Erasmus University Rotterdam

Erasmus School of Economics

BSc International Business Economics and Economics

Bachelor Thesis

The willingness to pay for renewable electric energy in the Slovak market

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Final Version

Submitted 1.8.2022

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Executive Summary

The climate crisis is one of the hottest scientific topics in the 21st century because of its urgency and complexity. The energy sector requires a shift to renewable energy sources (RES). As they become affordable to the mass public, studying pricing strategies to maximise their potential is vital for developing fast and efficient solutions. This paper, therefore, aims to study the willingness to pay (WTP) for electricity from renewable sources in Slovakia, a scientifically almost untouched area. It is also one of a few studies that use modern machine learning techniques to predict the WTP for electricity from sociodemographic variables. The results are substantial from academic and policy perspectives: for an improved analysis with complex methods such as multinomial logit, improved pricing and nudging towards environmentally friendly solutions. The research, highly relevant for both society and managers, poses the central question: "What is the willingness to pay for electricity from renewable resources in Slovakia? Can sociodemographic variables and pro-environmental behaviour be used to price electricity from renewable resources efficiently?". The following sub-questions were formulated to answer the main research question: "What is the energy mix of Slovakia? What is the market, regulatory and subsidy structure for electricity from renewable sources? Which macroeconomic, microeconomic and behavioural factors influence the electricity consumption in Slovakia? What is the average price elasticity of electricity for a megawatt hour? What is the willingness to pay for electricity from renewable resources in Slovakia? Can customer and sociodemographic heterogeneity be used to improve the electricity pricing from renewable resources?".

The literature review showed that the potential for RES production and consumption is favourable in the long term, and the electricity demand is inelastic. Furthermore, individual attributes of RES electricity contracts and sociodemographic characteristics as factors impacting WTP for RES electricity were analysed in the literature. Income, environmental attitudes, concerns, behaviour, awareness about the market, production location and type of RES were identified as impactful. Finally, sociodemographics and pro-environmental behaviour were significant predictors of the WTP for RES electricity. Seven hypotheses were formulated. The first hypothesis was that the average WTP for RES electricity is larger than €2. The second hypothesis proposed that at least one RES has a significant and positive effect on WTP. The remaining hypotheses stipulated a significant positive effect of local production, income, environmental concerns, attitudes, pro-environmental behaviour and awareness about the market on WTP for RES electricity. The research methodology included conjoint analysis and market simulation through choice experiment, with three regression models: logarithmic, conditional logistic and lasso regressions.

The main finding is that the average WTP for RES electricity in the sample is €5.75 for any RES and €6.49 for solar energy, which is also the answer to the first part of the central research question. Other individual sources are insignificant. Local production almost doubles this value (an increase of €6.05) within the

collected sample. The analysis found significant positive effects for pro-environmental attitudes, concerns and behaviour on WTP for RES electricity. Income was insignificant. The effects of awareness about the market and bills are mixed, and the null hypothesis could not be rejected. The market simulation showed that RES electricity would be preferred under perfect conditions and without branding effects. Finally, 62% and 65% of correct predictions were achieved with the mixed effects random forest model and standard random forest, respectively. With the collected sample and data, the prediction accuracy was insufficient for a successful market implementation, which is the answer to the second part of the central research question. The main recommendation to the electricity suppliers is to use price premiums of up to €6 per month for RES electricity. The value can be increased further by offering locally produced solar energy certificates. For policymakers, the main implications were that people are willing to invest in RES solutions, and with a subsidy, the investment can experience a massive shift towards RES. Lastly, the main implication for scientists is that a further study with a larger and more representative sample and more complex methods such as multinomial logit can provide better answers to the questions. In addition, solving the challenge of predicting the WTP for RES electricity with ML techniques could improve the implications even further.

Chapter 1: Introduction

1.1 Introduction to the willingness to pay for green electricity

There is little scientific dispute about climate change being caused by greenhouse gas (GHG) emissions (Gray, 2007), and the largest sector by absolute amount is undoubtedly energy, accounting for 73% of global GHG emissions. The absolute energy use in residential buildings is 10.9% (Ritchie, 2020). Therefore, consumers can significantly reduce global emissions just by using electricity from renewable sources (RES). However, as RES electricity is a public good, there is a market failure. Thus, for example, the European Commission mandated member states to reach 20% of consumed electricity to be produced from renewable sources by 2020. For many states, this meant a significant investment into RES production infrastructure. The size of government investment and the cost of such solutions can be crucially decreased if consumers engage in it and willingly pay for such solutions. This thesis aims to answer what is the customers' willingness to pay (WTP) for electricity from RES and which factors influence it. The research into the Slovak market is relatively untouched on this topic, and RES electricity demand is low, yet the country has enormous potential for RES. These conditions create a perfect opportunity to study how to increase the demand and design efficient policies to increase RES share.

1.2 Relevance of the study

As the climate change crisis is becoming progressively urgent, the research into the microeconomic and marketing effects of pricing electricity from RES is relevant from all points of view – managerial, societal and academic.

1.2.1 Scientific relevance

While several studies examine the market for green electricity, policy instruments and subsidies to increase the demand for it and household consumption, no single study focused entirely on the WTP for RES electricity and its predictiveness in Slovakia. Based on the research done in neighbouring countries, this study will contribute to the literature on WTP for RES electricity. Moreover, this paper employs modern machine learning (ML) techniques to predict and assess the predictive quality of the WTP for electricity. Such techniques are novel in WTP for RES electricity and WTP research. So far, only a few papers employed ML in predicting WTP in general. Therefore, contributing to the existing literature would profoundly affect the research into the demand for energy from renewables and stimulate further research in this area in the Slovak Republic.

1.2.2 Social relevance

In terms of societal importance, it is an urgent matter to start shifting towards RES and increase funding for such solutions to become cheaper. As the global warming crisis prevails, reducing the amount of CO_2 emissions is an essential task for every country. As mentioned, the energy industry is the largest polluter because a substantial amount of electricity is generated from fossil fuels. Thus, understanding the population's attitudes toward pricing electricity from renewable sources is crucial for developing strategies to increase its share in the energy mix. The research also focuses on understanding which factors besides pricing influence the demand for RES electricity. The societal importance of the research will ultimately help achieve global sustainability goals, which Slovakia is committed to, and help the environment in the long term.

1.2.3 Managerial relevance

From a managerial point of view, it is essential to understand how people react to the change in electricity price should electricity generation become solely dependent on renewable resources. While people might not stop consuming electricity at all, it is essential to study how different energy sources and other factors affect the consumers' decision-making so they could be efficiently nudged towards the more environmentally friendlier options. Understanding how people react to green electricity pricing for policy improvements is also essential. Thus, the managers of electricity suppliers and government officials need to know the effects of price changes on demand for green electricity.

1.3 Research questions

1.3.1 The main research question

As engineering solutions to the production of electricity from RES are not yet as developed as the production from fossil fuels, many challenges hinder its use in every household on the planet. Among the most prominent ones are high entry costs, unreliable supply, environmental challenges and higher prices per megawatt hour (MWh). Hence, it is crucial to understand how the population reacts to changes in pricing for the supply of electricity and how this phenomenon and other factors influence the demand for RES electricity. Moreover, with the emergence of the most recent war crisis in Ukraine, a neighbouring state to Slovakia, the importance of researching alternative energy sources for Slovakia increased drastically. This is because the country depends on unreliable gas, oil and nuclear fuel supply solely from Russian Federation, and the second problem is that the pipeline goes through Ukraine. Therefore, the following main research question has been formulated:

What is the willingness to pay for electricity from renewable resources in Slovakia? Can sociodemographic variables and pro-environmental behaviour be used to price electricity from renewable resources efficiently?

Several theoretical and empirical sub-questions are formulated to understand the WTP for green electricity and its predictiveness to answer the main research question.

1.3.2 Research sub-questions

From a theoretical standpoint, it is necessary to understand energy production and consumption in Slovakia. It is also necessary to analyse the market for electricity in terms of suppliers and their pricing and analyse whether there are subsidies for electricity from renewable resources. Thus, the first theoretical sub-question is:

What is the energy mix of Slovakia? What is the market, regulatory and subsidy structure for electricity from renewable sources?

Furthermore, the theory should answer which factors play a crucial role in influencing consumer behaviour in the market for green and standard electricity. Therefore, the second theoretical sub-question is:

Which macroeconomic, microeconomic and behavioural factors influence the electricity consumption in Slovakia?

After analysing the theory, the research continues with the empirical part to draw conclusions about Slovakia's green electricity market. Firstly, the price elasticity of electricity is analysed in the megawatt hours for the last 20 years in the Slovak market. Thus, the third sub-question is:

What is the average price elasticity of electricity for a megawatt hour?

Secondly, the WTP for green electricity is computed from the primary data. The fourth sub-question is as follows:

What is the willingness to pay for electricity from renewable resources in Slovakia?

Moreover, it is vital to assess customer heterogeneity and predict the WTP for renewable electricity based on the sociodemographic factors and customer segments so that electricity suppliers improve the pricing and offering of green electricity. Thus, the question is:

Can customer and sociodemographic heterogeneity be used to improve electricity pricing from renewable resources?

1.4 Ethical issues and research limitations

The research faces a possible ethical issue in the data collection process where the data handling must ensure complete anonymisation and confidentiality of the responses. This will be resolved by requiring consent to handle respondent data and ensuring anonymisation and security processes happen. Secondly, a possible research limitation lies in the data sampling and corresponding biases. Lastly, there are limitations in the survey design and methodology that might exhaust respondents from drawing valuable insights which might influence decision-making.

1.5 Thesis structure

The thesis is structured into five chapters. This chapter introduces the topic and contains the main research question, sub-questions, and limitations. The second chapter provides a literature review of the research published on the topics of the electricity market in Slovakia, green electricity, WTP, and consumer behaviour. Each sub-question is analysed, and three hypotheses are formed in the second chapter. The third chapter explains the research methodology, data collection and bias prevention. In the fourth chapter, the research outcome is presented. Finally, the fifth chapter contains the summary of findings, answers the main research question and sub-questions, raises the discussion about the validity of the results and gives recommendations for practice and future research.

Chapter 2: Literature Study

2.1 Conceptualisation of important terms

2.1.1 Electricity from renewable sources

For this study, electricity generated from RES is defined as any electric energy produced from a resource that is renewable by natural processes, or its energy potential is close to indefinite with the current technological level. Typically, RES have significantly lower CO2 and particulate matter (PM10, PM2.5) emissions from production, although they pose some other environmental challenges. Not only is their harnessing technologically more challenging than traditional sources, RES are less reliable because they depend on natural conditions. This results in excess supply during ideal conditions and excess demand in hindered conditions. The following RES are currently harnessable and are defined according to official information (Ministry of Environment of the Slovak Republic, 2022): wind, solar, geothermal, hydropower and biomass energy. Most RES definitions are generally known apart from biomass, which is solar energy stored chemically by organisms. This energy is released by burning matter, such as firewood.

Nuclear energy is sometimes referred to as green with no direct emissions, but this research does not consider it as such because it is not renewable by definition.

