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The Impact of Russia's Invasion of Ukraine on Germany's Energy Choice Attitudes among Residents in German States with Nuclear Power Plants in Commission or Decommissioned

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Abstract: This paper examines the impact of Russia's invasion of Ukraine on the Germany public's energy choices. Along with much of Europe, Germany was hit by Russia reducing and then cutting its gas supplies. Although alternative sources have been found, this exposes the vulnerability of Germany's energy market to outside control. An online survey of 600 German consumers was conducted in August 2022. The results suggest that 70% of participants were concerned about the shortage of oil and natural gas supply after Russia's invasion of Ukraine, and 60% were concerned about the shortage of electricity supply. The invasion led many participants to support maximizing the use of existing power plants, including nuclear and coal-fired power plants, as an alternative to dependency on Russian supplies. There was an increase in people supporting the expanded use of renewable energy as a solution to the crisis. States with nuclear power plants were seen as needing to reduce and decarbonize their natural gas and coal-fired power generation while advancing their energy mix. The results suggest that the *Energiewende* approach and objectives have broad public support.

Keywords: Germany; energy policy; Russian–Ukraine war; renewable energy; logistic analysis

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1. Introduction

Russia began its military invasion of Ukraine on 24 February 2022. Following this invasion, multiple countries, including Europe and the United States, imposed economic sanctions on Russia. Then, on 30 May 2022, the EU agreed to ban the import of Russian oil as an additional sanction against Russia [1]. Russia's state-run Gazprom announced plans to reduce the supply of Nord Stream gas by 80% on 25 July 2022. This prompted the EU to agree on the following day (July 26) that it would reduce natural gas consumption by 15% compared to the past five years for the period from August 2022 to March 2023 [2]. On September 2 of the same year, the G7 agreed to set a cap on the trading price of Russian oil, with the aim of reducing Russia's oil revenues and depleting Russia's military funding [3]. Subsequently, on 9 September 2022, the EU energy ministers convened a meeting at which they revealed their intentions to proceed with preparations to set a price cap on Russian natural gas [4]. With the EU-imposed sanctions on Russia, the disruption to the global supply chain has produced a ripple effect on the global economy [5]. Energy and food prices have soared worldwide as a result of the economic sanctions, trade restrictions, and policy interventions introduced against Russia [6,7]. Within the EU, energy and fuel supply shortages have led to increases in the price of gasoline for transportation within the Eurozone, and the consumer price index related to transportation has also increased [5]. Mišík [8] states that the lack of a unified external energy security policy has made it difficult for the EU to adopt a unified energy position in response to Russian military

aggression. Mbah et al. [9] argue that while the global financial sanctions against Russia were introduced to cripple Russia's economy and impede its military aggression against Ukraine, the impact of the military aggression has extended to the global economy, resulting in a surge in the prices of crude oil and natural gas. This military invasion is predicted to hinder economic growth by negatively impacting household consumption, disrupting supply chains, inflating utilities costs, and raising commodity prices [9,10]. Thus, Russia's military invasion of Ukraine has triggered an energy crisis in Europe.

The surge in energy prices following the military invasion directly impacted Germany, which had made the decision to phase out nuclear power by the end of 2022 and had been gradually decommissioning its reactors. In Germany, the crisis in Ukraine led to increasing concerns regarding energy, and the country announced that two out of three nuclear power plants would remain operational until April 2023 [11]. As of 2023, Germany is compelled to address the current challenge to its energy security, with ordinary German citizens under threat from rising energy prices.

