Decarbonization of the energy sector in Belgium and the Netherlands

Identifying heterogenous energy generation preferences and willingness to pay for nuclear energy

Master in Spatial, Transport and Environmental Economics
Erika De Keyser
Academic year 2019-2020
Supervisor: Dr. M. G. Lijesen

Abstract

Cutting back carbon dioxide emissions is an important step in the battle against climate change. To contribute to this decarbonization process, the power sector can use three main technologies: renewable energy, nuclear energy and fossil fuel plants equipped with carbon capture and storage (CCS) mechanisms. This study aims to determine public preferences for decarbonization pathways in the energy sector. Almost 10 years after the Fukushima accident, this paper investigates people's willingness to pay for nuclear energy relative to other technologies if all combinations of technologies reach full decarbonization. A discrete choice experiment was designed to confront respondents with hypothetical choice sets differing in cost, minutes of power outage and share of nuclear energy, renewable energy or fossil fuels equipped with CCS. A latent class logit model was fitted to the data. Three classes of respondents could be distinguished in the sample: two classes who are in favor of nuclear energy compared to fossil fuels with CCS and one class, containing over 50% of the respondents in the sample, preferring both renewables and fossil fuels with CCS over nuclear energy. The probability to belong to a certain class differs across socio-economic characteristics, political preferences, knowledge and concern about nuclear energy, climate change or future generations. The results indicate that the public does not always prioritize cost-efficiency: eco-toxicity seems to be a characteristic worth considering in the decarbonization process.

Keywords: Stated Choice Experiment (SCE); stated preferences; latent class analysis; logistic regression; willingness to pay; energy transition. JEL Q42, Q49, Q51

1 Introduction

In 2015, the Paris Agreement promised to strive towards a limitation of global temperature increases to 1.5°C above pre-industrial levels (United Nations, 2015). To achieve this goal, the power sector must cut back its emissions at a high rate. The Intergovernmental Panel on Climate Change (IPCC) mentions four main technological solutions to decarbonize the power sector: apart from energy efficiency measures, deployment of low-carbon technologies such as renewable energy sources (RES), fossil fuel plants equipped with carbon capture and storage (CCS) mechanisms and nuclear energy will be needed on a large scale (Bruckner et al., 2014).

However, nuclear power plants bring along other issues. Poumadère, Bertoldo, & Samadi (2011) researched public perceptions of several power generation technologies such as nuclear energy. They conclude that the public is particularly concerned about nuclear energy since the Fukushima accident. Apart from safety issues, the public worries about the disposal of the high-level radioactive waste. Public opinion in the European Union has been opposed to nuclear energy for a long time (European Commission, 2007). Despite consensus on the cost-efficiency of nuclear energy (Jägemann, Fürsch, Hagspiel, & Nagl, 2013; Simoes, Nijs, Ruiz, Sgobbi & Thiel, 2017; Capros et al., 2014 and Zappa, Junginger & Van den Broek, 2019), some countries are still not willing to reinvest in nuclear energy given the societal difficulties concerning safety and waste. For example, Germany and Switzerland formally stated to phase out their nuclear energy plants (International Atomic Energy Agency, 2019a-2019b).

Decarbonizing the European energy sector without nuclear energy seems possible in terms of energy demand, but it will bring along higher costs (Jägemann et al., 2013; Zappa et al., 2019; Connolly, Lund and Mathiesen, 2016). Whether the technically feasible but expensive scenario of nuclear-free decarbonization will be employed, depends on positions of each country towards nuclear energy. Almost 10 years after the Fukushima accident, it is interesting to research to which extent people are still critical towards nuclear power generation. This paper investigates people's willingness to pay for nuclear energy in the decarbonization process. Three research questions were addressed:

> *Which technologies do people value the most in a decarbonized energy mix?*
>
> *How do people value nuclear energy compared to affordable decarbonization needed to fight climate change?*
>
> *How are socio-economic characteristics, political preferences, knowledge or concern about nuclear energy, climate change or future generations related to the valuation of nuclear energy compared to other energy technologies?*

To answer these research questions, a Stated Choice Experiment (SCE) was designed. This stated preference technique confronts respondents with hypothetical choice sets. A major advantage of this technique is that the alternatives and attributes in the choice set can be hypothetical. Respondents can express their opinion on the hypothetical trade-off between nuclear energy and expensive decarbonization. By carrying out a SCE on energy system preferences, policymakers can get an indication of the public's opinion on prioritizing cost-efficiency or other characteristics such as eco-toxicity in the decarbonization process. The results could indicate how much people are willing to 'overinvest' in nuclear-free decarbonization.

Performing a similar experiment in America in 2001, Roe, Teisl, Levy and Russell found that American consumers are generally willing to pay more for emission reduction when it stems from renewable energy compared to nuclear energy. A similar study was carried out by Morita & Managi (2015) in Japan, where public attention towards electricity production was considerably high after the Fukushima nuclear accident in 2011. They measured citizen's willingness to pay (WTP) for electricity produced by renewables, nuclear power or natural gas, as well as the effects of providing positive or negative information on nuclear energy. Results indicated that Japanese citizens had a negative WTP for electricity produced by nuclear power regardless of the information they received. Murakami, Ida, Tanaka and Friedman (2015) conduced a similar study in Japan and the US, finding that both US and Japanese consumers express a negative willingness to pay for nuclear energy. In a similar SCE experiment carried out in Korea, Byun & Lee (2017) concluded that the perceived danger related to the electricity source is the most important factor in consumers' choice, leading to a preferred reduction of nuclear power and increase of renewable energy by Korean consumers. Nevertheless, few studies on this topic have been carried out in European countries. Given that the public acceptance issues and political debates related to nuclear energy and fossil fuel are slightly different in European countries compared to Asian countries such as Japan - who experienced all the negative effects of the Fukushima accident in 2011 – this lack of research provides an interesting opportunity. This study not only represents an application to Belgium and the Netherlands, but also adds new elements such as respondents' knowledge on nuclear energy and climate change, concern about these topics and political preferences. Additionally, the application of latent class techniques was not found in previous studies on this subject and could therefore lead to new insights. Despite receiving the same electricity mix, the techniques used to generate electricity can induce different emotions in a heterogenous population. This study thus adds novel insights by unravelling the impact of respondents' political preferences, knowledge on nuclear energy and climate change and concern about these topics on energy generation preferences.

In the following chapter, the methodological approach of this study will be discussed. This includes an elaboration on the survey design and model specifications. In a next chapter, the results will be presented and discussed, including descriptive statistics as well as calculations of the willingness to pay and class composition. Lastly, the conclusion summarizes the main findings and research gaps.

2 Methods

2.1 Survey design

In this study, a SCE is designed to analyse consumers' preferences for electricity generation sources in both the Belgian and Dutch decarbonization process. Consumers review hypothetical situations and choose their preferred option.

Some biases and errors can occur in a SCE, specifically for this experiment related to costs, emissions and safety of nuclear and RES. For example, an *information bias* occurs when a respondent has incorrect information on the context, so the answers might not represent his true answer. A *starting point bias* can occur when respondents are influenced by the set of available responses to the experiment. A *hypothetical bias* occurs when individuals tend to respond differently to hypothetical scenarios than they would to the same scenarios in the real world. Another bias that may occur is a *strategic bias,* where a respondent desires a specific outcome and fills in answers that are in line with these outcomes. Unless a respondent has personal connections with either the nuclear energy, fossil fuel or RES industry, this bias seems unlikely. Finally, respondents might not carefully read instructions or understand the questions. (Tietenberg & Lewis, 2018).

To minimize these biases, the attribute values are chosen to be as realistic as possible. For example, the variables related to costs are based on the average monthly electricity costs in the Netherlands. Respondents with a Belgian nationality are presented with a different range of costs, since monthly electricity bills in Belgium are significantly higher than in the rest of Europe. Before presenting the different choice sets, the survey includes a small block of information that explains the context of the study, to ensure that all respondents have a clear understanding of what is asked. The provided information entails an introduction to the need to decarbonize the power generation sector in light of the European Green Deal, as well as an introduction of the 3 most promising technologies to accomplish full decarbonization of the electricity sector. A last remark mentions that respondents will have to make 15 choices where they evaluate different electricity generation scenarios that always accomplish full decarbonization.

> *In December 2019, the European Union proposed the "European Green Deal". The goal is to become carbon neutral by 2050. An important part of this strategy is to lower the CO_2-emissions of electricity generation to zero. To accomplish a completely carbon neutral power system, 3 technologies could play a major role:*
>
> *1. Renewable energy such as solar and wind energy;*
>
> *2. Nuclear energy;*
>
> *3. Fossil fuels combined with carbon capture and storage (CCS). The CO_2 that is emitted in fossil fuel combustion processes, is captured and for example stored beneath the surface of the earth.*
>
> *In the next part of the questionnaire, we ask you to choose between a number of scenarios for carbon neutral electricity production. 15 choice sets follow. All scenarios accomplish a completely carbon-free electricity generation, but they differ in the used technologies, cost and power supply stability.*

This information is accompanied by simple illustrations for each technology to enhance understanding, as presented in figure 1.

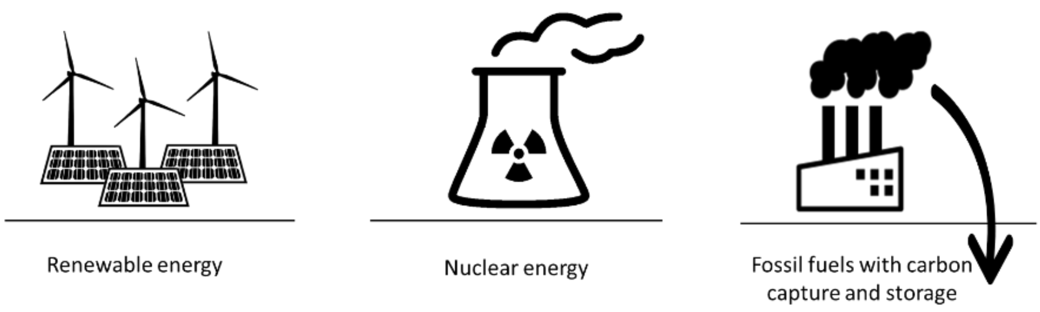

Figure 1: Illustrations for each technology

2.1.1 Choice attributes

A first attribute included in the experiment is the share of nuclear energy, fossil fuels with CCS and renewable energy. In striving for a decarbonized society, these technologies will play a large role. The share of nuclear energy, fossil fuels with CCS and renewable energy are complementary; they always add up to 100%. The goal of this research is to compare the trade-off that consumers make in costs, operational safety and other perceived external costs or benefits related to each technology. The estimation of the risk of damages is deliberately left to the respondents as this influences their preference for either technology.

