D4.1

The Role of Behaviour and Heterogeneity for the Adoption of Technologies

August 2018

About this report

This report describes the execution, results, and insights from Task 4.1 of the REEEM project, which analyses pathways towards a low-carbon energy system for the European Union. Details are provided of a large-scale stated preference survey exercise covering three EU Member States: the United Kingdom, Finland, and Croatia. The survey exercise focused on household choices around domestic heating and personal mobility. The report describes the data collection process and presents the results in the form of a statistical regression analysis which identifies salient relationships and drivers behind causal variables. The report discusses options for implementing the revealed behavioural data in whole system techno-economic energy systems models, such as those used for climate and energy policy assessment throughout Europe.

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About REEEM

REEEM aims to gain a clear and comprehensive understanding of the system-wide implications of energy strategies in support of transitions to a competitive low-carbon EU energy society. This project is developed to address four main objectives: (1) to develop an integrated assessment framework (2) to define pathways towards a low-carbon society and assess their potential implications (3) to bridge the science-policy gap through a clear communication using decision support tools and (4) to ensure transparency in the process.

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1 Task Description

The main task description for work package 4.1 of the REEEM project sets out the core aims and objectives of the project as follows:

"This task will enable the better modelling of the adoption of energy efficient, innovative and novel technologies in homes and private transportation as described in the SET-Plan. Specifically, this task will collect empirically-derived stated-preference and revealed-preference data on individual actors' technology preferences, sensitivity to supply interruptions and demand flexibility. Data from a sample of countries will be used to estimate differences in preferences across the EU member states. Tools will be developed for analysing technology uptake for end-uses (e.g. discrete choice models) and to determine the key factors influencing decisions. Their outputs will be used to inform the modelling in WP6 (e.g. technology specific discount rate parameters, inconvenience costs, price response) and harmonise the aggregation of the data (e.g., consumer groups) for input into the EU-wide energy system model (together with WP6)."

2 Scoping and Setting of Objectives

For the purposes of determining firm outputs and deliverables from Work Package 4.1, the research team has interpreted the brief as calling for:

- Derivation of key metrics for characterising individual preferences, synthesised from empirically derived stated preference surveys across multiple EU member states.
- Concrete recommendations on methods and data for improved modelling of technology adoption in homes and private transport in energy systems models, specifically the TIMES-PanEU model which is being extended under WP6

The team first carried out a literature review of past studies investigating the modelling of human behaviour in energy systems (described in Section 2.1) in order to identify common themes before identifying task objectives (described in Section 2.2).

2.1 Literature review

A literature review of different approaches to modelling consumer behaviour with a special focus on empirically derived quantitative approaches was carried out using a structured keyword search of various online databases including Scopus and Web of Science. Table 1 below summarises the studies that were identified during this review process utilising a number of key criteria, including the aims of each study, the methods applied, the types of decisions that were modelled, and which factors different research teams then tested as sensitivities.

The review reveals that most studies aimed to identify the drivers/determinants behind a single type of decision taken by consumers, while a few further studies went beyond to also explore the potential impact of energy and climate policies on these decisions. The reviewed studies tended to be highly specialised and were focused on a specific technology or sector (e.g. residential heating and heat pumps, transport and personal vehicles) at the national or subnational levels. Studies focused mainly on purchasing decisions related to these technologies rather than other forms of behaviour, such as how users might operate them.

On the methodological side, most reviewed studies approached their study of decision making from a consumer utility and choice modelling perspective, with a variety of modelling approaches being used. Discrete choice models and other statistical models were the most common, while a few studies employed agent based models of individual sectors or created links between discrete choice models and system-wide energy models. All reviewed studies gathered data utilising surveys that were either performed on a representative sample of the population (to explore general relationships between energy and behaviour) or a purposive sample which targeted a specific group, such as beneficiaries of specific government grants for energy technology installations (in an attempt to explore the specific impacts of targeted policies).

On the basis of this literature review, the research team concluded that major factors influencing purchasing decisions that would be explored in Work Package 4.1 should include:

i. Socio-demographics (income, age, etc.)
ii. Physical attributes of the systems being purchased (vintage, type, size, location or spatial variables, performance)
iii. Economic considerations (capital costs, fixed and variable operational costs)
iv. Non-economic considerations (ecological attitudes, access to information about technologies, infrastructure availability etc.)

Table 1 - Literature review

Aim	Approach to behaviour	Decision	Influencing Factors	Interesting conclusions
Drivers and barriers behind homeowners' decisions focusing on existing houses for residential heating systems in Germany (Michelsen and Madlener, 2016)	Purposive survey to build binary logit model for adoption and MNL for non-adoption (Revealed preferences)	Replacement purchases of residential heating systems	• Socio-demographics (e.g. income, age, number of households) • Attributes of the home (vintage class, type, size, etc.) • Costs • Spatial variables (administrative unit, rural vs urban, certain climate zone)	• Energy ladder approaches tend to explain decisions based on socio-demographics • Drivers: Environmental protection, lower dependency on fossil fuels, knowledge • Old habits and perceptions identified as main barrier to new technology adoption
Determinants of energy savings adoption's in the residential sector of Tunisia (Singh, Muetze and Eames, 2010)	Representative survey to build MNL model (Revealed Preferences)	Adoption of energy saving technologies	• Socio-demographics • Attributes of the home	
Purchasing behaviour of house owners in Germany with respect to residential heating systems (Decker and Menrad, 2015)	Representative survey to build MNL model	Adoption of residential	• Socio-demographics	• Influential factors included

	(Revealed preferences)	heating systems	• Attributes of the home • Costs • Spatial variables • Ecological attitudes (5 clusters) • Information (experience of a product, external information)	socio-demographics, information, ecology, future price trends
Impact of energy savings' policies on home renovation decisions in the UK (Lee, Yao and Coker, 2014)	Representative survey to build MNL which is then built into an ABM in a domestic stock model (Revealed preferences)	DCM focuses on renovation decisions (insulation, adoption of residential heating systems, etc.)	• Socio-demographics • Attributes of the home • Costs • Spatial variables • Ecological attitudes (consumer groups based on UK DEFRA clusters) • Information	• Model validation with past insulation penetration. • Model can provide future energy demand and associated emissions, uptake of technologies, cost-effectiveness of policies • Current policies will fall short of meeting 80% decarbonisation targets (residential sector specific which means other sectors

				need to decarbonize more) • Current subsidies could act as a disincentive
Consumer awareness and willingness to adopt GSHP for domestic heating and cooling in Greece (Karytsas and Theodoropoulou, 2014)	Representative survey with logistic regression analysis (Willingness to adopt)	Awareness and adoption of GSHP	• Socio-demographics • Attributes of the home • Economic aspects • Environmental considerations and energy saving attitudes (environmental concerns / attitude, energy efficiency, GHG emissions, local air quality, health risks) • Energy supply security (security of fuel supply,	• Influence of socio-demographics on awareness discussed • People with lower incomes were found to be more inclined to consider GSHP systems • Household size and type were not found to be significant

		independence from conventional fuels, fuel stability) • Comfort consideration and aesthetics • General attitudes (compatibility with habits, lifestyle) • Social reasons and information / knowledge (socially subjective norms, time required to collect information, knowledge of the system, decision strategy: repetition-social comparison, desire to improve image, number of peers, complexity)	
Factors affecting private homeowner's choice of heating systems when renovating in Finland (Rouvinen and Matero, 2013)	Representative survey to build MNL and RPL model (Stated preferences	• Socio-demographics • Attributes of the	• Random component in

	experiment)		home • Economic aspects • Spatial variables	the RPL which complements the MNL used to relax restrictive independence of irrelevant alternatives. • MNL results used to simulate market shares under various policy scenarios • Preferences implemented as staying constant, while changes in policies are represented as permanent
Motivational factors influencing homeowner's residential heating systems adoption in Germany (Michelsen and Madlener, 2013)	Purposive survey to carry out PCA and CA (Revealed preferences)	Adoption and non-adoption of residential heating systems	• Socio-demographics • Attributes of the home • Spatial variables • Cost aspects • General attitude • Government grant • Reactions to external threats (environmental	• Identifies 3 adopter types: Convenience-oriented, Consequences-aware, Multilaterally-motivated

			or energy supply security considerations) • Comfort considerations • Influence of peers	
Influence of homeowner's preferences about residential heating system-specific attributes on adoption in Germany (Michelsen and Madlener, 2012)	Purposive survey to build MNL (Revealed preferences)	Adoption and non-adoption of residential heating systems	• Socio-demographics • Attributes of the home • Costs • Spatial variables	• Heterogeneity found to be most important. People that adopt certain technologies have different motivations • Split of survey into existing homes and newly build homes
Impacts of policy on diffusion of sustainable heating systems in Norway (Maya Sopha, Klöckner and Hertwich, 2011)	Representative survey to build DCM and ABM (Stated preferences)	Adoption of residential heating systems	• Socio-demographics • Costs • Spatial variables • Social network	• Heterogeneity of decision strategy from empirical survey: 23.5% choose to stick with the same technology • Limitations: approach provides qualitative insights not quantitative

				• Perceptions and conditions are fixed through time. • Focus on perception on heating attributes not on real attributes of heating systems
Influence of perceived product characteristic on adoption of microgeneration technologies by homeowners in Ireland (Claudy, Michelsen and O'Driscoll, 2011)	Purposive survey with descriptive statistics and Contingent Valuation (CV) approach to build bivariate probit model for estimating WTP (stated preference)	Adoption of microgeneration technologies	• Relative advantage (environmental friendliness, independence) • Compatibility (habits and routines) • Trialability • Complexity • Compatibility related costs • Risk (performance, social) • Subjective norms • Knowledge	• Estimates independent variables on willingness-to-pay • Relative advantage, compatibility, trialability, complexity and observability explain 49-87% of variation in adoption rates
Factors that influence the choice of heating system based on perceptions in Norway (Sopha *et al.*, 2010)	Purposive survey to build MNL (revealed preference)	Adoption of wood pellet stove vs air-to-air heat pump and electric heating	• Socio-demographic • Heating system attributes (functional	• Electric heating found to be preferred by older people • Electric heating use positively

			reliability, costs, fuel supply security) • Spatial variables • Decision strategy • Communication (Social network)	correlated income • Regional spatial variation found to have an impact on heat pump adoption (Eastern and Southern parts of the country found to be more likely to choose wood pellet heaters)
Determinants of households' adoption of residential heating systems in Germany (Braun, 2010)	Purposive/Representative survey to build MNL (stated preferences)	Adoption of residential heating systems	• Socio-demographics • Costs • Spatial variables	• Subsamples include owner occupiers and those renting properties • Influences of income and household size found to vary between East and West Germany
Integrating household behaviour and heterogeneity into TIMES model for France (Cayla and Maïzi, 2015)	Representative housing survey, national transport and travel to parametrize TIMES. Additionally, representative survey to quantify impact of income on purchasing behaviour applying simple descriptive	Demand and adoption of residential heating systems and transport technologies	• Residential sector: o Access to technologies (type of housing, ownership status)	• Only income tested as behavioural variable • Time horizon 2050 • Constant implicit return rates.

		statistics and single variable linear regressions (stated preference)		(1) No wood, solar SHW for flats (2) No insulation for tenants o Level of demand (space-living area, insulation, income, size of household) (1) Level of demand for space-heating (2) Initial thermal quality for home (3) Space heating service factors (4) Level of demand for DHW o Behaviour (income) (1) Implicit hurdle rate (2) Capital constraint • Transport sector: o Access to	• Perfect foresight with scenarios of increasing prices • Higher incomes found to link to lower required rate of returns • Higher incomes linked to a higher proportion of households being ready to replace their equipment • No specific time when people make decisions

			technologies (urban area, vehicle ownership) (1) Public transport supply (2) Access to vehicles o Level of demand (Urban Area, activity, size of household) (1) Distance to amenities (2) Number of trips/person (3) Level of demand for mobility o Behaviour (income) (1) Implicit hurdle rate (2) Capital constraint	
Combining Top-Down and Bottom-Up approaches to energy-economy modelling using discrete choice methods with the CIMS model (Rivers and Jaccard, 2006)	Representative survey to build MNL to estimate implicit discount rates and intangible costs, and degree of market heterogeneity (stated	Adoption and diffusion of technologies	• Socio-demographics • Costs • Spatial variables • Social network	• Estimation of implicit discount rates found to be consistent with revealed

	preferences)	effects	preference research • Revealed preference data cons: (1) highly collinear and exhibit little variability in market place. (2) May be less appropriate for policy analysis (3) difficult to gather for new technologies • Estimates implicit discount rate and intangibles by comparing non-cost components to annual cost • Heterogeneity parameter estimated equivalent to “scale” of the MNL.

Integrate consumer choice aspects from a discrete choice model in TIMES model for California [19]	Representative survey to build MNL based simulation model for soft linking with TIMES	Adoption and diffusion of personal vehicles	• Socio-demographics • Costs • Spatial variables • Driving profile • Risk attitude	• Logit formulation used to capture utility • Enhance the LDV behavioural representation of these models • Integration of COCHIN-TIMES with MA^3T model to capture consumer preferences for vehicles
Evaluating homeowners' retrofit choices in Croatia under a large-scale analysis of a national energy efficiency scheme (Matosović and Tomšić, 2018)	Discrete choice modelling carried out on four energy efficiency measures included in a national building retrofit scheme using data on 4610 privately owned homes	Willingness-to-pay for energy efficiency measures	• Socio-demographics • Cost variables • Spatial variables (NUTS 3 disaggregation)	• Willingness-to-pay found to be similar across income classes • Ability to invest is the deciding factor affecting uptake • Significant free-riding discovered in three out of the four assessed policy measures

2.2 Task Objectives

Based on the literature review and the task description, the research team proposed to focus on the economic and non-economic factors influencing households' decisions in the transportation and residential sectors of three EU Member States: the United Kingdom, Finland, and Croatia. This decision was informed by the availability of specific in-country expertise from REEEM partner institutions as well as the overall project budget and the time horizons for project delivery. It was proposed to build out a core data set using three surveys that would cover socio-demographic information as well as forming the basis of stated preference experiments that would be used for developing discrete choice models.

The cross-country comparison enabled by such an approach represents an original and novel contribution to the literature in this field. The proposed objectives and focal areas for this study were defined as follows:

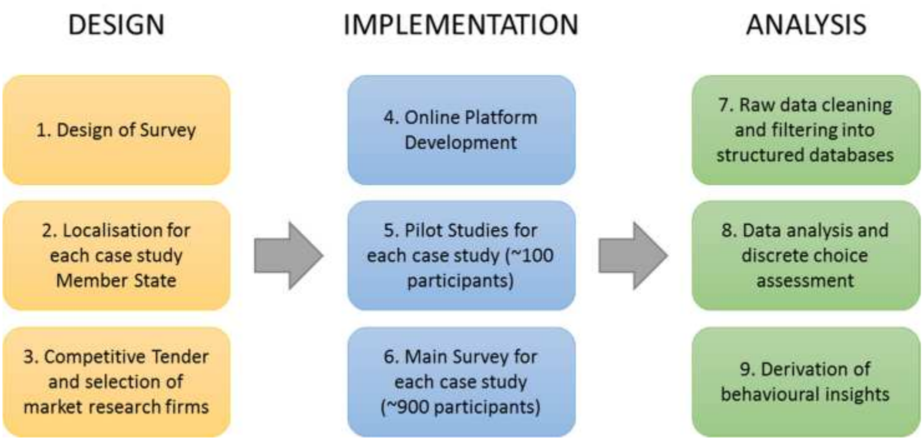
- Assess and attempt to quantify the influence of economic and non-economic considerations on household adoption of:
    - Residential heating systems
    - Personal vehicles
- Use survey data to construct discrete choice models for both sectors (personal vehicles and residential heating systems) and for each case study Member State (UK, Finland, Croatia).
- Use the discrete choice models to provide technology and user group specific intangible costs, for those non-economic factors that can be monetised.
- For those non-economic factors where monetisation is not possible (e.g. data shows that costs do not matter to decision makers or where the survey data does not allow converting non-economic considerations into costs), to construct other quantitative datasets and tools to characterise consumer decision-making processes in a way that can be implemented in energy models.
- Compare the variation in consumer behaviour across sectors and especially across countries, highlighting the implications of the findings for policy.

The discrete choice models, one for each sector and each country, will be used to inform WP6 by providing guidelines for a household disaggregation that captures the heterogeneity of choice behaviour and ideally, intangible costs to be added for each combination of a group of households and a technology to reflect their non-price behaviour.

3 Process Overview

The end-to-end process for executing Task 4.1 is illustrated below in Figure 1. The project can be thought of as being carried out in three distinct phases, although in practice there was a degree of iteration between the *design* and *implementation* phases as minor edits to the surveys themselves were sometimes made following the discovery of issues that appeared during implementation (changes to the language in surveys following clarification of translations, for examples).

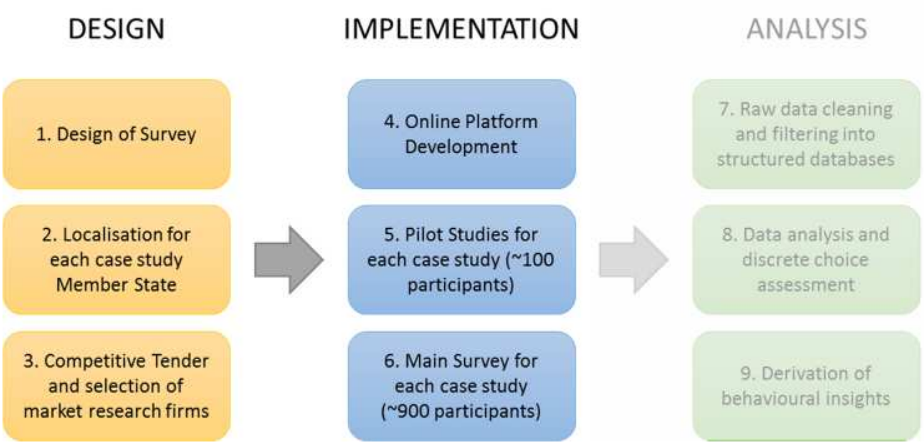
Figure 1 - Task 4.1 Process Overview



4 Design and Implementation

This section details the process of developing the survey (*design* stage) and collecting the required data across each of the case study Member States (*implementation* stage).

Figure 2 - Design and Implementation Project Stages



4.1 Design

The survey itself was originally designed in English at the UCL Energy Institute in collaboration with internal energy research and social science experts who specialise in energy systems modelling, household domestic energy demand (including survey design), transport energy demand, and transport mode choice studies. The survey was then localised into Finnish (*Suomi*) and Croatian (*Hrvatski*) in collaboration with local experts at Aalto University and Energy Institute Hrvoje Požar (EIHP).

This national localisation effort not only included professional translations of the survey questions into the appropriate national languages but also involved making specific changes to technology selection and costs to ensure that specific national contexts and conditions were respected. For example, it was established through discussions with EIHP that the use of wood burning stoves for domestic heating was particularly significant in Croatia, while this is actually relatively uncommon in the UK. The technologies included in the stated preference experiment were therefore modified to include this nationally important technology option.

Table 1 provides a summary overview of the various factors that were investigated as part of the survey, grouped into various categories.

Table 2 - Factors Surveyed

Category	Factors Explored as Part of The Survey
Socio-demographic	Gender, age, area of residence (urban/suburban/rural), household income, housing tenure, education level, work status, household size
Dwelling	Type, age, number of bedrooms, size of residential dwelling

Economic	Typical expenditure on heating, typical expenditure on transport, perspectives on: upfront costs, annual costs (operation & maintenance costs)
Environmental	Perspectives on carbon emissions
Technological	Perspectives on technology ease of use, usage patterns (heating hours per day)
Heating system ownership and knowledge of heating systems	Heating system(s) owned, familiarity with different heating systems, perspectives on: their ease of use, reliability, costs, climate change impact, local pollution impact, ease of acquisition, space requirements, impact on the resale value of homes, environmental credentials
Vehicle ownership and knowledge of vehicles	Number of cars owned, car brand, car type, identification of the main driver, driving type and purpose, perspectives on the pros and cons of electric vehicles, familiarity with diesel, electric and hybrid cars technologies
Transport behaviour	Main reason(s) for using a car, frequency of various driving ranges, frequency of various travel modes (car sharing, public, walking, etc.),
Psychological	Environmental friendliness, access to information, personal innovativeness, assessment of reliability, effectiveness, user control, ease-of-use, maintenance costs, installation costs, importance of installer selection, importance of advice from trusted individuals, typical reasons and rationale for heating system replacement Factors affecting vehicle purchase (safety, performance, fuel economy, etc.)

4.2 Implementation

Professional market research firms with access to large panel databases of participants were used for this study. This was required in order to ensure that nationally and statistically representative sets of participants were targeted in each of the case study countries. A competitive tender process was carried out in each EU member state and separate contracts were awarded for survey firms operating in the United Kingdom, Finland, and Croatia.

The research team then worked directly with the three survey companies (SIS International for the UK, Taloustutkimus Oy for Finland, and IPSOS for Croatia) to implement the survey questions across separate country-specific online questionnaire platforms which were used for data collection.