2.1.2 Willingness to pay & utility

To study how RES electricity contracts are financially valued, willingness to pay is conceptualised. WTP is defined as the maximum financial value the consumer states they will pay to gain an electricity supply contract (Angner, 2017). This value is non-incentivised; therefore, the stated WTP might not equal the actual WTP. In addition, the framing of the posed question influences the WTP. In this context, it is a gain frame, meaning consumers will imagine a utility gain from the purchase (Angner, 2017). The utility gained is defined as consumers' internal preference for specific attributes and their respective levels of the electricity supply contract. Similarly to the WTP, utility is only revealed through stated preferences, and real consumer preferences might differ. All prices in the paper are in euros adjusted to 2022 prices.

2.1.3 Price Elasticity

Price elasticity is a measure used for studying the effect of a change in the price of a good on demand for that same good. Mathematically, it is defined as follows:

$$e_{(p)} = \frac{dQ/Q}{dP/P}$$

where e(p) is price elasticity, Q is quantity demand of the good and P is the price of the good.

2.2 Market for electricity in Slovakia

The electricity market analysis answers the first sub-question. Firstly, the economic and behavioural characteristics of Slovakia are presented, followed by the geography, climate and RES potential of Slovakia. Then, the electricity market is analysed in terms of electricity production, supply chain, regulations and recent developments, finishing with a summary of findings.

2.2.1 Geography, climate and potential for renewable energy sources in Slovakia

Slovakia is a landlocked country in Central Europe, and its climate is classified as temperate continental with four seasons in Köppen's classification with high average temperatures difference between seasons (Slovak Hydrometeorological Institute, 2022). As the country has a hilly profile, regional differences in climate occur. The Koncek regional classifications (Slovak Hydrometeorological Institute, 2022) are presented in Figure A2.1 in Appendix 2. These differences create heterogenous weather and climate conditions that empower or hinder the efficiency of RES electricity production. For example, wind farms' profitability significantly varies even between neighbouring municipalities. Likewise, hydropower potential is non-existent in the flatter south of the country. In addition, the variance in conditions has a crucial impact on household energy consumption, especially those with electric heating and cooling. In terms of RES production, Slovakia has a technical potential equalling 24.4 terawatt hours (TWh), with current electricity consumption being approximately 30 TWh (Culková et al., 2011; SEAS, 2021). Only 23% of produced electricity comes from RES, although showing the second fastest growth in Europe (Piekut, 2021). The most underused renewable is geothermal energy, which is projected to grow significantly and has massive economic potential for the region (Jenčová, 2020). Solar energy is also underused. Large-scale wind farming is not expected to be prominent because of political and cultural reluctance and low potential (Lofstedt, 2008). The hydropower potential is almost fully utilised. Lastly, biomass is viewed negatively for the future because it causes particulate matter pollution (Hajdúchová et al., 2014). The potential of each RES is summarised in Table 2.:

Table 2.1 – Potential of renewable energy sources in terawatt hours (TWh)

Energy source	Present using	Accessible potential	Technical potential	Economical potential	Market potential
Geothermal energy	0.34	5.96	6.30	2.34	1.21
Wind energy	0.00	0.61	0.61	0.14	0.04
Solar energy	0.01	5.19	5.20	1.24	0.35
Small hydropower	0.20	0.83	1.03	0.21	0.08
Biomass	3.52	7.71	11.24	3.30	0.81
Total	4.07	20.30	24.38	7.22	2.50

Adapted source: Culková et al., 2011.

2.2.2 Electricity production, consumption and energy mix in Slovakia

Slovakia produced approximately 29 TWh in 2020 (IEA, 2022), almost equal to the country's consumption needs (SEAS, 2021). The production trend has been stable at around 28 TWh for the past ten years, indicating a shift from fossil fuels to renewables and nuclear instead of higher production, even though the consumption has steeply risen until 2018. Afterwards, it started to decline slightly. The highest share of production has nuclear, producing 54% of all electricity. The second largest share comes from RES (24%), followed by fossil fuels (22%). In particular, RES consist of hydropower (17% of total production), biomass (5%) and solar (2%). Natural gas constitutes 3% of production, coal accounts for 7% and oil only 1%. Electricity is massively used by Slovakia's industry, comprising 49% of the consumption. The second largest consumers are commercial and public services (24%), closely followed by residential consumers (22%). A small amount is used by transportation (2%) and agriculture (1%).

2.2.3 Regulations of the electricity market in Slovakia

The electricity market in Slovakia has several regulatory bodies that control it. Three ministries influence the production of electricity: the Ministry of Transport and Construction impacts the construction of new power plants, the Ministry of Investments, Regional Development and Informatisation influences innovative projects for RES harnessing, and the Ministry of Economy foresees sufficient electricity production for economic growth. The market is regulated by the Ministry of Finance, which sets taxes, grants and subsidies, and the Regulatory Office for Network Industries (RONI), which overlooks whether the market is in balance and consumer rights are not violated (ÚRSO, 2022c). Although the market was liberalised in 2007, for conducting business in the energy sector in Slovakia, firms need a permit from RONI, with some exceptions defined by law. In addition, the Ministry of Environment ensures conditions set by European Commission are fulfilled and protects the nature of Slovakia.

Similarly to other markets, Slovakia offers subsidies to incentivise the use of RES electricity. Besides value-added tax (21%), all electricity apart from that produced from RES is subject to excise duty (Cansino, 2010; Ministry of Finance of the Slovak Republic, 2007). The excise duty is capped at 1.32€/MWh; however, private households are exempted from paying it, meaning only business consumers are incentivised to purchase green electricity. Another support form is direct subsidies (SIEA, 2022), which are only applicable for purchasing and installing small electricity-producing devices such as solar panels, wind turbines or biomass boilers. Therefore, there is no financial incentive to switch to electricity from RES for a private household when having an electricity supply contract. This is supported by a low long-term vision and insufficient subsidies on the market for quicker adoption (Hajdúchová et al., 2014).

2.2.4 Energy supply chain in Slovakia

There are three actors in the electricity supply chain in Slovakia: producers, suppliers and distributors (Grečko, 2022; ÚRSO, 2022c). There are hundreds of electricity producers from RES and other energy sources. The suppliers are companies that essentially trade electricity. They order a certain amount of planned electricity production from the producers on the futures market for a negotiated price and then sell it directly to the consumers or on the international spot trade market. Suppliers correct any deviation in electricity consumption by purchasing power on the spot market as all of the production is ordered within the first few days of the year. They can purchase electricity from any source, and the cost efficiency or added value is the core of their business. Many of the suppliers already offer electricity that is produced solely from RES. The offer is either a supplement product to the contract in the form of an additional monthly fee for a guarantee of electricity origin or the provider purchases electricity solely from RES electricity plants. Because it is physically impossible to ensure delivery of only clean energy, suppliers prove that the consumed amount of electricity comes from RES by providing certificates of origin (Hajdúchová et al., 2014). Suppliers are also the sole actor that offers electricity contracts to consumers. The complete overview of suppliers and their RES offer, along with a final price for 1 MWh, is summarised in Table A2.1 in Appendix 2. Suppliers also manage payments to and issues with electricity distributors. Only three distributors operate the network based on geographical location: western, eastern and middle Slovakia distributors. They charge a fee for using the network, which is regulated by RONI, as opposed to market prices which RONI only caps. The regulated tariff consists of two fees: a fixed part for each delivery point and a variable part based on time (high/low tariff). In the end, the consumer only needs to know who is their electricity supplier and their final price for 1 MWh, consisting of a production price plus transaction fees (36.2%), distribution fees (25.3%), transport (5.5%) and losses (8%), system services (4.6%), system operation fees (20.2%), contribution to the National Nuclear Fund and taxes (ÚRSO, 2022c).

2.2.5 Recent developments in the market

With increasing tensions at the Russian-Ukrainian border from September 2021, the spot market for electricity reacted with a continual price rise, stemming from uncertainty about gas and oil supply. The gradual increase started to fade at the beginning of 2022 but boomed after Russian Federation decided to invade Ukraine on February 24, 2022. For instance, 1 MWh cost around €50 in May 2021 and €195 in April 2022, with a maximum of €303 in March 2022 (ÚRSO, 2022a). At the end of March 2022, all electricity providers were in trouble because they could not fulfil contract requirements; one provider (A.En) even ended their operation. The most problematic issue for electricity suppliers was to correct consumption deviations as those are compensated with spot market purchases, which were fourfold the pre-crisis average. However, suppliers must fix the price in consumer contracts, meaning they purchased all deviations in planned supply at heavy losses. On top of that, sellers on the spot market asked for substantial bank guarantees. As a result of the market failure, it was impossible to switch the supplier in March 2022, with some consumers having contracts revoked. Had a consumer faced such a situation or their supplier terminated operation, they were appointed a supplier of last resort, SPP, a state-owned firm. SPP is the only supplier capable of facing such heavy prices as it is backed by the government (Grečko, 2022). On April 1, 2022, RONI presented a set of measures for saving the market from collapse, among which were measures for building new RES power plants, the possibility of increasing contracted prices, and regulation of production prices (Kováč, 2022).

2.2.6 Summary

In summary, Slovakia has the economic potential to increase RES consumption in the long term. The climate conditions for specific technologies and electricity consumption vary significantly throughout the country but do not cause the impossibility of RES adoption. In particular, geothermal has a solid potential with private, small-scale solutions. Slovakia already produces 24% of electricity from RES, potentially increasing this figure. The electricity market is liberalised, although regulated to protect consumer rights. It experienced a market failure and price crisis due to a war conflict in 2022, speeding the urge to shift towards RES. If the country solves short-term challenges and improves investment planning, RES have an enormous economic potential for both consumers and the state.

2.3 Factors influencing electricity consumption

The second sub-question about the macroeconomic, microeconomic and behavioural factors is answered in the following paragraph.

2.3.1 Economic & behavioural factors

The most prominent macroeconomic factors that increase energy consumption are GDP and unemployment rate, both increasing financial abilities and thus consumption. Second, population growth affects the country's energy consumption in absolute terms. GHG emissions also play an essential role in determining the country's electricity consumption. Other important increasing factors are poor residential planning and low socioeconomic status. Oil price is also crucial in increasing electricity consumption. The increase in the following factors has an inverse effect on energy consumption: the proportion of the female population, healthcare expenditure, energy taxes, improved energy labelling, the external balance of goods and services and RES share (Araghi, 2014; Chen 2017; Zaharia, 2019). From the microeconomic standpoint, income is, unsurprisingly, the most influential factor. The more a household can spend on appliances, the higher the electricity consumption. Tied to that are consumption habits and choice of specific appliances such as refrigerators and air conditioners. Then, poor individual household planning, transportation preference and education about private RES benefits influence energy consumption. Interestingly, electricity prices do not decrease consumption (Araghi, 2014; Chen 2017; Zaharia, 2019).

