases-of-Electric-Vehicles-in-Ireland.pdf

SEAI Report, 2020. *Encouraging heat pump installations in Ireland:Strategies to maximise heat pump installation and the savings produced Behavioural Insights Paper Series.* [Online]
Available at: https://www.seai.ie/sites/default/files/data-and-insights/behavioural-insights/publications/heatpump-adoption-survey/Encouraging-heat-pump-adoption-homeowner-survey.pdf

SEAI Report, 2024. *Encouraging heat pump adoption in heat pump ready oil-heated homes.* [Online]
Available at: https://www.seai.ie/sites/default/files/data-and-insights/behavioural-insights/publications/heatpump-adoption-survey/Encouraging-heat-pump-adoption-homeowner-survey.pdf

SEAI, 2025. *Annual Energy Data - Residential.* [Online]
Available at: https://www.seai.ie/data-and-insights/seai-statistics/residential
[Accessed 14 September 2025].

Shakeel, S. R., Yousaf, H., Irfan, M. & Rajala, A., 2023. Solar PV adoption at household level: Insights based on a systematic literature review. *Energy Strategy Reviews,* Volume 50, p. 101178.

Sherren, K., Chappell, E. & Parkins, J., 2021. Chapter 2: Strategies for Integrating Quantitative Methods into Critical Social Acceptance Research. In: *A critical approach to the social acceptance of renewable energy infrastructures: Going beyond green growth and sustainability.* Cham: Springer International Publishing, pp. 23-42.

Sheth, J. N., Newman, B. I. & Gross, B. L., 1991. Why We Buy What We Buy: A Theory of Consumption Values. *Journal of Business Research,* 22(2), pp. 159-170.

Shove, E., 2018. What is wrong with energy efficiency?. *Building Research & Information,* 46(7), pp. 779-789.

Snape, J., Boait, P. & Rylatt, R., 2015. Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling. *Energy Policy,* Volume 85, pp. 32-38.

Spandagos, C., Rea˜nos, M. A. T. & Lynch, M. A.´., 2022. Public acceptance of sustainable energy innovations in the European Union: A multidimensional comparative framework for national policy. *Journal of Cleaner Production,* Volume 340, p. 130721.

Steg, L., Shwom, R. & Dietz, T., 2018. What Drives Energy Consumers?: Engaging People in a Sustainable Energy Transition. *IEEE Power and Energy Magazine*, 5 January, 16(1), pp. 20-28.

Stern, P. C., 2000. Toward a Coherent Theory of Environmentally Significant Behavior. *The Society for the Psychological Study of Social Issues,* 56(3), pp. 407-424.

Strazzera, E., Meleddu, D., Contu, D. & Fornara, F., 2024. Willingness to pay for innovative heating/cooling systems: A comprehensive appraisal of drivers and barriers to adoption in Ireland and Italy. *Renewable and Sustainable Energy Reviews,* Volume 192, p. 114192.

Stuhm, P., Baumann, M. J. & Weil, M., 2025. Approaching social acceptance of energy technologies: ten European papers showcasing statistical analyses–a targeted review. *Energy, Sustainability and Society,* 15(1), pp. 1-30.

Thollander, P., Palm, J. & Rohdin, P., 2010. Categorizing Barriers to Energy Efficiency: An Interdisciplinary Perspective. In: *Energy Efficiency.* s.l.:IntechOpen, pp. 49-62.

UCLA, 2021. *Statistical Methods & Data Analysis.* [Online]
Available at: https://stats.oarc.ucla.edu/r/dae/ordinal-logistic-regression/

Veblen, T., 1900. *Conspicuous Consumption in The Theory of the Leisure Class.* Online: EliScholar, Yale University Library.

Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D., 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, 27(3), pp. 425-478.

Vesely, S. & Klöckner, C. A., 2020. Social Desirability in Environmental Psychology Research: Three Meta-Analyses. *Frontiers in Psychology,* Volume 11, p. 1395.

Weber, L., 1997. Some reflections on barriers to the efficient use of energy. *Energy Policy,* 25(10), pp. 833-835.

Wenzelburger, G. & Jensen, C., 2022. Comparative Public Policy Analysis: Shortcomings, Pitfalls, and Avenues for the Future. *Polit Vierteljahresschr,* Volume 63, pp. 295-313.