Broadly speaking, each of these three sub-projects involved three key stages (also shown in Figure 1):

- **Online Platform Development:** working with the contractors to design and test the online web questionnaire pages, test the question flow logic (which questions to skip etc. under different combinations of responses) and to look for errors or bugs that could impede the smooth execution of the survey study (for example uncovering web page crashes resulting from unhandled exception errors or the use of undefined variables in text entry fields).

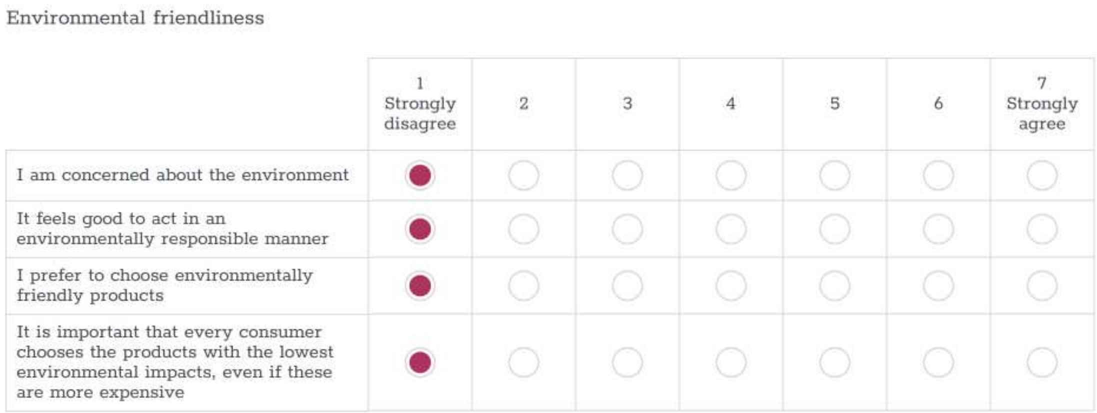
- **Pilot Study:** carrying out a pilot study on a small sample population of between 100-125 participants. This was performed in order to establish whether back-end data collection from the web survey platforms was operating as expected and to preview whether or not data were being gathered in a useful format or not.

- **Main Survey:** running the main survey itself on the remaining 900 respondents, giving a total sample size of approximately 1000 participants for each of the national studies.

4.2.1 Example Questions: Attitudes

The survey features a range of demographic and socio-economic questions, such as age, gender, educational status, home ownership status, and occupational status. The survey also asks a number of questions around attitudes and user perception of technologies, where respondents get information from to make choices and how "innovative" or forward thinking they perceive themselves to be, etc. For example, see Figure 3.

Figure 3 - Example Screen Capture from UK Survey Showing Environmental Friendliness Questions


Environmental friendliness

	1 Strongly disagree	2	3	4	5	6	7 Strongly agree
I am concerned about the environment	●	○	○	○	○	○	○
It feels good to act in an environmentally responsible manner	●	○	○	○	○	○	○
I prefer to choose environmentally friendly products	●	○	○	○	○	○	○
It is important that every consumer chooses the products with the lowest environmental impacts, even if these are more expensive	●	○	○	○	○	○	○

4.2.2 Example Questions: Heating Systems

In line with the aims and objectives of the task, the survey asked specific questions about ownership, knowledge and understanding of, and attitudes towards different home heating systems, including spending on bills. For example, See Figure 4 and Figure 5.

Figure 4 – Example Screen Capture from UK Survey Showing Heating System Questions – Knowledge and Understanding

How familiar are you with the following heating systems?

	I have never heard of it	I have just heard the name, but do not know anything else about it	I know a little about it (e.g. some general ways in which it differs from my current system)	I'm quite familiar with it and know how it works
Gas central heating	●	○	○	○
Oil central heating	●	○	○	○
Electric storage heating	●	○	○	○
Fuel wood central heating	●	○	○	○
District heating	○	●	○	○
Solid fuel boiler	●	○	○	○
Heat pump	○	○	●	○
Open fireplace	○	○	○	●

Figure 5 – Example Screen Capture from UK Survey Showing Heating System Questions – Beliefs About Characteristics

How well do you believe the following factors describe each heating system?

Heat pump	1 Not at all	2	3	4	5	6	7 Very well	I don't know
Easy to use	○	○	○	●	○	○	○	○
Reliable	○	○	○	●	○	○	○	○
Low costs	○	○	○	○	●	○	○	○
Bad for climate change	○	○	○	○	○	●	○	○
Bad for local pollution	○	○	○	●	○	○	○	○
Requires little own work	○	○	○	●	○	○	○	○
Easy to acquire	○	○	○	○	●	○	○	○
Requires little space	○	○	○	○	○	●	○	○
Increases the selling value of the house	○	○	●	○	○	○	○	○
Generally environmentally friendly	○	○	●	○	○	○	○	○

4.2.3 Example Questions: Personal Mobility

As well as investigating user attitudes to domestic heating systems, the survey sought detailed questions about personal mobility choices, and in particular car ownership. For example, respondents were asked about the number of cars in their household, the make and model of each vehicle, which member(s) of the household owns or drives the car(s), and for what main reason(s) they undertake journeys by car. The survey also featured a smaller number of questions about transport mode choice in general, as illustrated in Figure 6.

Figure 6 - Example Screen Capture from UK Survey Showing Personal Mobility Questions – Mode Choice

How often do you use the below modes of transport?

	Daily	At least once a week	Several times a month	Once a month at most	Once or twice a year	Never	Don't know
Public transport	●	○	○	○	○	○	○
Own Car	○	○	○	○	○	●	○
Taxi	○	○	○	○	●	○	○
Car sharing	○	○	○	○	●	○	○
Motorcycle	○	○	○	○	○	●	○
Cycle	○	○	●	○	○	○	○
Walk at least a kilometer	●	○	○	○	○	○	○

4.2.4 Stated Preference Questions

Finally, we carried out two stated preference exercises; one for heating systems and one for private vehicles. Participants were offered a range of choices and asked to make selections several times based on changing sets of parameters. This approach can be used to provide insights into how different individuals prioritise different characteristics (cost, reliability, convenience etc.) and what trade-offs they are willing to make between them, an approach which attempts to mimic the selection process for high value products that can occur in real world marketplaces (Ben-Akiva and Lerman, 1985). An example of one of the selection screens is provided below in Figure 7. These exercises provided data for the discrete choice modelling activity discussed later in Section 5.4.

Figure 7 – Example Screen Capture from UK Survey Showing Stated Preference Screen for Domestic Heating Systems

Assuming that you are in the market for a new heating system — Which of the following options would you choose? We ask you to choose multiple times based on the changing costs and characteristics of the systems available.

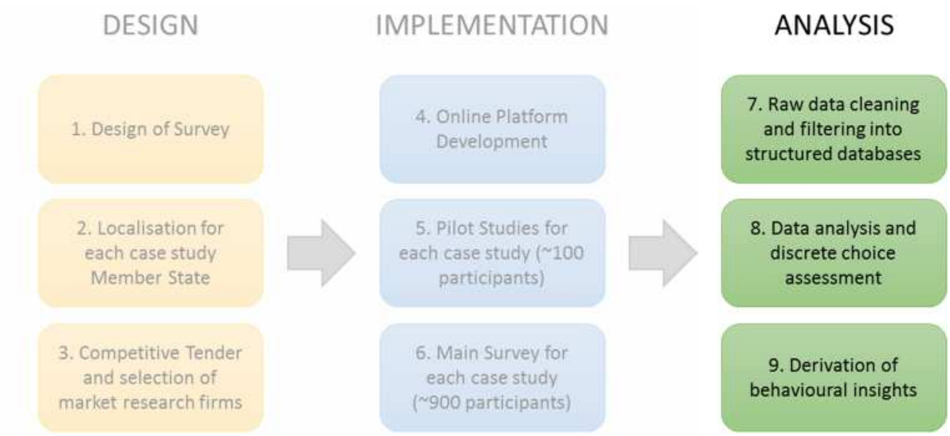
Select one

	Gas	Electric Storage	Heat Pump	Solid Fuel
Purchase Price	£1,000	£1,000	£9,600	£2,000
Annual cost	£600	£1,200	£210	£240
CO2 emissions, where the typical house in the UK emits about 3 tonnes per year	Very low emissions (0-1 tonnes)	Average emissions (3 tonnes)	Very low emissions (0-1 tonnes)	High emissions (more than 4 tonnes)
Own Work	Substantial	Some	Substantial	Some
Your choice				

5 Analysis and Insights

This section details the process of carrying out *analysis* on the large datasets collected during the surveys.

Figure 8 - Project Analysis Stage



5.1 Analysis Methodology

The analysis methodology can be summarised as follows:

- **Raw Data Cleaning and Filtering into Structured Databases:** The survey data in its raw form from each contractor represents a large-scale source of information on behavioural energy data, but it is largely unstructured (i.e. as SPSS and/or CSV files). Not only is such a large volume of data difficult to interpret by visual inspection alone, but the different survey companies used separate notational conventions and file formats for presenting their information which makes direct comparisons between country datasets impossible without further processing. The raw data were "cleaned" to obtain usable information in a structured database format suitable for performing further analysis and mathematical operations. Cleaning data involves a variety of steps. Data were first subjected to a series of dimensional and logic tests using automated scripting techniques to identify potential sources of error such as blank fields, null value fields, or the presence of unexpected variables (e.g. text entry inside of numerical fields). In some cases, missing information necessitated the use of a slightly smaller sub-sample of the overall ~1000 respondents being used for analysis. For example, in the UK survey, a small number of records (17 out 1000) were found to have had information on the age of the respondents missing, so these records were excluded from parts of the analysis exploring the relationship between age and decision making. Data were also transferred from their original file formats (SPSS and/or CSV files) into other database formats, for example SQL, MS Access and MS Excel files as appropriate.

- **Data Analysis and Discrete Choice Assessment:** Data were evaluated using a structured set of formal analytical methods to yield relevant insights for energy system modelling and for policymaking. This included the construction of Discrete Choice Models (DCMs) to determine exploratory factors behind respondent characteristics and responses e.g. in order to assess whether there were patterns in attitudes and decision-making characteristics that were particular to individuals from identifiable socio-demographic groups (such as age, education level etc.)

  - The research team first carried out a straightforward comparison between each case study country to obtain a general overview of some of the trends and patterns observed in the three survey samples. These are described in Section 5.2 and Section 5.3.

  - The team then built three Discrete Choice Models using the open source software package PythonBiogeme. All attribute values were first processed using linear transformation functions in order to ensure that they were within a single order of magnitude of one another to guard against scaling issues where large numerical variables might dominate the solution space. The explanatory variables were then tested against key socio-demographic indicators using a genetic optimisation algorithm with around 200 variables.

- **Derivation of behavioural insights:** The insights from the discrete choice analysis itself is detailed further in Section 5.4.

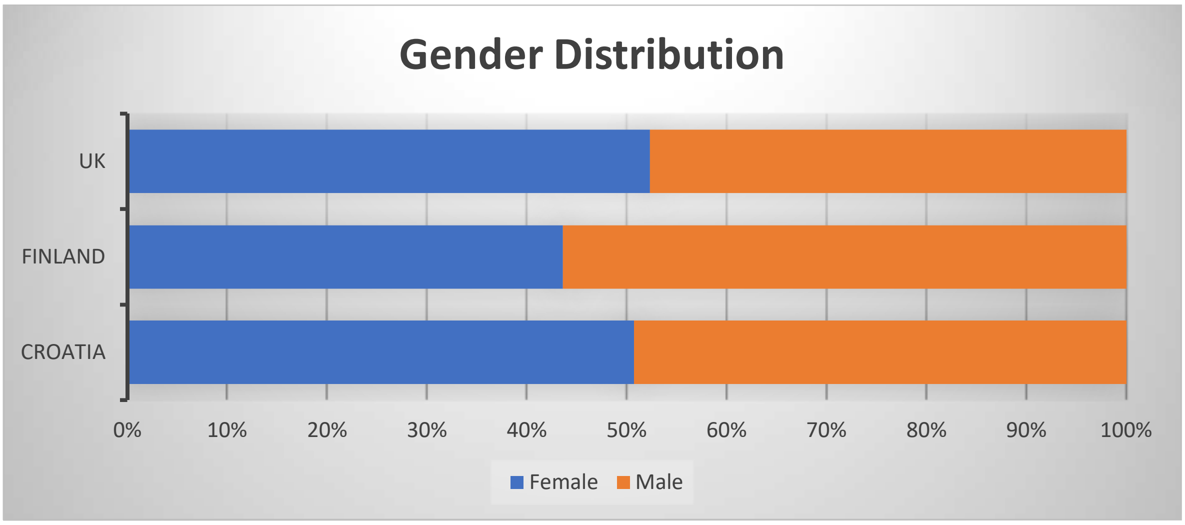
5.2 Socio-demographics and Existing Equipment Ownership

Each survey covered 50+ questions (see Table 2 for the factors surveyed) and not all of the results are visualised or discussed here (numbers of bedrooms in each home, heating hours per dwelling, driving distance profiles, travel modes etc.). The research team has focused here on those elements which are most salient in terms of characterising individual household behaviour and decision making in large-scale energy systems models such as those being used in WP6 of the wider REEEM project. This section provides an overview of the survey response samples across each case study Member State, characterising respondents in terms of various socio-demographic measures, such as their age, education, employment status, dwelling type, and their existing home heating and vehicular equipment.

5.2.1 Gender and Age

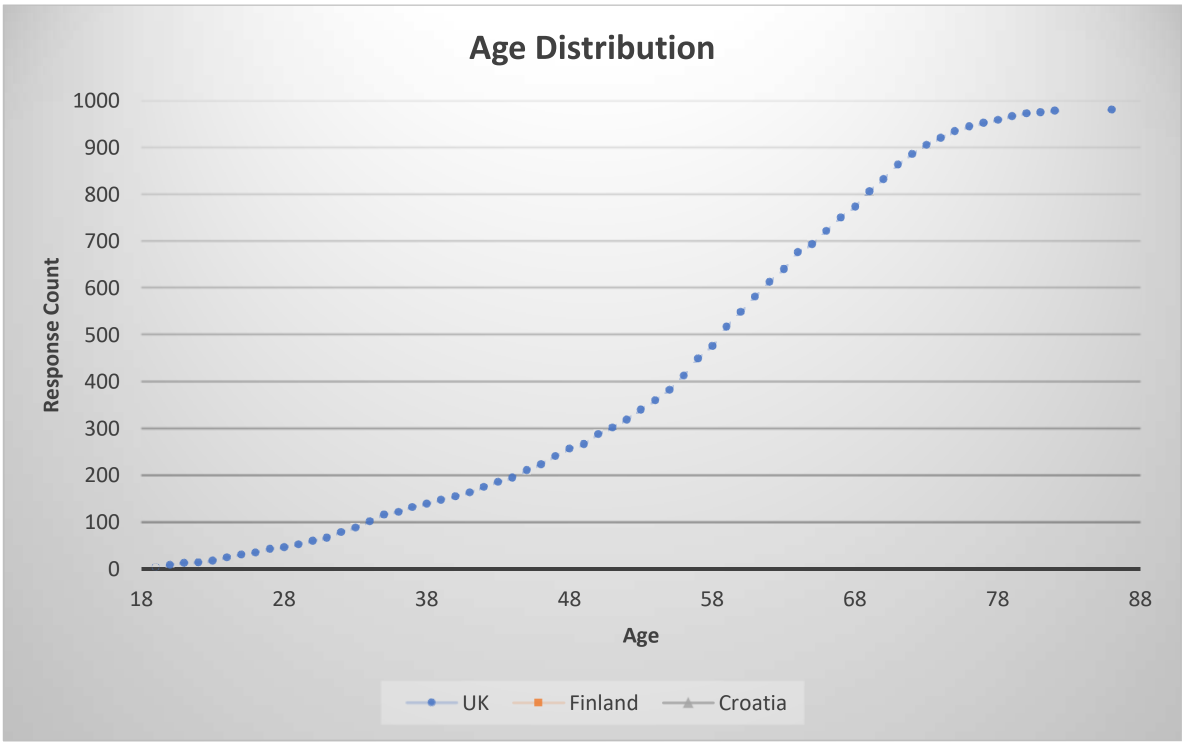
Across each case study Member State the various surveys were able to achieve a roughly equal balance of male and female respondents. Figure 9 illustrates that the Finnish sample has slightly more male respondents, while the UK and Croatian samples both had slightly more female respondents than male respondents.

Figure 9 – Gender Distribution of Survey Respondents



The relative age distribution of the survey samples for each country is presented in Figure 10. Different survey companies had access to different panels of respondents across slightly different age distribution ranges. In the Croatian study, the age profile of respondents was very close to the national distribution – the median age of the population is around 43 while the median age of the sample is approximately 42. The UK survey was completed by an older set of respondents than the national average (the median age of UK population is around 44-45, while the survey median was 59). Likewise, the median age for the Finnish sample was 55, while the national median is around 43.

Figure 10 – Age Distribution of Survey Respondents



5.2.2 Employment, Education, and Income

Figure 11 indicates the distribution of respondents in terms of their occupational status. The two largest groups across all three countries were full time employees and retired people, with the Croatian sample having the largest proportion of respondents in full-time employment and the fewest retired individuals. This is likely to reflect the different age distributions found between the three surveys. Direct comparison against official labour statistics for Finland, Croatia and the UK are challenging to carry out against these samples due to differences in economic activity classifications and in sampling boundaries across demographic groups.

Figure 11 – Employment Status of Respondents

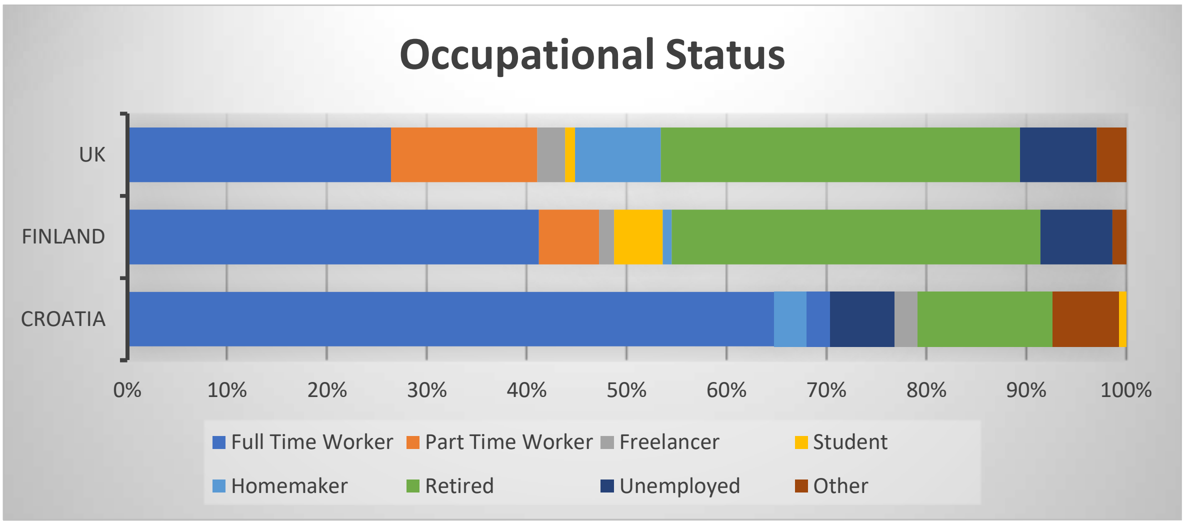


Figure 12 displays the distribution in educational achievement across the response sample. Compared against the UK and Croatian data samples, a higher proportion of Finnish respondents had a university level or postgraduate education, but the Finnish respondents also had a higher fraction of individuals in the primary education category.