2.3.2 Cultural factors

Culturally, Slovakia is a masculine society, valuing success, heroism, assertiveness and material reward over consensus and caring (Szmigin & Piacentini, 2018). On average, Slovaks prefer products with high performance and attributes denoting strength. Such products ultimately help to build the image of wealth and status, as opposed to feminine cultures, where cooperation and wellbeing of the society are favoured. Slovaks are, therefore, likely to purchase products with characteristics that might have higher energy consumption. Concerning electricity, Slovaks are typically conservative. Although interested, Slovaks are not quick adopters of new technologies and prefer financial and service comfort, e.g., natural gas for heating (Piekut, 2021). With a long payback period and high entry costs, Slovaks seek higher financial support from the state, after which they would be more willing to adopt RES technologies (Culkova et al., 2011).

2.3.4 Summary

Several macroeconomic and microeconomic factors influence electricity consumption. The most prominent factors are GDP, GHG emissions, population growth, labour force, the proportion of the female population, and residential and household planning. Additionally, income and consumer preference for appliances and structural quality of the house also influence consumption and education about RES options. Lastly, it has been presented that in a masculine society such as Slovakia, consumers are, on average, more likely to prefer their consumption over the wellbeing of society and have a conservative opinion about private energy generation from RES.

2.4 Price elasticity of electricity

As discussed in the paragraphs before, electricity consumption depends on various factors, several of them being macroeconomic. Furthermore, electricity contracts in Slovakia are closed for a more extended period with fixed prices in the contract (ÚRSO, 2022c). Electricity is also an essential good billed as utilities and something that is not purchased in real-time. These facts imply that price elasticity can only be observable in the long term. However, macroeconomic and microeconomic factors significantly affect electricity consumption more than price because purchasing ability increases relatively faster than electricity price (Araghi, 2014; Chen 2017; Zaharia, 2019). Indeed, in several states elasticity of electricity is inelastic (Burke & Abayasekara, 2018; Fan & Hyndman, 2011) in the interval between -0.4 to -0.1. In terms of real-time, the price elasticity of electricity is also unsurprisingly low, considering consumers cannot purchase electricity on the spot market and thus have no idea of its existence (Lijesen, 2007). On the other hand, long-term elasticity might be slightly larger, closer to -1, as the industry consumption can drive it higher (Burke & Abayasekara, 2018). Such a phenomenon can be explained by the fact that electricity-intensive industrial activities move to lower-priced states.

2.4.1 Observation

The logarithmic regression analysis of the Slovak market data from 2000 to 2020 showed that the residential price elasticity equals -0.06. Therefore, a 1% increase in price leads to a 0.06% decrease in demand, suggesting strong inelasticity. While the coefficient is not significant at the 5% level, the confidence interval of the coefficient is not smaller than -1, and thus, the demand cannot be elastic. The observational results are summarised in Table 4.1.

Table 2.2 – Results of the logarithmic regression for elasticity

Variable	Estimated coefficient	Confidence interval
Price	-0.06 (0.04)	-0.15; 0.03
R^2	0.11	
Observations	20	

Note: Standard errors are reported in the brackets. The significance is as follows: * for p<0.1, ** for p<0.05 and *** for p<0.01.

In summary, the price elasticity of electricity is found to be low (inelastic) in both the short term and long term for residential buildings, with the industry sector having larger elasticity in the long term.

2.5 Willingness to pay for electricity from renewable sources

2.5.1 Willingness to pay for RES electricity in other countries

As electricity from RES is becoming increasingly urgent, several markets have established their WTP for such electricity. In neighbouring countries around Slovakia – Poland and the Czech Republic – residents are willing to pay relatively low, around €2–€3 per month (Alberini et al., 2018; Novák, 2015; Kowalska-Pyzalska, 2019). In Slovenia, a country very related to Slovakia geographically, culturally and economically, the WTP for RES electricity is around €1.22 for low-consuming households and €4.01 for high-consuming households (Zorić & Hrovatin, 2012). Slovakian neighbours share many similarities with these countries, so the WTP can be expected to be similar (Piekut, 2021). Looking at other countries, the largest WTP is from €15 up to €20 in Japan, Finland, Spain and USA (Nomura & Akai, 2004; Sundt & Rehdanz, 2015; Roe et al., 2001; Knapp et al., 2020). The average WTP across all countries where it was researched is $7.16 (Soon & Ahmad, 2015). Other European countries, such as Italy and Germany, also have above-average WTP, all being countries with higher GDP per capita than Slovakia (Alberini et al., 2018; Sundt & Rehdanz, 2015; Bigerna & Polinori, 2014). Moving further from Europe, China residents attach a higher value to smog reduction with their WTP for RES electricity, around €3 (Guo et al., 2014). In South Korea, consumers view green electricity as a differentiated good on the market with WTP very low, around €1. However, this is on top of mandatory contributions, which every household must pay (Kim et al., 2013). Finally, a relatively high WTP for green electricity has been found in Lebanon as an alternative to displacing diesel generators (Dagher & Harajli, 2015).

In conclusion, the WTP is higher in larger countries with higher GDP. In countries similar and regionally close to Slovakia, the WTP for green electricity is approximately €2 per month. As it was noted that Slovakia recently improved RES infrastructure, the following hypothesis has been formed:

H1: The average willingness to pay for electricity from renewable sources in Slovakia is above €2

2.5.2 Factors influencing consumer preference for renewable solutions

Electricity from renewable sources is a public good (Wiser, 1998; Andor et al., 2018; Kowalska-Pyzalska, 2019). This means that economic agents tend to free-ride, effectively decreasing individual WTP. In practice, consumers' WTP for RES electricity increases when they are presented an environmental impact of their actions, feel peer, family or even societal pressure or are exposed to green marketing (Ek & Söderholm, 2006; Lange et al., 2018; Dagher & Harajli, 2015; Rowlands et al., 2003). As suggested by the theoretical part, income and age profoundly affect WTP for green electricity (Knapp et al., 2020; Guo et al., 2014; Zorić & Hrovatin, 2012). Next, environmental attitudes and concerns positively affect WTP for RES electricity. Knowing more about the environmental cost of non-renewable electricity and worrying about the environmental future enlarges WTP for RES electricity. Likewise, positive attitudes towards and pro-environmental behaviour are also associated with higher WTP for RES electricity (Zorić & Hrovatin, 2012; Novák, 2015; Hansla et al., 2008; MacPherson & Lange, 2013; Rowlands et al., 2003; Lange et al., 2018). Additionally, consumers are also influenced by the fact who benefits from the contribution. Generally, WTP is higher if the electricity is produced locally or the final beneficiary is a local institution rather than an international corporation. This also applies to situations where the contribution decreases local air pollution (Rowlands et al., 2003; Novák, 2015; Guo et al., 2014). On top of that, consumers tend to react with lower WTP if they learn that energy-intensive industrial companies have exemptions or that the contribution to the scheme is unequal (Andor et al., 2018). Pro-environmental behaviour, awareness about the market and green marketing also have a profound positive effect on WTP for green electricity. Consumers preferring environmentally friendly products are likely to choose such an alternative in the electricity market (Zorić & Hrovatin, 2012; Guo et al., 2014; MacPherson & Lange, 2013; Boztepe, 2012; Bukhari, 2011; Wiser, 1998; Lange et al., 2018). In Slovakia, green marketing has even higher importance as consumers are often unaware of the options on the market (Csikósová et al., 2012). There is mixed evidence about the effect of a RES type and WTP for such electricity. In some circumstances, consumers have differing preferences for individual RES. Hydropower has the lowest WTP, and wind is often discouraged on even the highest political levels because of its appearance (Sundt & Rehdanz, 2015; Lofstedt, 2008). On the other hand, the type of RES sometimes does not affect WTP (Kim et al., 2013; Soon & Ahmad, 2015). Framing also has a tremendous impact on WTP. For example, the WTP significantly decreases by presenting the payment per kilowatt hour as opposed to a monthly contribution (Sundt & Rehdanz, 2015; Nomura & Akai, 2004).

In conclusion, several factors affecting WTP for RES electricity are significant. Income, positive environmental attitudes, concerns, pro-environmental behaviour, awareness about the market and local production have a positive effect. Electricity consumption, wind type of energy and hydropower have a negative effect.

H2: At least one renewable source of energy has a statistically significant positive or negative effect on the willingness to pay for electricity from renewable sources in Slovakia

H3: Local production has a statistically significant positive effect on the willingness to pay for electricity from renewable sources in Slovakia

H4: Income has a statistically significant positive effect on the willingness to pay for electricity from renewable sources in Slovakia

H5: Positive environmental attitudes, environmental concern and pro-environmental behaviour have a statistically significant positive effect on the willingness to pay for electricity from renewable sources in Slovakia

H6: Awareness about the market and bills has a statistically significant positive effect on the willingness to pay for electricity from renewable sources in Slovakia

2.6 Predictability of WTP from sociodemographics and pro-environmental behaviour

As mentioned in the previous part, several factors influence WTP of RES electricity, among which are many sociodemographic variables, attitudes and behavioural characteristics. Among these are age, household income, region, electricity consumption, environmental attitude, environmental concern, and pro-environmental behaviour measured by a series of tasks (Lange et al., 2018). It can be expected that these significant factors will have a predictive power to achieve sufficient prediction accuracy. However, research into accurately predicting actual WTP is limited; for RES electricity, it is almost non-existent. In terms of willingness to pay for insurance, ML has shown promising results with accuracy above 0.8 (Nguyen et al., 2022).

In summary, there is little scientific evidence on predicting the WTP outcome for RES electricity. The empirical evidence shows that sociodemographics significantly predict the actual WTP for RES electricity and pro-environmental behaviour task performance. The prediction performance will be evaluated on the accuracy metric.

2.7 Summary of findings and a conceptual research model

The literature review has shown that the potential for RES production and consumption is favourable in the long term, driven by European Union's policies and small-scale private solutions. The partially free market has recently experienced a failure and increased the need to innovate. The literature review also discussed several microeconomic and macroeconomic factors that affect electricity consumption, together with cultural specifics of Slovakia. In the short and long term, electricity demand is inelastic. Furthermore, the review focused on individual attributes of RES electricity contracts and sociodemographic characteristics as factors impacting WTP for RES electricity. Income, attitudes, concerns, behaviour, awareness about the market, location of production and type of RES were identified to be impactful in the literature. Finally, the review summarised that sociodemographics and pro-environmental behaviour have a potential for predicting the WTP for RES electricity. The conceptual research model is presented in Figure 2.1:

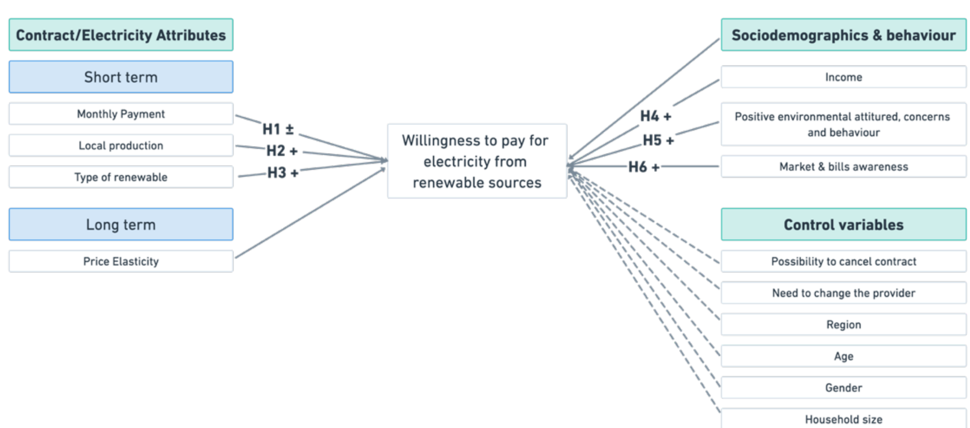

Figure 2.1 – Conceptual research model

Chapter 3: Research Methodology

In this chapter, the research method is discussed by describing and explaining the choice of methodology, presenting a research design model, followed by data collection and description and finishing with data analysis methods description.