Wittneben [12] notes that the accident at the Fukushima Daiichi nuclear power plant led to the temporary shutdown of older generation reactors in Germany and prompted a reevaluation of the safety of all nuclear facilities. The Fukushima accident served as an opportunity for citizens to voice opposition to the Merkel administration's policy of supporting nuclear power, and the combination of Germany's confidence in renewable energy technology, its history of opposition to nuclear power, and its close cultural ties to Japan resulted in a major blow to the ruling coalition. Furthermore, Renn et al. [13] note that the German government announced the Energiewende in 2011 and clearly outlined its goal of reducing the energy supply from fossil fuels from 80% to 50% by 2020 and the phasing out of nuclear power plants in 2022. They went on to state that, despite these objectives, the share of coal-fired power generation remained unchanged, and CO_2 emissions increased slightly from 2011 to 2013. Wiertz et al. [14] suggest that the Russian military invasion marks a turning point in Germany's energy policy, with a reduction in its dependence on Russian natural gas, and the use of coal, nuclear power, and LNG for power generation, which is at odds with the goals of the Energiewende, which is regarded as a bridge to next-generation energy, accelerating the introduction of additional funding for renewable energy. Steffen [15] states that while oil and gas from Russia remain crucial for European countries, the ongoing military invasion has prompted a transformation in Europe's energy policy. They also argue that with the ongoing Russian military invasion, the focus now lies in how to effectively reflect public support for policies aimed at the gradual phase-out of fossil fuels and the incremental introduction and support of renewable energy in energy policy actions. In Germany, rising energy prices and public support for security have been reflected in the Energiewende and energy choices. However, amidst the acknowledged energy crisis in Europe, no previous research could be found that examines the "voices of the residents" to identify the type of energy policies German citizens support and the energy choices they make.

We use Germany as a case study and conduct a web survey on energy choices following Russia's invasion of Ukraine. Furthermore, we statistically analyze and examine whether the Russian invasion of Ukraine has had an impact on the perspectives of German citizens regarding their energy choices and provide a discussion based on the results.

Note that in group decision making, the expressed opinions of social individuals may be contradictory or diametrically opposed to their own private opinions and inner feelings [16–18]. Therefore, the expressed private opinion model was developed to study decision-making mechanisms involving private opinions. Dong et al. [18] stated that when pressure increases monotonically, the expressed opinions of a group often reach consensus, and the time to reach consensus is closely related to the rate of pressure increase. In this paper, we examine whether the social pressure of an energy crisis affects the decision-making mechanisms of states that operate or dismantle nuclear power plants.

Additionally, in this paper, we would like to examine whether there are statistical differences among regions, while keeping in mind the evaluations of local residents in

states where nuclear power plants remain in commission or have been decommissioned (NPP states), which are sensitive to Russia's invasion of Ukraine.

The structure of the paper is as follows. Section 2 presents the research methods, including the structure of this paper, design of the web survey, target regions, data aggregation method, and comparison and estimation methods. Section 3 seeks to understand the concerns of participants regarding oil, natural gas, and electricity shortages; their attitudes to renewable energy such as solar power and wind power; and their desire to halt nuclear power generation. Additionally, we aim to grasp how participants regard the 10-point plan to reduce energy dependence on Russian natural gas and their reasoning for and against solar and wind power. In Section 4, we use ordinal logistic regression analysis to estimate whether the type of power energy generation supported by German participants due to Russia's military invasion of Ukraine differs depending on personal attributes, such as whether they live in an NPP state. In addition, using binary logistic regression analysis, we examine whether the differences in the reasons for and against natural-gas-fired power, coal-fired power, solar power, and wind power are based on personal attributes, such as whether or not you live in an NPP state. Sections 5 and 6 we summarise and discuss the implications of the study for Germany's future energy choices.

2. Materials and Methods

2.1. Research Hypotheses

In this section, we explain the null hypothesis to be tested after consideration of how the Russian invasion of Ukraine has affected the energy supply in Germany.