Figure 12 - Highest Level of Education Attained amongst Respondents

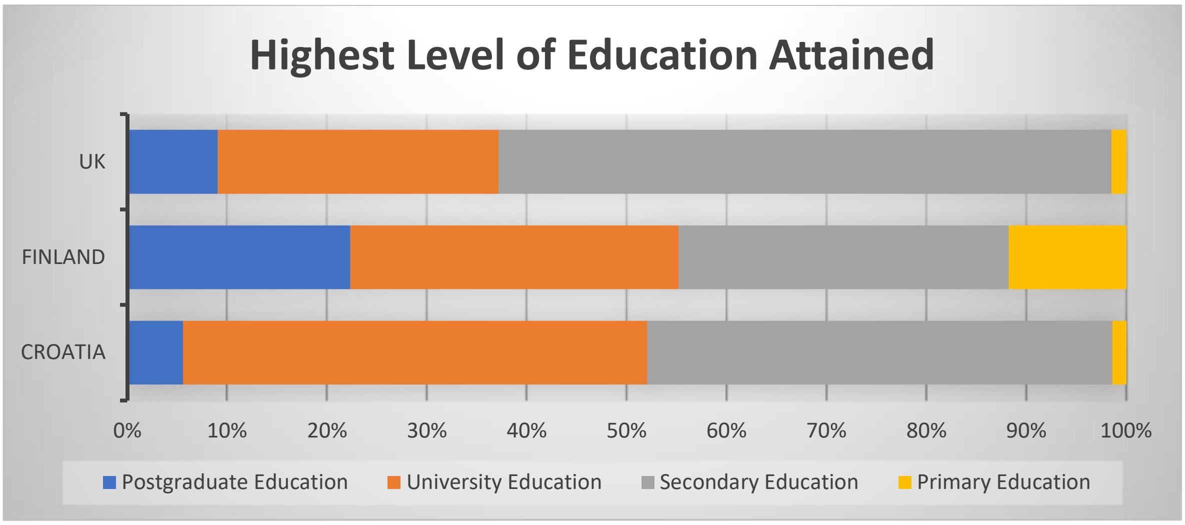
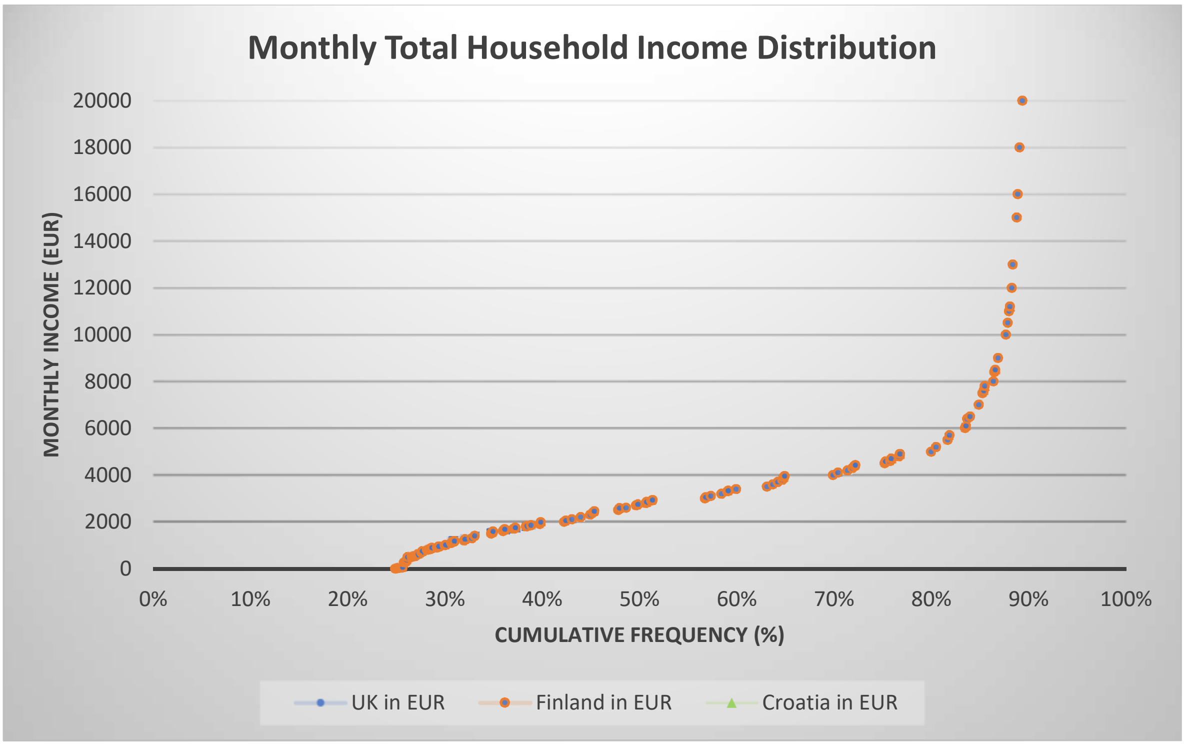


Figure 13 provides a comparison of stated total household monthly incomes (post tax) across the sample (with GBP £ converted to EUR € at a rate of 1.138 and HRK kn converted to EUR € at a rate of 0.135). All UK respondents reported some income, while between 20-25% of Finnish and Croatian respondents stated definitively that their monthly household income was €0 – this may reflect different understandings of monthly vs. personal income. The largest self-reported total monthly household incomes reported in the UK sample and Croatian samples are equivalent to around €12,000 and €27,000 at current exchange rates, while around 10% of the Finnish sample reported monthly incomes in excess of €20,000. For visualisation purposes and to enable a cross comparison with the other country data we have truncated the vertical axis at €20,000, but the largest earner in Finland reports a post-tax monthly income of around €7m. The large number of Finnish respondents (100+) reporting high incomes at the top end of the distribution does represent a large outlier when compared to the rest of the dataset, but not one which can be obviously attributed to user input error, as 90% of the Finnish respondents reported incomes that are of similar orders of magnitude to those found in other countries.

Figure 13 - Distribution of Stated Monthly Incomes Amongst Respondents



5.2.3 Household Location, Dwelling Type and Tenure

Figure 14 details the breakdown of respondents in different countries by the type of area where they report that their household is located. It is important to note that this question only measures how the respondents themselves choose to characterise their surrounding environment rather than using any concrete measures such as population or built urban density. All three study samples contain a mixture of respondents who state that they live in different urban/suburban/rural areas. Only a few respondents in Finland and Croatia (less than ten in each case) were either unsure of how to characterise their surroundings or preferred not to specify the type of area where they lived.

The Croatian sample had the highest fraction of respondents who perceived themselves as urban dwellers, at around 65%. Respondents in both the UK and Finland reported lower numbers, at around 30% in both cases. The Finnish and Croatian samples both reported around 20% of respondents identifying their homes as being in rural areas, while the UK study found a higher number of (self-reported) rural inhabitants (just over 40%). Finally, the Finnish study had a higher number of individuals who identified as living in suburban areas, between 2-3 times more the levels found in Croatia and the UK. There are of course cultural, linguistic, geographical and environmental differences between the UK, Finland and Croatia. What a British person considers to be a "*rural*" area may not necessarily resemble in quantitative terms what is understood by *"maaseutu"* (rural area) in Finnish, so the self-reported nature of the responses must be noted if these data are to be applied in modelling exercises. Another complicating factor is that statistical agencies in different countries do not have universal definitions of what constitutes an *"urban"* or *"rural"* area, instead relying on administrative geography (i.e. city or district names).

Figure 14 – Profile of Respondents by Urban / Rural / Suburban Area

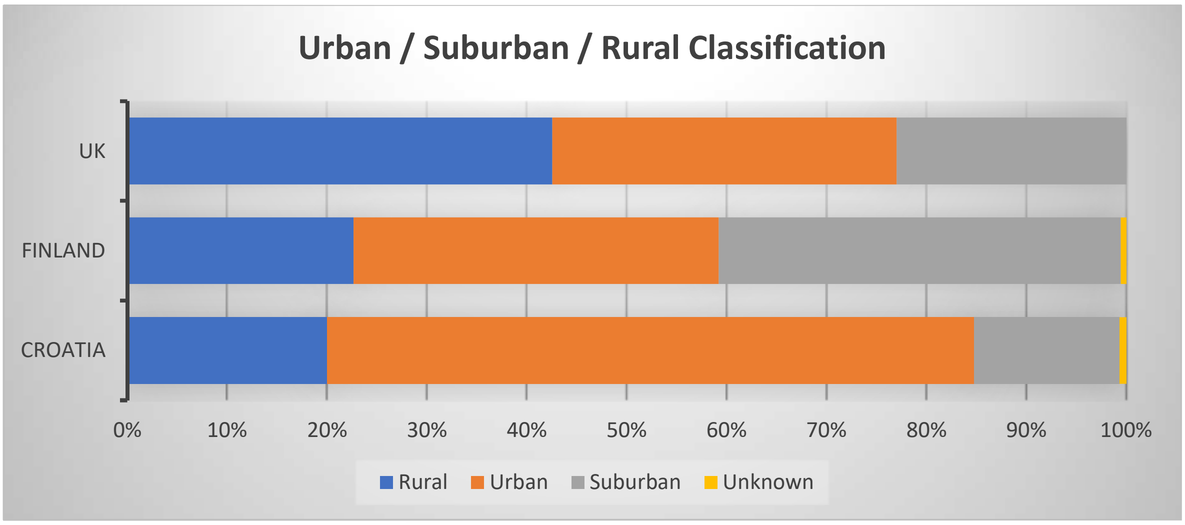


Figure 15 illustrates the dwelling types occupied by each household, while Figure 16 shows the housing tenure of respondents (i.e. whether they own their own homes or rent their homes). In terms of dwelling types, the research team found that many UK respondents used the free text entry field in the survey to specify morphological terms that are specific to the United Kingdom, such as the concept of a *"Bungalow"* (a detached house with all rooms at ground level) and a *"Semi-Detached"* home (a form of row house with external facing walls on one side). In order to simplify the international comparison between dwelling types, the *"Semi-Detached"* data has been aggregated in the chart below along with *"Terraced"* homes (row homes), although it remains present in its original form in the raw data for the study.

There are marked differences between each survey sample in terms of their reported housing morphology and tenure. The UK sample is perhaps notable for having only a very small number of respondents who live in residential apartment buildings, and a correspondingly much larger number who live in terraced houses. The UK data has the largest number of housing tenants in the sample (44%), with the Finnish survey being second at 27% and the Croatian study third at 18%.

Figure 15 – Profile of Respondents by Dwelling Type

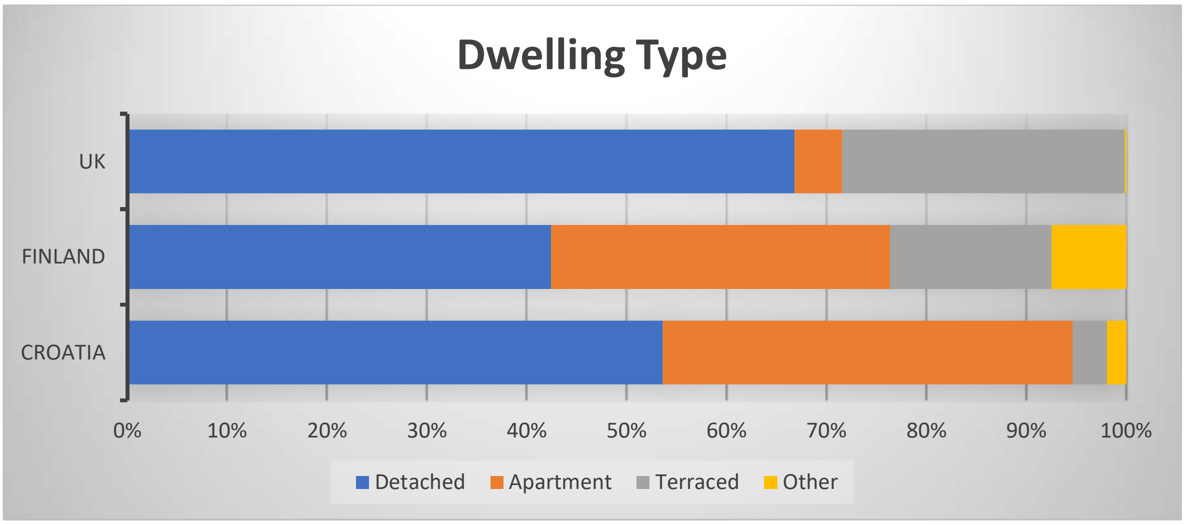
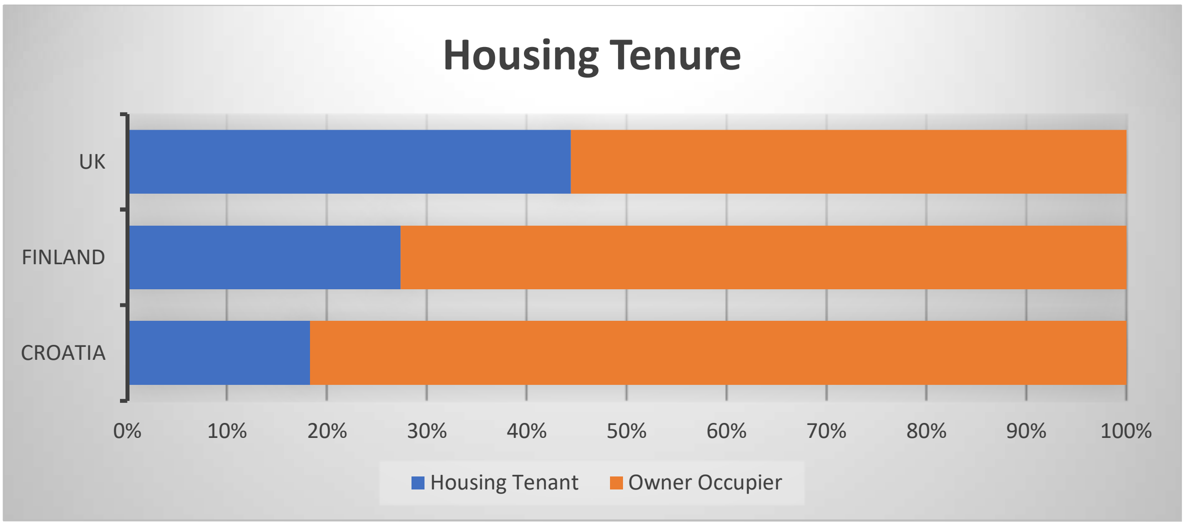


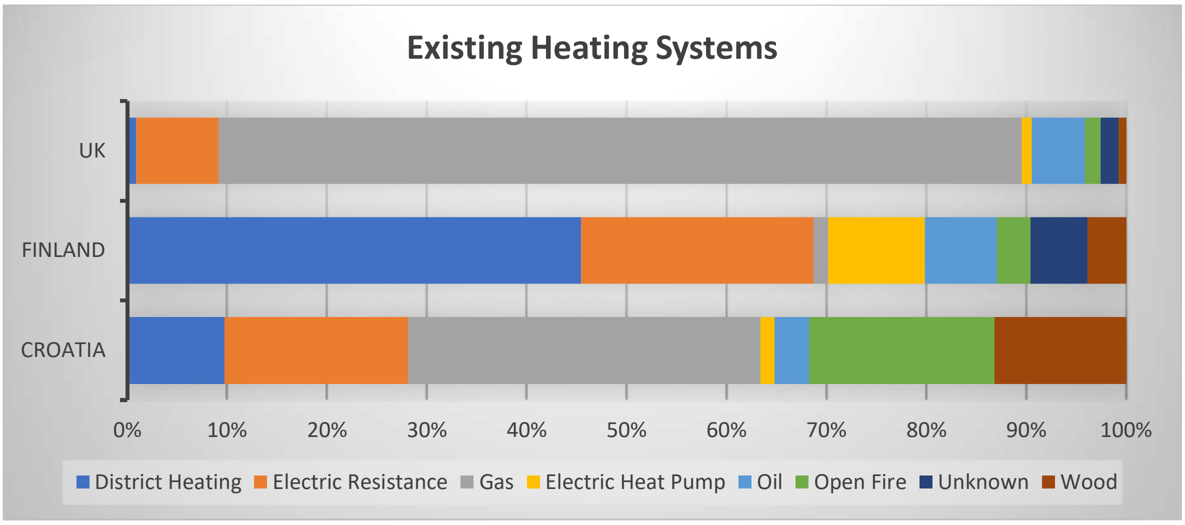
Figure 16 – Housing Tenure



5.2.4 Existing Heating Systems

Figure 17 compares and contrasts the different heating systems that were found in each national survey group against each other. There are very large differences in the makeup of the heating technology stock between the three countries. In the case of the UK, gas boilers are by far the single largest and most dominant group of heating technologies owned by respondents, with an 80% market share. Finland, on the other hand, has a much more diverse set of domestic heating technologies amongst the sample population: district heating had the single largest slice of market share at 45%, with electric resistance heating and electric heat pumps in second and third place respectively. Croatia is even more diverse than Finland, with no single technology holding more than a 35% market share. The Croatian sample is notable in comparison to the UK and Finnish ones for having a large number of homes being heated using wood and/or open fireplaces. It is interesting to reflect on how these levels of existing appliance ownership might impact on user's knowledge and understanding of different heating systems (discussed later in Section 5.3.4) and their actual propensity to purchase different types of heating system (explored in Section 5.4.1).

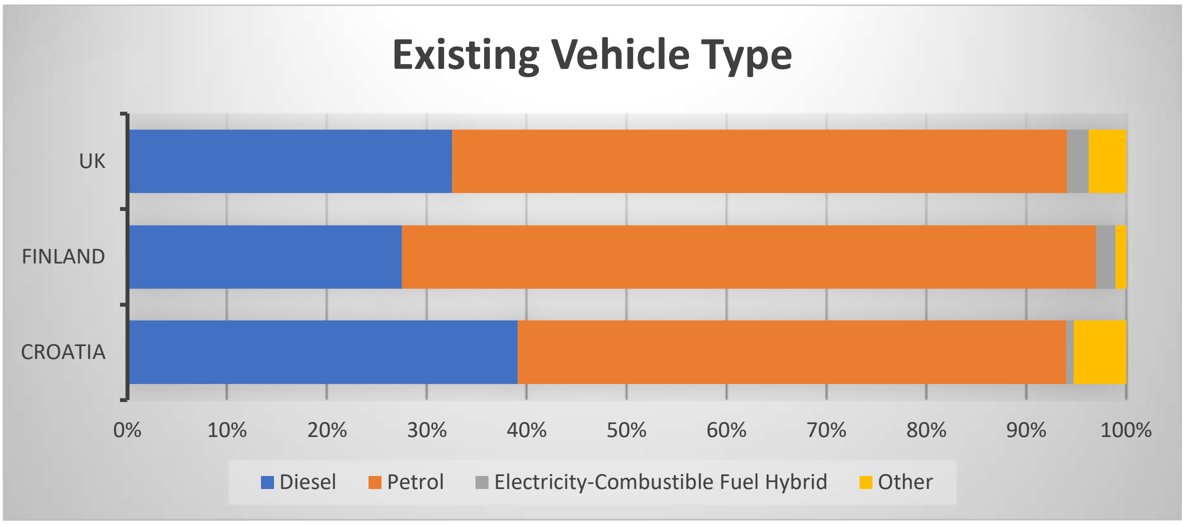
Figure 17 – Profile of Respondents by Existing Heating Systems



5.2.5 Existing Vehicles

Figure 18 below illustrates the differences in vehicle technologies found amongst survey respondents in each case study Member State. All three case study countries are broadly similar in terms of the overall breakdown of vehicles by fuel. Petrol dominates, with diesel in second place, and all other fuel types being minority players with combined market shares of less than 5%. This included vehicles that operate on biofuels, petrol-oil fuel mixtures (such as those found in older 2-stroke engine designs) and battery electric vehicles. The UK and Croatian data was notable for containing small numbers of respondents who owned vehicles that operate on compressed natural gas (CNG), and liquefied petroleum gas (LPG), neither of which were found in the respondent profiles for Finland.

Figure 18 – Profile of Respondents by Existing Vehicle Types



5.3 Attitudes and Knowledge

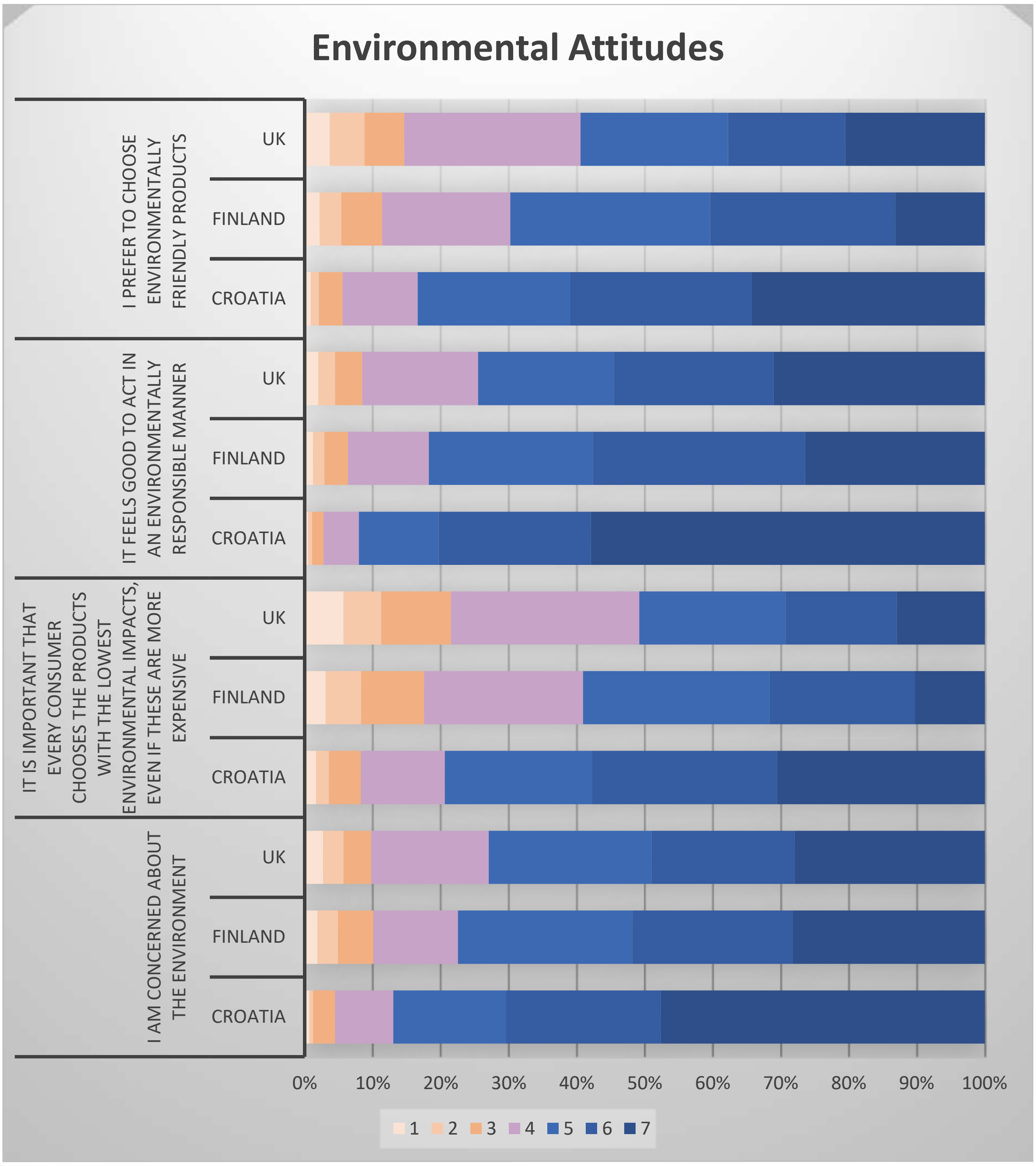
This section provides an overview of some of the different attitudes expressed by survey respondents in different countries, as well as their own self-assessed priorities when it comes to factors that influence their selection of heating systems and vehicles. Also discussed are the survey respondents own perspectives on their levels of knowledge regarding different heating systems and vehicle types.