3.1 Research Design Model

The paper started with reviewing the literature, identifying the gaps in current research and forming hypotheses. Then, the data collection methodology was defined, and all data were collected afterwards. Firstly, the secondary data was analysed, and the outcome was interpreted. Then, the primary data was analysed and interpreted. Together, results were compared to the literature review and hypotheses, and conclusions and recommendations were finalised. The study started in April 2022 with a time horizon to finish by August 2022. The data collection process happened in the first three weeks of May 2022.

3.2 Data

3.2.1 Data collection methods

For this study, both primary and secondary data were collected. Primary data were obtained by conducting an online survey through Qualtrics software. The questionnaire was divided into three parts. Firstly, respondents were asked to provide consent and general information about themselves, such as income, sociodemographics, attitude toward the environment and environmental concerns. In the second part, respondents performed a pro-environmental behaviour task consisting of four statements. Finally, consumers were presented with 12 choice sets of two alternative electricity contracts and chose one from each set. A preview of the choice set is depicted in Figure 3.1.

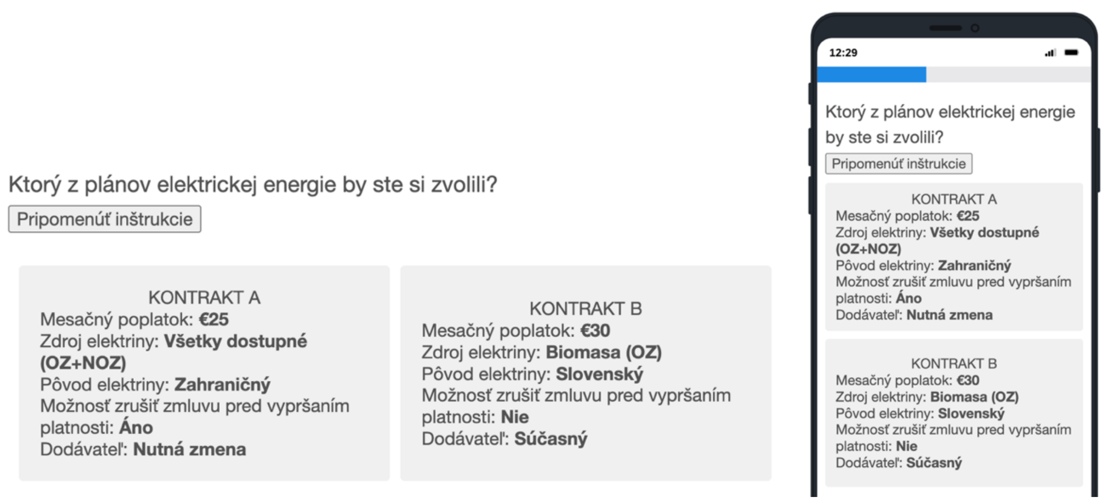

Figure 3.1 – Choice set example

The complete questionnaire is in Appendix 3. The questionnaire was distributed through online platforms and social media, particularly Facebook and Reddit. The survey was sent directly and distributed through

Facebook's paid advertising platform to ensure a higher number of responses and external validity. This is a non-probabilistic sampling method, including snowball and convenience sampling, together with a self-selection bias. These limitations occur because of limited resources. The paid promotion of the survey was conducted using own funding. The budget for the ad was €40, and it was used to target people older than 25 years of eight cities plus 25km. The ad for the promotion included a call to action to fill out the survey and described the topic briefly. Overall, the ad generated 152 clicks with a 2.5% click-through rate. The ad visual is in Figure A2.2 in Appendix 2. Secondary data were collected from databases created by credible institutions or government bodies. In particular, datasets from Passport by Euromonitor and Statistical Office of the Slovak Republic. These sources gather data on their own or collect data from statistical offices in target countries. They are reputable and reliable sources. Data about electricity consumption and average electricity prices in Slovakia for the recorded period were obtained to compute the price elasticity.

3.2.2 Data description

The primary sample contained survey responses started by 163 respondents, out of which 112 observations were completed. The secondary sample contained 20 observations about electricity prices and consumption in Slovakia from 2000 to 2020. The descriptive statistics of continuous and binary variables are summarised in Table 3.1.

Table 3.1 – Descriptive statistics of the samples

Variable	Obs.	Mean	Std. dev.	Median	Min	Max
Age	112	38.52	13.13	36	18	65
Proportion of females	112	0.40	0.49	0	0	1
Energy Consumption Knowledge	112	0.44	0.50	0	0	1
Electricity bill p/m	112	67.50	40.50	54	5	200
Household size	112	2.88	1.30	3	1	7
Knows at least one green provider	112	0.15	0.36	0	0	1
Count of providers	112	3.84	2.02	4	1	12
High energy appliances	112	4.04	1.37	4	1	8
Price of electricity (p/kWh)	20	148.6	26.80	153.8	76.9	179.3
Quantity of consumed electricity (kWh)	20	16,985,167	696,991	17,062,629	15,372,877	18,077,490

The following were categorical or ordinal variables: region, energy tariff, owned appliances, electricity providers, environmental concern, RES attitude, and four pro-environmental behaviour questions. The distributions of these variables are summarised in Figures A2.4-A2.11. Overall, the sample cannot be considered representative of the Slovak population. The middle Slovakia region is underrepresented with a female proportion, while the eastern Slovakia region is overrepresented. However, the deviations are not severe, and the sample still provides relevant information.

3.3 Data analysis methods

Three quantitative methods were used for data analysis. Quantitative methods were selected because qualitative research cannot answer the research questions. All hypotheses were tested at the 5% significance level.

3.3.1 Regression models

The observation of price elasticity was done using logarithmic regression. This method was selected because it is used for simple modelling of a percentual change in both dependent and independent variables. From its definition, price elasticity can be computed from a logarithmic regression. The regression equation is as follows:

$$ln(Q_e) = \beta_0 + \beta_1 ln(P_e) + \epsilon$$

where Q_e is electricity consumption, P_e is the average price for 1MWh, $\beta_0$is the intercept, $\beta_1$is the elasticity and ϵ is the error term.

The second model is a conditional logistic regression for studying the outcomes of the conjoint analysis. Conditional logistic regression is a method used for predicting a binary outcome by producing a probability of such an outcome on a 0 to 1 scale, stratified across respondents and choice sets. The stratification is needed to account for the fact that the same respondent sees 12 choice sets with two alternatives, producing 24 rows of responses. The following is the complete logistic regression equation:

$$U_{nj} = \beta_0 + \beta_{\mathrm{i}} X_{ij} + \gamma_{\mathrm{i}} X_{ij} C_{kn} + \epsilon_{nj}$$

where U_{nj} is the utility of the n-th consumer from alternative j, X_{ij} is the i-th feature of the j-th alternative, $C_{kn}$is the k-th characteristic of the n-th consumer, $\beta_0$is the intercept, β_i is the i-th feature coefficient, γ_{i} is the i-th feature and k-th characteristic coefficient and ϵ_{nj} is the error term of the n-th consumer for j-th alternative

The third model used to investigate hypotheses four to six is a lasso regression. Lasso regression is a linear regression using shrinkage to reduce the number of predictors. Because of multicollinearity and many interaction terms in the full model, binomial lasso regression was employed to reduce insignificant terms and simplify the model (Bhadra et al., 2019). The data were modified and standardised so that one row contained information about the choice, and the range of values was from 0 to 1. The modification was a simple subtraction of choice A attribute values from choice B. Thus, the equation of the model slightly changed:

$$U_{nj} = \beta_0 + \beta_{\mathrm{i}}(X_{ij} - X_{ij-1}) + \gamma_{\mathrm{i}}(X_{ij} - X_{ij-1}) C_{kn} + \epsilon_{nj}$$

where U_{nj} is the utility of the n-th consumer from alternative j, X_{ij} is the i-th feature of the j-th alternative, $C_{kn}$is the k-th characteristic of the n-th consumer, $\beta_0$is the intercept, β_i is the i-th feature coefficient, γ_i is the i-th feature and k-th characteristic coefficient and ϵ_{nj} is the error term of the n-th consumer for j-th alternative

3.3.2 Conjoint analysis

The conjoint analysis was used to uncover the respondents' preferences, in particular by a choice experiment. In such an experiment, participants are presented with choice sets with two alternatives. The alternatives represent electricity supply contracts with attributes identified in the literature review. The respondents are asked to choose a contract if they need one in the survey response. As they select the most preferred set, they expose their utility. After evaluating each choice set, it is possible to compute utilities and, combined with price, WTP for RES electricity. This is calculated from maximum differences of the price attribute, from which the financial value of one utility point is extracted. Then, the value is multiplied by the utility from the target attribute. Each alternative has five attributes: monthly payment, energy source, beneficiary, electricity origin, possibility to cancel the contract before expiry and supplier. Monthly payment is the amount the respondent pays for electricity, and its levels are computed from the inputted value. The levels are €-5, €0, €+2 and €+5. Thus, each respondent sees their own levels. For instance, when the respondent inputs a monthly payment of €50, all possible levels are €45, €50, €52 and €55, respectively. The addition to the monthly payment has been selected as several electricity suppliers offer an option to guarantee RES electricity for a small addition to the contract. In contrast, others have RES electricity by default, and their price is lower than traditional suppliers (ÚRSO, 2022b). Therefore, both empirical possibilities are covered by the levels. The energy source has been selected based on the availability of sources on the market and electricity production (Culková et al., 2011; IEA, 2022). As there is mixed evidence on whether there is a difference in attitudes and WTP across RES, it is important to research it in the Slovak context (Kim et al., 2013; Sundt & Rehdanz, 2015; Soon & Ahmad, 2015; Lofstedt, 2008). This attribute has five levels: all RES, wind, solar, hydro, biomass and all available. Geothermal has been omitted since this source produces little electricity. Additionally, all RES have been restricted to be combined with only higher or same-priced contracts to study WTP. Electricity origin, an attribute with two levels, was selected as there is evidence that having a local versus the international producer of RES increases WTP (Novák, 2015; Rowlands et al., 2003). The possibility of cancelling the contract before expiry (yes/no) and the supplier (current/change needed) attributes have been both selected to study the recent effects of the market development (Grečko, 2022). The choice sets were designed using a Bayesian D-efficient design (Huber & Zwerina, 1996), fulfilling four properties: level balance, orthogonality, minimal level overlap, and utility balance. All attributes and their levels are in Table 3.2.