Werff, E. v. d., Steg, L. & Keizer, K., 2013. It is a moral issue: The relationship between environmental self-identity, obligation-based intrinsic motivation and pro-environmental behaviour. *Global Environmental Change,* Volume 23, pp. 1258-1265.

Werff, E. v. d., Steg, L. & Keizer, K., 2013. The value of environmental self-identity: The relationship between biospheric values, environmental self-identity and environmental preferences, intentions and behaviour. *Journal of Environmental Psychology,* Volume 34, pp. 55-63.

Wheatley, J., Doorly, M., Ryan, L. & Meles, T. H., 2022. *Clean energy technology adoption – policy analysis for a cleaner future.* [Online]
Available at: https://publicpolicy.ie/environment/clean-energy-technology-adoption-policy-analysis-for-a-cleaner-future/

Whitmarsh, L. & O'Neill, S., 2010. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. *Journal of Environmental Psychology,* 30(3), pp. 305-314.

Zeckhauser, R. J. & Samuelson, W., 1988. Status Quo Bias in Decision Making. *Journal of Risk and Uncertainty,* 1(1), pp. 7-59.

Appendix

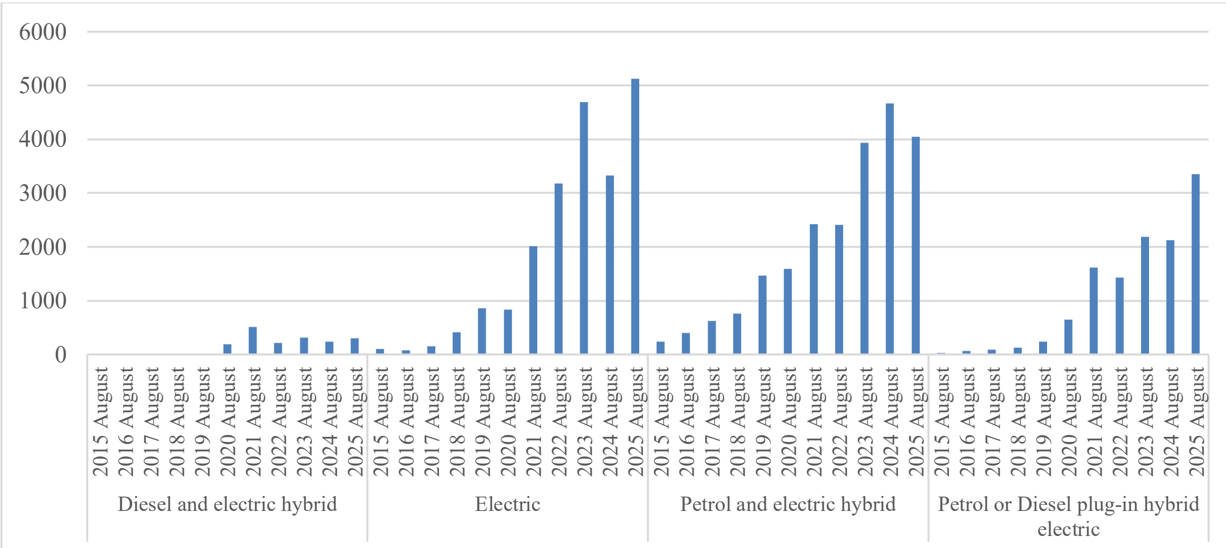

Figure A1: Year-wise licensing trend for different types of electric vehicles. Source: Central Statistics Office (CSO), Ireland, https://www.cso.ie/en/releasesandpublications/ep/p-vlftm/vehicleslicensedforthefirsttimemarch2025/