5.3.1 Environmental Attitudes

Figure 19 compares environmental attitudes amongst survey participants in response to 4 questions. Respondents were asked score their responses on a scale of 1 to 7, with a score of 1 indicating that this attribute has no effect on their choices and a score of 7 indicating that this has the highest level of importance for them. This is sometimes called a Likert Scale or a Likert-style question format, where respondents are asked to agree or disagree with a statement posed to them (Likert, 1932). The central response i.e. 4 out of 7, is designed to reflect a neutral position (Johns, 2005). A known issue with Likert-style survey questions is that respondents can often tend to agree more often than they disagree with the questions posed to them, which can frequently cause the entire distribution to shift in the direction of “agree” rather than “disagree”, a phenomenon known as acquiescence bias (Schuman and Presser, 1981). For practical purposes, acquiescence bias means that the insights presented here are likely to be more useful for understanding the relative preferences of respondents (i.e. comparing attitudes between different countries or demographic groups) rather than absolute preferences (i.e. taking the results to be representative of the target population as a whole).

It can be seen from Figure 19 that there are differences between all three countries. Most participants afforded environmental issues a score of 4 (indicating a neutral position) or higher, with the strongest agreement being found in Croatia, the lowest in the UK, and Finland being in between the two. It is interesting to reflect on the different age structures between the survey samples, discussed earlier in section 5.2.1, and how attitudes might change across age groups (this is explored in greater detail in Section 5.4). It's also clear from the figure how the strength of the statement affects the level of agreement that appears in response. In all three countries, the stronger the statement, the weaker the apparent degree of agreement. For example, *"it is important that every consumer chooses the products with the lowest environmental impacts, even if these are more expensive"* might be perhaps considered the strongest statement, and appears to have the most negative responses. It is worth noting that no explicit trade-offs are required with these responses, so survey participants are not forced to choose between or prioritise different factors (as is the case in the two stated preference exercises, discussed later in Section 5.4).

Figure 19 – Distribution of Responses to Environmental Attitudes Questions



5.3.2 Priorities for Heating Systems

Figures 20, 21 and 22 shows how respondents from different countries stated that they prioritised different attributes of heating systems when making purchase decisions. As with the responses discussed in Section 5.3.1, these are scored on a scale of 1 to 7 with no explicit trade-offs being required – this means that few respondents appear to have used the lower half of the scale, with most responses being in the scoring range of 4 (a neutral position) to 7 (indicating high importance).

Figure 20 shows that UK respondents' top three priorities (assessed by how many respondents scored an attribute as being between a "5" and a "7") were reliability, effectiveness and ease of use, while their bottom three ranked attributes were being independent of the gas or electricity network, the advice of family and friends, and the appearance of the heating system. For Finland (Figure 21), the top three priorities for respondents were reliability, running costs, and indoor air quality, with the bottom three being the appearance of the heating system itself, advice from family and friends, or advice from the existing heating system engineer. For Croatia (Figure 21), the survey respondents had reliability, effectiveness, and maintenance costs as their top priorities, with the bottom three being their own knowledge of the heating system, the advice of family and friends, and the appearance of the heating system.

Figure 20 – UK Sample Responses to Questions Regarding Heating System Attributes

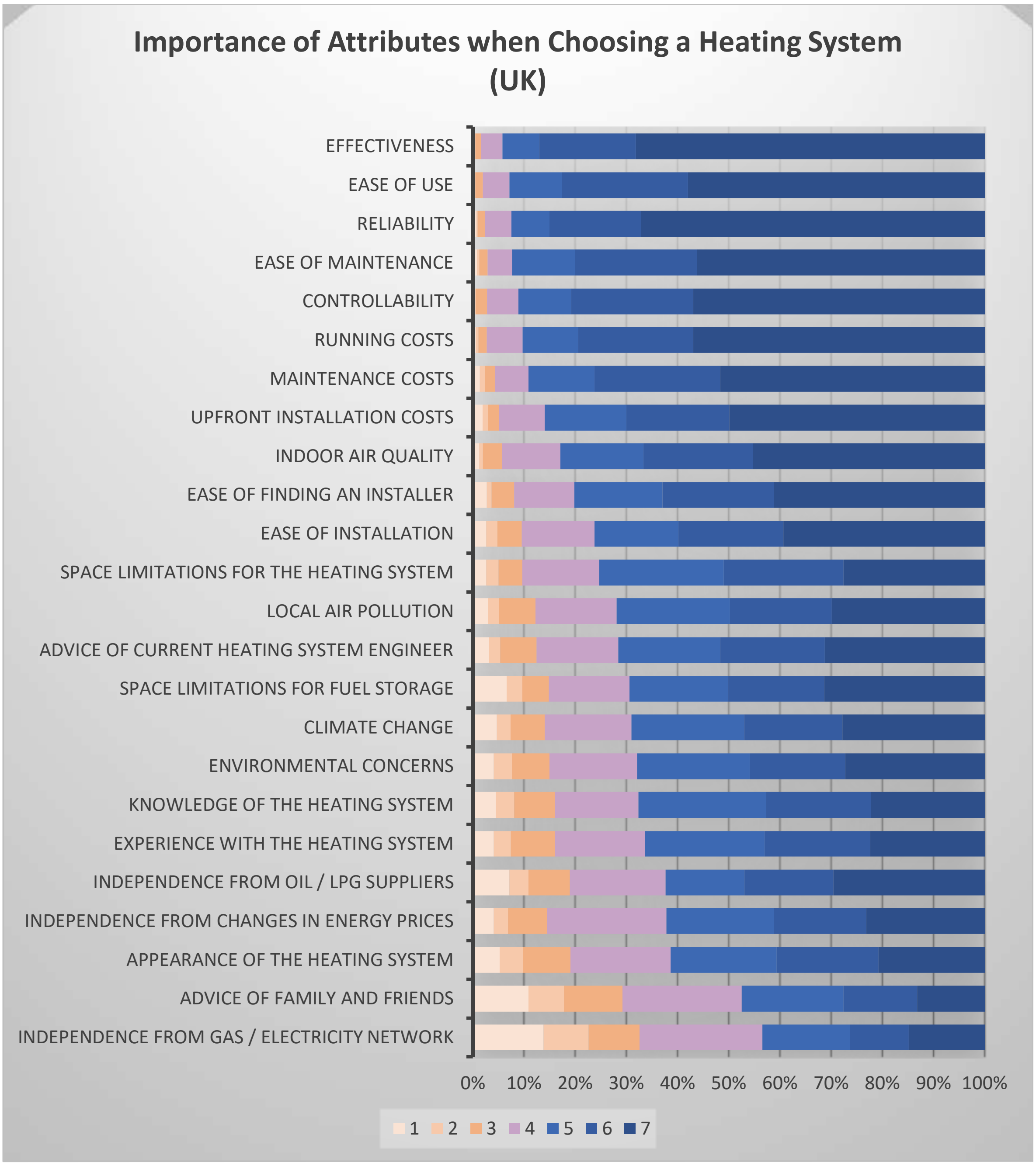


Figure 21 – Finland Sample Responses to Questions Regarding Heating System Attributes

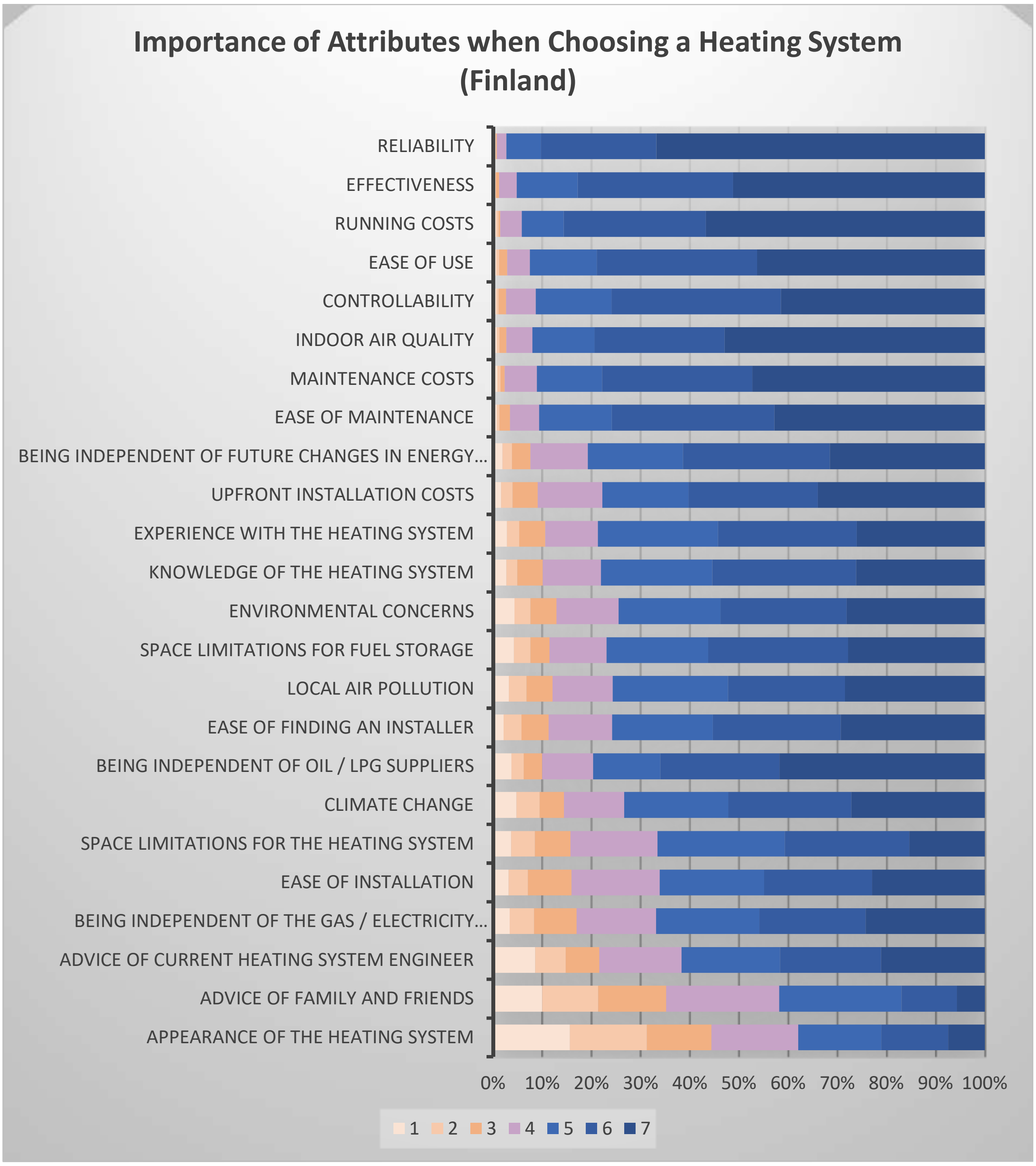
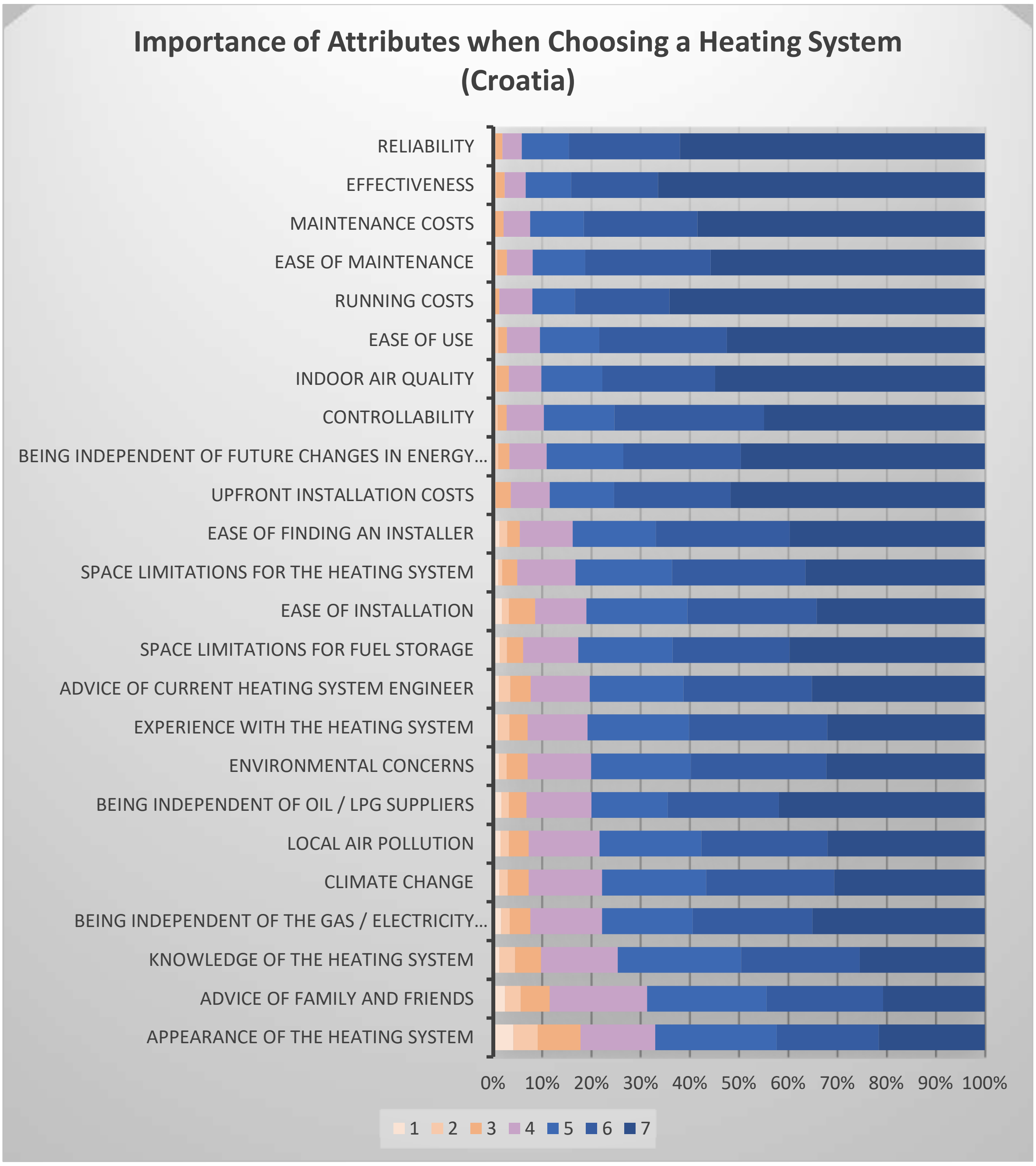


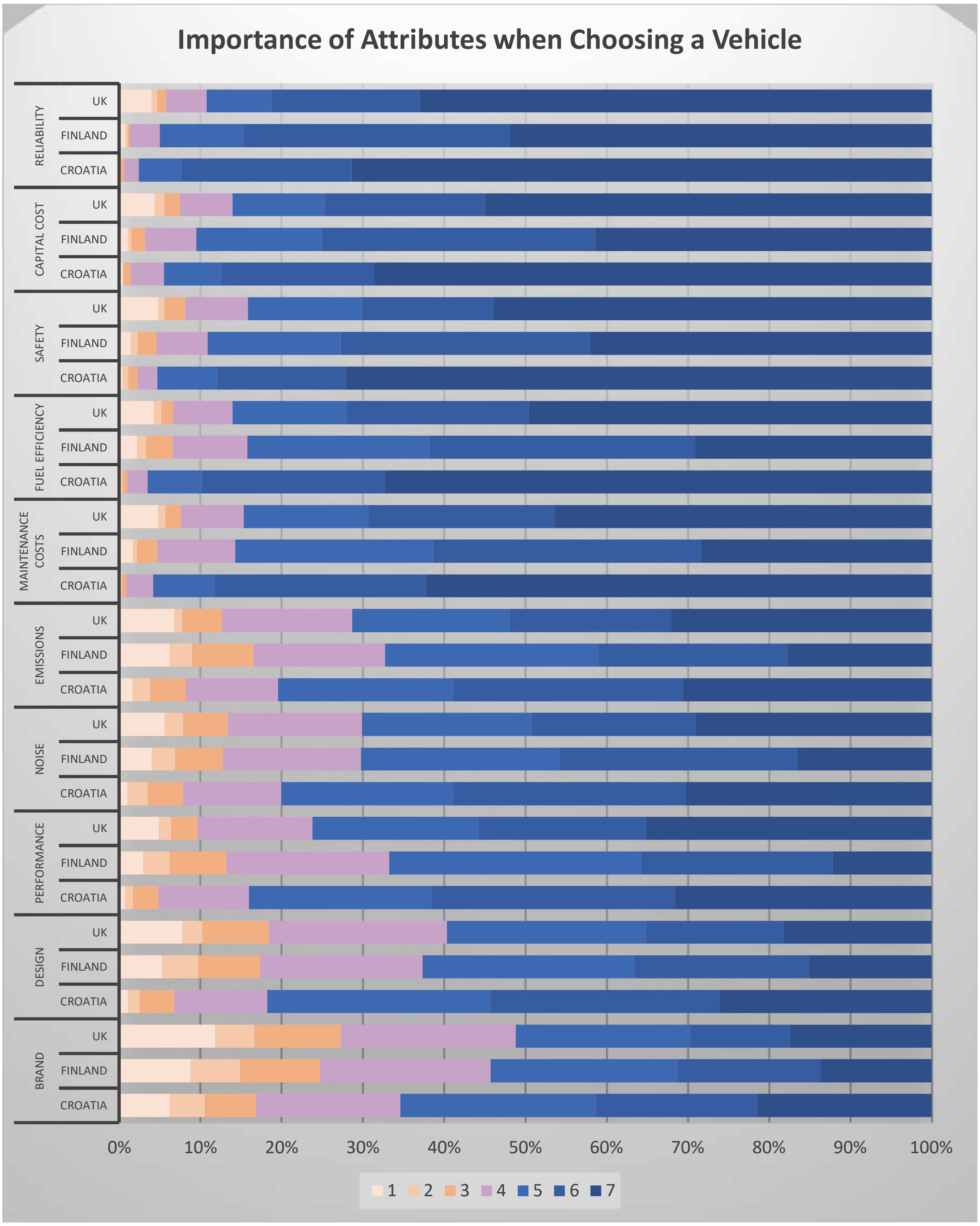
Figure 22 – Croatia Sample Responses to Questions Regarding Heating System Attributes



5.3.3 Priorities for Vehicles

Figure 23 illustrates how different survey respondents prioritised different attributes of vehicles. Respondents across all three countries reported that attributes such as reliability, safety and capital costs were generally the most highly valued, whereas factors such as the design of the vehicle and the brand were viewed as being less important. Across all three countries, the Croatian data on vehicular preferences appeared to differ the most from the UK and Finnish data, which were more broadly in agreement.