An important element in the debate about a good energy mix is the cost of technologies. Recent research in electrical power system modelling has been focusing on modelling different decarbonization scenarios under constraining assumptions. Most studies pursue a lowest-cost approach. For example, Jägemann et al. (2013); Simoes et al. (2017); Capros et al. (2014) and Zappa et al. (2019) all mention nuclear energy as one of the cheapest options to decarbonize the European power system. Van Zuijlen et al. (2019) look at the Western European region, arguing that nuclear energy is a cost-effective way of providing capacity. Total system cost estimations from Zappa et al. (2019) of fully renewable decarbonization scenarios compared to decarbonization scenarios by 2050 that allow for non-renewable energy sources such as nuclear energy, imply a cost increase of 29% (€410bn to €530bn). Jägemann et al. (2013) find a total system cost increase of 8,6% (i.e. from €1387bn to €1506bn) when considering a decarbonization scenario that minimizes costs while allowing for both nuclear and CCS compared to a scenario that minimizes costs while employing CCS but no nuclear energy. Connolly et al. (2016) find that a 100% renewable energy system in Europe is technically possible by applying a 'Smart Energy' approach that connects heating, cooling and transport systems. They estimate that this scenario costs 10-15% more than a *Business As Usual* (BAU)-scenario, while it will create more than 10 million additional direct jobs. An overview of the estimated cost increases of decarbonization with and without nuclear energy is given in figure 1.
In Belgium, an average family pays €921/year for electricity, which translates to €76,75/month. In the Netherlands however, an average family pays only €629/year or €52,41/month (VRT, 2018). Following Connolly et al. (2016), a fully renewable scenario would cost 10-15% more, leading to €84,43 – €88,26/month in Belgium and €57,65 - €60,72/month in the Netherlands. Assuming the estimated cost increase of Zappa et al. (2019), the costs of a fully renewable scenario would be even higher. To keep the attribute levels realistic, the level of the cost attribute ranges from €55 to €98 a month for Belgian respondents and from €38 to €68 a month for non-Belgian respondents.

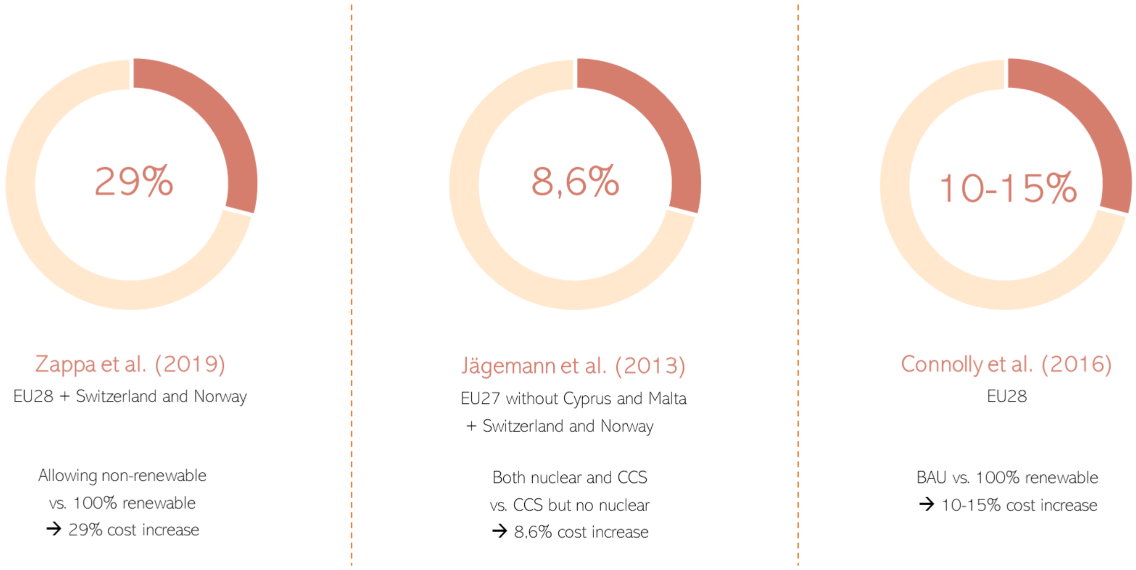

Figure 2: Estimated cost increases of decarbonization with and without nuclear energy

Lastly, an important characteristic of a technology is the stability of the electricity supply. Except for innate characteristics of energy technologies and the cost of the energy mix, some consumers might also be concerned about stability of the energy supply. Power outages could interrupt production processes and other important elements of our daily life. Therefore, it is relevant to include a measure of power outages in addition to the attributes related to the share of nuclear and renewable energy. Arguments concerning the stability of the energy supply seem to disadvantage weather-dependent renewable energies. Simoes et al. (2017) argue that to ensure system stability in decarbonization of the European power system, the share of variable electricity (wind and solar energy) should remain below the maximum share of 50% while the remaining demand can be satisfied with gas for 7-28%, nuclear for 20-54% and other RES (e.g. biofuels) only for 4-13%. Considering the energy system in the UK, Hobley (2019) mentions that nuclear energy is cheaper and provides more energy security, while he recognizes that it entails issues such as nuclear waste storage, political will and public acceptance. In 2018, the average duration of power outages in Belgium was about 19 minutes, a decrease compared to the previous years (VREG, 2019). In the Netherlands, the average household did not have electricity for 27 minutes in 2018, while this number decreased to 20 minutes in 2019 (Netbeheer Nederland, 2020). Because these levels are already very low, 30 minutes/year is the lowest attribute level taken into account.

Table 1 gives the attributes included in each choice set as well as their levels. An example of a full choice set is provided in Appendix A.

Table 1: Attributes and attribute levels

Attribute	*Attribute levels*
Share of nuclear energy	0% - 25% - 50% - 75% - 100%
Share of renewable energy	0% - 25% - 50% - 75% - 100%
Share of fossil fuels with CCS	0% - 25% - 50% - 75% - 100%
Electricity cost (NL) in Euros/month	38 – 46 – 52 – 60 – 68
Stability of the energy supply in minutes of power outage per year	30 – 90 – 180 – 240 – 360

2.1.2 Individual characteristics

Multiple characteristics could influence consumers' energy system preferences. People's attitude on this issue could differ across political systems. Goebel, Krekel, Tiefenback and Ziebarth (2015) agree that there is a clear relationship between political systems and support for nuclear energy. For example, the Fukushima disaster caused an increase in support for the Greens since phasing out nuclear energy has been one of the core objectives of the German green party. In the UK, this increase in Green party supporters was present as well, but only for people living close to nuclear reactors. People's position on nuclear energy is not only decisive for their support for political parties, but the political debate could also contribute to their position on the nuclear issue. Latré, Thijssen and Perko (2019) conducted a public opinion survey in Belgium in 2015 to analyse how people use political party cues in determining their support for nuclear energy. They found that there is significant cue taking on the issue of nuclear energy: citizens seem to use political parties' points of view as guidance when taking a position on the issue. Latré et al. (2019) conclude that Belgian political parties seem to have a polarizing impact on public opinion on nuclear energy. Considering these results, indicating that voters of parties with a clear position on nuclear energy can experience significant cue taking from those parties, it seems relevant to include a political preference variable in the analysis. Following Latré et al. (2019), a Flemish 'issue owning' party that is strongly against nuclear energy is the green party Groen, while 'policy defending' parties arguing in favour of nuclear energy are the right-winged parties N-VA and Vlaams Belang (VB). The relationship between right-winged political preferences and support for nuclear energy has been established in research before. For example, carrying out a survey on the support of nuclear energy in Europe, Pampel (2011) found that rightist political views increase the support for nuclear energy. Other Flemish parties, including social democratic parties, communist parties and the Flemish liberal party, join the Green parties in their opposed position towards nuclear energy (Santens, 2019). Expanding this reasoning to the Dutch political system, Dutch issue owning parties are CU, D66, GroenLinks, PvdD and PvdA, while policy defending parties who are in favour of nuclear energy are CDA, VVD, PVV and FVD (NOS, 2018).

Personality traits such as risk aversion could also influence people's opinions. For example, Goebel et al. (2015) find that, after the Fukushima disaster, more Germans considered themselves as "very risk averse". This is an important characteristic to take into account in the analysis. Therefore, it is interesting to ask people whether they believe the risk of operational accidents in nuclear power plants is high or low. Many factors influence this. For example, psychological research shows that our brain favours uncritical acceptance of exaggerations of the likelihood of extreme and improbable events (Kahneman, 2012). Consequently, it is likely that people will overestimate the probability of a nuclear disaster. Additionally, the continued operation of powerplants that should have been retired, as well as the increasing frequency of shutdowns due to unforeseen maintenance operations in Belgium, could influence respondents' answer on this question. Similarly, it is interesting to ask respondents how concerned they are about climate change or the wellbeing and safety of future generations.

Another aspect that could influence consumers' preference is their knowledge or involvement. In the analysis of Latré et al. (2019), whether respondents had knowledge on the issue or were involved with it played a role in how people use political party cues to determine their support for nuclear energy. Byon and Lee (2017) confirm that knowledge about fossil fuels and climate change can influence preferences for electricity generation sources.

Finally, the analysis of Byun and Lee (2017) showed that consumers' preferences for an electricity generation source can be significantly influenced by age, number of preschool children (significantly increasing concerns about danger of the generation source), education level, awareness of renewable energy and the amount of their electricity bill. Therefore, control variables on gender, age, education and income are included as well.

Table 2 gives the included individual characteristics and their levels. An overview of the questions on knowledge and attitude is given in Appendix A.

Table 2: Included individual characteristics

Variable	*Definition*
Gender	Male – Female – Other
Age	< 25 years – 25-50 years – > 50 years
Highest education level	Primary education – Secondary education – Bachelor degree – Master's degree or higher
Monthly household income (gross)	< 4000 euro – 4000-8000 euro – > 8000euro
Political preference	Political party voted for during the last national or federal elections (NL/BE)
Knowledge about adverse effects of nuclear energy	3 true/false questions
Knowledge about climate change	3 true/false questions
Concern about nuclear power	5 Likert scale (5-point) questions
Concern about climate change	3 Likert scale (5-point) questions
Concern about future generations	3 Likert scale (5-point) questions

2.2 Model specifications

The main method to analyse data generated by Stated Choice Experiment is a conditional logit model, relating the probability of choosing an alternative to the attribute levels of the alternatives. However, since energy technology decisions can give rise to many emotions that are related to hard to measure background variables, people may differ in their valuation of energy technologies based on unobserved characteristics. Latent class analysis identifies unobserved class membership to analyse heterogeneous consumer preferences. Therefore, a latent class logit model is applied in this study.