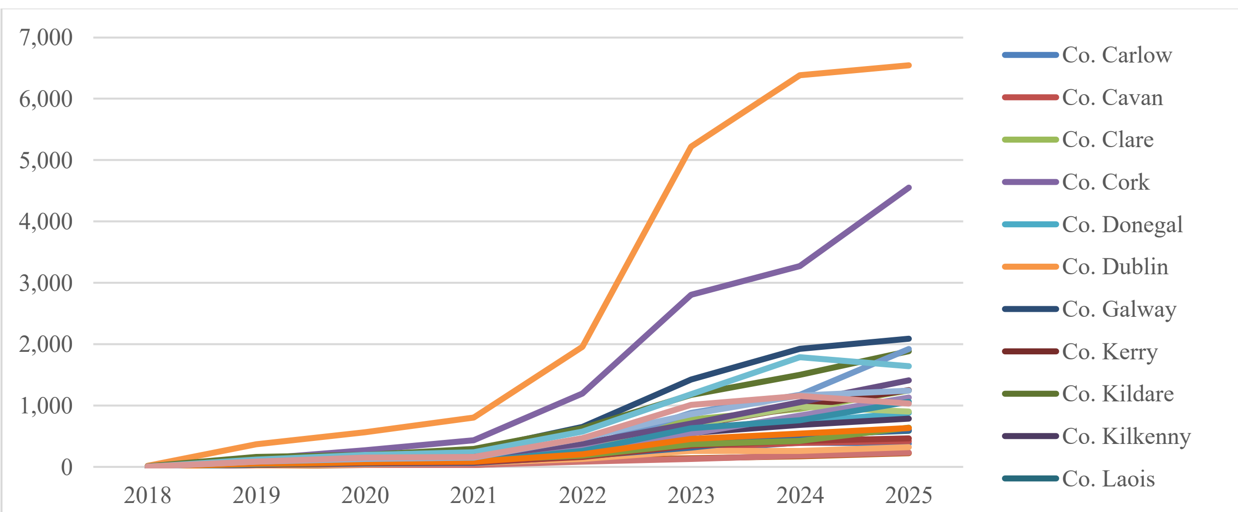

Figure A2: Annual county-wise solar PV installation measures. Source: Sustainable Energy Authority of Ireland (SEAI),https://www.seai.ie/grants/home-energy-grants/home-upgrades.Note:include measures installed under National Home Retrofit Programmes-Community energy grants scheme, National home energy upgrade scheme, Solar PV scheme excluding warmer home scheme up to 31.12.2025.

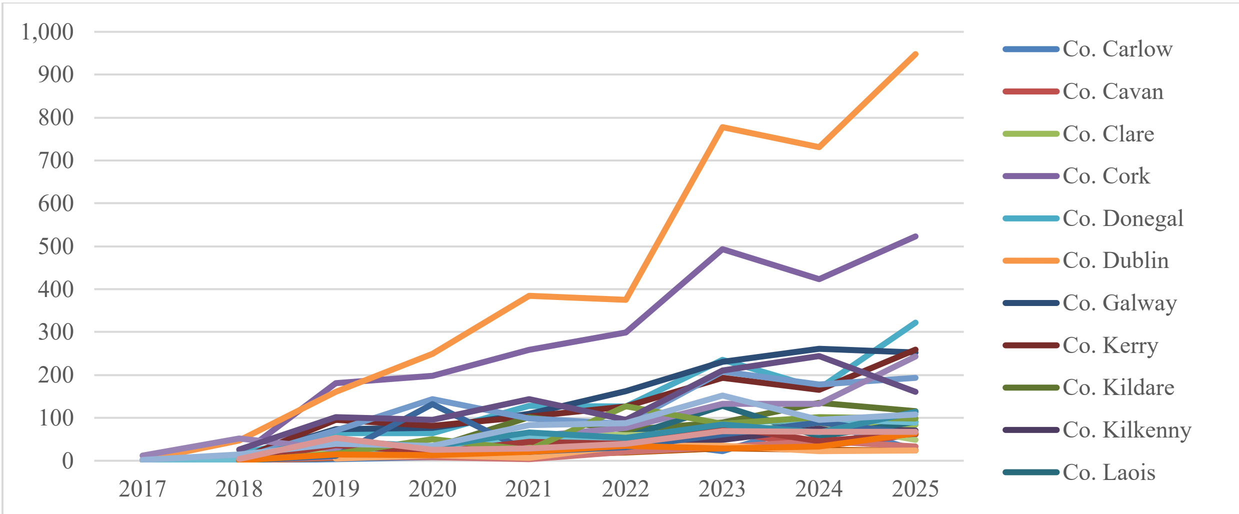

Figure A3: Annual county-wise HP installation measures. Source: Sustainable Energy Authority of Ireland (SEAI), Ireland,https://www.seai.ie/grants/home-energy-grants/home-upgrades.Note:include measures installed under National Home Retrofit Programmes-Community energy grants scheme, National home energy upgrade scheme, Solar PV scheme excluding warmer home scheme up to 31.12.2025.