Figure 23 – Profile of Responses Regarding Vehicle Attributes



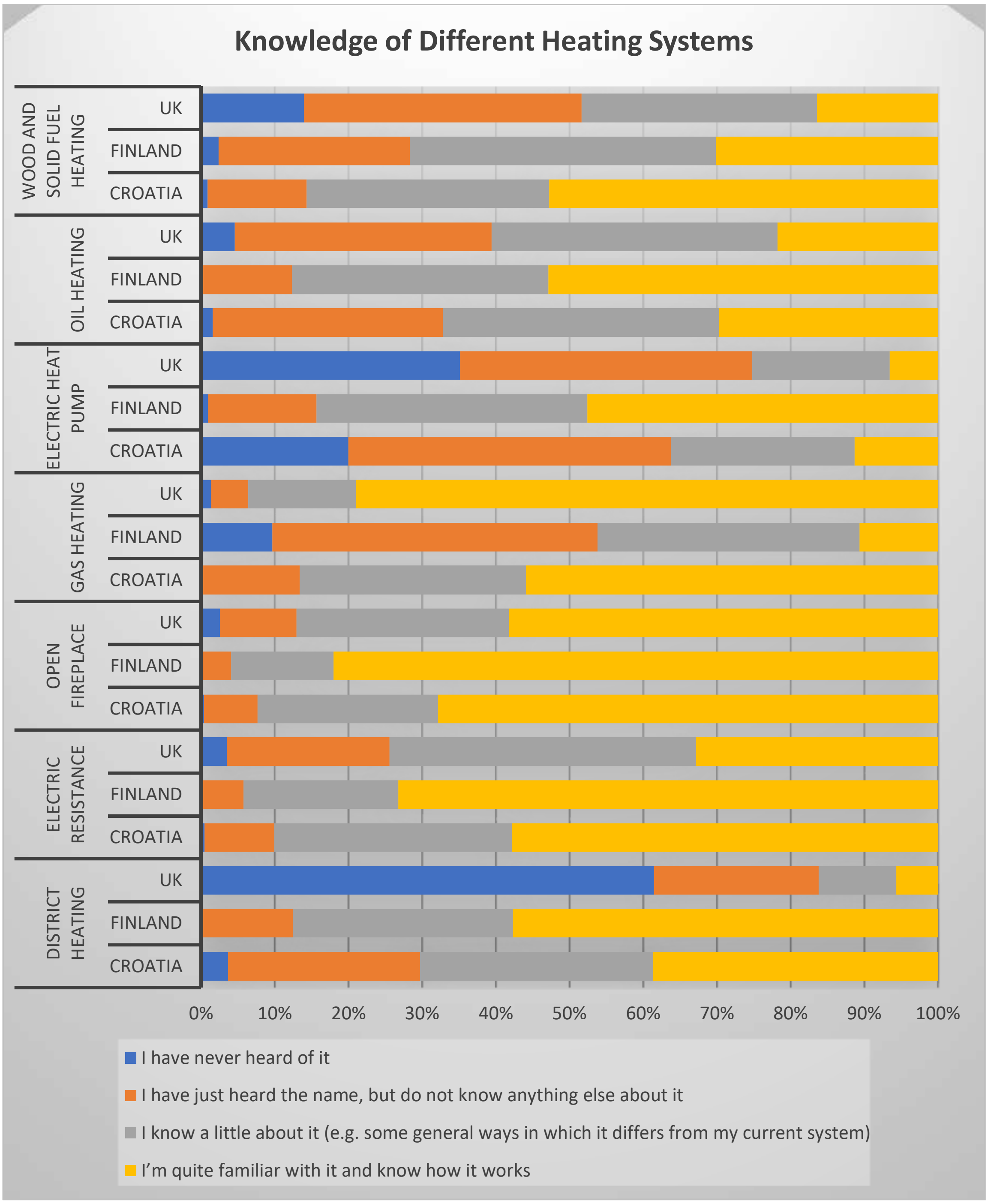
5.3.4 Knowledge of Heating Systems

Figure 24 illustrates how survey participants assessed their own knowledge of different types of heating systems. There are a few critical differences between countries that merit discussion. District heating is relatively unknown in the UK sample, with around 60% of respondents professing total ignorance of the term, and a further ~20% noting that they had *"…heard the name, but do not know anything else about it"*. So, close to 80% of the sample population were unfamiliar with this type of heating system. A similar situation exists for electric heat pumps, with 35% of the sample saying that they had *"never heard"* of the term, while around a further 35% said that they had heard the name but otherwise knew nothing about it. The most familiar heating systems for the UK respondents were gas heating, open fireplaces, and electric resistive heating, with gas heating being by far and large the dominant choice, with close to 80% of the respondents noting that they were *"…familiar with it and know how it works"*. This is unsurprising, given the dominance of gas heating in the existing housing stock and amongst the survey sample, as discussed in Section 5.2.4.

The Finnish respondents in the survey were overall less likely to express a total lack of familiarity with different types of heating systems, which might reflect a greater diversity of technological options in the Finnish housing stock (see Section 5.2.4). Overall, the Finnish sample expressed high degrees of confidence with various kinds of heating system, with more than 50% of the sample saying that they were familiar with district heating, electric resistive heating, electric heat pumps, oil heating, and open fireplaces. In complete contrast to the UK sample, the least familiar heating system for Finnish respondents was gas heating, with more than 50% of respondents saying that they had not heard of this type of heating system or had heard the name, but nothing else.

The Croatian survey sample were the most familiar overall with wood and solid fuel heating, as well as open fireplaces, out of all three countries (this is in line with the distribution of existing heating systems identified in Section 5.2.4). The Croatian sample were the least familiar with oil heating and electric heat pumps, and showed a similar response profile to the UK in regard to these two technology areas.

Figure 24 – Profile of Responses Regarding Knowledge of Different Heating Systems



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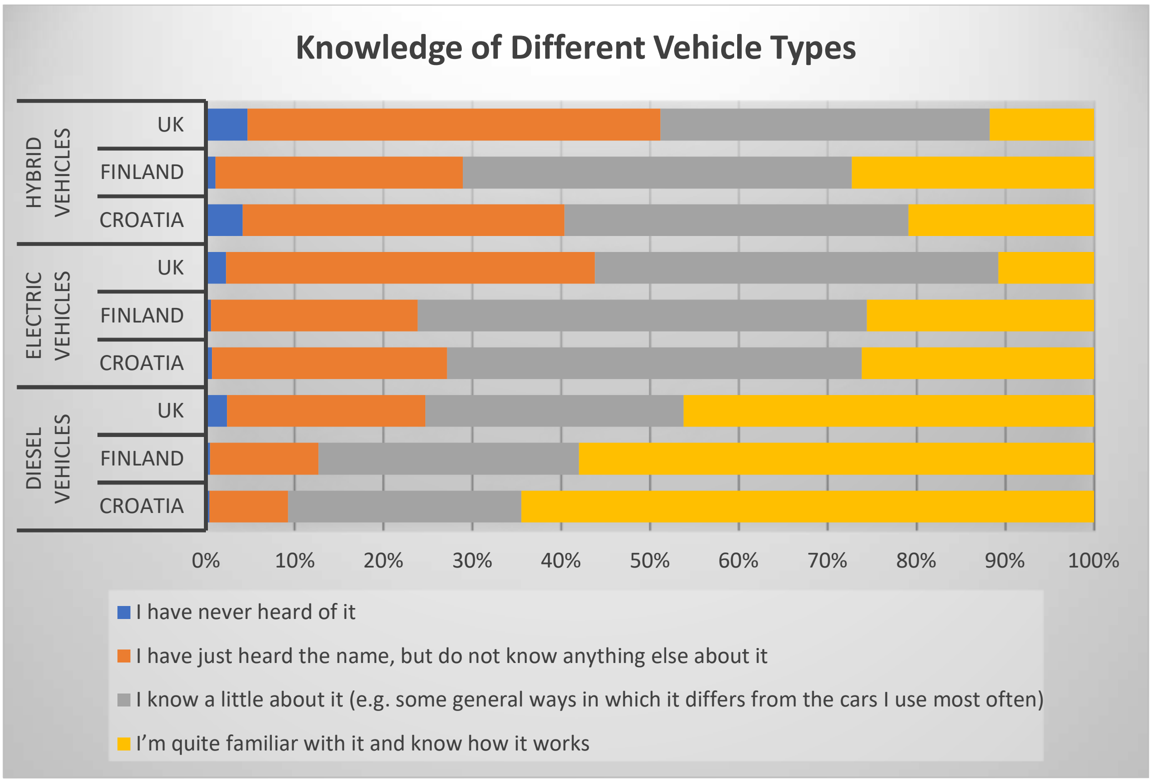
5.3.5 Knowledge of Vehicles

Figure 25 illustrates how survey participants assessed their own knowledge of different types of vehicle. In comparison to heating systems, the pattern across different countries is fairly similar. Respondents in all three countries assessed their own understanding of diesel vehicles as being the highest, with around 45-55% of the sample expressing that they knew how these vehicles operate. Respondents expressed less familiarity with electric vehicles and hybrid vehicles; in the UK only around 10% of the sample were familiar with electric or hybrid vehicles in comparison to Finland and Croatia, where this was close to 20-25%.

Figure 25 – Profile or Responses Regarding Knowledge of Different Vehicle Types



5.4 Behavioural Insights from the Discrete Choice Analysis

This section discusses key results from the discrete choice analysis modelling, described earlier in Section 4.2.4 and Section 5.1.

Multinomial logistic models (MNLM) are a specific type of discrete choice model, and the research team developed separate MNLMs to investigate the factors that influence the choice of residential heating systems and vehicle technologies in each case study country. A MNLM explains choice behaviour as a set of preferences, ranking all potential outcomes, where the consumer is assumed to choose the most preferred available outcome to maximise their own utility (Ben-Akiva and Lerman, 1985). MNLMs have thus been adopted widely in many studies to investigate factors influencing consumers' choice of residential heating technologies and transport technologies (Byun et al., 2018; Decker and Menrad, 2015; Hackbarth and Madlener, 2013; Laureti and Secondi, 2012; Lillemo et al., 2013; Michelsen and Madlener, 2012; Rouvinen and Matero, 2013; Ruokamo, 2016; Scarpa and Willis, 2010; Willis et al., 2011).

In MNLM formulation, the utility (U) for an alternative of technology i for an individual n (n = 1, 2, ..., N) can be expressed as follows:

$$U_{ni} = V_{ni} + \varepsilon_{ni}$$

V_{ni} is the systematic observable component or mean utility value of the alternative i and for an individual n. ε_{ni} is the random error component associated with an alternative i for an individual n. The observable systematic utility, V_{ni}, is given by:

$$V_{ni} = \alpha_i + \beta_{ik} X_{nk}$$

Where X_{nk} is a vector of the explanatory variables (k=1, 2, …, K), such as consumer n's age, household income, dwelling type, ownership of appliances, etc., β_{ik} is a vector of the unknown parameters associated with the explanatory variables X_{nk} and α_i is the alternative-specific constant, which also reflects the average (system-specific) impacts of factors that are not observed and included in the model.

The probability of consumer n's choice of a specific technology option m can then be represented as follows:

$$P(y_n = m|X_{nk}) = \frac{\exp(\beta_{ik} X_{nk})}{\sum_{i=1}^{I} \exp(\beta_{ik} X_{nk})}$$

Where y_n is consumer n's choice of heating systems or vehicle technologies; I is the total number of choices, e.g. in this study there are 4 types of different heating systems shown for UK respondents' consideration.

The coefficients of the model and their significance were estimated using the PythonBiogeme package, which uses maximum likelihood estimation to determine those coefficients (Ben-Akiva and Lerman, 1985; Bierlaire, 2016). The considered socio-demographic factors were introduced into the model sequentially as explanatory variables to investigate their significance in influencing consumers' choices. Only those factors that were determined to be statistically significant were retained for further analysis and are discussed further in the following sections.

The constructed MNLMs with identified influential factors, along with corresponding coefficients, for heating technology and vehicle technology choices are provided in Appendix A-C.

5.4.1 Heating Technology Choices

The identified influential factors for heating technology choice are listed in Table 3 - Factors affecting consumers' heating technology choices in the three countries.

Category	UK	Finland	Croatia

Socio-demographic	Age	●	●	●
	Gender		●	●
	Area	○	●	
	Region		●	○
	Household income	●	●	●
	Education level	◐	◐	
	Number of children	●	●	●
	Number of residents	●		
	Work status	●	●	●
Dwelling	Type	●	◐	○
	Age	●	◐	○
	Number of bedrooms			●
Economic	Capital cost	○	●	●
	Annual cost	○	●	●
	Heating bill		●	
Environmental	GHG emissions	●	●	◐
Technological	Ease of use	○	●	◐
	Heating hours per day	●	●	●
	Experience (e.g. used to install a particular system)	○	●	○
Ownership of heating system	Existing systems	●	●	●
Knowledge of heating system	Familiarity with heating systems	●	◐	○
	Easy-of-use	◐	◐	●
	Costs	○	●	◐
	Reliability		○	◐
	Climate change impact		○	◐
	Local pollution impact	○	●	●
	Space requirements	○	○	
	Impacts on the resale value of homes	◐	●	◐
	Environmental credentials	◐	○	○
Psychological	Environmental friendliness	○	○	○
	Access to information	◐	○	○
	Personal innovativeness	◐	◐	○
	Importance of advice	●	●	●
	User control	●	●	
	Maintenance costs	●		
	Installation costs	●		
	Typical reasons and rationale for heating system replacement	◐	◐	◐

Note: ●: high relevance; ◐: medium relevance; ○: low relevance.

Table 3 shows that a wide range of factors across all 8 of the categories investigated in the survey (originally introduced in Section 4.1, Table 2) were found to be influential determinants of user choices in the UK, Finland and Croatia. However, the strength of different factors and how much they were observed to influence decisions varied considerably across countries:

- **Socio-demographics:** Among socio-demographic factors, gender was found to influential for Finnish respondents, but not for the UK respondents. Geographical and spatial variables were also found to be significant for Finland and Croatia. Unlike in the Finnish and Croatian cases, the UK survey company did not have specific information on where individual respondents were located in terms of their geographical or administrative sub-regions (i.e. postcodes) so this variable was not assessed for the UK. It was found that only the UK respondents' choices appeared to show a correlation against the number of inhabitants living in each household.

- **Dwellings:** In terms of the physical attributes of the dwellings in which households live, the discrete choice modelling exercise revealed that a larger number of variables related to housing morphology and age were found to be influential for the UK respondents in comparison to the Finnish and Croatian respondents. While respondents living in *detached* houses in the UK, Finland, and Croatia all appeared to show a preference for *heat pumps* and *solid-fuels* over other technologies, it was only in the case of the UK that the influence of other morphologies (such as whether dwellings were *semi-detached* homes or *apartments*) appeared be correlated against heating technology choices. There is however a complex picture emerging in relation to heating system selection and dwelling characteristics, as our initial analysis of the sample data appears to show that Croatian may have their preferences for heating system selection correlated against the number of bedrooms in each household. Unpicking this complexity is an ongoing process requiring further analysis, as bedroom numbers, housing morphologies and numbers of inhabitants per dwelling may all be proxies for other drivers of technology selection such as household heating requirements and household activity patterns linked to lifestyle and demographics.

- **Economic:** It was found that UK respondents value economic factors quite differently from Finnish and Croatian respondents. Both Finnish and Croatian respondents are clearly influenced by the capital costs and annual costs of all of the heating systems included in the stated preference exercise, whereas for UK respondents, only the annual running costs of *gas boilers* and the capital costs of installing *solid fuel* heaters were identified as being influential, with no correlations found between cost and selection for the other technologies. Finally, only Finnish respondents' decisions appear to be affected by the magnitude of their current heating bills.

- **Environmental:** The GHG emissions of heating systems are found to have a strong influence on UK and Finnish respondents' choices of heating system while the strength of this link for Croatian respondents appears to be significantly lower.

- **Technological:** Finnish respondents are strongly influenced by variables related to the ease-of-use of individual heating systems and their past experience of installing similar heating systems, for all heating technologies. For example, Finnish respondents are less likely to choose heating systems whenever it is suggested that substantial efforts are needed to operate the system (regardless of technology). For UK respondents, this is the case only for *gas boilers* and *solid fuel* boilers, with no discernible effects visible in the data for the other heating technologies. Finally, Croatian respondents were only found to be influenced by the ease-of-use of technologies in the case of *heat pumps* and *solid-fuel* options.

- **Existing Ownership:** UK, Finnish, and Croatian respondents were found to be affected by most of the variables that relate to their current ownership of existing heating systems. It appears to be the case that where respondents live in a dwelling with a specific heating system, they are more likely to choose the same heating system again. A visual illustration of which heating systems were selected based on respondents' existing installed heating system is provided in Figure 26. For example, more than 70% of UK respondents who already have a gas boiler system installed said that they would select a gas boiler system again, and around 60% of UK respondents who already have an electric heat pump system were shown to select a heat pump again as part of the stated preference exercise regardless of changing costs and performance values. In Finland, around half of the respondents who already own electric heat pumps said that they would choose the same technologies again, while 45% of households who presently use district heating systems or electric resistive heating selected these same technologies again. In Croatia, around 80% of the respondents who have heat pumps installed expressed the intention to choose heat pumps again, while respondents who currently own gas heaters, electric resistive heaters, and wood-fuelled boilers also showed a higher willingness to choose these same technologies. These observations suggest that respondents' choices regarding future heating system choices might actually be strongly anchored to their existing ownership of similar systems, irrespective of their stated priorities for selecting heating systems as discussed earlier in Section 5.3.1.

. The large number of variables (more than 200) makes visualisation of the results non-trivial. For discussion purposes, the research team have chosen to group some variables together in the table. For example, the *"Area"* factor shown in Table 3 is actually an aggregate proxy for three separate urban, suburban and rural area variables. The colour of the circles in the table suggests how often the individual variables related to a factor group are found to be influential – the darker colour is used to illustrate increased influence. For instance, only the binary variable for urban area (i.e. urban or not) is found to be influential on UK respondents' choice of heating technology, whereas all three area variables are found to be influential for the choices of the Finnish respondents. As a result, we have indicated that "*Area*" is a significant factor in both cases, but have chosen to represent the circle for the UK as being at the lightest end of the greyscale spectrum (because only one area variable is significant), while the circle for Finland is displayed using the darkest colour (because all area variables are significant). As for the Croatian respondents, no area related variables were found to be influential on their choices of heating technologies. Therefore, no circle is displayed in the corresponding cell. The full lists of influential variables in a non-aggregated format can be found in Appendices A-C.

Table 3 - Factors affecting consumers' heating technology choices in the three countries.

Category		UK	Finland	Croatia
Socio-demographic	Age	●	●	●
	Gender		●	●
	Area	○	●	
	Region		●	○
	Household income	●	●	●

	Education level	◐	◐	
	Number of children	●	●	●
	Number of residents	●		
	Work status	●	●	●
Dwelling	Type	●	◐	○
	Age	●	◐	○
	Number of bedrooms			●
Economic	Capital cost	○	●	●
	Annual cost	○	●	●
	Heating bill		●	
Environmental	GHG emissions	●	●	◐
Technological	Ease of use	○	●	◐
	Heating hours per day	●	●	●
	Experience (e.g. used to install a particular system)	○	●	○
Ownership of heating system	Existing systems	●	●	●
Knowledge of heating system	Familiarity with heating systems	●	◐	○
	Easy-of-use	◐	◐	●
	Costs	○	●	◐
	Reliability		○	◐
	Climate change impact		○	◐
	Local pollution impact	○	●	●
	Space requirements	○	○	
	Impacts on the resale value of homes	◐	●	◐
	Environmental credentials	◐	○	○
Psychological	Environmental friendliness	○	○	○
	Access to information	◐	○	○
	Personal innovativeness	◐	◐	○
	Importance of advice	●	●	●
	User control	●	●	
	Maintenance costs	●		
	Installation costs	●		
	Typical reasons and rationale for heating system replacement	◐	◐	◐

Note: ●: high relevance; ◐: medium relevance; ○: low relevance.

Table 3 shows that a wide range of factors across all 8 of the categories investigated in the survey (originally introduced in Section 4.1, Table 2) were found to be influential determinants of user choices in the UK, Finland and Croatia. However, the strength of different factors and how much they were observed to influence decisions varied considerably across countries:

- **Socio-demographics:** Among socio-demographic factors, gender was found to influential for Finnish respondents, but not for the UK respondents. Geographical and spatial variables were also found to be significant for Finland and Croatia. Unlike in the Finnish and Croatian cases, the UK survey company did not have specific information on where individual respondents were located in terms of their geographical or administrative sub-regions (i.e. postcodes) so this variable was not assessed for the UK. It was found that only the UK respondents' choices appeared to show a correlation against the number of inhabitants living in each household.

- **Dwellings:** In terms of the physical attributes of the dwellings in which households live, the discrete choice modelling exercise revealed that a larger number of variables related to housing morphology and age were found to be influential for the UK respondents in comparison to the Finnish and Croatian respondents. While respondents living in *detached* houses in the UK, Finland, and Croatia all appeared to show a preference for *heat pumps* and *solid-fuels* over other technologies, it was only in the case of the UK that the influence of other morphologies (such as whether dwellings were *semi-detached* homes or *apartments*) appeared be correlated against heating technology choices. There is however a complex picture emerging in relation to heating system selection and dwelling characteristics, as our initial analysis of the sample data appears to show that Croatian may have their preferences for heating system selection correlated against the number of bedrooms in each household. Unpicking this complexity is an ongoing process requiring further analysis, as bedroom numbers, housing morphologies and numbers of inhabitants per dwelling may all be proxies for other drivers of technology selection such as household heating requirements and household activity patterns linked to lifestyle and demographics.