First, according to EIA statistics, Germany's nuclear power generation ratio peaked at 31.29% in 1997, before declining to 22.43% in 2012. Thereafter, following the Fukushima Daiichi nuclear power plant accident in 2011, Germany's nuclear power generation ratio fell sharply, dropping to 11.7% in 2020, the lowest level in 30 years. On the other hand, the household electricity price in Germany in 2021 (USD 32.14/100 kWh) has soared to 2.67 times the price in 2000 (USD 12.06/100 kWh), which was the lowest in the past 30 years. According to EIA statistics, Germany's nuclear power generation ratio (11.75%), thermal power generation ratio (46.81%), and hydroelectric power generation ratio (3.46%) increased in 2021, while the renewable energy ratio (38.36%) fell. In other words, even before the Russian invasion of Ukraine, the proportion of energy generated from non-renewable sources was increasing in Germany. Germany was dependent on Russia for 55% of its natural gas, 34% of its crude oil, and 50% of its coal imports in 2021. However, Germany plans to reduce this dependence on Russian energy to 0% for coal and oil by the end of 2022, and to 10% for natural gas by the summer of 2024. [19]. Germany has plans to reduce its dependence on Russian energy sources, aiming to reach 0% for coal and oil by the end of 2022 and reduce natural gas dependency to 10% by the summer of 2024.

As a result of Germany's compliance with the economic sanctions, trade restrictions, and policy interventions imposed by various countries against Russia, domestic price levels have risen. The rate of increase in Germany's consumer price index (IMF) in 2021 was 3.21%, which is comparable to that in 1991 (3.47%) after German reunification. Germany enacted a Coal Phase-Out Act in August 2020, with the aim of phasing out all coal-fired power plants by 2038 at the latest [19]. For this reason, although Germany may be temporarily dependent on coal-fired power generation, the use coal as a long-term energy supply source has become unfeasible. Moreover, there is widespread opposition in Germany to any reliance on Russian natural gas for electricity; thus, Germany cannot expect to rely on Russian natural gas or coal for the generation of its power supply.

In Germany, many citizens support renewable energy; however, solar and wind power are not constant energy sources, being dependent on natural conditions, making the power supply unstable. Additionally, as energy prices are soaring in Germany, there is some opposition to a focus on solar and wind power alone. In this paper, we begin by confirming the question: "Will the Russian invasion of Ukraine affect Germany's energy choices?" However, the multiple factors influencing people's energy choices are also influenced by

the personal attributes of the residents living in each region. To confirm the presence of the influence of these personal attributes, this article tests four hypotheses.

To begin, we statistically verify two hypotheses regarding the extent to which residents' decision making and attitudes differ according to personal attributes such as gender, parental status, age, number of household members, education level, and income level. First, we will test whether Hypothesis (1) is rejected (null hypothesis (H_0): "There are no differences in energy choices among participants based on individual attributes"). Second, we will test whether Hypothesis (2) is rejected (null hypothesis (H_0) : "There are no differences in the reasons for supporting or not supporting electric power generation among participants based on personal attributes").

The explanatory variables are calculated by introducing a cross term between individual attributes and NPP state × individual attributes. Three variables for individual attributes were introduced as qualitative variables: gender (male = 1, female = 0), children under 12 years old (yes = 1, no = 0), and NPP state (other states = 0) (see Appendix A).

Several studies have suggested that individual attributes can affect energy choice behavior.

First, Mills et al. [20] found that family age composition patterns influence household energy use behavior. In a study of eleven European and Scandinavian countries, they found that (i) households with young children tend to conserve energy for environmental reasons, (ii) households with a high proportion of elderly people tend to emphasize economic savings, and (iii) households with a high level of education tend to introduce energy-efficient technologies and practice energy conservation. Karasmanaki [21] examined the factors influencing willingness to pay for renewable energy using the EU as a case study. He concluded that willingness to pay for renewable energy is mainly influenced by individual environmental awareness and demographics, specifically age, gender, education level, and income status.

Trotta [22] found that in a UK case study, energy-saving behavior and purchases of energy-efficient investments were linked to environmental factors, but that retro-fitting of homes was more closely identified with sociodemographic factors such as housing type, income, age, marital status, and so on. Niamir et al. [23] examined the factors that induce and inhibit changes in household energy behavior, using the Netherlands and Spain as case studies. They found that awareness and social and personal factors were as important as monetary considerations, in particular education and dwelling type.