Table 3.2 – Overview of all possible attributes and levels

Attributes	Levels					
Monthly payment {answer+}	**€-5**	€0	€2		€5	
Energy source	**All RES**	Wind	Solar	Hydro	Biomass	All available
Electricity origin		**Local**			International	
Possibility to cancel the contract before expiry		**Yes**			No	
Supplier		**Current**			Change needed	

Note: The most desired options are in bold. The price decrease was restricted to 'All available' option in italics.

3.3.3 Market simulation

The market simulation was done using the coefficients from the conditional logistic regression model. The following formula was used for the market share calculation:

$$Market\ share = \frac{e^{V_i}}{e^{V_i} + e^{V_{i+1}} \ldots + e^{V_{i+j}}}$$

where $e^{V_{ni}}$ is the average utility based on preferences of i-th contract and j is the number of contracts in the market

3.3.4 Machine learning algorithm

Two supervised ML algorithms were implemented to predict the WTP for RES electricity (Athey & Imbens, 2019; Breidert et al., 2006; Dzyabura & Yoganarasimhan, 2018; Hair & Sarstedt, 2021, Hajjem et al., 2012). Specifically, random forest and mixed effects random forest were used for a regression prediction task, after which the data were manually transformed to a binary prediction task (classification problem). Had the task been just a simple classification, the model's accuracy would decrease as the model would not be able to recognise that the sum of each pair's choices is always equal to one. This is because consumers chose among two alternatives, so for every set, an alternative with a higher predicted probability is classified as 1. The accuracy metric of the model is defined as:

$$Accuracy = \frac{T_P + T_N}{T_P + F_P + T_N + F_N}$$

where T_P, T_N are numbers of true positives and negatives, respectively, and F_P, F_N are numbers of false positives and negatives, respectively.

The data were split into the training and validation dataset using a random 80/20 split with a consistent random state for all models, stratifying based on the choice set ID. The variables (features) used for predicting the outcome were a vector of sociodemographic, attitude and behaviour responses and choice sets. The complete list of features is the same as the complete model for lasso regression. The mixed effects random forest is a method that builds many decision trees based on random sampling from the training data and then decides on the output based on the majority voting method from all decision trees. By specifying fixed effects, mixed effects and cluster id vectors, the model can recognise the effects of the features in the clustered data. Random forest is the same, only without mixed and fixed effects specification.

3.4 Bias prevention

There are several bias threats to the validity of the results. In terms of external validity, the main biases are in the sample collection process. Because of non-probabilistic sampling, the data was not random and thus skewed towards a bias. This stems from the fact that snowball and convenience sampling was used. Snowball and convenience sampling mitigation was done by enlarging the data set and promoting the survey to cities with no connection to friends and family circles. Furthermore, since the survey completion process could not be individually verified due to data protection rules, self-selection bias was also present in the data. The advertisement to respond was also self-selective by design.

The internal validity was increased by using real attributes and their level based on the current contract offer of electricity suppliers. The respondents felt they chose from real options with real impact. Still, there was a high probability that respondents recognised these tasks and the pressure to respond in the desired behaviour and accordingly adjusted their preferences (Lange, Steinke & Dewitte, 2018; Ek & Söderholm, 2006). Additionally, having 12 choice sets might have exhausted the respondents, so the final choice sets possessed a smaller informational value. This was evident in the learning rate as the response time dramatically decreased in the last few sets.

There was limited space to eliminate the biases mentioned above due to limited resources. Therefore, they are recognised in interpreting results and, if possible, corrected in the data.

Chapter 4: Research Outcome

The results of the conjoint, market simulation and prediction analyses are summarised in this chapter. The results are then discussed with respect to the research sub-questions, ultimately leading to the answer to the main research question of the WTP for RES electricity in Slovakia and whether it can be predicted for efficient pricing from sociodemographic variables and pro-environmental behaviour.

4.2 Willingness to pay for renewable electricity

The first empirical sub-question seeks to answer the Slovak consumers' WTP for RES electricity. All hypotheses from the second to seventh lead to answer this question. The first hypothesis was that the average WTP for all RES electricity sources is higher than €2. Using the results of the conditional logistic regression (maximum difference in the price factor and utility of the All RES option), the average WTP of the collected sample was €5.75. This amount is higher than the expected amount and is also statistically significant at the 1% level; thus, the null hypothesis is rejected. Interestingly, the WTP is even higher for solar electricity (€6.49) and drastically lower for biomass (€0.13). Both effects are statistically significant at the 1% level. Although showing a higher average WTP than standard electricity, hydropower and wind were not statistically significant. Despite that, the second null hypothesis that there is no statistically significant positive effect on WTP from all RES was rejected.

Table 4.2 – Average willingness to pay for contract attributes

Contract Attribute	Willingness to pay
Energy Source[All RES]	€ 5.75
Energy Source[solar]	€ 6.49
Energy Source[biomass]	€ 0.13
Electricity source[Local]	€ 6.05
Contract[Can change]	€ 3.78
Supplier[No change]	€ 2.67

Note: only statistically significant coefficients are displayed

The remaining factors are also statistically significant at the 1% level. Local production has a positive effect and the second largest WTP. Combined with RES, the electricity contract for local solar energy is €12.54. Thus, the third null hypothesis is also rejected. Furthermore, in the baseline model, the possibility to change the contract and no need to change it to acquire the desired option were statistically significant at the 1% level. The average WTP for these attributes was €3.78 and €-2.67, respectively. The results of the models are in Table 4.3.

Table 4.3 – Results of the regression models

Variable	Estimated coefficient conditional logit	$e^{coefficient_{clogit}}$	Estimated coefficient lasso	$e^{coefficient_{lasso}}$
Intercept	-	-	-1.80	0.17
Price	-0.13 (0.03)***	0.87	-2.50	0.08
Energy Source[All RES]	0.34 (0.10)***	1.41	-	-
Energy Source[solar]	0.44 (0.09)***	1.56	-	-
Energy Source[hydro]	0.06 (0.11)	1.06	-	-
Energy Source[wind]	-0.02 (0.11)	0.98	-	-
Energy Source[biomass]	-0.41 (0.12)***	0.66	-	-
Electricity source[Local]	0.40 (0.06)***	1.50	-	-
Contract[Can change]	0.25 (0.05)***	1.29	-	-
Supplier[No chagne]	0.18 (0.05)***	1.20	-	-
Income*Price diff	-	-	-0.50	0.61
Income*solar diff	-	-	-0.98	0.37
RES attitude*Price diff	-	-	0.03	1.03
RES attitude*wind diff	-	-	0.87	2.39

RES attitude*solar diff	-	-	1.39	4.00
RES attitude*hydro diff	-	-	0.68	1.98
Concern*Price diff	-	-	2.50	12.14
Concern*wind diff	-	-	0.20	1.22
Concern*solar diff	-	-	0.46	1.58
Task score*Price diff	-	-	1.26	3.53
Task score*All RES diff	-	-	1.42	4.13
Task score*solar diff	-	-	0.04	1.04
Knows green provider*Price diff	-	-	2.01	7.48
Knows green provider*All RES diff	-	-	-0.24	0.79
Knows green provider*solar diff	-	-	0.18	1.20
Knows green provider*hydro diff	-	-	-1.44	0.24
Providers count*Price diff	-	-	-4.17	0.02
Providers count*solar diff	-	-	-0.02	0.98
Observations	112	112	112	112

Note: Standard errors are reported in the brackets. * for p<0.1, ** for p<0.05 and *** for p<0.01. The baseline is effect coded (1/0/-1) and is as follows: Price[0], Energy source[all available], Electricity source [International], Contract[Cannot Change], Supplier[Change needed]. The lasso regression does not report p-values and only coefficients not equal to 0 are reported in the table.

The lasso regression model incorporated all interaction terms to study multiple hypotheses. Because p-values in regularised regression are a relatively new research area, coefficients are treated as significant for prediction and interpreted when not dropped by the lasso regression (treated as equal to 0). The statistical package also does not report p-values.

The fourth hypothesis was that income increases WTP for RES electricity. The interaction term of income and price is negative while the income and All RES interaction is dropped. Only the interaction of income and solar is not 0 and is negative. Negative signs indicate decreasing utility with higher income, price and solar energy. Therefore, the null hypothesis cannot be rejected, and it is concluded that higher income groups have lower preference and WTP for solar energy.

Next, positive environmental attitudes, environmental concerns and pro-environmental behaviour were expected to affect WTP for RES electricity positively. The interaction terms of price and all three variables were positive. In the sample, reporting higher scores in the questions lead to a higher preference for more expensive contracts. Some energy sources' interaction terms were dropped. For environmental attitudes, wind, solar and hydropower yield utility increase in the model. Higher concern was associated with a higher preference for wind and solar contracts while pro-environmental behaviour for All RES.

Biomass was dropped in all three interactions, probably because people associate it with dirtiness and pollution. Overall, all variables were associated with higher WTP, and the null hypothesis is rejected.

Lastly, market awareness was expected to affect WTP for RES electricity positively. Variables' number of known providers' and 'knowing any green provider' represented this hypothesis. The variables' interaction terms with price differed in signs. Knowing more providers was associated with heavy utility loss from the price increase. The interaction terms of the number of known providers and energy sources were mostly dropped, apart from solar. Having a negative sign, the WTP for solar energy is smaller with increasing prices. Finally, knowing green providers was associated with higher utility from increasing pricing, suggesting that respondents who knew at least one green provider opted for higher-priced contracts. The interaction terms with All RES and hydropower were negative; thus, the WTP decreases for these types of energy. The only positive sign had solar, so respondents who know at least one green provider have a larger WTP for electricity generated from solar energy. The null hypothesis cannot be rejected.

4.3 Market simulation

A market simulation was performed to analyse the performance of a new contract in the market. Firstly, three existing contracts were analysed for market share, after which the new contract was added to the analysis. Contract attributes were extracted from existing electricity contracts. In the current market setting simulation with three contracts, Greenlogy, a Slovak RES electricity provider, is expected to have a 46% share, followed by ZSE, which offers a €4 addition for Slovak electricity from solar panels. Although being the cheapest, Magna holds the smallest share. After introducing a contract similar to Greenlogy, the new product would get a 41% market share. However, these results are highly skewed, as Greenlogy is not observed to have such a high market share, even though the simulation is for three and four contracts. In reality, people often opt for more traditional providers or stick to the current ones, as switching the contract mid-term is often complicated, costly or impossible. Branding effects were, however, beyond the scope of this research. The results are summarised in Table 4.4:

Table 4.4 – Results of the market simulation

Supplier	Monthly payment	Energy source	Electricity source	Contract	Supplier	Market Share	Market Share
ZSE Energia	€ 24.54	solar	Slovak	Cannot change	Current	38%	23%
Greenlogy	€ 19.43	All RES	Slovak	Cannot change	Current	46%	27%
Magna energia	€ 18.57	all available	International	Cannot change	Current	16%	9%
New	€ 20.57	All RES	Slovak	Can change	Need change		41%

Note: Monthly payment calculated for a middle Slovak household with 2.5 MWh yearly electricity consumption. The simulation was performed on the baseline conditional logistic regression model.