UCD CENTRE FOR ECONOMIC RESEARCH – RECENT WORKING PAPERS
SRAITH PÁIPÉAR OIBRE AN IONAID UM THAIGHDE EACNAMAÍOCHTA COBÁC

WP25/02 Zilong Li: 'International and Domestic Border Effects in China: Multilateral Resistances, Trade Substitution Patterns and Linguistic Differences' March 2025
WP25/03 Karl Whelan: 'The Gambler's Ruin with Asymmetric Payoffs' March 2025
WP25/04 David Madden: 'What Factors Are Associated with the Decline in Young People's Mental Health During the Early Stages of the Covid Pandemic?' March 2025
WP25/05 Zilong Li: 'Home Bias in Trade within China: The Role of Trust' March 2025
WP25/06 Bing Guo, Sarah Parlane, Lisa Ryan: 'Regulatory Compliance in the Automobile Industry' March 2025
WP25/07 Zhiyong Huang, Fabrice Kämpfen: 'Do Health Check-Ups for Seniors Improve Diagnosis and Management of Hypertension and Diabetes in China?' April 2025
WP25/08 Bernardo S. Buarque, Ronald B. Davies, Ryan M. Hynes, Gianluca Tarasconi, Dieter F. Kogler: 'The Uneven Regional Geography of Telecommunication Standard Essential Patents' April 2025
WP25/09 Ronald B. Davies: 'Deriving the Trump Tariffs' April 2025
WP25/10 Ciarán Mac Domhnaill, Lisa Ryan, Ewa Lazarczyk: 'When markets merge: evidence from Ireland's integration with the European wholesale electricity market' April 2025
WP25/11 Sara Amoroso, Ronald B. Davies: 'M&As and Innovation: A New Approach to Classifying Technology' April 2025
WP25/12 Margaret Samahita, Martina Zanella: 'Confident, but undervalued: evidence from the Irish Economic Association Conference' April 2025
WP25/13 Xidong Guo, Zilong Li, Zuzanna Studnicka, Jiming Zhu: 'Environmental Unfamiliarity and Work Performance: Evidence from Chinese Basketball during COVID-19' June 2025
WP25/14 Ronald B. Davies, Gianluca Santoni, Farid Toubal, Giulio Vannelli: 'Multinational Network, Innovation and the Growth of Employment' July 2025
WP25/15 Patrick Honohan, Cormac Ó Gráda: 'PETER NEARY James Peter Neary 11 February 1950 –16 June 2021' June 2025
WP25/16 Ronald B. Davies, Mahdi Ghodsi, Francesca Guadagno: 'Innovation interactions: multinational spillovers and local absorptive capacity' June 2025
WP25/17 Yota D. Deli, Manthos D. Delis, Adele Whelan: 'Education and Credit' June 2025
WP25/18 Yota Deli, Manthos D. Delis, Iftekhar Hasan, Panagiotis N. Politsidis, Anthony Saunders: 'Corporate tax changes and credit costs' July 2025
WP25/19 Constantin Bürgi, Wanying Deng, Karl Whelan: 'Makers and Takers: The Economics of the Kalshi Prediction Market' July 2025
WP25/20 Chiara Castelli, Ronald B. Davies, Mahdi Ghodsi, Javier Flórez Mendoza: 'Drivers of Foreign Direct Investment in the EU: Regulatory Distance and Revealed Technological Advantage' July 2025
WP25/21 David Madden: 'Mental Health Resilience During the Covid Pandemic: Evidence from a Sample of Irish Women' August 2025
WP25/22 Karl Whelan: 'Agreeing to Disagree: The Economics of Betting Exchanges' September 2025
WP25/23 Ronald B. Davies: 'Innovation and Emissions in Europe' September 2025
WP25/24 Karl Whelan: 'Ambiguity and the Variance of Gambles' October 2025
WP25/25 Alan de Bromhead, Ronan C. Lyons, Johann Ohler: 'Build Better Health: Evidence from Ireland on Housing Quality and Mortality' October 2025
WP25/26 David Madden: 'Covid-19 Related Excess Mortality: An Analysis by Age for Selected Countries' November 2025

UCD Centre for Economic Research
Email economics@ucd.ie