Previous studies on willingness to pay (WTP) for environmental goods have shown that choice behavior differs depending on gender and whether one has children or not; Dupont [24] in a study of Spain and the Netherlands, found significant WTP differences between men and women with children and their childless counterparts, particularly between men.

Regarding explanatory variables related to individual attributes, the results of ordinal and binomial logistic regression analyses using Kazakhstan [25] and Switzerland [26] as examples confirmed statistical differences in intentions and attitudes around nuclear energy depending on gender, presence of children, age, number of household members, educational level, and income level. Therefore, personal attributes were also introduced into the estimation equation in this paper.

Several studies have demonstrated that those living near NPPs are more likely to be supportive or involved in campaigns for the dismantling of NPPs and prefer alternative energy sources. Hoti et al. [27] found that living near an NPP was a factor in shaping support for decommissioning campaigns, along with political alignment and levels of trust in the nuclear power industry.

The study by Frantal et al. [28] on the effects of proximity to the Dukovany NPP in the Czech Republic on statistical and perceived economic employment benefits found that those living within 15 km of the NPP had more positive perceptions and were more likely to be positively impacted than those living further away. Age, education, and employment status were also factors.

Bertsch et al. [29] found in a study in Germany that support for renewable energy is influenced by socio-demographic factors as well as proximity to the power sources. At a national level, there was widespread public support, whereas at the local level, support was more ambivalent, with concern in particular for the impact on the landscape. Age and education were found to be the key sociodemographic variables.

A study in China by Zhao et al. [30] found that individual attributes such as age, education, gender, and environmental awareness were factors in individual evaluation of coal-fired power generation and preferences for reduction in health-damaging pollutants rather than reduction in CO_2.

Since these previous studies have found that living within the vicinity of a nuclear power plant can influence energy choice behavior, this was included as a variable. The three NPP states introduced as explanatory variables are Baden-Württemberg, Freistaat Bayern, and Niedersachsen.

In line with the above discussion of individual attributes, and in line with the authors' previous studies [25,26], these variables have been included in the ordinal and binomial logistic regression analyses in the current research.

As a result of the Russian attack on a nuclear power plant in Ukraine, the safety of nuclear power plants during war has been discussed in the EU. In Germany as well, many residents in NPP states have a sense of crisis. Therefore, due to this invasion, we will statistically verify the following two hypotheses regarding residents living in NPP states.

Third, we will test whether Hypothesis (2) is rejected (null hypothesis (H_0): "There are no differences in energy choices among German residents based on whether they live in NPP"). Fourth, we will test whether Hypothesis (2) is rejected (null hypothesis (H_0): "There are no differences in reasons for supporting or not supporting electric power among German residents based on whether they live in NPP states").

A survey instrument was developed to test the hypotheses. The questionnaire in this paper is mainly divided into a Likert scale (5-point scale) and dummy variables (0 and 1 question items). The survey questions for estimating the null Hypotheses (1) and (3) use a 5-point Likert scale. The items used in analyzing Hypotheses (1) and (3) are support for natural gas, support for solar energy, and support for wind energy. The analysis of Hypotheses (2) and (4) uses the items support for coal-fired energy, support for solar power, and support for wind power. When estimating Likert scale data, ordinal logistic regression analysis is applied. Ordinal logistic regression analysis is a type of regression analysis used for multivariate data when the objective variable is an ordinal variable with three or more categories. Although the predictive values of the logistic regression model fall within the range of 0 to 1, it is difficult to interpret the estimated parameters themselves as it is a nonlinear model. In ordinal logistic regression analysis, marginal effects can be estimated and the degree to which a 1-unit change in the explanatory variable affects the change in the probability of the objective variable can be estimated and observed in a step-by-step manner. Therefore, in this paper, we apply ordinal logistic regression analysis to estimate the marginal effects. Binary logistic regression analysis is applied to null Hypotheses (2) and (4).

2.2. Research Target Regions

Figure 1 shows the locations of nuclear power plants in Germany and the regions surveyed.