- **Economic:** It was found that UK respondents value economic factors quite differently from Finnish and Croatian respondents. Both Finnish and Croatian respondents are clearly influenced by the capital costs and annual costs of all of the heating systems included in the stated preference exercise, whereas for UK respondents, only the annual running costs of *gas boilers* and the capital costs of installing *solid fuel* heaters were identified as being influential, with no correlations found between cost and selection for the other technologies. Finally, only Finnish respondents' decisions appear to be affected by the magnitude of their current heating bills.

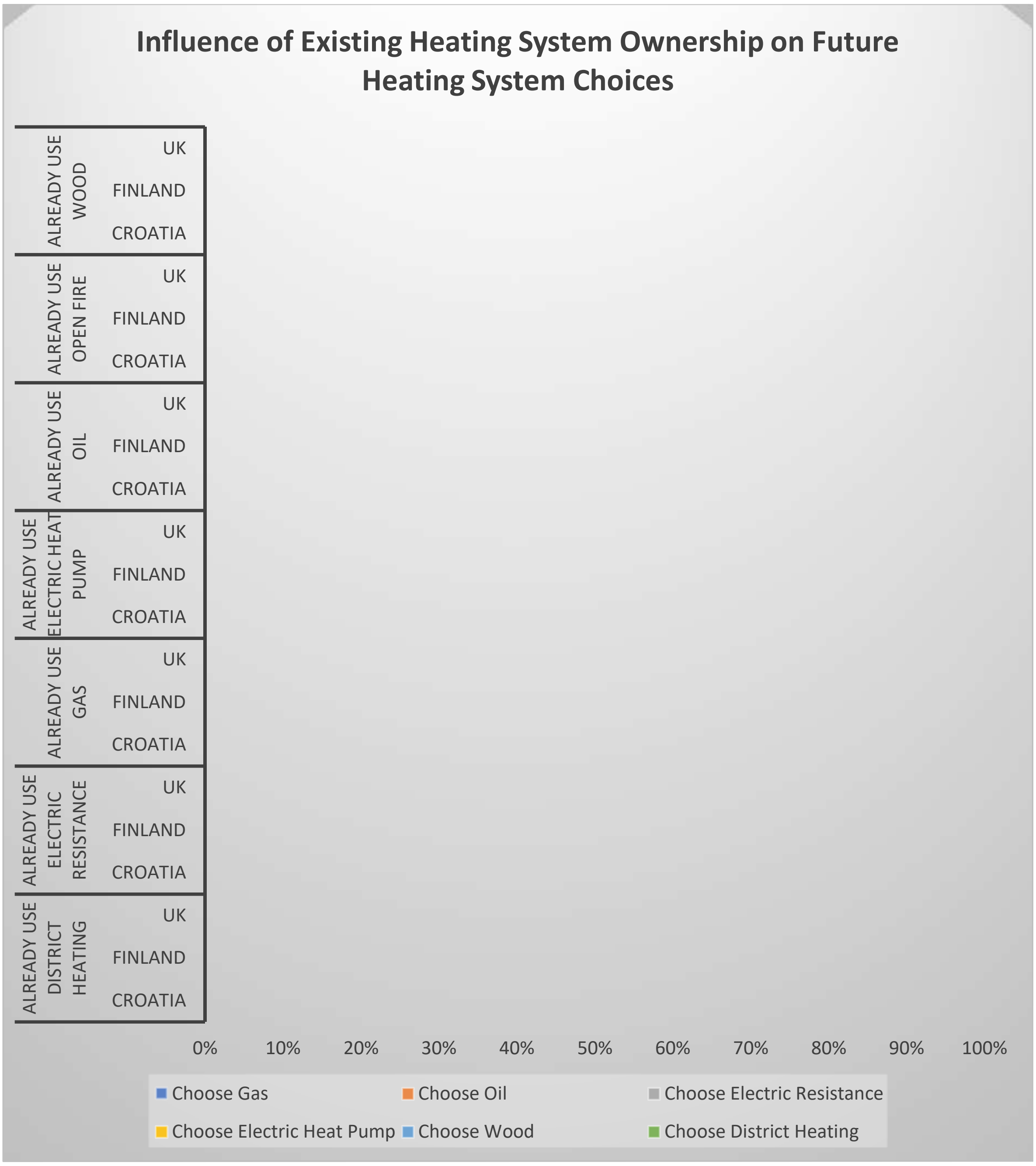
- **Environmental:** The GHG emissions of heating systems are found to have a strong influence on UK and Finnish respondents' choices of heating system while the strength of this link for Croatian respondents appears to be significantly lower.

- **Technological:** Finnish respondents are strongly influenced by variables related to the ease-of-use of individual heating systems and their past experience of installing similar heating systems, for all heating technologies. For example, Finnish respondents are less likely to choose heating systems whenever it is suggested that substantial efforts are needed to operate the system (regardless of technology). For UK respondents, this is the case only for *gas boilers* and *solid fuel* boilers, with no discernible effects visible in the data for the other heating technologies. Finally, Croatian respondents were only found to be influenced by the ease-of-use of technologies in the case of *heat pumps* and *solid-fuel* options.

- **Existing Ownership:** UK, Finnish, and Croatian respondents were found to be affected by most of the variables that relate to their current ownership of existing heating systems. It appears to be the case that where respondents live in a dwelling with a specific heating system, they are more likely to choose the same heating system again. A visual illustration of which heating systems were selected based on respondents' existing installed heating system[1] is provided in Figure 26. For example, more than 70% of UK respondents who already have a gas boiler system installed said that they would select a gas boiler system again, and around 60% of UK respondents who already have an electric heat pump system were shown to select a heat pump again as part of the stated preference exercise regardless of changing costs and performance values. In Finland, around half of the respondents who already own electric heat pumps said that they would choose the same technologies again, while 45% of households who presently use district heating systems or electric resistive heating selected these same technologies again. In Croatia, around 80% of the respondents who have heat pumps installed expressed the intention to choose heat pumps again, while respondents who currently own gas heaters, electric resistive heaters, and wood-fuelled boilers also showed a higher willingness to choose these same technologies. These observations suggest that respondents' choices regarding future heating system choices might actually be strongly anchored to their existing ownership of similar systems, irrespective of their stated priorities for selecting heating systems as discussed earlier in Section 5.3.1.

[1] The space and length limitations of the survey (designed to last around 45 minutes) meant that only a limited number of options were available for selection under the stated preference exercises. The options on offer were chosen in part due to specific national circumstances. The UK stated preference exercise did not offer district heating as a choice, while the Finnish survey did not allow gas heating as a choice. This is because district heating is extremely prevalent in Finland while being almost non-existent (in absolute terms) in the UK, while the converse is true for gas heating (as discussed in Section 5.3.4, knowledge of heating systems also varies between countries). As a result of this, we have not shown results for Finnish respondents who already use gas (because they could not select gas again) or UK users of district heating systems or oil heating systems (who could not select these options again).

Figure 26 – Influence of Existing Heating System on Respondent's Heating System Choices



- **Knowledge and Psychological Factors:** For both the UK and Finland, our analysis found that a higher degree of familiarity with a heating system technology appears to increase the likelihood that a respondent will select the corresponding system in the discrete choice experiment. However, familiarity with heating systems was found to be less of an influential driver in the case of the Croatian survey sample. For Croatian respondents, only their choice of *gas boilers* appeared to be affected by their level of familiarity with this technology. Moreover, UK, Finnish, and Croatian respondents all appear to be influenced by advice from others and the space requirements for a heating system installation (which is interesting because objectively these were ranked amongst the lowest of all factors across all three countries in Section 5.3.4). The ease of controlling a heating system as technology choice criterion was only found to be an influential determinant of technology selection in the case of UK and Finnish respondents. Finally, it appears that respondents' choices could also be affected by other factors such as the likelihood of a heating system raising the resale value of their home .

5.4.2 Vehicle Technology Choices

The influential factors identified for vehicle technology choice across the three case study countries are illustrated below in Table 4 in an aggregated fashion (using similar notational conventions to that for heating systems as discussed at the start of Section 5.4.1)**Error! Reference source not found.**. A more detailed breakdown for all three countries can be found in Appendices A-C.

Table 4 – Factors affecting consumers' vehicle technology choices in the three countries.

Category		UK	Finland	Croatia
Socio-demographic	Age		●	●
	Gender	●		●
	Area	○	○	○
	Region		◐	◐
	Household income	●		●
	Housing tenure	●		●
	Education level	○	○	◐
	Number of children		●	
	Work status	●	◐	●
Dwelling	Type	●	◐	
	Age	●	●	◐
	Number of bedrooms		●	
Economic	Capital cost	●	●	●
	Annual cost	●	●	●
Environmental	GHG emissions	◐	○	◐
Technological	Driving range	○	◐	○
Ownership of heating system	Number of cars owned		●	
	Car type	●	◐	◐

Knowledge of vehicles	Familiarity with car technologies	●	●	●
	Driving range			○
	Easiness of use	○		○
	Costs	○		
	Safety	○		
Transport behaviour	Ownership of driver license	●	●	●
	Ownership of private parking space	●		
	Main reason(s) for using a car	◐	◐	◐
	Frequency of various driving ranges	◐	○	○
	Frequency of various travel modes	●	●	○
Psychological	Environmental friendliness	○	◐	◐
	Access to information	○	◐	◐
	Personal innovativeness	◐	◐	◐
	Brand	●	●	●
	Model		●	●
	Costs	●	●	●
	Noise	●	●	
	GHG emissions	●	●	●
	Performance	●	●	
	Reliability	●	●	
	Safety	●		●
	Style	●		

Note: ●: high relevance; ◐: medium relevance; ○: low relevance.

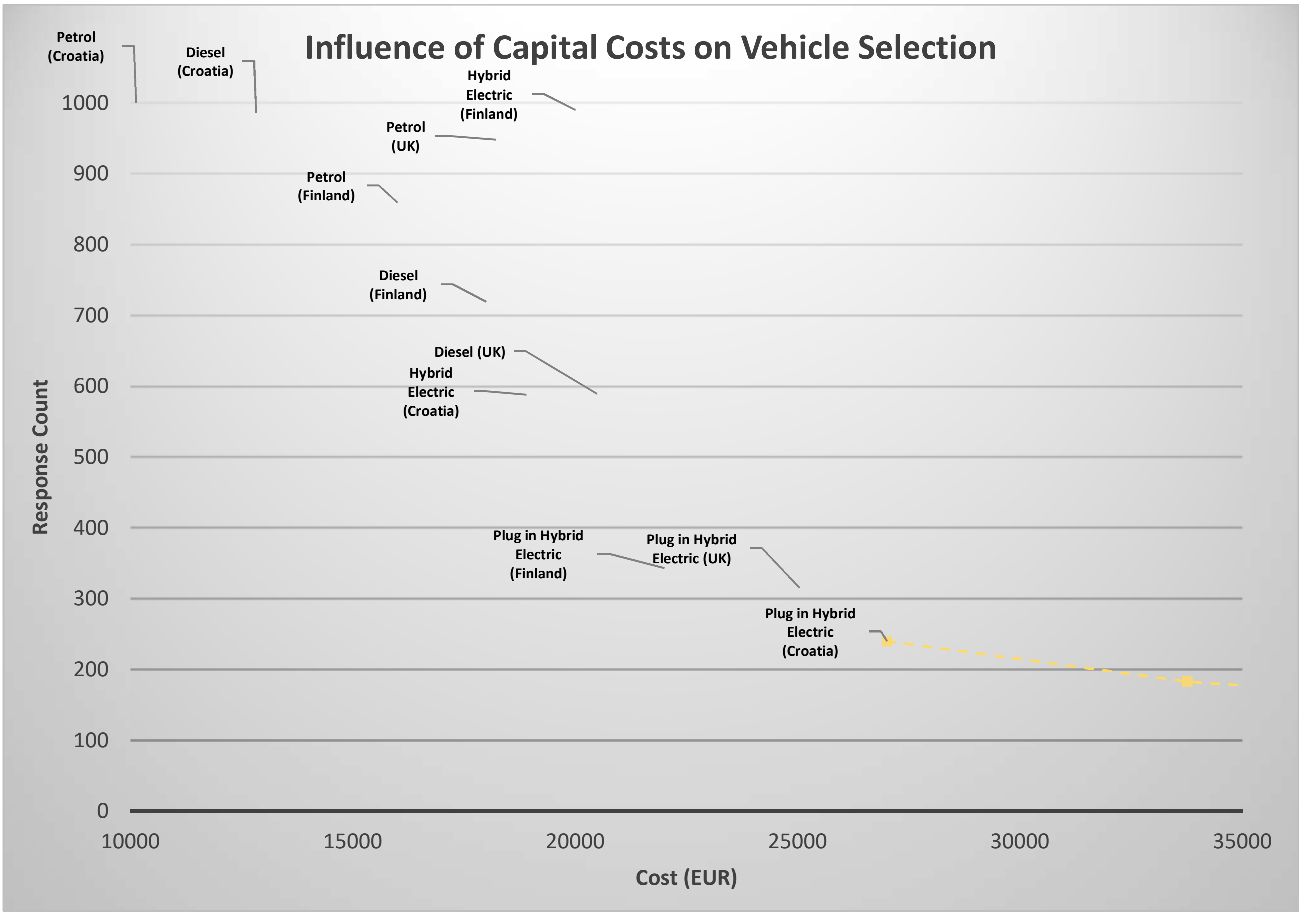
As is the case with heating technology choices, covered above in Section 5.4.1, many factors across all 8 categories were found to be influential for UK, Finnish, and Croatian respondents but their respective influences vary across these countries.

- **Socio-demographics:** Socio-demographic factors were found to have distinct influences on vehicle technology choices in different countries, with age, gender, income, housing tenure, family size, and geographical location all being influential to different degrees. For example, older respondents from the Finnish sample were found to choose *petrol* cars more frequently than younger ones, while older respondents from the Croatian sample appeared less likely to choose *diesel* cars. However, age did not appear in our analysis as an influential factor driving vehicle technology selection for UK respondents. With regard to gender, the analysis revealed that male respondents in the UK appeared less likely to choose *plug-in hybrid electric vehicles* than female respondents, while male respondents in Croatia were found to be less likely to choose *diesel* cars when compared to female respondents. At the same time, correlations between vehicle technology selection and gender were not observed in the Finnish sample data. Household income and housing tenure only appear to affect UK and Croatian respondents' choices, e.g. UK respondents are more likely to select *diesel* cars when their household incomes are higher, but in a complete reversal of trend, this was found to be the exact opposite in the case of Croatian respondents. Conversely, only Finnish respondents appear to have their choice of vehicles correlated against the number of children who live in their households. Additionally, there are some geographical location specific factors that can be reported for Finland and Croatia – for example, Finnish respondents from *Helsinki* appear to be more likely to select *hybrid electric vehicles* than Finnish respondents in other parts of the country. Croatian respondents from *Dalmacija*, *Lika i Banovina*, and *Slavonija* appear to be more likely to choose *plug-in hybrid electric vehicles* than the other Croatian respondents. The lack of panel data information on UK respondents' addresses meant that these geographical details could not be explored in the case of the UK.

- **Dwellings:** Dwelling-related factors appear to be influential with regard to householder vehicle choices in all three countries. The UK, Finnish, and Croatian respondents all exhibit patterns of technology selection that appear linked to the age of their homes, which is interesting, because there is no obvious *a priori* relationship between the age of a building and an occupant's preferences for their choice of car. UK respondents living in older homes were found to be more likely to choose *hybrid vehicles* and *plug-in hybrid electric vehicles.* On the other hand, Finnish respondents living in older homes tended to choose *petrol* cars more frequently. Croatian respondents living in older homes appear more likely to choose *plug-in hybrid electric vehicles*. Dwelling morphology was also found to correlate strongly with vehicle choice. Respondents living in terraced houses in the UK and Finland are both more likely to have selected *petrol* cars, while only UK respondents living in flats appeared to choose *plug-in hybrid electric vehicles* more often. The extent to which dwelling age and morphology are direct drivers of vehicle selection and to what extent these measures are proxies for other factors (e.g. income) is interesting to reflect on.

- **Economic:** Unlike the case found for heating technology choices, economic factors were observed to be influential determinants of technology selection across the survey samples in all three counties. Figure 27 not only provides an indicator of how preferences for vehicles change amongst consumers in different countries with respect to changes in costs, but also which vehicle types are the most popular. It can be seen that in all cases and for all vehicle types the number of respondents selecting an individual vehicle type decreases as costs increase. But marked differences exist between countries. For example, the leading new vehicle type in the UK (selected the highest number of times by respondents) is the *petrol* vehicle, while in Finland, the data show that *hybrid electric vehicles* are the most popular. In Finland, the data on costs show that *diesel* vehicles are thought of more or less in similar terms as *petrol* vehicles, while in the UK, there is a clear separation in preferences.

Figure 27 – Influence of Capital Costs on Vehicle Choices



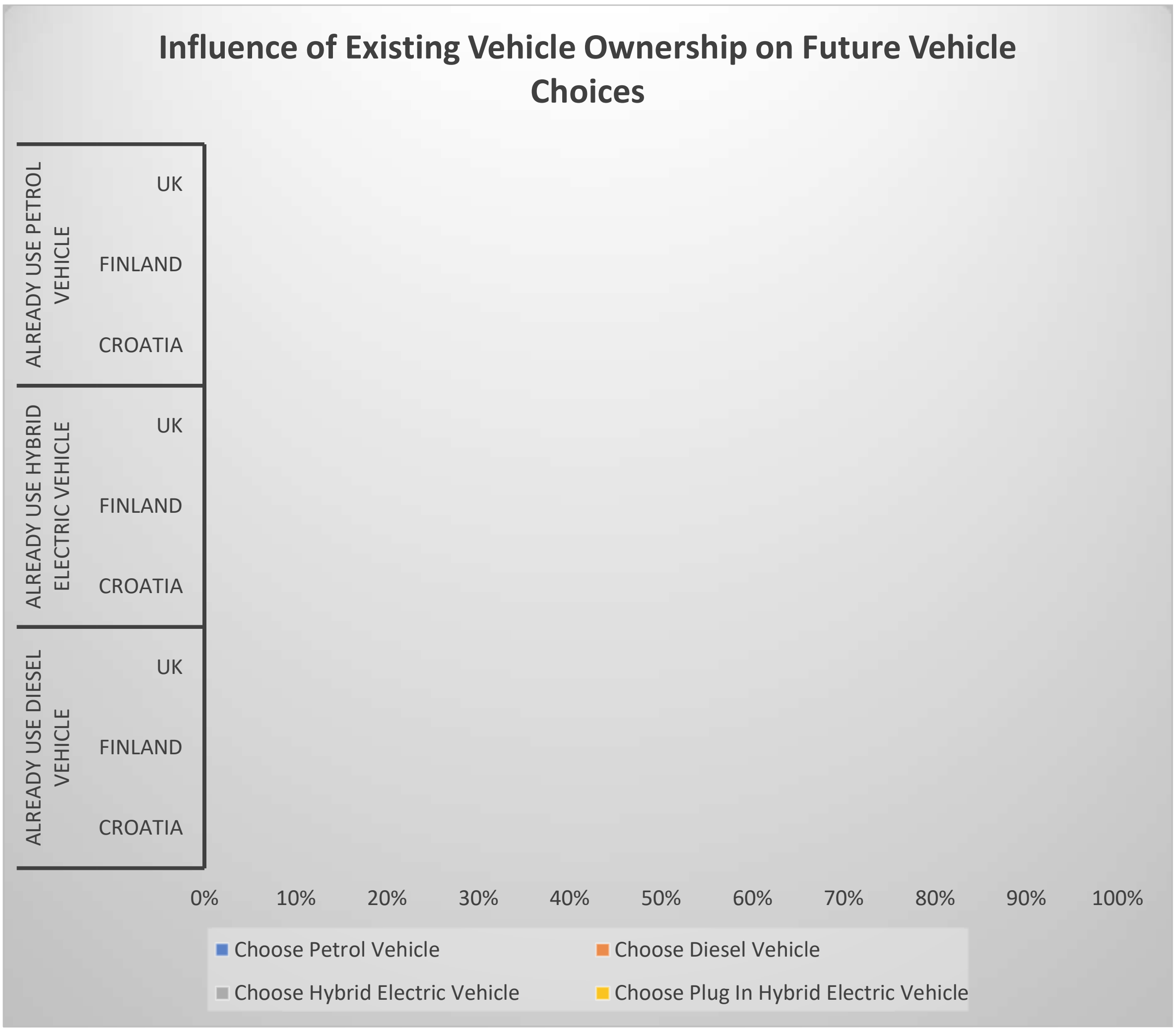
- **Environmental:** In contrast to the findings for heating systems (Section 5.4.1), environmental factors such as GHG emissions were found to be less influential drivers of vehicle technology selection in the case of the UK and Finnish survey samples. However, for Croatian respondents, the apparent influence of environmental factors on their choices of heating system and vehicle technology were similar.