4.4 Prediction of the willingness to pay for green electricity

The last sub-question of this paper was questioning whether the customer and sociodemographic heterogeneity can be used to improve the pricing of electricity from renewable resources. Both random forest models used the same interaction terms as the lasso regression model. The resulting accuracy of the mixed effects random forest model was 62.12%. It is expected that with a random prediction, approximately 50% of the answers would be correct; thus, 62% is very low. The performance did not improve when changing the choice dimension as with the lasso regression. A slightly better performance (65%) was achieved with standard random forest. Both scores are insufficient for successful market implementation. Explanations for such a low accuracy score include insufficiency and unsuitability of the data or efficiency of the experiment design. It is possible that the variables in the non-parametric regressions provided insufficient quality for prediction.

Furthermore, only 112 respondents filled the survey, which is low compared to the number of predictors (117 in the full model), although the reduction of predictors did not improve the performance. Moreover, there might not be enough variability in the sociodemographic variables in the sample. For example, due to sample size, there might not be enough observations for sufficient variability in income groups across regions, age and other control variables. Just by chance, some groups might show similar behaviour, while with a larger sample, differences could occur. There were also no respondents with the last two tariffs (D6 and D7). Because respondents filled multiple choice sets, the experiment resulted in a time series format, which is inferior for ML prediction tasks. The algorithm cannot learn from the fact that it is always 12 responses per consumer.

Lastly, the experiment was designed with utility-neutral choice sets. Every set was optimised so that the probability of choosing either option is close to 50%. This could hinder the performance of the ML algorithm if there were no empirically dominant options. Therefore, the predictability of the WTP for RES electricity is not justified in this sample using the same techniques. Ultimately, the findings from this sample suggest limited explanatory power for improving pricing efficiency using customer heterogeneity.

4.5 Summary of key results

In summary, there were three main results of the analyses: conjoint, market simulation and prediction. In the conjoint analysis, WTP for RES electricity has been estimated from the primary sample. The average WTP is €5.75 for all RES, with a slightly higher value (€6.49) for solar energy. The remaining RES were either statistically or monetarily insignificant. This is also the answer to the first part of the main research question and the first empirical sub-question. Then, the effect of local production has been estimated and found to be positive, increasing the WTP for electricity by €6.05. Furthermore, random effect terms were added to the baseline model. Firstly, the effect of income was studied, but no significant positive effect of income on WTP for RES electricity has been found. The effects of pro-environmental attitudes, concerns and behaviour on WTP for RES electricity were then estimated. The analysis showed that all three positively affect WTP for RES electricity in the sample, with each affecting different types of RES. Ultimately, the effect of awareness about the market was studied with the last model. The analysis pointed out that knowing the green provider increases WTP for contracts and solar electricity while knowing more providers has insignificant effects on WTP for RES electricity but decreases WTP for contracts in general. Furthermore, a market analysis of three and four contracts was conducted. In such a limited market with perfect knowledge and ideal conditions, consumers would prefer RES with a market share of 46% for a current provider and 41% for a new, improved contract. Finally, the prediction analysis with ML showed that this sample did not provide sufficient quality for a prediction task. The overall prediction accuracy is 62% for mixed random forest and 65% for the standard random forest. The answer to the second part of the central research question and the second empirical sub-question is, therefore, that several factors such as pro-environmental attitudes, concerns and behaviour can be used for improved pricing and but not for prediction implementation.

Chapter 5: Conclusions & Recommendations

The final chapter presents a summary of key findings from the literature and this paper, followed by their comparison and research conclusions. Then, recommendations for electricity providers and policymakers are suggested as well as for future research. Finally, the chapter ends with research limitations.

5.1 Summary of key findings from the literature

As mentioned before, the literature review provided several key findings. From a theoretical perspective, it has been shown that Slovakia has excellent potential for producing and consuming RES electricity. There must be, however, more efficient policies that support both private and conceptual solutions for RES electricity. Secondly, microeconomic, macroeconomic and cultural factors affecting electricity consumption were analysed in the literature. Income, GDP, GHG emissions, population growth, labour force, the proportion of the female population, residential and household planning, labelling, education about RES options, consumer preference for appliances and structural quality of the house were found to have a significant effect. Slovak culture is identified as masculine and, therefore, marketing of products often focuses on prominent and strong features of products that enhance one's status. Furthermore, the literature review has shown that the electricity demand is inelastic in the long term, which is logical considering consumers cannot drastically decrease their average consumption after some point. Then, the attributes of electricity contracts offering RES and behavioural factors affecting the choice of RES contracts were studied. The most influential are income, attitudes, concerns, behaviour, awareness about the market, production location and type of RES. Lastly, the sociodemographics and pro-environmental behaviour's association with WTP for RES electricity was reviewed for prediction tasks. The literature suggested that such data can predict the WTP for RES electricity.

5.2 Summary of key findings of this research

The first main finding is that the average WTP for RES electricity in the sample is €5.75 for any RES and €6.49 for solar energy. Other individual sources are not significant, or the sample is unwilling to pay as much for them. In addition, local production almost doubles this value. The average WTP for local RES production increases by €6.05 within the collected sample. These results showed statistically significant positive effects for pro-environmental attitudes, concerns and behaviour on WTP for RES electricity. No statistical significance was found for income. The effects of awareness about the market and bills are mixed; thus, the null hypothesis could not be rejected. The market simulation showed that RES electricity would be preferred under perfect conditions and without branding effects. Finally, the prediction was unsuccessful, with only 62% and 65% correct prediction with the mixed effects random forest model and standard random forest.

5.3 Conclusions

In conclusion, several findings of this paper are similar to what the literature suggests. However, many of the hypotheses do not support the literature findings. Some of the conjoint analysis findings confirm what has been found in the literature, while other findings were not statistically proven to be as hypothesised. The most important finding that the average WTP for RES electricity is positive and higher than €2 was confirmed with the data from the sample. Similarly, the effect of particular RES on the WTP has been confirmed to be the same as current research suggests. Pro-environmental attitudes, concerns and behaviour were also found to affect WTP for RES electricity positively. In contrast to the literature findings, income could not be statistically proven to affect WTP for RES electricity. Part of the effect of market awareness (number of known providers) is also different than in the literature. The market simulation showed that RES options would be preferred if consumers knew about RES options, were open to changing their provider and knew all the options on the market. Although this would make the market greener and RES funding significantly better, it is unrealistic. Firstly, the simulation did not realistically account for the branding effects of providers and, secondly, current RES production would not cover such demand. Finally, the prediction of WTP for RES electricity from consumer characteristics and behaviour is drastically different to what the literature suggests.

5.4 Recommendations for electricity providers and policymakers

As the current market is experiencing a crisis, insights from this paper are positive in the Slovak market context. The regulatory bodies in Slovakia recommend investments in RES as one of the solutions to the market crash, and high WTP for RES electricity produced in Slovakia are promising to achieve this goal. Since the current pricing model uses only one maximum of €6 in addition to the monthly payment for RES electricity and the WTP found in the sample was €5.75, an introduction of plans with a higher price tag could increase the efficiency of the funding and total investment. Electricity providers and policymakers can also utilise the fact that consumers are willing to pay more for electricity from solar energy that is locally produced and stimulate such production. Electricity providers can charge higher prices for certificates of local RES electricity, while policymakers can increase subsidies and stimulate local solar electricity production. In addition, the possibility of changing the contract mid-term being important is relevant information for regulatory bodies that can improve consumer rights in the market. The same applies to the importance of not having to change the provider, which indicates that customers feel there is too much hassle when switching to a new contract, thus reducing the market's efficiency. Policymakers can improve regulations so that no hidden clauses and sales pressure hamper customers' efforts to switch providers. Many indicated they would not want to switch only to avoid the paperwork and contact with the provider.

5.5 Recommendations for future research

While many of the results confirm current research on the topic, the external validity of the results is limited and thus not applicable to the Slovak population. It is therefore recommended that an externally valid study would be conducted. The main recommendation would be to use a more complex method for data analysis, such as a multinomial logit model with a third option representing the respondent's current contract based on input values or a "none" option for those without a contract. The adaptive conjoint analysis would also be appropriate. The more extensive study could also better explore the relationship between pro-environmental behaviour and its predictors and the WTP for RES electricity. The conjoint task could be more realistic by employing agents mimicking real-life contract sales situations. Implementing branding effects, private RES electricity generation, and subsidy schemes would also improve research implications. The biggest question remains whether the WTP for RES electricity can be predicted in the Slovak market, and perhaps a single study focusing only on this could be relevant for future research. Such as study could employ more sophisticated ML models like neural networks that would overcome the specificities of conjoint experiments or introduce another method for obtaining customer utility and WTP. Overall, the study provided some critical insights into the RES electricity market in Slovakia and contributed to the literature by applying methods used in other markets. Building on the results could be promising for future research.

5.6 Research limitations

Several limitations hinder the conclusiveness of the results. First, due to limited resources and data collection biases, the results have poor external validity and refrain only from the studied sample. Most importantly, it was snowball sampling and voluntary bias. Adding to that, a relatively smaller sample size (N=112) could be problematic and significantly reduce the explanatory and predictive power of the models. Secondly, although the design of the experiment mimicked actual contracts' attributes and presented balanced choices, it does not fully replicate authentic customer choices. In particular, task adaptation, pressure from expectations, length of the survey and the constraint of only two choices skewed the results. Another limitation was in the Lastly, the design of the conjoint analysis created obstacles to the efficient prediction of the choices, specifically by repeating 12 choices and creating an efficient Bayesian design which maximises the probability of two choices being balanced, directly influencing the learning of ML models.