In the Stated Choice Experiment, consumers compare choice alternatives based on their conditional indirect utilities and choose the alternative with the highest value. Following McFadden (1973), the utility of consumer *n* from choosing alternative *j* is defined as follows:

$$U_{nj} = V_{nj} + \varepsilon_{nj} = \beta_n X_j + \varepsilon_{nj} \tag{2.2.1}$$

In this equation, V_{nj} represents the deterministic component of consumer utility that can be explained by observable attributes. The deterministic component is composed of the attributes X_{nj} of each alternative and their respective coefficients β_{nj}. These coefficients represent the tastes of each consumer for each attribute. The stochastic component ε_{nj} indicates random variation that cannot be explained by the model. It is unlikely that all consumers have the same preferences and thus choose the same alternatives, so unobserved heterogeneity is important. It is assumed that this stochastic term follows an Extreme Value Type I (*EVT I*) distribution. The observed component of utility V_{nj} can also be rewritten to include a constant k_j, as in equation 2.2.2. This term captures the average effect of all factors that are not included in the model. By including this alternative specific constant, the stochastic component ε_{nj} has zero mean by construction.

$$V_{nj} = \beta_n X_j + k_j \tag{2.2.2}$$

One can now calculate the probability that the utility of one alternative is higher than the utility of another alternative:

$$Prob(u^1 > u^2) = Prob\ (v^1 + \varepsilon^1 > v^2 + \varepsilon^2) \tag{2.2.3}$$

$$Prob(u^1 > u^2) = \frac{e^{v^1}}{e^{v^1} + e^{v^2}} = \frac{e^{x_{n1}\beta_n}}{e^{x_{n1}\beta_n} + e^{x_{n2}\beta_n}} \tag{2.2.4}$$

When carrying out a logistic regression, the coefficients can be interpreted as odds ratios. The odds of choosing outcome 1 compared to outcome 2 are specified in equation 2.2.5.

$$\frac{P_{n1}}{P_{n2}} = \frac{\frac{e^{v^1}}{e^{v^1} + e^{v^2}}}{\frac{e^{v^1}}{e^{v^1} + e^{v^2}}} = \frac{\frac{e^{x_1\beta}}{\sum_j e^{x_j\beta}}}{\frac{e^{x_2\beta}}{\sum_j e^{x_j\beta}}} = \frac{e^{x_1\beta}}{e^{x_2\beta}} = e^{(x_1 - x_2)\beta} \tag{2.2.5}$$

The odds ratio of choosing an alternative as opposed to the baseline category then simplifies to $e^{x_j\beta}$.

The latent class logit model assumes unobserved heterogeneity by including a number of classes with differences preferences, i.e. different coefficients β_{nj}. Within each class, individuals share preferences, but preferences are different across classes. The probability to belong to class q is given as w_{iq}. These class probabilities depend on a set of constants γ_q with $\gamma_1 = 0$, as specified in equation 2.2.6.

$$w_{iq}(\gamma) = \frac{e^{\gamma_q}}{\sum_{q=1}^{Q} \gamma_q} \tag{2.2.6}$$

The unconditional probability of choices by individual n is then given by equation 2.2.7.

$$P_{nj} = \sum_{q=1}^{Q} w_{nq}(\gamma_q) \left[\frac{e^{x_1 \beta_q}}{\sum_{j=1}^{J} e^{x_j \beta_q}}\right] \tag{2.2.7}$$

Since one of the choice attributes included in the choice sets is the cost of the scenario, it is now possible to calculate the value of the other choice attributes, namely the share of nuclear energy, the share of renewable energy and the duration of power outages. The ratio of the marginal utilities of these attributes to the marginal utility of the cost indicates the willingness to pay for 1 unit of the attribute. However, the marginal utilities of the attributes depend on one another since the share of renewables, fossil fuels and nuclear energy add up to 100%. Therefore, it is assumed that as the share of nuclear energy or renewables increases with 1%, the share of fossil fuels decreases with 1%.

$$Value\ Of\ Nuclear\ Energy = VONE = -\frac{\delta V/\delta NUCL}{\delta V/\delta COST} = -\frac{\beta_{Nucl}}{\beta_{Cost}} \tag{2.2.8}$$

$$Value\ Of\ Renewable\ Energy = VORE = -\frac{\frac{\delta V}{\delta REN}}{\frac{\delta V}{\delta COST}} = -\frac{\beta_{Ren}}{\beta_{Cost}} \tag{2.2.9}$$

$$Value\ Of\ Power\ Outages = VOPO = -\frac{\frac{\delta V}{\delta OUTAGE}}{\frac{\delta V}{\delta COST}} = -\frac{\beta_{Outage}}{\beta_{Cost}} \tag{2.2.10}$$

3 Results and discussion

3.1 Descriptive statistics

The survey was sent out using Qualtrics software at the end of March 2020. 603 complete responses were collected. Of these 603 observations, 20 were left out of consideration due to inconsistent responses: respondents who indicated the same or a similar answer on the statements “I am worried about future generations” and “I am not worried about future generations” were considered to be inattentive. A summary of socio-economic characteristics of the remaining 583 respondents is given in table 3.

Table 3: Socio-economic statistics

Variable	*Level*	*Total*	*Belgian (53,17%)*	*Dutch (20,24%)*	*Other nationality (26,59%)*
Gender	Man	250 (42,88%)	141 (45,48%)	38 (32,20%)	71 (45,81%)
	Woman	329 (56,43%)	168 (54,19%)	79 (66,95%)	82 (52,90%)
	Other	4 (0,69%)	1 (0,32%)	1 (96,91%)	2 (1,29%)
Age	< 25 years old	244 (41,85%)	122 (39,35%)	63 (86,44%)	59 (38,06%)
	25 – 50 years old	246 (42,20%)	122 (39,35%)	41 (34,75%)	83 (53,55%)
	>50 years old	93 (15,95%)	66 (21,29%)	14 (11,86%)	13 (8,39%)
Education	Primary	7 (1,20%)	6 (1,94%)	1 (96,91%)	0 (0%)
	Secondary	108 (18,52%)	56 (18,06%)	35 (29,66%)	17 (10,97%)
	Bachelor	200 (34,31%)	97 (31,29%)	52 (44,07%)	51 (32,90%)
	Master or higher	268 (45,97%)	151 (48,71%)	30 (25,42%)	87 (56,13%)
Monthly income	< € 4000	262 (44,94%)	98 (31,61%)	72 (61,02%)	92 (59,35%)
(Gross)	€ 4000 – 8000	228 (39,11%)	147 (47,42%)	35 (29,66%)	46 (29,68%)
	> € 8000	93 (15,95%)	65 (20,97%)	11 (9,32%)	17 (10,97%)

For Belgian and Dutch respondents, a question regarding their political preferences on the national level was included. Given that only a Dutch and English version of the survey were distributed, mainly Flemish Belgian citizens were expected to fill in the survey. Therefore, Walloon political parties were not included. Respondents that live in Wallonia vote for different parties, included in the category ‘Other’. 7 Belgian respondents and 5 Dutch respondents chose to fill in the survey in English and, as a consequence, were not asked about their political preference. Out of 303 remaining Belgian respondents, 14 (4,62%) respondents did not want to state their political preference (‘WINZ’), while only 3 (2,54%) of Dutch respondents did not want to state which party they voted for. Additionally, 5 Belgian respondents (1,65%) did not vote, while 10 of the 118 Dutch respondents (8,85%) did not vote. This difference can be attributed to the fact that there is a voting obligation in Belgium. 9 (2,97%) Belgian respondents were not yet eligible to vote (‘NSGR’), i.e. respondents under 18 years old or expats, while 6 (5,31%) Dutch respondents were not eligible to vote. Of the remaining respondents

303 Belgian and 113 Dutch respondents, the share of voters for each significant Flemish or Dutch party is given in table 4.

Table 4: Political preference statistics

Flemish Political Parties	*Political Preferences Belgian respondents (%)*	*Results of Federal Elections 2019 – only Flemish parties (%)*[1]	*Dutch Political Parties*	*Political Preferences Dutch respondents (%)*	*Results of National Elections 2017 (%)*[2]
PvdA	2,31	12,74	*CU*	3,54	3,4
S.pa	3,63	9,93	*D66*	18,58	12,2
Groen	30,69	9,04	*CDA*	7,96	12,4
CD&V	16,83	13,19	*FVD*	0,89	1,8
Open VLD	13,53	12,78	*GroenLinks*	30,97	9,1
N-VA	19,14	23,70	*PvdD*	2,65	3,2
VB	1,65	17,78	*PvdA*	8,85	5,7
Other	2,97	1,04	*VVD*	7,96	21,2
			SP	0,89	9,1
			PVV	0	13,0
			50Plus	0	3,1
			Other	0,89	5,6

It seems that the survey did not capture an accurately representative image of Flemish voters: voters of VB (i.e. the Flemish nationalist party) are underrepresented, as well as voters of PvdA (i.e. the communist party) and S.pa (i.e. the socialist party). Voters of the green party 'Groen' are majorly overrepresented, as are voters of CD&V. Voters of Open VLD are overrepresented as well, while voters of the right party N-VA are underrepresented. For Dutch respondents, a similar image can be seen: voters of the green party 'GroenLinks' are overrepresented while voters of the extreme right parties PVV and FVD are underrepresented. Additionally, voters of the left party PvdA and democratic party D66 are overrepresented while voters of the liberal party VVD are underrepresented.

Three questions of knowledge on nuclear energy and three questions of knowledge on climate change were asked. If the respondents answered all three questions correctly, they are grouped under 'very good knowledge'. If they answered two out of three questions correctly, they receive the label 'good knowledge'. The label 'little knowledge' represent respondents who answered one or zero of the questions correctly. In figure 3, a summary of these results for all respondents is given. It seems that most respondents have very good knowledge on nuclear energy, but even more respondents have a very good knowledge base on climate change.

[1] Source: VRT NWS, 2019. The results were re-calculated, only taking Flemish parties into account.
[2] Source: Kiesraad, 2017.