- **Technological:** The maximum driving range of vehicles before refuelling or recharging is required has some effect on vehicle selection choices, with the influence of this factor being more pronounced amongst Finnish respondents than UK and Croatian respondents.

- **Existing Ownership:** Existing ownership of vehicle technologies can be seen as a crucial factor influencing future vehicle choices from the constructed DCMs. The analysis reveals that existing ownership of a given vehicle type increases a respondents' tendency to choose a similar vehicle type in all three countries. Figure 28 visualises the influence of existing vehicle ownership on future vehicle choices[2]. As with heating systems (Section 5.4.1), Figure 28 illustrates what appear to be strong anchoring effects arising from existing technology ownership. Owners of petrol vehicles in all three countries are likely to choose petrol vehicles again. Similarly, diesel vehicle owners in all three countries appeared to strongly prefer diesel vehicles. Finally, hybrid electric vehicle owners were found to be likely to select a hybrid electric vehicle for their next car in both the UK and Finland, but not in Croatia. In an interesting reversal of trend, our data appears to show that hybrid electric vehicle owners in Croatia were as likely to choose a diesel car in future as they were another hybrid electric vehicle. The very small total number of respondents with hybrid electric vehicles in all three country samples (UK = 17, Finland = 16, Croatia = 7) should of course be borne in mind when interpreting these findings.

[2] This is displayed only for existing owners of petrol, diesel, and hybrid electric vehicles (which collectively comprise the majority of the survey sample as discussed in Section 5.2.5). The visualisation below eliminates choices made by owners of minority fuel options like biofuel, battery electric, CNG, LNG, and petrol-oil mixture vehicles (for older 2-stroke engine designs). Collectively households using these fuels comprise less than 2% of all households in the sample, and results are in any case unlikely to be statistically significant (for biofuels, battery electric, CNG etc.) due to the low respondent counts.

Figure 28 – Influence of Existing Vehicle Ownership on Respondent's Vehicle Choices



- **Transport Behaviour:** Factors relating to respondents' transport behaviours were found to be influential determinants of their choices. If *"driving children to school"* is selected as one of the respondents' major reasons to use cars in all three countries, then the analysis finds that *hybrid electric vehicles* and *plug-in hybrid electric vehicles* are selected more frequently. In contrast, respondents who state that they use their cars primarily for leisure purposes show different preferences in the UK and Finland. UK respondents who use their cars mostly for leisure appear in the data analysis to be more likely to choose *diesel* cars, whereas their Finnish counterparts are less likely to choose *diesel* cars. Distinctive influences can also be found for factors related to the frequency of various trip distances by car. UK respondents who regularly drive on trips of between 100-300 km tend to choose *hybrid electric vehicles* more often; however, Finnish respondents who often drive trips of the same range expressed a preference for *diesel* cars. Similarly, factors related to the frequency of various travel modes (i.e.

travel by public transport, taxi, private car, motorcycle, cycling, walking etc.) influence respondents' choices quite differently between the UK, Finland, and Croatia. For example, respondents who reported that they walked long distances more often appeared to be more predisposed to purchasing *hybrid electric vehicles* and *plug-in hybrid electric vehicles* in both the UK and Finnish samples respectively, but a reverse effect was observed in the Croatian data.

- **Knowledge and Psychological Factors:** Familiarity with different vehicle technologies was observed to affects respondents' vehicle technology choices in all three countries. When respondents in these three countries expressed a higher degree of familiarity with a given vehicle technology, they were found to be more likely to choose that corresponding technology in the stated preference exercise. Specific views on electric vehicle technology appeared to affect UK and Croatian respondents. Respondents in both the UK and Croatia who expressed their belief that EV's were complicated to use were found to be less likely to choose EV's, whereas this was not observed amongst Finnish respondents. Finally, many psychological factors are also revealed as being influential in terms of how they respondents' vehicle technology choices. A full list of these influences can be found in Appendices A-C.

5.5 Summary of Insights from Discrete Choice Analysis

In general, the analysis finds that survey respondents' choices of technologies are strongly influenced by economic factors, such as capital costs, but that costs do not fully explain decision making. There are also some interesting exceptions (discussed below) to the rule, such as the fact that UK respondents' choice of heating systems appears to be only weakly driven by economic considerations. The analysis finds that respondents exhibited a degree of preference for technologies with low CO_2 emissions instead of carbon-intensive ones, but that this varied in strength between different countries and between heating systems and vehicle technologies. Past experiences with individual technologies, such as existing ownership and familiarity with their operation, appears to strongly increase respondents' willingness to select the same technology again, e.g. having a diesel car currently would increase the chance of choosing a diesel car, and having a gas boiler appears to strongly increase the chance of choosing a gas boiler.

5.5.1 Cross-Cutting Insights Between The UK, Finland and Croatia

The analysis of survey data from the UK, Finland, and Croatia reveals several factors that consistently affect respondents' choices of heating systems and vehicle technologies.

- **Heating technology choices:**
  - **Cost factors**, **emissions**, and **convenience/effort** were found to be influential for *gas* and *solid fuel* heating.
  - **CO_2 emissions** also seem to partly drive the choice of *heat pumps* and *electric resistive heaters*

- **The type of existing heating system** and **house types** seem to be explanatory variables for all heating system technology choices.
- Other **socio-demographic factors** such as age, household size, and education level appear to be significant drivers of heating system uptake.
- **Dwelling characteristics**, such as house type and age, also appear to be influential drivers of heating technology choice.
- **Familiarity with a heating technology** appears to increase the chance of choosing the same technology.
- **Knowledge of heating systems** and **psychological factors** frequently affect heating technology choices. However, the influences of these factors appear to be less pronounced than those of the other factors discussed.

- **Vehicle technology choices:**
  - **Capital and annual costs** appear to affect all vehicle choices.
  - **CO2 emissions** appear to influence choices around *petrol* and *diesel cars*.
  - **Max range** seems to be significant for *hybrid* and *plug-in electric vehicles*.
  - As with heating, **socio-demographic factors** such as age, area, and education level were also found to be influential.
  - **Dwelling characteristics**, such as house type and age, were also found influential drivers of vehicle technology choices, although the extent to which dwelling characteristics are actually a proxy for other factors, such as income, needs further investigation.
  - **Existing vehicle ownership** appears to strongly increase the chance of individuals choosing similar types of vehicle in future.
  - **The purposes of car usage,** the typical **driving distances** and **transport mode choices** all appear to be significant explanatory variables for vehicle choices.
  - **Familiarity with a vehicle technology** also appears to motivate the selection of the same vehicle technology.
  - **Psychological factors** are frequently found to affect vehicle technology choices. However, as is the case with heating systems the influences of these factors appear to be less pronounced than those of the other factors.

5.5.2 Differences between countries and between sectors

As well as a general commentary on common observations across all three case studies, it is also useful to reflect on where the survey samples also appear to reveal differences between countries.

- **UK respondents:**
  - **Differences between the UK and other countries**
    - Unlike the other countries, **gender** does not appear to be an influential factor for the choice of heating system in the UK.
    - Furthermore, compared to the other countries, the influences of **dwelling characteristics** in the UK are stronger on the choices of both heating system and vehicle technology. The extent to which dwelling characteristics are proxies for other factors needs additional exploration in future.
    - **Economic factors** were found to be significantly less influential on UK respondents' choices of heating system as compared to other countries.
    - The respondent's **knowledge of heating systems** seems to be less influential on the choice of heating system in the UK when compared to other countries.
    - Compared to the other countries, UK respondents are more strongly influenced by **psychological factors** with regard to their choices of both heating system and vehicle technology.
  - **Differences between home heating and vehicle technology choice in the UK context**
    - **Age and Household structure**, such as number of residents in the household and the number of children, only appears to affects the choice of heating system, but not vehicle technology.
    - **Economic factors** appear to be more influential on the choice of vehicle technology than the choice of heating system.
    - **Environmental factors**, such as GHG emissions, appear to be more influential for the choice of heating system than for vehicle technology.
    - The respondent's prior **knowledge of technologies** appears to have a stronger influence on the choice of vehicle technology than on the choice of heating system.

- **Finnish respondents:**
  - **Differences between Finland and other countries**

- Compared to respondents in the other countries, Finnish respondents are more often influenced by **socio-demographic factors** when it comes to their choices of heating system; but less so in terms of their choices of vehicle technology.
- In Finland, **economic factors**, such as capital costs of heating system, have the strongest influences on heating system choice amongst all three studied countries.
- **GHG emissions** seems to have less influence on the choice of vehicle technology in Finland as compared to the other countries.
- **Technical factors** appear to affect the choices of both heating system and vehicle technology to a greater degree in Finland than they do in the other countries.
- Finland appears unique in this study as it is the only country where the **number of cars owned** in a household appears to influence the respondents' choice of vehicle technology.
- Unlike the other countries, **knowledge of electric vehicles** does not appear to affect the choice of vehicle technology in Finland (either positively or negatively).

o **Differences between home heating and vehicle technology choice in the Finnish context**

- **Dwelling characteristics** in Finland appear to show stronger influence on the choice of vehicle technology than on the choice of heating system.
- **Economic factors** appear to consistently affect Finnish respondents' choice of both heating system and vehicle technology.
- **Knowledge of technologies** seem to have a stronger effect when it comes to heating technology choices than is the case for vehicle technologies (the exact reverse of the observed trend in the UK).
- **Psychological factors** in Finland appear to affect more frequently the choice of vehicle technology than the choice of heating system.

- **Croatian respondents:**

o **Differences between Croatia and other countries**

- **Socio-demographic factors** appear to exert a stronger influence on the choice of heating system in Croatia than they do in the other two case study countries.
- Compared to the other two countries, **dwelling characteristics** appear to be less influential for both heating systems and vehicle technology in Croatia.

   - **Knowledge of heating system** affects the choice of heating system more often in Croatia than in the other two countries.
   - **Psychological factors** appear to be less influential for both the choices of heating system and vehicle technology in Croatia than in the other two countries.

- **Differences between home heating and vehicle technology choice in the Croatian context**
   - **Socio-demographic factors** appear to be more influential for vehicle technology than for heating system.
   - **Knowledge of technologies**, on the other hand, is more influential for heating system than for vehicle technology.

6 Integrating Behavioural Insights into Energy System Models

This section briefly discusses various approaches for integrating behavioural insights into energy system models and makes specific recommendations regarding how the behavioural insights from Task 4.1 can usefully feed into the energy modelling activity being undertaken as part of the wider REEEM project under Work Package 6.

The results above provide information about how different factors affect the decisions of the respondents in the three surveyed countries. While this allows one to consider behavioural factors in energy models, the specific model type, the description and disaggregation of consumers in the model and, most importantly, the range of significant factors identified all have strong implications for what can, and should, be done to reflect the findings in the energy system model.

The model used in REEEM is based on the linear optimisation based TIMES platform (Loulou *et al.*, 2016) and thus all equations used in the model **need to be linear**; therefore the predefined market share functions that are produced as outcomes of the DCM model can't be implemented directly. What's more, the TIMES model relies on cost optimisation, which means that it **assumes costs to be a significant**, or even the only, factor for driving decisions. The model also has a strong focus on technologies and their costs and generally has **limited representation of any other factors**, many of which might still be very relevant for decision making. Finally, the model usually **doesn't reflect agent heterogeneity**, but instead relies on a small number of representative agents for large consumer groups.

Based on the above, the two key approaches for including behavioural factors are (1) adding cost and consumer group specific disutility costs to technologies or, in case costs are not an influential factor for decisions, (2) constraining the model to follow the choices implied by the development of the non-cost factors. For both approaches, one needs to disaggregate consumers in the model according to the factors that are to be considered.

In approach (1), one uses the DCM results and monetises the non-cost elements for each group and technology to the represented in the model in such a way that the likelihoods of individuals from specific groups to pick a specific technology do not change. This approach then means that each of the groups considered needs to be explicitly separated in the model, with distinct heating/car transport demands, technology representations etc. Also, the number of influencing factors quickly increases the number of such groups that need to be created. For example, disaggregating people to low-mid-high income cohort, rural-urban-suburban cohorts and 18 to 30, 30 to 60 and above 60 cohorts would create already 27 (3^3 combinations) different consumer groups that would need to be modelled. The number of factors considered therefore need to remain fairly low. For an example of a previous implementation following this approach, see McCollum et al., (2017).

Approach (2) differs in that costs are considered to be a non-factor and therefore monetisation of non-cost elements is not possible. As the model still relies on costs for its decisions, one needs to reflect the non-cost drivers externally in the model, through the use of constraints. This approach also requires one to distinguish the relevant consumer groups explicitly and then create constraints that reflect the decision-making dynamics into the model. Depending on the exact drivers and the options available in the model, this may require explicit separation of consumer groups in the model or use of more aggregate constraints that have been built separately outside the model. An example of an application can be found in Li et al., (2018).

In the case of our DCM, costs are significant for transport, but less so for heating technologies, suggesting possibly a mixed approach. The exact factors that should be considered strongly depends on the exact structure of the current Pan-EU TIMES model and what the WP6 team considers feasible to do in terms of further disaggregating consumers. The latter is not only a question of changing model structure, but also of finding the necessary data for disaggregating, and projecting, the consumer groups. Finally, our survey covered only three of the 28 EU countries and methods are needed for extrapolating the results to the remaining 25 countries. A potentially promising approach for this could be to consider social influence similarities between member states and project the findings of the surveys based on those (and other, national energy system specific, characteristics). For an example of this, see Pettifor et al., (2017a) and Pettifor et al., (2017b).

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Appendix A - Discrete Choice Model Results for UK Consumers' Technology Choices

Table A.1 Factors affecting UK consumers' heating technology choices

Variable	Gas heater		Elc heater		Heat pump		Solid heater	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
ASC	0.126	0.45	0.327***	0.13	0.482*	0.05	-1.010*	0.01
Age	0.092*	0						
Urban			0.239*	0.01				
Post-graduate education			0.440*	0	0.429*	0	0.291*	0.04
Primary level education	-0.457*	0.03						
Env: concerned about environment							0.141*	0
Env: everyone should choose environmental friendly products			0.092*	0	0.179*	0		
House age: 60~100 years old			0.258*	0.02				
House age: 0~30 years old	0.152*	0.05						
House age: 30~60 years old	0.179*	0.01						
Number of children							-0.120*	0.04
Monthly income after taxes			-0.101*	0				
Household size					-0.114*	0		
House type: bungalow					0.520*	0.01		
House type: detached					0.215*	0.02		
House type: flat							2.000*	0
House type: maisonette							1.310*	0.01
House type: semidetached	0.321**	0.07			0.527*	0.01	0.728*	0
Info: receive advertising recently			0.134*	0	0.040**	0.09	0.046**	0.06
Info: ask friend for new tech			0.129*	0				
Info: keep up-to-date myself	0.124*	0						
Info: ask a professional							0.077*	0
Innovation: people ask me for advice	0.182*	0						
Innovation: owning new technologies to distinguish from others					0.172*	0		
Innovation: owning new technologies for personal enjoyment	0.112*	0						
Innovation: seek information about latest technologies	-0.148*	0	0.180*	0				
Innovation: know must-have technologies							0.120*	0
Work: full-time			-0.220*	0.04	-0.512*	0	0.512*	0
Work: looking after home	0.454*	0.01			0.362**	0.1	0.790*	0
Work: part-time							0.508*	0

Variable	Gas heater		Elc heater		Heat pump		Solid heater	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Work: unemployed							0.460*	0
Gas heater: annual costs	-0.154*	0						
Gas heater: GHG emissions about 3 tonnes/year	-0.286*	0						
Gas heater: GHG emissions more than 4 tonnes/year	-0.520*	0						
Gas heater: no own work	0.339*	0						
Gas heater: some own work	0.299*	0						
Heat pump: GHG emissions more than 4 tonnes/year					-0.233*	0.01		
Solid boiler: capital cost							-0.430*	0
Solid boiler: GHG emissions about 3 tonnes/year							-0.482*	0
Solid boiler: GHG emissions more than 4 tonnes/year							-0.658*	0
Solid boiler: no own work							0.254*	0
Existing system: electric heater	-0.413*	0.01	0.780*	0				
Existing system: gas heater	0.586*	0						
Existing system: heat pump			1.730*	0	2.260*	0		
Existing system: oil boiler	-0.530*	0						
Existing system: open fireplace							1.440*	0
Existing system: wood-fueled boiler			1.200*	0			2.620*	0
Familiarity with gas heater	0.244*	0						
Familiarity with solid fuel boiler							-0.089**	0.08
Familiarity with wood-fueled boiler							0.335*	0
Hours of heating	0.388*	0			0.305*	0	0.325*	0
Choice factor: advice of family/friends			0.137*	0	0.107*	0		
Choice factor: appearance of heater	-0.050*	0.03						
Choice factor: controllability			-0.135*	0.01				
Choice factor: how easy to use					-0.232*	0		
Choice factor: effectiveness					0.163*	0.03		
Choice factor: independent of future energy prices					0.158*	0		
Choice factor: independent of oil/LPG suppliers							-0.080*	0
Choice factor: indoor air quality			-0.146*	0			0.144*	0
Choice factor: own knowledge of heater			-0.233*	0			0.065*	0.04
Choice factor: maintenance costs	0.151*	0						
Choice factor: easiness of maintenance	0.154*	0						
Choice factor: reliability of heater			-0.190*	0	-0.215*	0	-0.207*	0
Choice factor: running costs	-0.177*	0						
Choice factor: space limits for heater			0.200*	0	-0.078*	0.03		
Choice factor: upfront costs			0.134*	0			0.156*	0

Variable	Gas heater		Elc heater		Heat pump		Solid heater	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Views on elc heater: easy to acquire			-0.260*	0				
Views on elc heater: require little space			0.200*	0				
Views on elc heater: low costs			0.154*	0				
Views on gas heater: bad for local pollution	-0.074*	0						
Views on gas heater: environmental friendly	0.079*	0						
Views on gas heater: increase house value	0.037*	0.01						
Views on heat pump: environmentally friendly					0.147*	0		
Views on heat pump: require little own work					-0.203*	0		
Views on heat pump: low costs					0.208*	0		
Views on wood-fueled heater: increase house value							0.168*	0
Views on wood-fueled heater: require little own work							-0.136*	0
Used to install heat pump					0.581**	0.06		

Note: *: p-value < 0.05; **: p-value < 0.1; ***: p-value < 0.15.

Table A.2 Factors affecting UK consumers' vehicle technology choices

Variable	Petrol vehicle		Diesel vehicle		Hybrid EV		Plug-in EV	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
ASC	0.309	1	0.79	1	-0.571	1	-0.781	1
Male							-0.541*	0
Rural					-0.192*	0		
Driver license	0.184*	0.01						
House owner	0.099**	0.1						
Post-graduate education					0.526*	0	0.792*	0
Env: everyone should choose environmental friendly products							0.145*	0
House age: 60~100 years old							0.580*	0
House age: more than 100 years old					0.430*	0	0.546*	0
House age: 0~30 years old							0.403*	0
House age: 30~60 years old			-0.241*	0				
Monthly income after taxes			0.068*	0				
House type: Detached	0.167*	0.01						
House type: Flat							1.720*	0
House type: Flat in other purposed buildings			0.378**	0.07				
House type: Terraced	2.490*	0						
Info: receive car advertising recently			0.067*	0				
Info: ask a professional	0.089*	0						
Innovation: people ask me for advice	0.122*	0						
Innovation: Owning new technologies to distinguish from others					0.069*	0.02	0.069**	0.07
Innovation: Owning new technologies for personal enjoyment	0.083*	0						
Innovation: seek information about latest technologies			0.266*	0	0.195*	0	0.151*	0
Work: Full-time	0.249*	0.01	0.341*	0				
Work: looking after home			0.737*	0				
Work: Part-time	0.414*	0	0.812*	0	0.391*	0		
Work: retired	0.532*	0	0.370*	0.01	0.297*	0		
Work: student	1.490*	0	1.690*	0	0.857**	0.1		
Diesel car: annual cost			-0.222*	0				
Diesel car: capital cost			-1.390*	0				

Variable	Petrol vehicle		Diesel vehicle		Hybrid EV		Plug-in EV	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Diesel car: lower emissions (2~3 tonnes/year)			-0.272*	0				
Diesel car: average emissions (5 tonnes/year)			-0.305*	0				
Hybrid EV: annual cost					-0.181*	0		
Hybrid EV: capital cost					-1.240*	0		
Hybrid EV: driving range					0.056**	0.1		
Petrol car: annual cost	-0.071*	0.01						
Petrol car: capital cost	-1.070*	0						
Petrol car: average emissions (5 tonnes/year)	-0.243*	0						
Plug-in EV: annual cost							-0.286*	0
Plug-in EV: capital cost							-0.747*	0
Purpose: drive children			0.201**	0.07	0.380*	0	0.472*	0
Purpose: running errands					0.176*	0.01		
Purpose: leisure			0.182*	0.02	-0.221*	0		
Purpose: shopping	0.343*	0						
Own private parking space	0.143*	0.03						
Own CNG car			1.430*	0.01				
Own Diesel car			1.620*	0	0.579*	0		
Own duel fuel (electricity+combustion) car			2.480*	0	3.450*	0	4.060*	0
Own LPG car					1.680*	0		
Own petrol car	0.696*	0			0.348*	0		
Own petrol+oil mixture car	2.040*	0.01						
View EV: easy to refuel							0.075*	0.01
View EV: complicated to use					-0.094*	0	-0.146*	0
View EV: more expensive to buy but cheaper to maintain					0.129*	0	0.080*	0.02
View EV: safe					0.167*	0	0.081*	0.01
View EV: fulfill transport need							0.177*	0
Frequency of driving between 100~300 miles					0.195*	0		
Frequency of driving more than 300 miles			0.246*	0			0.270*	0
Frequency of driving less than 50 miles	0.066*	0			0.071*	0		
Frequency of using car-sharing			0.134*	0				
Frequency of using own car	0.107*	0						

Variable	Petrol vehicle		Diesel vehicle		Hybrid EV		Plug-in EV	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Frequency of using public transport	0.053*	0						
Frequency of using taxi					0.087*	0		
Frequency of walking			-0.068*	0			0.064*	0
Familiarity with diesel car			0.242*	0				
Familiarity with EV							0.318*	0
Familiarity with hybrid EV					0.425*	0		
Choice factor: brand			0.046*	0.05				
Choice factor: purchase price	0.085*	0.02						
Choice factor: emissions			-0.186*	0	0.093*	0.01	0.369*	0
Choice factor: fuel economy							0.255*	0
Choice factor: maintenance cost			0.287*	0	0.262*	0		
Choice factor: need of maintenance	0.114*	0	0.159*	0				
Choice factor: noise			0.077*	0.02	0.141*	0		
Choice factor: operating costs	0.254*	0	0.176*	0				
Choice factor: performance	0.065*	0.02						
Choice factor: reliability					0.092*	0.05		
Choice factor: safety	0.158*	0	0.217*	0	0.204*	0		
Choice factor: style	0.116*	0	0.065*	0.04				

Note: *: p-value < 0.05; **: p-value < 0.1; ***: p-value < 0.15.