In the figure, red indicates nuclear power plants that were decommissioned after 14 March 2011, and blue represents those that remained in commission. Of the six nuclear power plants that were in commission as of December 2022, three were subsequently decommissioned: the Brokdorf nuclear plant in Land Schleswig-Holstein (cooling water source: Eems River), the Grohnde plant nuclear in Niedersachsen (Weser River), and the Gundremmingen nuclear plant in Bayern (Danube River) [31]. As of September 2022, the nuclear plants that remained in commission were the Emsland nuclear plant in Niedersachsen (Eems River), the Isar nuclear plant in Bayern (Isar River), and the Neckarwestheim nuclear plant in Baden-Württemberg (Neckar River). The nuclear plants in commission

tended to be concentrated in former West Germany. Therefore, to investigate whether there are significant differences in responses between residents of NPP and non-NPP states, a nationwide web survey was conducted.

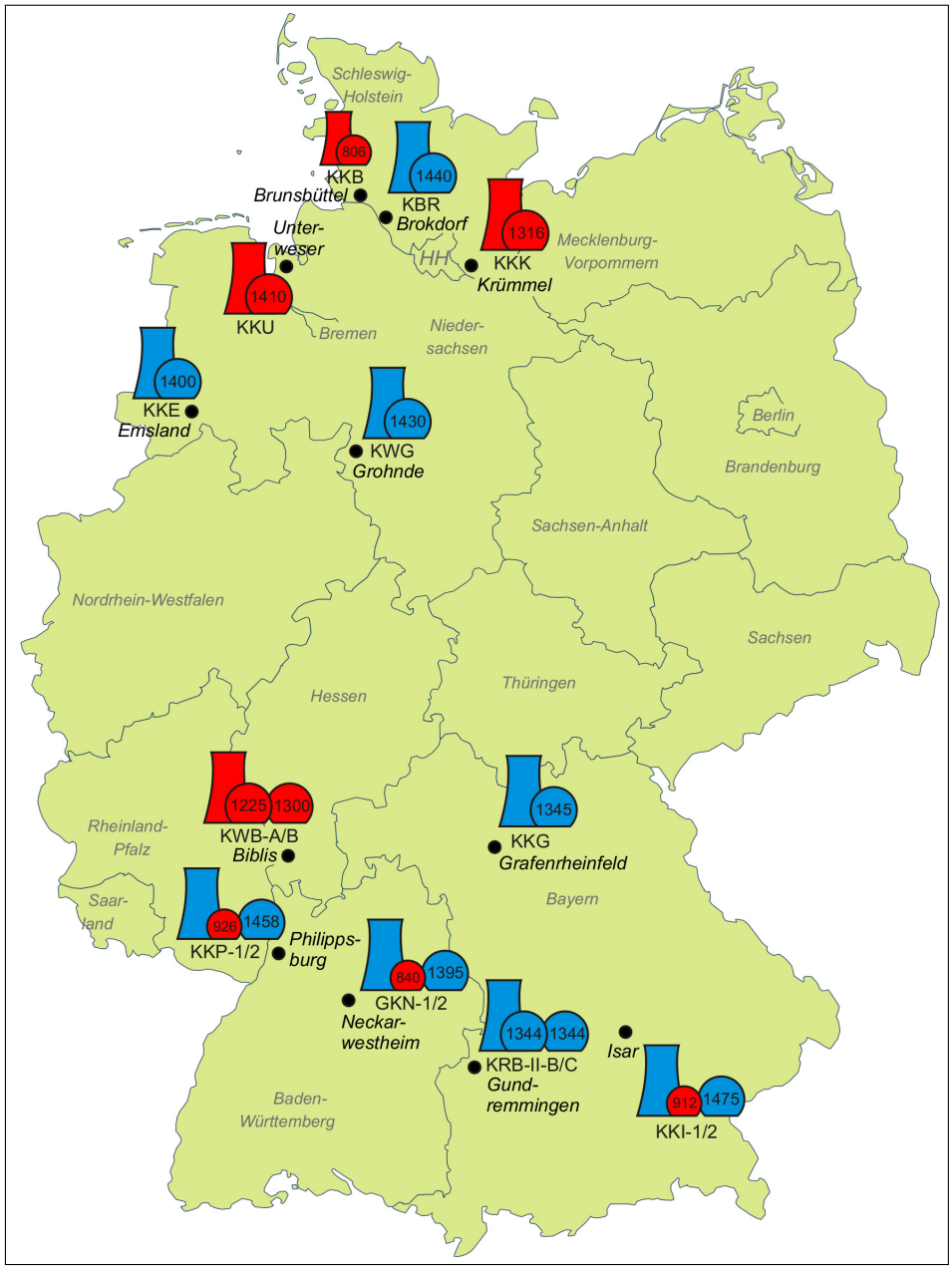


Figure 1. Nuclear power plants in Germany. Source: Kernkraftwerke in Deutschland.svg. Note: blue denotes operating reactors, red denotes decommissioned reactors.

2.3. Data Collection

The survey questionnaire was created using SurveyMonkey and then distributed to consumers via the web. The questionnaire was in English. A total of 687 participants responded to the questionnaire, with 600 completing the questionnaire. The response rate was 87.3%, and the response target was completed in one day, on Sunday, 28 August 2022 (Japan time). It should be noted that this is before the shutdown of nuclear power plants.

In statistics, $1.96051 - 0.5/n = 0.05$ is used as a simple way to determine the sample size [32,33]. Since the sample proportion is unknown because the survey was conducted before the survey, 0.5, which has the largest sample error, is included in this formula for the worst-case scenario. This formula yields n = 19.6, and if we collect a sample of 384 (n = 384),

we can estimate the 95% confidence interval of the population ratio within ±5% error. In other words, statistically, if the number of samples is about 400, the sample error can be estimated within ±5%.