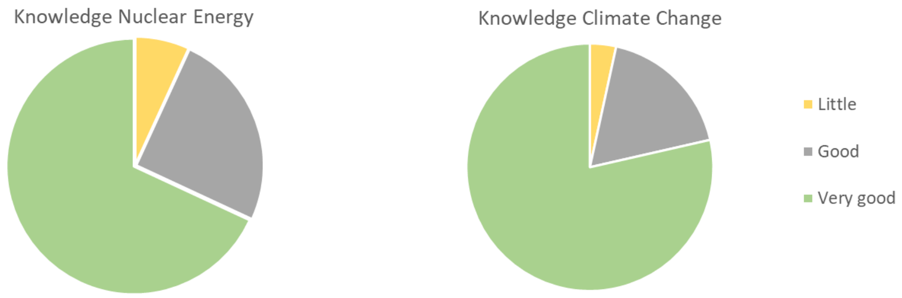

Figure 3: Knowledge statistics

Similarly, the scores on the 'concern'-questions can be coded and grouped together to represent a summation on respondents' concern on nuclear energy, climate change and future generations. From figure 4, it seems that most respondents are considerably concerned about nuclear energy and future generations, but even more concerned about climate change. The finding that most people are highly concerned about climate change is in line with findings of Shackley, McLachlan & Gough (2005) as well as many other existing European surveys such as the Eurobarometer (European Commission, 2019). The share of respondents that is not really concerned, i.e. with low or negligible concern, is the highest for nuclear energy and the lowest for climate change.

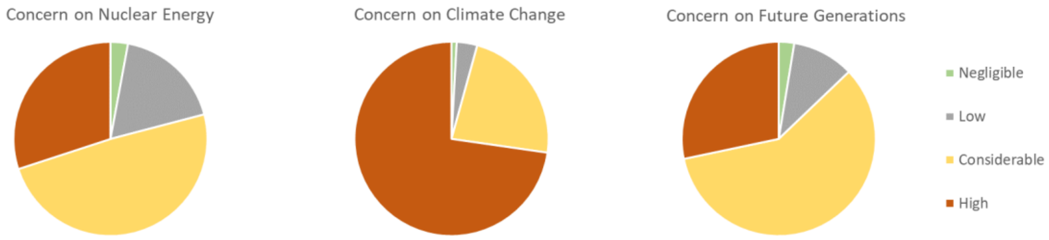

Figure 4: Concern statistics

3.2 Willingness-To-Pay

A logistic regression was carried out using R. The chosen specification consists of a 3-class model. This 3-class model proved a significant better fit than a 2-class model using a likelihood ratio test (LR = 588 with p-value 5,38 e^{-126}). Despite models with more classes proving even better fits, a 3-class model was chosen for ease of understanding. Commands used to generate these results are provided in Appendix B. The resulting coefficients and their robust standard error, t-test and p-value are given in Appendix C. A summary of all coefficients is given in table 5. All coefficients are significant at the 1% level.

Table 5: Summary of coefficients

	Class 1	*p-value*		*Class 2*	*p-value*		*Class 3*	*p-value*	
Cost	-0.0091	0.0034	**	-0.0321	2,53e-08	***	-0.0106	2.19e-05	***
Outage	-0.0041	< 2.2e-16	***	-0.0022	3,49e-07	***	0.0021	8,64e-12	***
Renewable energy	0.0171	< 2.2e-16	***	0.0943	< 2.2e-16	***	0.0499	< 2.2e-16	***
Nuclear energy	0.0104	< 2.2e-16	***	0.0561	< 2.2e-16	***	-0.0207	< 2.2e-16	***
Share	0,2401			0,2513			0,5086		

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Based on the coefficients in table 5, odds ratios (OR) can be calculated. The odds ratio represents the effect of the predictor on the likelihood that the scenario is chosen. The odds ratios for each predictor of each class are represented in table 6.

Table 6: Odds Ratios

	OR Class 1		*OR Class 2*		*OR Class 3*	
Cost	0,9910	**	0,9684	***	0,9894	***
Outage	0,9959	***	0,9979	***	1,0021	***
Renewable energy	1,0173	***	1,0989	***	1,0512	***
Nuclear energy	1,0104	***	1,0577	***	0,9796	***

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

The coefficient of the variable 'Cost' carries the value -0.0091 for class1, -0,0321 for class 2 and -0,0106 for class 3. A negative value makes sense since it indicates a dislike for a higher cost. Following calculations are based on the cost coefficient. Since the coefficients of nuclear and renewable energy are given relative to the coefficient of fossil fuels (i.e. β_{Foss} = 0), the WtP-values should be interpreted as relative to the WtP-value of a unit of fossil fuels. In other words, the VONE represents the WtP for replacing a unit of fossil fuels with a unit of nuclear energy.

$$VONE = -\frac{\beta_{Nucl}}{\beta_{Cost}} \tag{4.3.1}$$

$$VORE = -\frac{\beta_{Ren}}{\beta_{Cost}} \tag{4.3.2}$$

Table 7 gives the WtP-values for outages, renewable energy and nuclear energy for each class, or in other words, the VOPO, VONE and VORE.

Table 7: WtP-values

	Class 1	*Class 2*	*Class 3*
Cost			
VOPO	-0,45	-0,07	0,20
VORE	1,88	2,93	4,70
VONE	1,14	1,74	-1,95
	Nuclear energy and stability advocates	*Nuclear energy supporters*	*Renewable energy enthusiasts*

A negative valuation for power outages (VOPO) makes sense: people dislike each minute of power outage. People in class 1 are willing to accept €0,45/month for each additional minute of power outages. They have the highest dissatisfaction for power outages. Their valuation of nuclear energy (VONE) and renewable energy (VORE), however, is positive. Since an additional unit (i.e. 1%) of nuclear or renewable energy goes along with a decrease in fossil fuels, this WtP-value should be interpreted as the marginal willingness to pay relative to a unit of fossil fuels. It is apparent that people in class 1 are willing to pay €1,88/month for an additional unit of renewable energy and €1,14/month for an additional unit of nuclear energy. Given their negative valuation of power outages but positive valuation of nuclear energy compared to fossil fuels with CCS, this class is from now on referred to as *nuclear energy and stability advocates*.

In class 2, a similar pattern to class 1 can be observed: a negative VOPO but a positive VORE and VONE. However, their WtP-value for power outages is lower in absolute value: people in class 2 are satisfied with a compensation of €0,07/month for each additional minute of power outages. In contrast, they are willing to pay even more for an additional unit of both nuclear energy and renewable energy. This could also indicate a stronger dislike for fossil fuels with CCS. Because of the higher WtP-value for nuclear energy, members of class 2 are referred to as *nuclear energy supporters*.

Interestingly, the WtP-value for outages is positive in class 3. This would indicate that people are willing to pay €0,20/month for an additional minute of power outage. At first glance, this seems unrealistic. However, the choice sets were constructed in such a way that a scenario with 100% renewable energy never corresponds to less than 180 minutes of power outages. Due to collinearity, including quadratic components into the logistic regression in R is not possible, so the valuation of high shares of renewable energy is hard to determine. Including a dummy for '100% renewable energy' does not provide significant estimates: the coefficient of outage was still positive and significant for class 3 while the coefficient of the '100% renewable energy' dummy was not significant. The positive VOPO may also be related to a hypothetical bias: respondents might not indicate their true preferences because they know that the situation is hypothetical. When it comes to renewable energy, it is clear that respondents in class 3 have the highest valuation of renewable energy compared to fossil fuels: they are willing to pay €4,70/month to replace 1% of fossil fuel energy with 1% of renewable energy. This is in contrast with the valuation of nuclear energy: class 3 should be compensated with €1,95/month for an additional percentage of nuclear energy in their energy mix compared to fossil fuels. Given the valuation of renewable energy, which is not only positive but also takes on a very high value, members of class 3 are from now on referred to as *renewable energy enthusiasts*.

3.3 Class composition

For each individual, the probability to belong to a certain class can be calculated. From these numbers, the average probability for each group of individuals (e.g. Belgians) to belong to each class can be derived. This is given in Appendix D. People can also be assigned to classes individually, based on the highest probability to belong to a certain class. Within these assigned classes, the share of different groups of people (e.g. Belgians) can be calculated as opposed to the share in the whole sample. Appendix E represents the shares of each group of respondents as a deviation of the total sample share, expressed as the deviation relative to the sample share (e.g. (0,5-0,5317)/0,5317 for the share of Belgians in class 1). This way, it is possible to get a clear view of the class composition compared to the composition of the whole sample. However, class composition is very much dependent on the sample composition. Since the sample composition might not be representative, another approach is chosen to investigate class composition: including socio-economic characteristics into the class probability assignment. The coefficients provided by these estimates (table 8) should be interpreted with respect to the normalized class, in this case class 1 or *nuclear energy and stability advocates*. Because of singularity issues in R, not all dummy variables can be included in the analysis. Appendix E was used to determine which dummies to take into account. For example, since the deviation of the share of people with a gross household income between €4000-8000/month compared to the total sample share carries the opposite sign of the deviation of people with a lower or higher income for each class, this dummy is included. Appendix E also shows that it could be useful to merge people with a secondary education and a bachelor's degree, but unfortunately, R wouldn't allow this because of singularity issues. The lowest educational group (i.e. primary education) is very small and therefore not taken into account.

Table 8: Class probability coefficients

	Nuclear energy supporters	*p-value*		*Renewable energy enthusiasts*	*p-value*	
Men	0.8388	< 2.2e-16	***	-0.3647	2.90e-06	***
Dutch people	-0.0355	0.7711		-0.0340	0.7813	
Other nationalities	-0.7468	3.31e-11	***	-0.2252	0.0216	*
Younger than 25	-0.4598	4.43e-07	***	-0.5113	1.25e-09	***
Older than 50	0.1494	0.2157		0.4285	0.0001	***
Secondary education or lower	0.6669	2.67e-09	***	0.7405	5.15e-12	***
Masters' degree or higher	-0.8506	< 2.2e-16	***	-0.2358	0.0053	**
Gross household income between €4000-8000/month	-0.0427	0.6201		-0.2737	0.0005	***
Gross household income above €8000/month	-0.3029	0.012511	*	0.0061	0.9574	
Knowledge on nuclear energy	0.2757	9.83e-05	***	0.0289	0.6085	
Knowledge on climate change	0.2738	0.0003	***	0.6920	< 2.2e-16	***
Concern on nuclear energy	-0.0212	0.0547	.	0.2495	< 2.2e-16	***
Concern on climate change	0.2097	< 2.2e-16	***	0.0751	8.75e-05	***
Concern on future generations	0.0663	0.0025	**	0.1065	2.43e-07	***
Political preference favouring nuclear energy – Belgium	-0.4099	0.0006	***	-0.4777	5.03e-05	***
Political preference favouring nuclear energy - Netherlands	-1.1178	7.88e-05	***	0.1692	0.4955	
Green party Belgium – Groen	0.0572	0.7007		0.6201	3.95e-06	***
Green party Netherlands - GroenLinks	-0.6789	3.76e-05	***	-0.7780	1.96e-06	***

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Men seem to have a higher probability to be nuclear energy supporters than to be nuclear energy and stability advocates. People with non-Belgian and non-Dutch nationalities on the other hand, are more likely to be nuclear energy and stability advocates. Older people seem to be more likely to be renewable energy enthusiasts than nuclear energy and stability advocates, while young people are most likely to be nuclear energy and stability advocates. This may be related to the fact that people in the oldest age category, i.e. people older than 50, have experienced both the Chernobyl and Fukushima disasters and are thus more critical towards nuclear energy. People with a high education on the other hand, seem to be most likely to be nuclear energy and stability advocates and least likely to be nuclear energy supporters, while people with a secondary education degree or lower are least likely to be nuclear energy and stability advocates and most likely to be renewable energy supporters. Additionally, people with a gross household income between €4000-8000/month are less likely to be renewable energy enthusiasts than nuclear energy and stability advocates while people with a gross household income above €8000/month are less likely to be nuclear energy supporters.