Appendix B - Discrete Choice Model Results for Finnish Consumers' Technology Choices

Table B.1 Factors affecting Finnish consumers' heating technology choices

Variable	Oil-fuelled boiler		Electric heater		Heat pump		Solid boiler		District heat	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
ASC	0.093	1	1.01	1	-1.73	1	0.341	1	0.671	1
Age			-0.130*	0	-0.193*	0	-0.443*	0		
Monthly income after taxes	0.754*	0								
Male					0.382*	0				
Rural	-0.531*	0			1.160*	0.03				
Suburban					1.220*	0.02			0.335*	0
Urban					1.190*	0.03			0.264*	0.01
College education			0.137*	0.04						
Higher education level	0.299*	0.05	0.303*	0			0.319*	0.01	0.169*	0.04
House age: 30~60 years old	-0.266**	0.07								
House age: less than 30 years old	-0.358*	0.03								
House type: apartment					0.624*	0				
House type: detached					0.417*	0	0.181**	0.08		
Env: I prefer environmentally friendly products							0.133*	0		
Env: behave environmentally responsibly					0.073*	0				
Info: receive advertising recently					0.042*	0.01			0.034*	0.04
Info: keep up-to-date myself	-0.070**	0.07								
Innovation: people ask me for advice					0.125*	0	0.206*	0	0.098*	0
Innovation: owning new technologies for personal enjoyment	0.124*	0			0.059*	0.02			0.078*	0

Variable	Oil-fuelled boiler		Electric heater		Heat pump		Solid boiler		District heat	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Innovation: know must-have technologies							-0.138*	0	-0.090*	0
Innovation: seek information about latest technologies					-0.154*	0	-0.214*	0		
Innovation: owning new technologies to distinguish from others	-0.169*	0							-0.055*	0.04
Number of children	0.189*	0.04			0.227*	0	0.198*	0	0.149*	0.01
Helsinki			0.187*	0.01			-0.510*	0		
North East							-0.320*	0		
South									0.129**	0.06
Work: full-time			-0.632*	0	-0.632*	0	-0.488*	0	-0.474*	0
Work: looking after home					-0.940*	0.01				
Work: unemployed					-0.699*	0				
District heat: annual costs									-1.270*	0
District heat: capital costs									-1.230*	0
District heat: high GHG emissions									-0.119**	0.06
District heat: substantial own work									-0.828*	0
Electric heater: annual cost			-1.250*	0						
Electric heater: capital cost			-0.105*	0						
Electric heater: low GHG emissions			0.580*	0						
Electric heater: substantial own work			-0.844*	0						
Heat pump: annual cost					-0.136*	0				
Heat pump: capital cost					-0.908*	0				
Heat pump: low GHG emissions					0.589*	0				
Heat pump: substantial own work					-0.747*	0				

Variable	Oil-fuelled boiler		Electric heater		Heat pump		Solid boiler		District heat	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Oil boiler: annual cost	-0.615*	0								
Oil boiler: capital cost	-1.520*	0								
Oil boiler: low GHG emissions	0.397*	0								
Oil boiler: substantial own work	-0.723*	0								
Solid boiler: annual cost							-0.189*	0		
Solid boiler: capital cost							-1.220*	0		
Solid boiler: low GHG emissions							0.853*	0		
Solid boiler: no own work							0.318*	0		
Solid boiler: substantial own work							-0.423*	0		
Heating bill	-8.060*	0			-1.990*	0			-2.390*	0
Water heating bill					0.640*	0.01				
Existing system: district heat									0.582*	0
Existing system: electric heater			0.628*	0						
Existing system: gas heater			-0.800*	0			-1.810*	0	-1.050*	0
Existing system: heat pump					0.755*	0				
Existing system: oil boiler	1.470*	0								
Existing system: wood boiler	1.120*	0					1.210*	0		
Hours of heating									-0.146*	0.01
Choice factor: advice from repairer			-0.033*	0.03					-0.052*	0
Choice factor: controllability							0.074*	0.04		
Choice factor: easiness of maintenance			0.182*	0	0.155*	0			0.142*	0
Choice factor: indoor air quality			0.094*	0	0.121*	0	0.335*	0	0.131*	0
Choice factor: own experience			0.082*	0						

Variable	Oil-fuelled boiler		Electric heater		Heat pump		Solid boiler		District heat	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Choice factor: own knowledge of heater			-0.062*	0						
Choice factor: independent of future energy prices			-0.114*	0					-0.090*	0
Familiarity with heat pump					0.247*	0				
Familiarity with wood-fuelled boiler							0.246*	0		
Views on district heat: air pollution									-0.146*	0
Views on district heat: low costs									0.113*	0
Views on district heat: easy to acquire									0.045*	0
Views on district heat: harmful to climate change									0.095*	0
Views on district heat: increase house value									0.079*	0
Views on electric heater: air pollution			-0.136*	0						
Views on electric heater: low costs			0.114*	0						
Views on electric heater: easy to use			-0.069*	0.01						
Views on electric heater: increase house value			0.150*	0						
Views on electric heater: reliable			0.161*	0						
Views on heat pump: low costs					0.050*	0.01				
Views on heat pump: easy to acquire					0.044*	0.03				
Views on heat pump: easy to use					0.069*	0				
Views on heat pump: environmentally friendly					0.033**	0.06				
Views on heat pump: harmful to					-0.141*	0				

Variable	Oil-fuelled boiler		Electric heater		Heat pump		Solid boiler		District heat	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
climate change										
View on oil-fuelled boiler: air pollution	-0.145*	0								
View on oil-fuelled boiler: low costs	0.124*	0								
View on oil-fuelled boiler: easy to use	0.157*	0								
Views on oil-fuelled boiler: increase house value	0.118*	0								
Views on oil-fuelled boiler: require little space	0.185*	0								
Views on oil-fuelled boiler: require little own work	-0.144*	0								
View on wood-fuelled boiler: air pollution							-0.100*	0		
Views on wood-fuelled boiler: low costs							0.077*	0.01		
Views on wood-fuelled boiler: increase house value							0.099*	0		
Views on wood-fuelled boiler: require little own work							0.089*	0		
Used to install district heat									0.501*	0
Used to install electric heater			0.928*	0						
Used to replace electric heater			0.274*	0.04						
Used to replace heat pump					-0.844*	0.05				
Used to replace wood-fuelled boiler							1.030*	0		

Note: *: p-value < 0.05; **: p-value < 0.1; ***: p-value < 0.15.

Table B.2 Factors affecting Finnish consumers' vehicle technology choices

Variable	Petrol car		Diesel car		Hybrid EV		Plug-in EV	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
ASC	0.1	1	0.143	0.99	-0.035	1	-0.284	0.99
Age	0.341*	0			0.119*	0		
Rural							-0.183***	0.14
College education			0.239*	0				
House age: more than 100 years old	0.865*	0						
House age: 30~60 years old	0.484*	0.03						
House age: less than 30 years old	0.435*	0.05						
House age: 60~100 years old	0.627*	0.01			0.196*	0.04		
House type: apartment in a block with other functions			-0.453*	0				
House type: apartment in a purposed-built building			-0.395*	0	-0.161*	0.03		
House type: terraced	0.297*	0						
Env: everyone should choose environmental friendly products			-0.130*	0			0.166*	0
Env: I prefer environmentally friendly products			0.113*	0	0.064*	0.01		
Env: behave environmentally responsibly							0.166*	0
Info: receive car advertising recently							-0.074*	0
Info: ask a professional							-0.066*	0.03
Info: keep up-to-date myself							0.139*	0
Innovation: people ask me for advice							-0.102*	0
Innovation: Owning new technologies for personal enjoyment					0.096*	0	0.141*	0
Innovation: know must-have technologies					-0.059*	0		
Number of bedrooms	-0.560*	0.01						
Number of children							0.215*	0
Helsinki					0.110**	0.1		
North East	0.304*	0						
South							-0.297*	0.01
Work: freelancer	0.558*	0.01						
Work: unemployed	0.824*	0						
Diesel car: annual cost			-0.295*	0				
Diesel car: capital cost			-1.750*	0				
Diesel car: driving range			0.149*	0				
Hybrid EV: annual cost					-0.287*	0		
Hybrid EV: capital cost					-1.830*	0		
Petrol car: annual cost	-0.170*	0						
Petrol car: capital cost	-1.720*	0						
Petrol car: very low GHG emissions	0.194*	0						

Variable	Petrol car		Diesel car		Hybrid EV		Plug-in EV	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Plug-in EV: capital cost							-1.810*	0
Plug-in EV: driving range							0.390*	0
Own biofuel car	1.780*	0						
Own diesel car			0.698*	0				
Own duel fuel (electricity+combustion) car			-0.867*	0.01			0.721*	0.01
Own petrol car	0.695*	0	-0.502*	0				
Driver license	0.257*	0.02						
Frequency of driving between 100~300 km			0.143*	0				
Frequency of driving more than 300 km					0.153*	0		
Choice factor: brand					-0.108*	0		
Choice factor: model					0.105*	0		
Choice factor: GHG emissions					0.125*	0	0.149*	0
Choice factor: fuel economy					0.065*	0.04		
Choice factor: need of maintenance					0.103*	0		
Choice factor: maintenance cost							0.374*	0
Choice factor: noise					0.053*	0.04	0.131*	0
Choice factor: operating costs	-0.156*	0	0.208*	0				
Choice factor: performance					-0.108*	0	-0.237*	0
Choice factor: purchase price			-0.220*	0	-0.288*	0	-0.293*	0
Choice factor: reliability							-0.426*	0
Familiarity with diesel car			0.506*	0				
Familiarity with EV							0.307*	0
Familiarity with hybrid EV					0.626*	0		
Frequency of riding bicycle					0.030**	0.08		
Frequency of using car-sharing			-0.147*	0.01	-0.176*	0		
Frequency of using own car	0.090*	0			0.130*	0		
Frequency of using public transport					0.069*	0	0.140*	0
Frequency of using taxi							-0.226*	0
Frequency of walking					0.062*	0.01		
Number of cars			0.133*	0				
Purpose: other purposes					-0.209*	0	-0.459*	0
Purpose: drive children					0.310*	0		
Purpose: drive to work					-0.175*	0.01		
Purpose: leisure			-0.161*	0.02				

Note: *: p-value < 0.05; **: p-value < 0.1; ***: p-value < 0.15.

Appendix C - Discrete Choice Models Results for Croatian Consumers' Technology Choices

Table C.1 Factors affecting Croatian consumers' heating technology choices

Variable	Gas heater		Electric heater		Heat pump		Solid boiler	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
ASC			1.440*	0	-1.070*	0	-1.650*	0
Age					0.059*	0.01		
Male	0.221*	0			0.399*	0		
Region: Istria			-0.291*	0.01				
Region: Zagreb	0.241*	0						
Household income			-2.350*	0				
House age: more than 100 years							0.525*	0.01
House owner	0.190*	0.01						
House type: detached							0.332*	0
Number of bedrooms	-0.157*	0	-0.220*	0	-0.085*	0.01		
Number of children					0.121*	0		
Work: freelance			0.731*	0	0.777*	0		
Work: looking after home	-0.791*	0			-1.020*	0		
Work: student			0.493*	0	0.304*	0.01		
Existing system: district heating			-0.511*	0				
Existing system: electric heater			0.359*	0				
Existing system: electric storage heater			1.230*	0				
Existing system: gas heater	0.569*	0			0.412*	0		
Existing system: heat pump					1.400*	0		
Existing system: wood-fueled boiler					0.451*	0	0.773*	0
Used to install heat pump					-0.714*	0.01		
Hours of heating			-0.231*	0				
Gas heater: annual costs	-0.205*	0						
Gas heater: capital costs	-0.157*	0						
Gas heater: high GHG emissions	-0.174*	0.02						
Gas heater: very low GHG emissions	0.253*	0						
Electric heater: annual costs			-0.423*	0				
Electric heater: capital costs			-0.216*	0				
Electric heater: very low GHG emissions			0.380*	0				
Heat pump: annual costs					-0.230*	0		
Heat pump: capital costs					-0.220*	0		
Heat pump: no own work					0.151*	0.01		
Heat pump: substantial own work					-0.268*	0		
Solid boiler: annual costs							-0.149*	0
Solid boiler: capital costs							-0.172*	0

Variable	Gas heater		Electric heater		Heat pump		Solid boiler	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Solid boiler: substantial own work							-0.462*	0
Env: behave environmentally responsibly			-0.084*	0.03	0.218*	0	0.245*	0
Info: ask a professional			0.056*	0.03			0.077*	0
Info: keep up-to-date myself			0.224*	0	0.094*	0	0.120*	0
Innovation: owning new technologies for personal enjoyment			-0.130*	0				
Innovation: owning new technologies to distinguish from others			0.081*	0	-0.044*	0.01		
Choice factor: advice of family/friends					-0.064*	0		
Choice factor: easiness of maintenance	-0.137*	0						
Choice factor: how easy to use	0.099*	0						
Choice factor: independent of oil/LPG suppliers	-0.086*	0	-0.099*	0	-0.093*	0		
Choice factor: indoor air quality	0.137*	0						
Choice factor: easiness of finding an installer			-0.135*	0				
Choice factor: own knowledge of heater	0.096*	0	0.140*	0				
Choice factor: reliability of heater			0.109*	0	0.182*	0		
Choice factor: space limits for heater					0.081*	0		
Familiarity with electric heater			-0.269*	0	0.148*	0		
Familiarity with gas heater	0.225*	0						
Views on electric heater: air pollution			0.134*	0				
Views on electric heater: low costs			0.075*	0.01				
Views on electric heater: easy to use			-0.167*	0				
Views on electric heater: environmental friendly			0.079*	0				
Views on electric heater: harmful to climate change			-0.147*	0				
Views on electric heater: reliable			0.189*	0				
Views on electric storage heater: low costs			0.089*	0				
Views on electric storage heater: easy to use			-0.045*	0.03				
Views on gas heater: air pollution	-0.109*	0						
Views on gas heater: low costs	0.108*	0						
Views on gas heater: easy to use	-0.100*	0						
Views on gas heater: increase house value	0.037*	0.03						
Views on gas heater: reliable	0.176*	0						
Views on heat pump: air pollution					-0.220*	0		
Views on heat pump: easy to use					0.095*	0		

Variable	Gas heater		Electric heater		Heat pump		Solid boiler	
	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
Views on heat pump: harmful to climate change					-0.093*	0.01		
Views on heat pump: increase house value					0.207*	0		
Views on wood-fueled boiler: air pollution							-0.134*	0
Views on wood-fueled boiler: harmful to climate change							0.111*	0
Views on wood-fueled boiler: reliable							0.105*	0
Views on wood-fueled boiler: require little own work							-0.081*	0

Note: *: p-value < 0.05; **: p-value < 0.1; ***: p-value < 0.15.

Table C.2 Factors affecting Croatian consumers' vehicle technology choices

Variable	Petrol car		Diesel car		Hybrid EV		Plug-in EV	
	Coef	p value	Coef	p value	Coef	p value	Coef	p value
ASC			1.340*	0	-1.580*	0	-1.890*	0
Age			-0.224*	0				
Male			-0.283*	0				
Household income			-1.300*	0				
Urban			-0.134*	0.02			-0.301*	0
Region: Dalmacija							0.582*	0
Region: Lika i Banovina			0.268*	0.01			0.509*	0
Region: Slavonija			0.234*	0			0.406*	0
Driver license	0.813*	0	0.622*	0	0.839*	0		
Degree or Graduate education			-0.350*	0				
Primary level education					0.684*	0.01		
House age: between 30 and 60 years					0.627*	0		
House age: less than 30 years					0.501*	0		
House age: between 60 and 100 years	0.321*	0.01			0.500*	0.03		
House owner			-0.197*	0.02	-0.325*	0	-0.516*	0
Work: full-time							-0.642*	0
Work: looking after home			0.648*	0	0.667*	0		
Work: retired			0.340*	0	-0.311*	0		
Work: student							-0.927*	0
Own diesel car			0.785*	0				
Own duel fuel (electricity + combustion) car			1.330*	0	1.140*	0		
Own petrol car	0.568*	0						
Petrol car: annual cost	-1.170*	0						
Petrol car: capital cost	-1.460*	0						
Petrol car: low GHG emissions	0.214*	0						
Petrol car: very low GHG emissions	0.234*	0						
Diesel car: annual cost			-1.220*	0				
Diesel car: capital cost			-1.340*	0				

Variable	Petrol car		Diesel car		Hybrid EV		Plug-in EV	
	Coef	p value	Coef	p value	Coef	p value	Coef	p value
Diesel car: driving range			0.319*	0.05				
Diesel car: low GHG emissions			0.182*	0.01				
Diesel car: very low GHG emissions			0.248*	0				
Hybrid EV: annual cost					-1.500*	0		
Hybrid EV: capital cost					-1.300*	0		
Plug-in EV: annual cost							-0.153*	0
Plug-in EV: capital cost							-0.349*	0
Annual driving range			0.228*	0				
Frequency of driving between 50~100 miles	-0.097*	0					-0.260*	0
Frequency of using public transport							0.087*	0
Frequency of using taxi	-0.082*	0						
Frequency of walking			-0.055*	0.01			-0.126*	0
Purpose: drive children							0.247*	0
Purpose: to work							0.428*	0
Env: everyone should choose environmental friendly products					0.073*	0.03		
Env: concerned about environment							0.312*	0
Env: behave environmentally responsibly					0.083*	0.05		
Info: receive car advertising recently			-0.085*	0				
Info: ask a professional			0.087*	0	0.118*	0	0.186*	0
Info: ask friends					-0.127*	0	-0.190*	0
Info: keep up-to-date myself					0.131*	0		
Innovation: people ask me for advices			0.114*	0				
Innovation: owning new technologies for personal enjoyment							-0.430*	0
Innovation: know must-have technologies			-0.089*	0				
Innovation: seek information about latest technologies							0.188*	0
Innovation: owning new technologies to distinguish from others							0.226*	0
Choice factor: brand					-0.093*	0	-0.217*	0
Choice factor: design							0.090*	0.03
Choice factor: emissions					0.158*	0	0.467*	0
Choice factor: fuel economy			0.214*	0	0.210*	0	0.262*	0
Choice factor: maintenance cost							-0.304*	0
Choice factor: purchase price			-0.082*	0.03	-0.181*	0		
Choice factor: safety			-0.178*	0	-0.143*	0	-0.197*	0
Views on EV: driving range of 100 miles is enough for me							0.177*	0
Views on EV: complicated to use							-0.213*	0
Familiarity with diesel car			0.458*	0				

Variable	Petrol car		Diesel car		Hybrid EV		Plug-in EV	
	Coef	p value	Coef	p value	Coef	p value	Coef	p value
Familiarity with EV							0.351*	0
Familiarity with hybrid EV					0.555*	0		
Familiarity with petrol car	0.406*	0						

Note: *: p-value < 0.05; **: p-value < 0.1; ***: p-value < 0.15.