Long [34] states that the maximum likelihood method is used in ordinal logistic regression analysis, so a minimum sample size of 200 is required, with an additional 20 samples added for each explanatory variable. Estimation uses backward stepwise selection, so even if there were a maximum of 13 explanatory variables, the sample size would be 200 + (13 explanatory variables × 20 emails) = 460 emails, which satisfies the sample size for estimation. Binomial logistic regression analysis satisfies the estimation conditions if the number of samples is 10 times that of the less frequent category between 1 and 0; therefore, there is no problem with estimation.

However, the sample in this paper is small from a demographic point of view. Therefore, by using backward stepwise selection, we were able to use a small number of explanatory variables so that the principle of parsimony is reflected [33]. The model in this paper is a constrained model in two respects: (1) it assumes a significance level of 10% and therefore has a significant trend, and (2) it uses standard errors rather than robust standard errors to correct for heterogeneous variance.

In some cases, where samples are classified based on a combination of gender, age, and so on, the quota method is chosen to select samples proportional to the population from each group. However, as this method was not used in the survey, it was expected that the sample would be biased towards states with a higher population concentration. Regardless of this potential bias, the survey was compiled without any regional restrictions.

2.4. Analysis Methodology

In this section, we will explain the estimation method for ordinal logistic regression analysis. See Appendix A for a list of dependent and independent variables. First, we will conduct ordinal logistic regression analysis with four outcome variables: "Promotion of Natural Gas Power Generation", "Promotion of Coal Power Generation", "Promotion of Solar Power Generation", and "Promotion of Wind Power Generation". The outcome variables are categorized as follows: oppose = 1, somewhat oppose = 2, neutral = 3, somewhat supportive = 4, and supportive = 5. These categories are used for estimation. The model is similar to that used in a study modelling energy choices in Kazakhstan [33].

The explanatory variables are estimated by introducing personal attributes and the interaction of NPP states × personal attributes.

The explanatory variables related to personal attributes, gender (male = 1, female = 0), presence of children aged 12 or under (present = 1, absent = 0), and NPP state (NPP state = 1, other state = 0), were introduced as qualitative variables.