When it comes to knowledge about nuclear energy or climate change, it is apparent that people with a lot of knowledge on nuclear energy are more likely to be nuclear energy supporters than nuclear energy and stability advocates. Similarly, people with a lot of knowledge on climate change are most likely to be renewable energy enthusiasts and least likely to be nuclear energy and stability advocates.

Attitudes towards nuclear energy, climate change and the future, seem to be different across classes as well. People who are very concerned about nuclear energy or future generations are most likely to be renewable energy enthusiasts. Those who are not concerned about nuclear energy are most likely to be nuclear energy supporters, while those who are not concerned about future generations are most likely to be nuclear energy and stability advocates. People in the pro-nuclear classes see less danger in nuclear energy and are thus willing to pay more for an energy mix with more nuclear energy. People who are not concerned about climate change, on the other hand, are most likely nuclear energy and stability advocates, while people who are very concerned about climate change are most likely nuclear energy supporters.

Political preferences seem to indicate quite some differences in class composition as well. A dummy for 'voting on political parties who are in favour of nuclear energy' was included in the analysis for both Belgian and Dutch voters. For Belgium, these parties include the right-winged Flemish parties N-VA and VB. For the Netherlands, they include CDA, VVD, PVV and FVD. It seems that Belgian supporters of these parties are most likely to be nuclear energy and stability advocates and least likely to be renewable energy enthusiasts. Dutch voters of 'pro-nuclear' parties however, are less likely to be nuclear energy supporters while the class probability coefficient of renewable energy enthusiasts is insignificant. These voters could be overrepresented in class 1, i.e. the class of nuclear energy and stability advocates. Additionally, dummies for the Flemish and Dutch green parties were included, both arguing against nuclear energy. Voters of the Flemish green party Groen are significantly more likely to be renewable energy enthusiasts, while voters of the Dutch green party GroenLinks seem to be more likely to be nuclear energy and stability advocates. This suggests that there is more coherence between energy generation preferences and political preferences in Belgium than in the Netherlands. It could indicate that energy generation preferences are more important for Flemish voters than for Dutch voters when choosing a party to vote on, but it could also indicate that Flemish people use political party cues more than Dutch people in determining their support for nuclear energy.

4 Conclusion

The main aim of this study was to investigate heterogeneous preferences in energy generation technologies and to determine whether people are willing to invest in nuclear-free decarbonization. Starting from the assumption that people make their own trade-offs by comparing the nuclear safety issue or other external costs related to nuclear energy to the need for affordable decarbonization processes, an answer to this research question was sought through a discrete choice experiment. 583 complete responses were collected; mostly Belgian but also many Dutch respondents and respondents with a different nationality. Belgian and Dutch respondents indicated their political preference. These responses were used to test for the coherence of energy generation preferences and political preferences. Energy generation preferences could play a role in determining political preferences, but respondents could also use political-party cues to determine their support for nuclear energy (i.e. cue taking). Additionally, respondents were tested for their knowledge of nuclear energy and climate change and asked about their concern about nuclear energy, climate change and future generations. After answering these background questions, respondents were faced with 15 choice sets. In each choice set, they considered 3 scenario's that differed in cost, minutes of power outage, share of nuclear energy, share of fossil fuels with CCS and share of renewable energy. It was deliberately chosen to include CCS in the fossil fuel attribute so that each scenario would reach full decarbonization. This was explained to respondents before facing the choice sets and was illustrated using understandable icons. The degree of decarbonization could thus not be an explicit consideration in making their decision: respondents should be focused on the trade-off between energy mixes based on costs, minutes of power outages and innate external costs or benefits of the energy generation technologies that are not related to climate change.

The data was analysed using statistical computing program R. A latent class logit model distinguishing 3 classes provided significant results. Respondents in the class containing *nuclear energy and stability advocates* show a positive value of renewable energy (VORE) and value of nuclear energy (VONE), with a VORE and VONE of €1,88 and €1,14/month respectively. People with little knowledge on climate change or nuclear energy or people who are not really concerned about climate change or future generations are also more likely to be nuclear energy and stability advocates. Additionally, it seems that people with a non-Dutch or non-Belgian nationality are most likely to belong to this class, as well as young people and highly educated individuals. Finally, People who voted for Flemish right-winged parties N-VA and Vlaams Belang, i.e. Flemish policy defending parties, are most likely to belong to this class. This coherence between energy generation preferences and political preferences is not surprising.

In the *nuclear energy supporters* class, people showed a lower odds ratio for the cost attribute: the probability of choosing an energy mix decreased more than for other people when the cost of that energy mix was higher. This affects their willingness to pay for nuclear and renewable energy. However, since they also showed a high valuation for both of these energy generation technologies compared to fossil fuels with CCS, their WtP-values were still high: nuclear energy supporters are willing to pay €2,93/month for an additional percentage of renewable energy and €1,74 for an additional share of nuclear energy compared to fossil fuels with CCS. Men are more likely to be nuclear energy supporters. Additionally, people with good knowledge on nuclear energy are more likely to belong to this class than to another class, as well as people who are highly concerned about climate change. This seems to be an interesting difference between nuclear energy and stability advocates and nuclear energy supporters: while people with low or negligible concern about climate change or future generations are more likely to be nuclear energy and stability advocates, people who are highly concerned about climate change are more likely to be nuclear energy supporters. Despite a similar VONE and VORE, these classes might differ in their motivation to support nuclear energy. For example, nuclear energy supporters might be sceptical towards fossil fuels with CCS – and thus in favour of nuclear and renewable energy - because they believe fossil fuels with CCS to be less successful in fighting climate for reasons other than cost-efficiency or power outages.

Finally, slightly more than 50% of respondents belonged to the *renewable energy enthusiasts* class. In this class, people showed a very high marginal willingness to pay for renewable energy compared to fossil fuels, but a negative valuation of nuclear energy compared to fossil fuels with CCS. In other words, renewable energy enthusiasts are willing to pay a lot for nuclear-free decarbonization. They want to be compensated for allowing nuclear energy in their energy mix. People with good knowledge on climate change seem to be more likely to belong to this class than to the other two classes, as well as people with a secondary education or lower degree, or people who are highly concerned about nuclear energy or future generations. Interestingly, older people (i.e. people over 50 years old) are more likely to be renewable energy enthusiasts as well. This could be related to the negative VONE: people over 50 years old have experienced both the Chernobyl disaster in 1986 and the Fukushima disaster in 2011. Therefore, they could attach more value to the negative external costs of nuclear power and thus show a negative VONE.

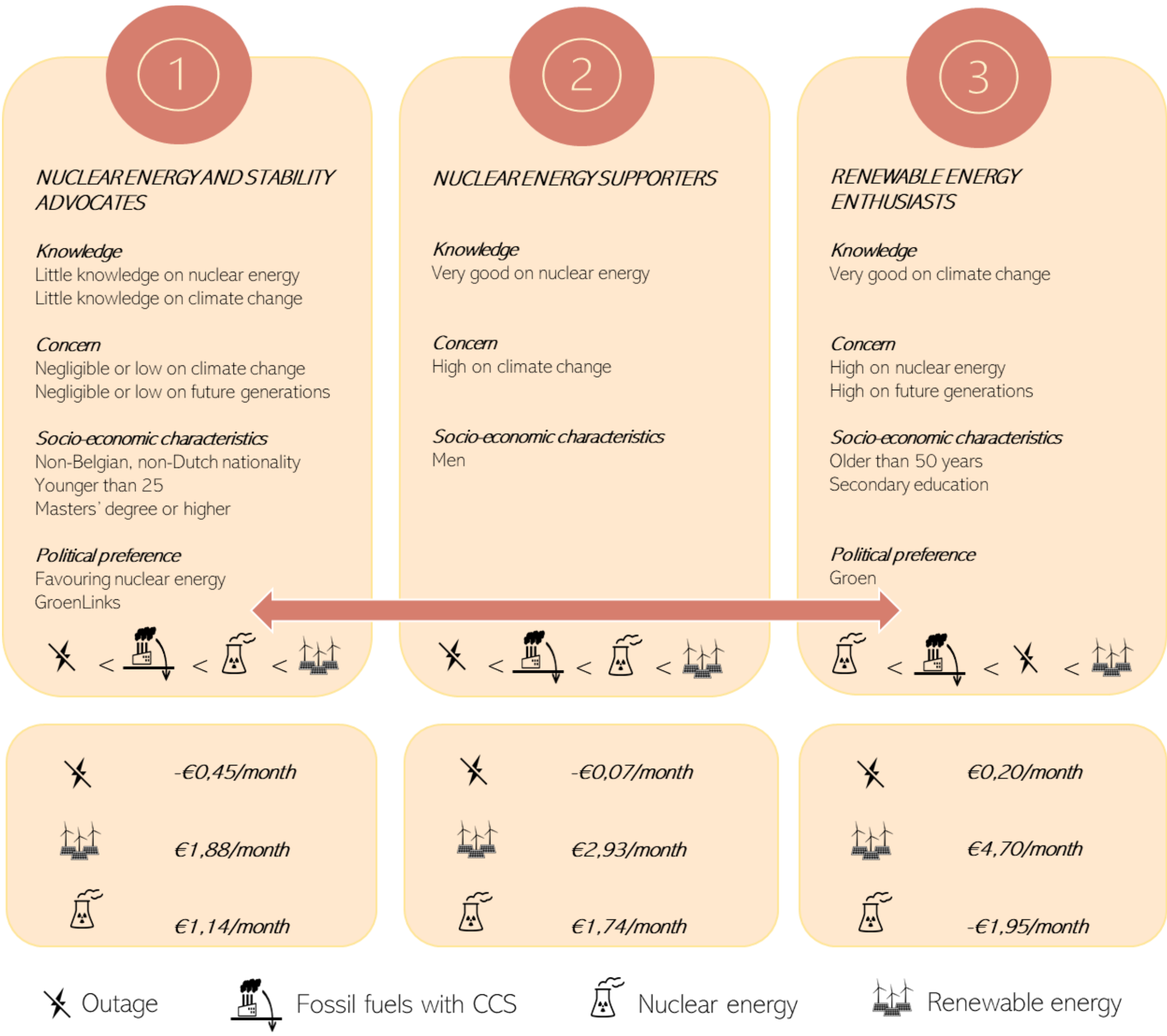

Figure 5: Class composition and WtP-values

Compared to an average electricity bill of €76,75/month in Belgium, a marginal WtP of €4,70/month (i.e. the VORE) is 6,1%. However, compared to an average of €52,41 in the Netherlands, it represents 9%. Assuming people with another nationality to have a similar electricity bill as Dutch people, the average electricity bill of people in the sample is €65,35/month. In that case, a marginal WtP of €4,7/month represents about 7,2% of their electricity bill: renewable energy enthusiasts are willing to pay about 7% more for *one* additional unit (i.e. 1%) of fossil fuels instead of nuclear energy, while they are willing to accept 3% of their monthly bill for an additional unit of nuclear energy. For nuclear energy and stability advocates and nuclear energy supporters, the VORE represents respectively 2,9% and 4,5% of the average electricity bill, while their marginal WtP for nuclear energy (i.e. the VONE) is 1,7% and 2,7%. These results suggest that all classes of respondents are willing to pay a lot more than their usual electricity bill for a 100% renewable energy mix, i.e. more than the estimated cost increases of a 100% renewable decarbonization scenario by Zappa et al. (2019) and Connolly et al. (2016). However, it should be noted that the possibility of a non-linear valuation of energy generation technologies was not researched in this study.