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Appendix 2: Figures & Tables

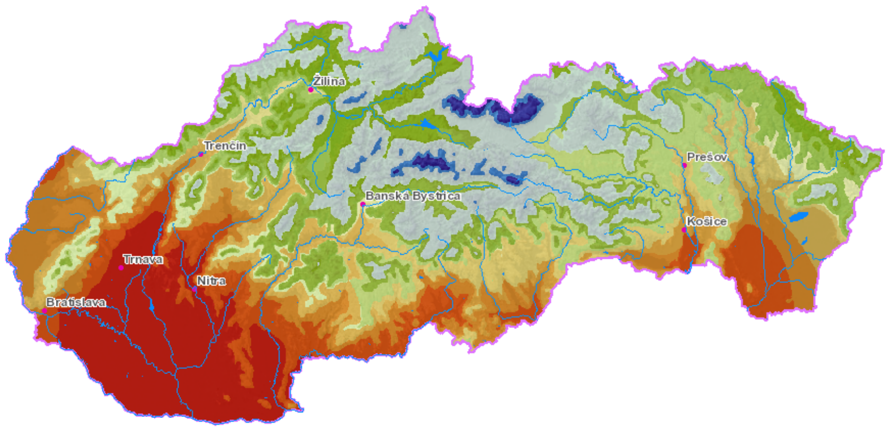


Figure A2.1 – Climate classification of Slovakia

Adapted source: Slovak Hydrometeorological Institute, 2022

Table A2.1 – Overview of electricity contracts in Slovakia

Supplier	Monthly payment	RES Electricity only Certificate
MAGNA ENERGIA a.s.	€ 18.57	No
A.En. Slovensko s.r.o.	€ 19.01	Ended operation
Pow-en a.s.	€ 19.37	No
Greenlogy a.s.	€ 19.43	Yes
Slovenské elektrárne – energetické služby, s.r.o.	€ 20.20	No
Stredoslovenská energetika, a. s.	€ 20.78	Yes, €2 p/m addition
EP ENERGY TRADING, a.s.	€ 21.16	No
UTYLIS s. r. o.	€ 21.47	No
ZSE Energia, a.s.	€ 21.54	Yes, €2-3 p/m addition
Východoslovenská energetika a.s.	€ 21.62	Yes, €2-6.5 p/m addition
Energie2, a.s.	€ 22.00	No
ELGAS, s.r.o.	€ 22.10	Yes, no price information
Slovenský plynárenský priemysel, a.s.	€ 23.38	Yes, €2 p/m addition
RIGHT POWER, a.s.	€ 25.50	Yes

Note: the prices are calculated for an average Middle-Slovak household with 2.5kWh consumption

Adapted source: ÚRSO, 2022b

Figure A2.2 – Decision tree example

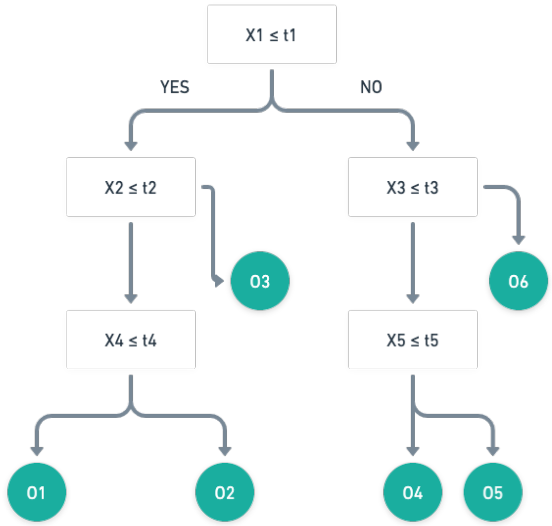
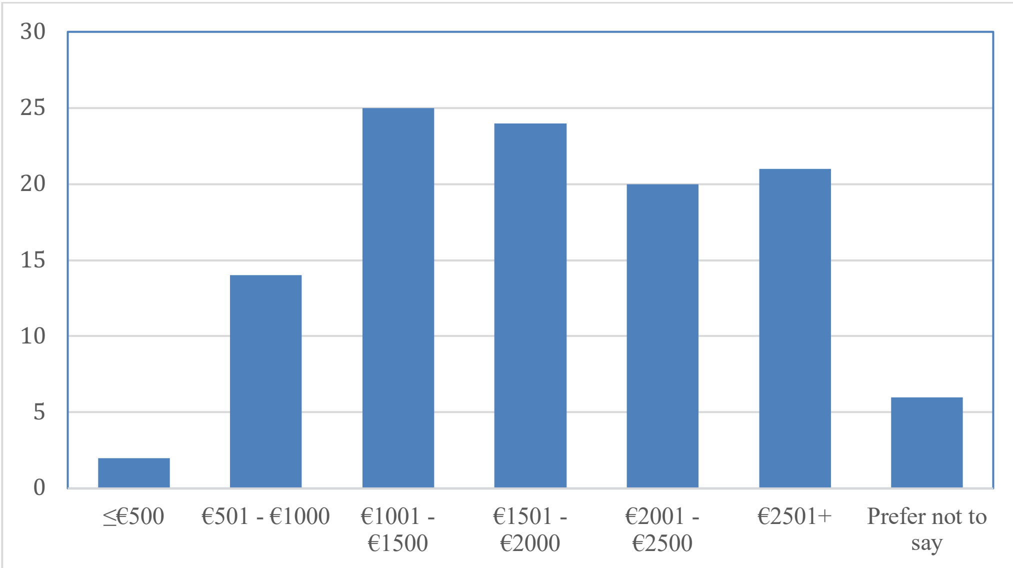


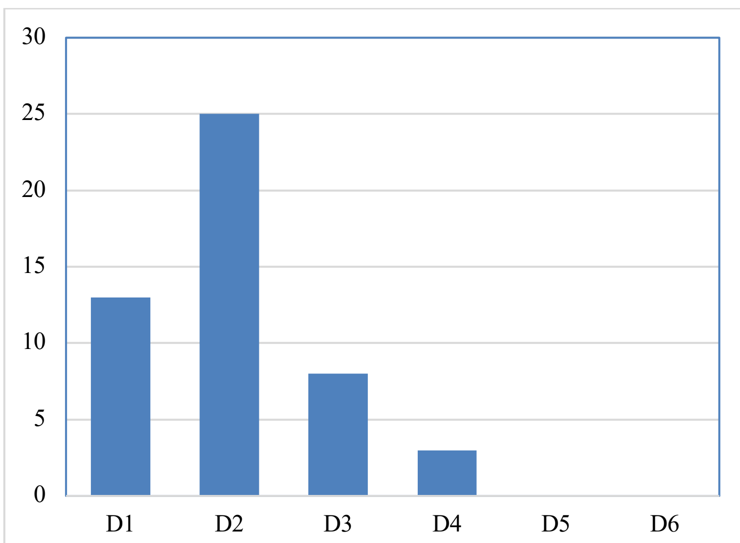
Figure A2.3 – Survey ad visual

Figure A2.4 – Income distribution of the sample



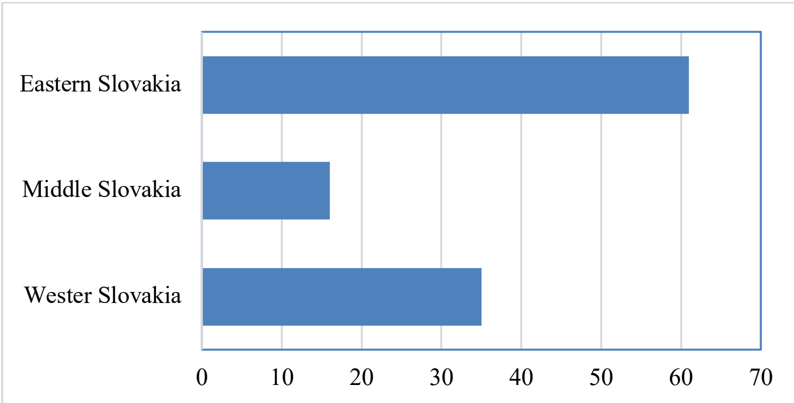
Note: N=112

Figure A2.5 – Electricity tariff distribution of the sample



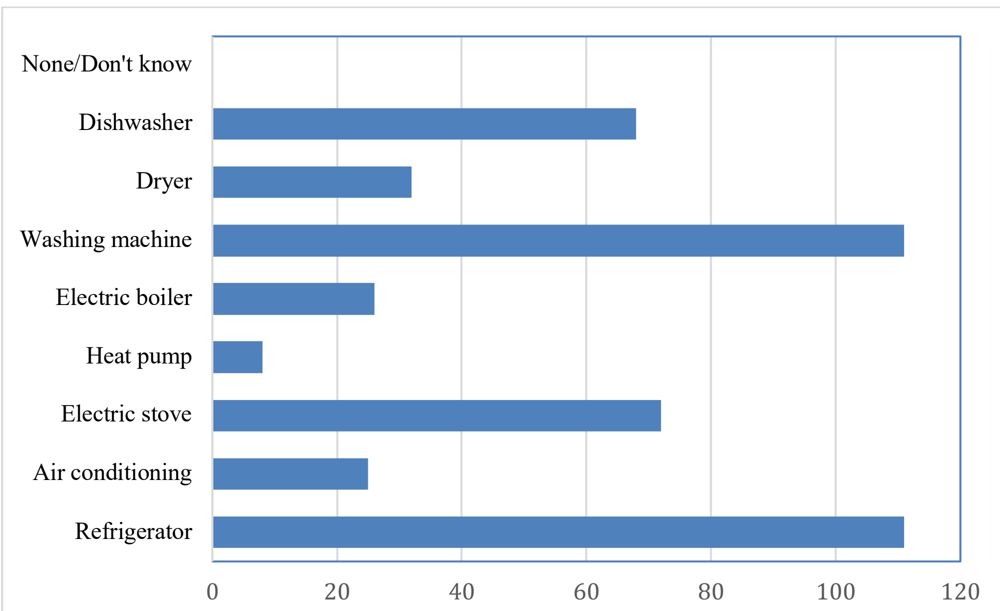
Note: N=49

Figure A2.6 – Regional distribution of the sample



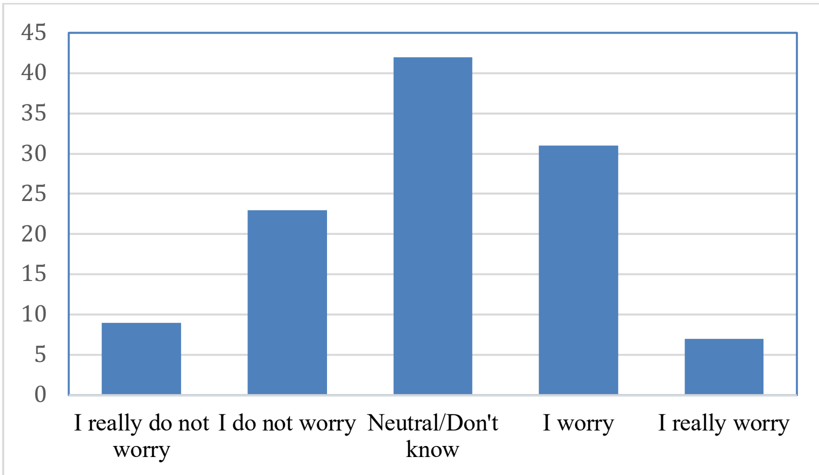
Note: N=112

Figure A2.7 – Owned appliances distribution of the sample



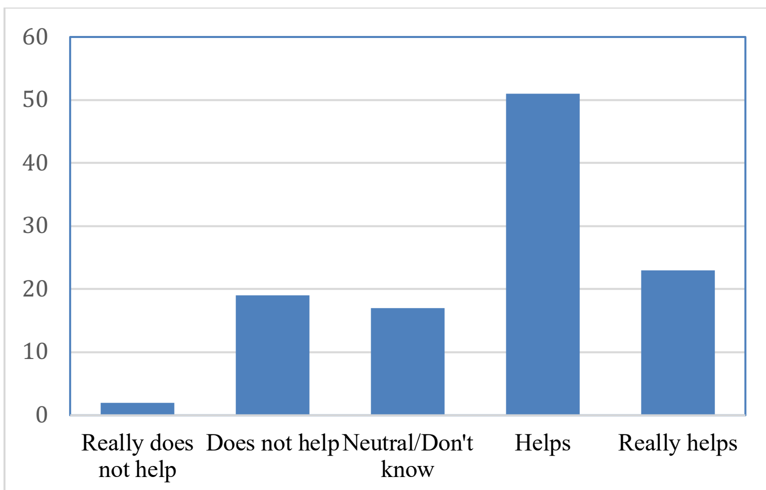
Note: N=112

Figure A2.8 – Answer distribution to the question "How much do you worry that electricity production will cause irreversible damage?" of the sample