Table 9: WtP-values in previous research

	Scope	*Decarbonization scenarios compared*	*WtP*
Murakami et al. (2015)	US Japan	1% more renewable energy and 1% less fossil fuels	€0,66/month €0,29/month
	US Japan	1% more nuclear energy and 1% less fossil fuels	-€0,67/month -€0,11/month
Roe et al. (2001)	US	1% more renewable energy and 1% decrease in emissions	€2,09/month
	US	1% more nuclear energy and 1% decrease in emissions	€0,65/month

The WtP-values found in this study are remarkably higher than WtP-values found in previous research in other countries, as shown by table 9. For example, Murakami et al. (2015) found that US consumers are willing to pay $0,71/month (i.e. €0,66/month) for an additional 1% increase in the use of renewable energy that goes along with 1% decrease in fossil fuels, while Japanese consumers are willing to pay $0,31 (i.e. €0,29/month). In this study, WtP-values are much higher. Even the class with the lowest WtP for renewable energy, is willing to pay €1,88/month for an additional 1% of renewable energy, which is almost three times as much as the willingness to pay of US consumers in the research of Murakami et al. (2015). When the increase in renewable energy and decrease in fossil fuels goes along with a 1% decrease in emissions, US and Japanese consumers are respectively willing to pay $12,21/year (i.e. €1,02/month) and $6,90 (i.e. €0,53/month) more. This is still less than our findings, while in this study, the increase in renewable energy does not mean a decrease in emissions - since it was explicitly stated that all scenarios reach full decarbonization. Murakami et al. (2015) found that both US and Japanese consumers express a negative willingness to pay for nuclear energy, consistent with findings of class 3 in this study. For example, Japanese people are willing to accept $0,72/month (€0,67/month) for an additional unit of nuclear energy instead of fossil fuels and US respondents are willing to accept $0,11/month (€0,11/month). Roe, Teisl, Levy and Russell (2001) also found that people are willing to pay significantly more when emission reductions stem from increased deployment of renewable energy technologies. This finding is consistent with the WtP-values found in this study: in each class, respondents are willing to pay more for an additional 1% of renewable energy while all energy mixes reach full decarbonization. For example, Roe et al. (2001) found that people who earn more than $40000/year with a degree and affiliation with an environmental organization are willing to pay $8,42/year for a 1% increase in nuclear fuel (and a 1% decrease in emissions) while they are willing to pay $27,10/year for a 1% increase in renewables (and a 1% decrease in emissions). This translates to €0,65/month and €2,09/month, which is a bit closer to the VONE and VORE estimates of *nuclear energy and stability advocates* in this study. However, for other population segments, Roe et al. (2001) found lower WtP-values.

This difference in WtP-values might indicate that Europeans are willing to pay more for renewable energy than US or Japanese citizens. It could be related to a higher environmental awareness or concern among European citizens. In a global survey carried out by Pew Research Center in 2018, Americans proved to be less likely to be concerned about climate change than Europeans, with as many American people pointing to climate change as a major threat as to North Korea's nuclear program (Fagan. & Huang, 2019). This survey also proved that concerns about climate change have risen significantly in many countries since 2013. Therefore, another explanation for the difference in WtP-findings could be that environmental awareness has rapidly increased over the last years, possibly leading to a higher willingness to pay for technologies that provide a clear solution to environmental issues. An important remark, however, is that respondents could be influenced by a hypothetical bias. It is likely that respondents who indicated a low valuation of the cost-attribute in the SCE, would attach more value to the cost of the energy mix in a realistic situation. This would drive their actual WtP-values down. The high WtP-values for renewable energy might also be related to a 'warm glow'-bias: people might indicate that they want a fully renewable energy mix at all costs to get the emotional reward of 'choosing something good'. Menges, Schroeder & Traub (2005) find evidence for a 'warm glow'-effect in the willingness-to-pay for electricity generated from renewables: individuals benefit from contributing to environmental quality when opting for green electricity.

The results indicate that there are indeed significant differences between people regarding their valuation of nuclear energy compared to fossil fuels and renewable energy. The degree of concern or risk-perception about nuclear energy, but also on climate change and future generations, seems to be an important factor in explaining why people have different energy generation preferences. For example, people who are very concerned about climate change are most likely to be nuclear energy supporters. This could mean that they are sceptical towards CCS. However, in a study exploring public perceptions on CCS, Shackley et al. (2005) find that a basic concern about climate change is a requirement to consider CCS as a legitimate option for decarbonization, but renewable energy is generally favoured. A small minority of their respondents was opposed to CCS, mainly for the moral reason that it is wrong to 'inject mother earth with an industrial waste product'. Respondents became more inclined to support CCS as the risks and opportunities were thoroughly discussed. Additionally, it appears that people with little knowledge on nuclear energy are more likely to be *nuclear energy and stability advocates*. This is in line with a study of Jones, Yardley and Medley (2019) who find that Germans, who claimed to have greater knowledge on nuclear energy, were less favourable to nuclear fusion than UK respondents. However, it also seems that people with great knowledge on nuclear energy are more likely to be *nuclear energy supporters*. These findings stand in contrast to the results of Jones, Yardley and Meldey (2019) and to general knowledge deficit models where public scepticism to a technology is attributed to a lack of understanding: there seems to be no clear link between knowledge of nuclear energy and support of the technology. The finding that people with good knowledge of climate change have a higher probability to be renewable energy enthusiasts, provides an interesting contribution to the knowledge deficit theories: it suggests that good knowledge of an existing issue is related to support of technologies that provide certain solutions. Renewable energy may be considered as a better solution to the problem of climate change compared to nuclear energy or fossil fuels with CCS.

Additionally, there are differences across political preferences, in line with Latré et al. (2019) and Karlstrom & Ryghaug (2014), who find that political party preference has a large impact on energy technology attitudes, respectively in Belgium and in Norway. However, the results of our study seem to indicate that preferences of Flemish respondents are more in line with the point of view of the political party that they support than those of Dutch respondents. This might be related to the fact that Belgium currently deploys more nuclear energy than the Netherlands and consequently, nuclear energy has been a larger issue in the public debate in Belgium.

A shortcoming of the design of this study was that it was only provided in Dutch and in English. Many Flemish and Dutch respondents were reached, but there was no way to reach a large Walloon population. Walloon political parties were thus also left out of consideration. As a consequence, the results of this study cannot be generalized to Belgian individuals, but at most to Flemish individuals. 310 of the 583 complete responses were Belgian respondents, 118 were Dutch and 155 had another nationality. Women are overrepresented in the sample (56,43%). Considering political preferences, it appears that extremely right-winged voters (i.e. Belgian party VB and Dutch party PVV) are underrepresented while green party supporters (i.e. Belgian party Groen and Dutch party GroenLinks) are overrepresented. This makes the results hard to generalize. Additionally, due to the high collinearity between the shares of a certain energy generation technology and its quadratic terms, non-linear preferences could not be tested. This is a major shortcoming since it can be expected that people dislike nuclear energy more if it takes on a large share in the energy mix. Next, a disadvantage is that, despite quantifying the valuation of choice attributes, there is no way to distinguish which external cost or benefit drives energy generation preferences. For example, respondents could implicitly consider the safety issues related to nuclear energy, but they might as well value the nuclear waste issue more. Similarly, respondents could consider uncertainty on fossil fuels with CCS or noise and landscape disturbance of renewable energy as a cost.

Future research could investigate non-linear demand: it may be so that consumers prefer renewable energy up to a certain extent, or that consumers dislike nuclear energy only after it reaches a certain share. Additionally, it could be interesting to investigate perceptions towards the relatively new carbon capture and storage technologies. If a knowledge deficit issue is present, consumers might undervalue this technology – and thus overvalue e.g. renewable energy compared to fossil fuels with CCS.

To conclude, the value of this research lies in the disclosure of heterogeneous consumer preferences. By investigating the public's energy system preferences, policymakers can get an indication of the public's opinion on prioritizing cost-efficiency or other characteristics such as eco-toxicity in the decarbonization process. It appears that many consumers place importance on perceived external costs and benefits of energy generation technologies, even if full decarbonization is reached. This paper indicates that many people (i.e. particularly renewable energy enthusiasts) are willing to 'overinvest' in nuclear-free decarbonization: they are willing to pay much more for renewable energy than for nuclear energy despite the realisation of full decarbonization in each scenario. By choosing to invest less in nuclear energy, policymakers may not choose the most cost-efficient energy mix, but they can enhance consumer welfare by considering consumers' preferences.

Appendix A

Knowledge questions

Is this statement true or false?

	True	False
Radioactive waste by nuclear power plants needs to be stored for thousands of years.	○	○
Exposure to radioactive waste is very dangerous for living beings.	○	○
Nuclear power plants emit more greenhouse gases than coal-fired power plants.	○	○
Global warming is caused by more intensive solar radiation.	○	○
There is no reason to believe that global warming is caused by humans.	○	○
Global warming will increase temperatures worldwide, cause more heat waves and droughts, increase sea levels and increase the frequency of hurricanes.		

Attitude questions

Indicate to which extent you agree with these statements on a scale of 0 (strongly disagree) to 5 (strongly agree).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Storage of nuclear waste forms an environmental risk.	◌	◌	◌	◌	◌
Storage of nuclear waste brings a risk for future generations.	◌	◌	◌	◌	◌
Nuclear power plants form a risk for our whole society.	◌	◌	◌	◌	◌
Keeping nuclear power plants running after their planned date of decommissioning brings a risk for employees and/or inhabitants of surrounding municipalities.	◌	◌	◌	◌	◌
Keeping nuclear power plants running after their planned date of decommissioning brings a risk for nature and everyone in the neighbourhood.	◌	◌	◌	◌	◌
Global warming does not form a risk for humans.	◌	◌	◌	◌	◌
Global warming forms a risk for everyone.	◌	◌	◌	◌	◌
We urgently need to take measures to fight global warming.	◌	◌	◌	◌	◌
I am worried about the wellbeing and safety of future generations.	◌	◌	◌	◌	◌
I am not worried about the wellbeing and safety of future generations.	◌	◌	◌	◌	◌
Future generations will have sufficient knowledge and technologies to solve problems that we currently cannot solve.	◌	◌	◌	◌	◌

Choice sets

Figure 6: Example choice set Belgian respondents

Figure 7: Example choice set Dutch respondents

Figure 8: Example choice set other nationalities

Appendix B

Following the guidelines of https://rpubs.com/msarrias1986/335556

```
rm(list = ls(all = TRUE))   # Clean objects
install.packages("gmnl")
install.packages("mlogit")
library("gmnl")           # Load gmnl package
library("mlogit")         # Load mlogit package
# Load data and put it into the required format

data <- read_excel("C:/Users/erika/Downloads/FinalData.xlsx")
data <- as.data.frame(data)
df01 <- mlogit.data(data,
                    id.var = "ID",
                    choice = "Choice",
                    varying = 3:23,
                    shape = "wide",
                    sep = "")
lc <- gmnl(Choice ~ COST + OUTAGE + REN + NUCL| 0 | 0 | 0 | 1,
          data = df01,
          model = 'lc',
          Q = 3,
          panel = TRUE,
          method = "bhhh")
summary(lc)
shares(lc)

pi_hat <- lc$Qir
colnames(pi_hat) <- c("q = 1", "q = 2", "q = 3")
dim(pi_hat)
round((pi_hat), 1)
```

Including socio-economic characteristics

```
lc <- gmnl(Choice ~ COST + OUTAGE + REN + NUCL| 0 | 0 | 0 |MALE + BELGIAN + OTHERNAT + Y25 + Y50 +
EDSEC + EDMAS + INC40008000 + KNUCL+ KCLIM + ANUCL + ACLIMATE + AFUTURE + FAVORBE +
FAVORNL + GROEN + GROENLINKS,
          data = df01,
          model = 'lc',
          Q = 3,
          panel = TRUE,
          method = "bhhh")
```

Following the guidelines of https://api.rpubs.com/tomanderson_34/lrt

Likelihood Ratio Test

```
A <- logLik(lc3)
B <- logLik(lc2)

teststat <- -2*(as.numeric(B)-as.numeric(A))
p.val <- pchisq(teststat, df = 4, lower.tail = FALSE)
```

Appendix C

```
Frequencies of categories:

      1       2       3
0.32762 0.34991 0.32247

The estimation took: 0h:0m:2s

Coefficients:
```

	Estimate	Std. Error	z-value	Pr(>|z|)	
class.1.COST	-0.009069	0.003095	-2.930100	0.003389	**
class.1.OUTAGE	-0.004071	0.000339	-12.02430	< 2.2e-16	***
class.1.REN	0.017121	0.001261	13.577900	< 2.2e-16	***
class.1.NUCL	0.010357	0.001167	8.872500	< 2.2e-16	***
class.2.COST	-0.032070	0.005756	-5.571500	0.000000	***
class.2.OUTAGE	-0.002152	0.000422	-5.094700	0.000000	***
class.2.REN	0.094340	0.003816	24.725500	< 2.2e-16	***
class.2.NUCL	0.056107	0.003319	16.902900	< 2.2e-16	***
class.3.COST	-0.010636	0.002505	-4.245100	0.000022	***
class.3.OUTAGE	0.002135	0.000313	6.827500	0.000000	***
class.3.REN	0.049931	0.001207	41.364100	< 2.2e-16	***
class.3.NUCL	-0.020651	0.001481	-13.94760	< 2.2e-16	***
(class)2	-3.392351	0.341165	-9.943400	< 2.2e-16	***
(class)3	-5.693949	0.275590	-20.66090	< 2.2e-16	***
MALE:class2	0.838792	0.082795	10.131000	< 2.2e-16	***
MALE:class3	-0.364688	0.077957	-4.678000	0.000003	***
class2:DUTCH	-0.035453	0.121834	-0.291000	0.771054	
class3:DUTCH	-0.033997	0.122461	-0.277600	0.781312	
class2:OTHERNAT	-0.746780	0.112601	-6.632100	0.000000	***
class3:OTHERNAT	-0.225233	0.098063	-2.296800	0.021630	*
class2:Y25	-0.459825	0.091063	-5.049500	0.000000	***
class3:Y25	-0.511321	0.084194	-6.073100	0.000000	***
class2:Y50	0.149358	0.120640	1.238000	0.215698	
class3:Y50	0.428492	0.112097	3.822500	0.000132	***
class2:EDSEC	0.666942	0.112075	5.950800	0.000000	***
class3:EDSEC	0.740457	0.107292	6.901300	0.000000	***
class2:EDMAS	-0.850607	0.094310	-9.019300	< 2.2e-16	***
class3:EDMAS	-0.235832	0.084579	-2.788300	0.005298	**
class2:INC40008000	-0.042663	0.086075	-0.495600	0.620147	
class3:INC40008000	-0.273697	0.078851	-3.471000	0.000518	***
class2:INC8000	-0.302922	0.121295	-2.497400	0.012511	*
class3:INC8000	0.006077	0.113781	0.053400	0.957408	
class2:KNUCL	0.275748	0.070800	3.894800	0.000098	***
class3:KNUCL	0.028924	0.056467	0.512200	0.608495	
class2:KCLIM	0.273767	0.075552	3.623600	0.000291	***
class3:KCLIM	0.692029	0.064071	10.801000	< 2.2e-16	***
class2:ANUCL	-0.021212	0.011040	-1.921400	0.054675	.
class3:ANUCL	0.249502	0.010687	23.346200	< 2.2e-16	***
class2:ACLIMATE	0.209656	0.023139	9.060800	< 2.2e-16	***
class3:ACLIMATE	0.075139	0.019154	3.922900	0.000087	***

class2:AFUTURE	0.066287	0.021893	3.027700	0.002464	**
class3:AFUTURE	0.106470	0.020622	5.163000	0.000000	***
class2:FAVORBE	-0.409867	0.119804	-3.421200	0.000624	***
class3:FAVORBE	-0.477733	0.117838	-4.054100	0.000050	***
class2:FAVORNL	-1.117759	0.283126	-3.947900	0.000079	***
class3:FAVORNL	0.169191	0.248229	0.681600	0.495496	
class2:GROEN	0.057233	0.148903	0.384400	0.700707	
class3:GROEN	0.620071	0.134395	4.613800	0.000004	***
class2:GROENLINKS	-0.678930	0.164709	-4.122000	0.000038	***
class3:GROENLINKS	-0.778032	0.163521	-4.758000	0.000002	***

```
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Optimization of log-likelihood by BHHH maximisation
Log Likelihood: -5979.6
Number of observations: 8745
Number of iterations: 28
Exit of MLE: successive function values within tolerance limit
```

Appendix D

	C1	C2	C3
Nationality			
Belgian	0.23	0.27	0.51
Dutch	0.25	0.29	0.46
Other	0.26	0.19	0.55
Gender			
Woman	0.22	0.18	0.60
Man	0.26	0.34	0.39
Age			
< 25 years	0.24	0.28	0.49
25 – 50 years	0.25	0.24	0.51
>50 years	0.23	0.21	0.56
Education			
Primary	0.15	0.14	0.71
Secondary	0.16	0.34	0.50
Bachelor	0.24	0.28	0.48
Master or higher	0.27	0.20	0.53
Income			
< €4000/month	0.24	0.23	0.54
€4000-8000/month	0.25	0.28	0.47
>€8000/month	0.22	0.25	0.53
Concern on nuclear energy			
Negligible	0.52	0.48	0.00
Low	0.38	0.40	0.23
Considerable	0.24	0.26	0.50
High	0.13	0.12	0.74
Concern on climate change			
Negligible	0.40	0.21	0.39
Low	0.66	0.18	0.15
Considerable	0.37	0.25	0.38
High	0.18	0.26	0.57
Concern on future generations			
Negligible	0.39	0.35	0.26
Low	0.45	0.29	0.26
Considerable	0.24	0.24	0.52
High	0.15	0.26	0.59

	C1	C2	C3
Nuclear energy knowledge			
Low	0.37	0.13	0.50
Good	0.25	0.21	0.54
Very good	0.23	0.28	0.50
Climate change knowledge			
Low	0.60	0.19	0.21
Good	0.30	0.20	0.50
Very good	0.21	0.27	0.52
Political preference			
PvdA (BE)	0.15	0.29	0.56
S.Pa (BE)	0.30	0.13	0.56
Groen (BE)	0.15	0.20	0.66
CD&V (BE)	0.26	0.25	0.50
Open VLD (BE)	0.19	0.40	0.41
N-VA (BE)	0.36	0.31	0.33
Vlaams Belang (BE)	0.38	0.02	0.60
Other (BE)	0.01	0.45	0.54
GroenLinks (NL)	0.23	0.28	0.49
PvdA (NL)	0.28	0.30	0.42
CU (NL)	0.00	0.76	0.24
CDA (NL)	0.31	0.10	0.58
D66 (NL)	0.23	0.37	0.40
PvdD (NL)	0.00	0.95	0.05
VVD (NL)	0.33	0.34	0.34
Other (NL)	0.72	0.01	0.26
Not eligible to vote	0.11	0.24	0.66
Blanco voters	0.39	0.20	0.40
Not wanting to state	0.23	0.28	0.49