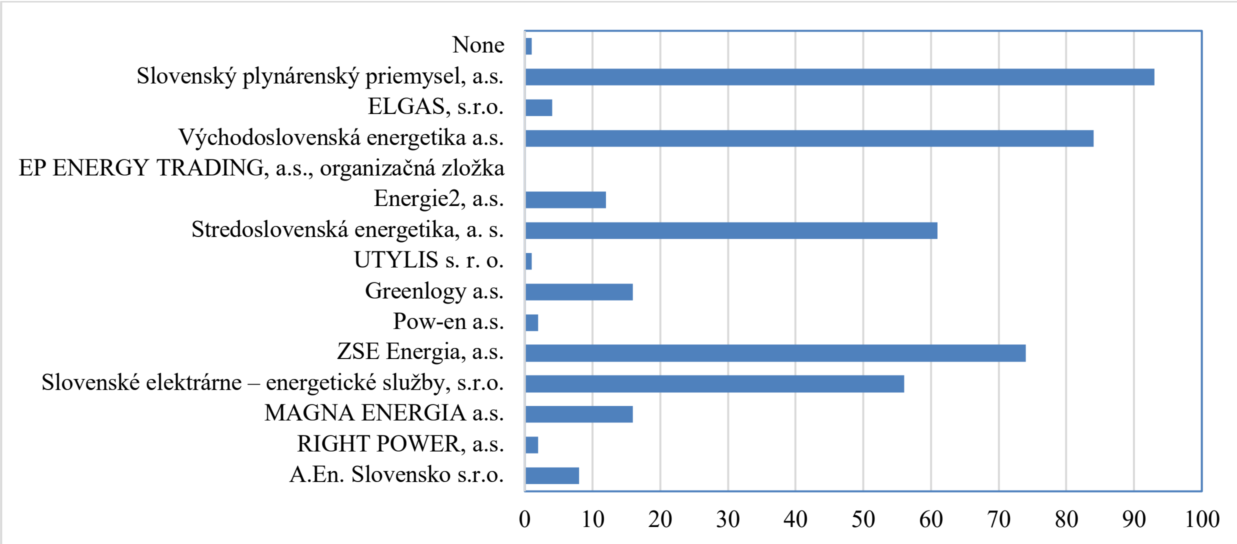
Note: N=112

Figure A2.9 – Answer distribution to the question "Do you think that RES electricity production helps the environment?" of the sample



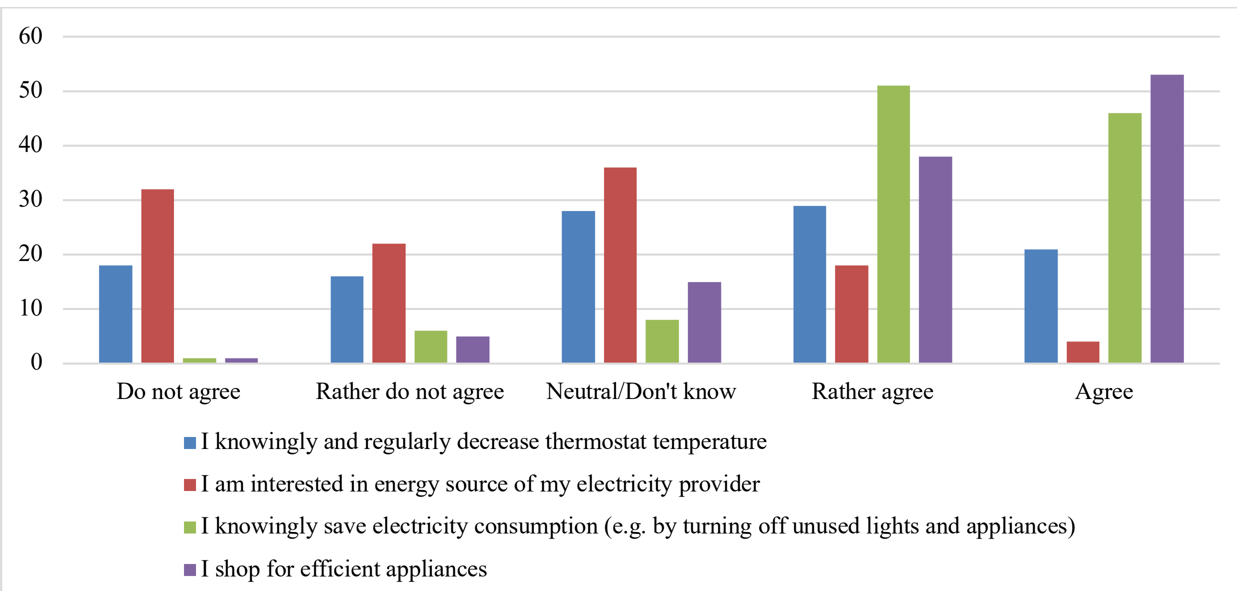
Note: N=112

Figure A2.10 – Known providers distribution of the sample



Note: N=112

Figure A2.11 – Pro-environmental behaviour task answers distribution of the sample



Note: N=112

Table A2.3 – Results of the lasso regression model

Variable	Coefficient
Intercept	-1.797
Real Price diff	-2.503
All RES diff	.
wind diff	.
solar diff	.
hydro diff	.
biomass diff	.
Slovak diff	.
Can Change diff	.
No change diff	.
Gender_f*Real Price diff	1.176
Gender_f*All RES diff	-0.112
Gender_f*wind diff	0.031
Gender_f*solar diff	0.179
Gender_f*hydro diff	-0.491
Gender_f*biomass diff	0.184
Gender_f*Slovak diff	0.062
Gender_f*Can Change diff	0.136
Gender_f*No change diff	-0.169
Age*Real Price diff	-1.172
Age*All RES diff	.
Age*wind diff	-0.871
Age*solar diff	.
Age*hydro diff	.
Age*biomass diff	-2.055
Age*Slovak diff	0.140
Age*Can Change diff	-0.949
Age*No change diff	-0.766
Income*Real Price diff	-0.497
Income*All RES diff	.
Income*wind diff	.
Income*solar diff	-0.982
Income*hydro diff	.
Income*biomass diff	.

Income*Slovak diff	0.429
Income*Can Change diff	.
Income*No change diff	1.447
No Income*Real Price diff	-0.542
No Income*All RES diff	.
No Income*wind diff	.
No Income*solar diff	-0.157
No Income*hydro diff	2.026
No Income*biomass diff	-2.626
No Income*Slovak diff	.
No Income*Can Change diff	.
No Income*No change diff	.
Region West*Real Price diff	.
Region West*All RES diff	0.488
Region West*wind diff	-0.798
Region West*solar diff	0.117
Region West*hydro diff	-0.259
Region West*biomass diff	-0.789
Region West*Slovak diff	-0.059
Region West*Can Change diff	1.092
Region West*No change diff	0.832
Region East*Real Price diff	.
Region East*All RES diff	-0.178
Region East*wind diff	.
Region East*solar diff	0.362
Region East*hydro diff	.
Region East*biomass diff	.
Region East*Slovak diff	.
Region East*Can Change diff	1.132
Region East*No change diff	-0.137
Household_size*Real Price diff	.
Household_size*All RES diff	.
Household_size*wind diff	.
Household_size*solar diff	.
Household_size*hydro diff	.
Household_size*biomass diff	0.426

Household_size*Slovak diff	.
Household_size*Can Change diff	1.742
Household_size*No change diff	0.155
Concern_1*Real Price diff	2.497
Concern_1*All RES diff	.
Concern_1*wind diff	0.201
Concern_1*solar diff	0.456
Concern_1*hydro diff	.
Concern_1*biomass diff	.
Concern_1*Slovak diff	.
Concern_1*Can Change diff	0.199
Concern_1*No change diff	0.325
RES_attitude_1*Real Price diff	0.026
RES_attitude_1*All RES diff	.
RES_attitude_1*wind diff	0.872
RES_attitude_1*solar diff	1.385
RES_attitude_1*hydro diff	0.682
RES_attitude_1*biomass diff	.
RES_attitude_1*Slovak diff	0.514
RES_attitude_1*Can Change diff	.
RES_attitude_1*No change diff	.
Know_green_provider*Real Price diff	2.012
Know_green_provider*All RES diff	-0.237
Know_green_provider*wind diff	.
Know_green_provider*solar diff	0.180
Know_green_provider*hydro diff	-1.443
Know_green_provider*biomass diff	.
Know_green_provider*Slovak diff	.
Know_green_provider*Can Change diff	-1.129
Know_green_provider*No change diff	0.232
Providers_count*Real Price diff	-4.168
Providers_count*All RES diff	.
Providers_count*wind diff	.
Providers_count*solar diff	-0.016
Providers_count*hydro diff	.
Providers_count*biomass diff	.

Providers_count*Slovak diff	-1.144
Providers_count*Can Change diff	0.219
Providers_count*No change diff	.
Task score*Real Price diff	1.263
Task score*All RES diff	1.417
Task score*wind diff	.
Task score*solar diff	0.042
Task score*hydro diff	.
Task score*biomass diff	.
Task score*Slovak diff	1.894
Task score*Can Change diff	.
Task score*No change diff	.
Observations	112

Note: No Income is a dummy for a group who wished not to reveal their income. Task score is a sum of pro-behavioural task scores. 'Diff' denotes a variable calculated by subtracting attributes of choice B and choice A

Appendix 3: Survey Questions

Part 1. Descriptive statistics

Q1: What is your age? A: Numeric entry

Q2: What is your gender? A: Binary choice + prefer not to say/other

Q3: What is your monthly household income ? A: 6 income brackets + prefer not to say

Q4: Do you know your electricity tariff? A: Y/N, if Y, ask tariff

Q5: What is your monthly payment for electricity? A: Numeric entry on slider

Q6: Where do you live? A: Three choices

Q7: What is your household size? A: Numeric entry

Q8: How many of these appliances do you own (refrigerator, AC, name some more)? A: Pick all that apply + None/Don't know

Q9: How concerned are you about impact on environment from electricity production? A: Likert scale 1-5

Q10: Do you think RES electricity can help improve environment? A: Likert scale 1-5

Q11: Which electricity providers on the list do you know? A: Pick all that apply + None

Part 2. Pro behavioural task

Select what applies:

Q12: I knowingly and regularly decrease thermostat temperature? A: Likert scale 1-5

Q13: I am interested in energy source of my electricity provider. A: Likert scale 1-5

Q14: I knowingly save electricity consumption (e.g. by turning off unused lights and appliances). A: Likert scale 1-5

Q15: I shop for efficient appliances. A: Likert scale 1-5

Q16-28: Choice sets A: Binary choice

Appendix 4: Data

Because of the sizes of the datasets, all used datasets are deposited in a Github repository for a period of at least 5 years on this link: https://github.com/dominikmecko/Thesis-Mecko-539056

Appendix 5: Programming Code

Because of the length of the programming file, all code is deposited in a Github repository for a period of at least 5 years on this link: https://github.com/dominikmecko/Thesis-Mecko-539056