Appendix E

	Class 1	*Class 2*	*Class 3*
Nationality			
Belgian	-6,29%	6,71%	-0,34%
Dutch	3,83%	19,26%	-11,07%
Other nationality	9,01%	-27,38%	9,06%
Gender			
Woman	-7,54%	-29,12%	17,55%
Man	9,84%	38,32%	-23,04%
Age			
25Y	-1,30%	10,41%	-4,42%
25-50Y	3,03%	-5,21%	1,11%
50Y	-4,59%	-13,52%	8,67%
Education			
Primary education	-39,61%	-42,53%	38,89%
Secondary education	-33,48%	37,78	-2,81%
Bachelor	-0,73%	14,57%	-6,73%
Master	15,07%	-24,99%	5,14%
Income			
< €4000/month	-1,64%	-12,53%	6,81%
€4000-8000/month	3,76%	18,15%	-10,51%
>€8000/month	-4,59%	-9,20%	6,58%
Political preferences			
Not eligible to vote	-71,62%	-5,18%	30,17%
Blanco	69,71%	-28,86%	-21,85%
Do not want to state	-0,12%	4,57%	-8,08%
Belgian parties			
PvdA	-37,26%	5,59%	8,91%
S.pa	19,77%	-66,40%	21,28%
Groen	-33,89%	-32,45%	27,06%
CD&V	11,95%	-5,80%	-6,58%
OPEN VLD	-25,02%	53,23%	-20,98%
N-VA	59,01%	8,32%	-34,28%
VB	75,67%	-100%	14,35%
Other parties	-100%	71,46%	6,54%
Dutch parties			
GroenLinks	-10,93%	-7,74%	1,65%
CU	-100%	142,13%	-47,69%
CDA	29,96%	-64,11%	16,32%
D66	-25,76%	23,02%	-10,30%
PvdA	16,89%	-3,15%	-16,30%
PvdD	-100%	223,45%	-100%

VVD	29,96%	7,68%	-30,21%
Other parties	158,30%	-100%	-30,64%
Knowledge on nuclear energy			
Little	55,28%	-50,74%	-4,76%
Good	4,35%	-14,48%	5,33%
Very good	-7,29%	10,55%	-1,47%
Knowledge on climate change			
Little	148,45%	-21,18%	-61,90%
Good	24,80%	-15,71%	-3,70%
Very good	-12,37%	4,47%	3,53%
Concern on nuclear energy			
Negligible	123,48%	89,08%	-99,86%
Low	60,94%	60,83%	-57,43%
Considerable	-2,51%	4,03%	-0,79%
High	-44,47%	-51,75%	45,47%
Concern on climate change			
Negligible	68,52%	-19,81%	-22,48%
Low	174,64%	-19,57%	-70,85%
Considerable	60,82%	-0,96%	-27,47%
High	-28,26%	1,46%	12,29%
Concern on future generations			
Negligible	69,06%	34,06%	-48,23%
Low	90,12%	20,62%	-51,42%
Considerable	-0,23%	-6,22%	3,12%
High	-38,55%	2,34%	16,60%

References

Bruckner T., Bashmakov I.A., Mulugetta Y., Chum H., de la Vega Navarro A., Edmonds J., … Zhang X., 2014: Energy Systems. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Byun, H., & Lee, C.-Y. (2017). Analyzing Korean consumers' latent preferences for electricity generation sources with a hierarchical Bayesian logit model in a discrete choice experiment. *Energy Policy*, *105*, 294–302. https://doi.org/10.1016/j.enpol.2017.02.055

Capros, P., Paroussos, L., Fragkos, P., Tsani, S., Boitier, B., Wagner, F., … Bollen, J. (2014). European decarbonisation pathways under alternative technological and policy choices: A multi-model analysis. *Energy Strategy Reviews*, 2(3–4), 231–245. https://doi.org/10.1016/j.esr.2013.12.007

Connolly, D., Lund, H., & Mathiesen, B. V. (2016). Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union. *Renewable and Sustainable Energy Reviews*, *60*, 1634–1653. https://doi.org/10.1016/j.rser.2016.02.025

European Commission. (2007). *Special Eurobarometer.* Retrieved from https://ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs_262_en.pdf

European Commission. (2019). *Standard Eurobarometer Spring 2019* . Retrieved from https://ec.europa.eu/commission/presscorner/detail/nl/IP_19_4969

Fagan., M., & Huang, C. (2019, December 30). A look at how people around the world view climate change. Retrieved from https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/

Goebel, J., Krekel, C., Tiefenbach, T., & Ziebarth, N. R. (2015). How natural disasters can affect environmental concerns, risk aversion, and even politics: evidence from Fukushima and three European countries. *Journal of Population Economics*, *28*(4), 1137–1180. https://doi.org/10.1007/s00148-015-0558-8

Hobley, A. (2019). Will gas be gone in the United Kingdom (UK) by 2050? An impact assessment of urban heat decarbonisation and low emission vehicle uptake on future UK energy system scenarios. *Renewable Energy*, 142, 695–705. https://doi.org/10.1016/j.renene.2019.04.052

International Atomic Energy Agency. (2019a). *Country Nuclear Power Profiles: Germany*. Retrieved from https://cnpp.iaea.org/countryprofiles/Germany/Germany.htm

International Atomic Energy Agency. (2019b). *Country Nuclear Power Profiles: Switzerland*. Retrieved from https://cnpp.iaea.org/countryprofiles/Switzerland/Switzerland.htm

Jägemann, C., Fürsch, M., Hagspiel, S., & Nagl, S. (2013). Decarbonizing Europe's power sector by 2050 — Analyzing the economic implications of alternative decarbonization pathways. *Energy Economics*, 40, 622–636. https://doi.org/10.1016/j.eneco.2013.08.019

Jones, C. R., Yardley, S., & Medley, S. (2019). The social acceptance of fusion: Critically examining public perceptions of uranium-based fuel storage for nuclear fusion in Europe. *Energy Research & Social Science*, *52*, 192–203. https://doi.org/10.1016/j.erss.2019.02.015

Kahneman, D. (2012). *Thinking, Fast and Slow* (Paperback ed.). New York, United States: Penguin Random House.

Karlstrøm, H., & Ryghaug, M. (2014). Public attitudes towards renewable energy technologies in Norway. The role of party preferences. *Energy Policy*, *67*, 656–663. https://doi.org/10.1016/j.enpol.2013.11.049

Kiesraad. (2017). *Uitslag van de verkiezing van de leden van de Tweede Kamer van 15 maart 2017*. Retrieved from https://www.kiesraad.nl/verkiezingen/verkiezingsuitslagen

Latré, E., Thijssen, P., & Perko, T. (2019). The party politics of nuclear energy: Party cues and public opinion regarding nuclear energy in Belgium. *Energy Research & Social Science*, *47*, 192–201. https://doi.org/10.1016/j.erss.2018.09.003

McFadden, D. (1973). Conditional Logit Analysis of Qualitative Choice. *Frontiers in Econometrics*, Academic Press, New York, 105-142.

Menges, R., Schroeder, C., & Traub, S. (2005). Altruism, Warm Glow and the Willingness-to-Donate for Green Electricity: An Artefactual Field Experiment. *Environmental & Resource Economics*, *31*(4), 431–458. https://doi.org/10.1007/s10640-005-3365-y

Morita, T., & Managi, S. (2015). Consumers' willingness to pay for electricity after the Great East Japan Earthquake. *Economic Analysis and Policy*, *48*, 82–105. https://doi.org/10.1016/j.eap.2015.09.004

Murakami, K., Ida, T., Tanaka, M., & Friedman, L. (2015). Consumers' willingness to pay for renewable and nuclear energy: A comparative analysis between the US and Japan. *Energy Economics*, *50*, 178–189. https://doi.org/10.1016/j.eneco.2015.05.002

Netbeheer Nederland. (2020, March). Energienet in 2019 zeer betrouwbaar - Netbeheer Nederland. Retrieved from https://www.netbeheernederland.nl/nieuws/energienet-in-2019-zeer-betrouwbaar--1342

NOS. (2018, November 6). Meerderheid Tweede Kamer voor kernenergie, maar of het ervan komt? Retrieved from https://nos.nl/artikel/2258185-meerderheid-tweede-kamer-voor-kernenergie-maar-of-het-ervan-komt.html

Pampel, F. C. (2011). Support for Nuclear Energy in the Context of Climate Change. *Organization & Environment*, *24*(3), 249–268. https://doi.org/10.1177/1086026611422261

Poumadère, M., Bertoldo, R., & Samadi, J. (2011). Public perceptions and governance of controversial technologies to tackle climate change: nuclear power, carbon capture and storage, wind, and geoengineering. *Wiley Interdisciplinary Reviews: Climate Change*, *2*(5), 712–727. https://doi.org/10.1002/wcc.134

Roe, B., Teisl, M. F., Levy, A., & Russell, M. (2001). US consumers' willingness to pay for green electricity. *Energy Policy*, *29*(11), 917–925. https://doi.org/10.1016/s0301-4215(01)00006-4

Santens, T. (2019, February 14). Van kernuitstap tot vliegtuigtaks: dit zijn de politieke voorstellen na 6 weken klimaatspijbelen. Retrieved from https://www.vrt.be/vrtnws/nl/2019/02/13/voorstellen-klimaatspijbelaars/

Shackley, S., McLachlan, C., & Gough, C. (2005). The public perception of carbon dioxide capture and storage in the UK: results from focus groups and a survey. *Climate Policy*, *4*(4), 377–398. https://doi.org/10.3763/cpol.2004.0428

Simoes, S., Nijs, W., Ruiz, P., Sgobbi, A., & Thiel, C. (2017). Comparing policy routes for low-carbon power technology deployment in EU – an energy system analysis. *Energy Policy*, 101, 353– 365. https://doi.org/10.1016/j.enpol.2016.10.006

Tietenberg, T. H., & Lewis, L. (2018). *Environmental and Natural Resource Economics*. Abingdon, United Kingdom: Taylor & Francis.

United Nations. (2015). *The Paris Agreement*. Retrieved from http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

van Zuijlen, B., Zappa, W., Turkenburg, W., van der Schrier, G., & van den Broek, M. (2019). Costoptimal reliable power generation in a deep decarbonisation future. *Applied Energy*, 253, 113587. https://doi.org/10.1016/j.apenergy.2019.113587l

VREG. (2019). *Rapport met betrekking tot de kwaliteit van de dienstverlening van de elektriciteitsdistributienetbeheerders en de beheerder van het plaatselijk vervoernet in het Vlaamse Gewest in 2018*. Retrieved from https://www.vreg.be/sites/default/files/document/rapp-2019-12.pdf

VRT NWS. (2019, May 26). The results as they come in. Retrieved from https://www.vrt.be/vrtnws/en/2019/05/26/the-results-as-they-come-in/#/2/15/1000/percentages

VRT. (2018, July 5). Stroomfactuur voor Belgische gezinnen. Retrieved from https://www.vrt.be/vrtnws/nl/2018/07/05/stroomfactuur-voor-belgische-gezinnen-op-een-na-hoogste-van-alle/

Zappa, W., Junginger, M., & van den Broek, M. (2019). Is a 100% renewable European power system feasible by 2050? *Applied Energy*, 233–234, 1027–1050. https://doi.org/10.1016/j.apenergy.2018.08.109