There are three states with nuclear power plants in commission: Baden-Württemberg, Freistaat Bayern, and Niedersachsen (see Figure 1). Additionally, Hessen and Schleswig-Holstein had nuclear power plants in commission until after the East Japan earthquake and tsunami in 2011, and they are included as NPP states. On the other hand, the Mülheim-Kärlich nuclear power plant was in commission until 1988 in Rheinland-Pfalz. This is the largest nuclear plant to be decommissioned in Germany, with its decommissioning begun in 2020. Therefore, Rheinland-Pfalz is categorized as a state with decommissioned nuclear power plants. Although Nordrhein-Westfalen had non-operational facilities like the Kalkar fast breeder reactor and gas reactors (AVR reactor, THTR-300, etc.) and Brandenburg had the Rheinsberg experimental nuclear power plant undergoing decommissioning, these states were not included.

Furthermore, age, household size, education (educational level), and income (average income) were introduced as continuous variables. Here, for age and income, we calculated the class representative values for each category (e.g., for the "40–50 years" age group, 45 years was used, and for the "EUR 8501–17,000" income level, EUR 2750.5 was used), and these were introduced as discrete variables into the continuous variables. Further, education was scored from 1 to 5, representing levels from junior high school (1) to doctoral

degree (5), and introduced as a discrete variable into the explanatory variables. All four of these continuous variables were introduced after logarithmic transformation.

The following six explanatory variables related to interaction terms were introduced into the regression equation: NPP State × Gender, NPP State × Children, NPP State × Age, NPP State × Household Size, NPP State × Education, and NPP State × Income.

For ordinal logistic regression analysis estimation, only the optimal estimation results are presented, taking into consideration the Akaike information criterion (AIC) values and likelihood ratio. Each explanatory variable was estimated using backward stepwise selection, with only the variables significant at the 1–10% significance level remaining until the optimal estimation results were obtained.

In the first table in Section 4 below, the term "cut" represents the threshold, with

$$Pr(y = 1) = Pr(\beta x < cut1), Pr(y = 2) = Pr(cut1 < \beta x < cut2)$$

Binomial Logistic Regression Analysis

A binomial logit model is estimated to determine whether there is any correlation between personal attributes and "10-Item Plan to Reduce the EU's Dependence on Russian Natural Gas", "Reasons for Supporting or Not Supporting Coal Power Generation", "Reasons for Supporting or Not Supporting Solar Power Generation", and "Reasons for Supporting or Not Supporting Wind Power Generation" as objective variables. In the binomial logistic regression analysis, each explanatory variable was also estimated using backward stepwise selection until the optimal estimation results were obtained.

3. Results

3.1. Sample Attributes

The sample attributes are shown in Table 1.

First, looking at gender, 43.2% of the respondents were men, and 56.8% were women. The average age was 36.8 years, with the largest number of respondents in the 30–44 years age group (45.5%), followed by the 18–29 years age group (32.5%). Approximately 59.7% of respondents did not have children (or grandchildren) under the age of 12 in their households. In terms of education, the highest number of respondents (31.8%) had attended "College or Technical", followed by "Secondary" (27.5%), and "Completed University/College or Tertiary Education" (25.7%). Geographically, the region with the highest population in the country, Nordrhein-Westfalen, accounted for the largest share of respondents (24.8%), followed by Baden-Württemberg (10.0%), Niedersachsen (9.8%), and Freistaat Bayern (8.5%), with a majority of respondents living in former West Germany. There are many nuclear power plants in commission or undergoing decommissioning/dismantling in the more industrial former West Germany. Therefore, it is expected that the research presented in this paper would be of great interest to the residents of former West Germany. Regarding occupation, many respondents were categorized as "Office worker" (18.5%), "Public employee" (11.0%), and "Factory worker" (10.3%). The average household size was 2.650 people, and the annual income per household was EUR 48,621 (which can be converted to USD 48,667 for the sample in this paper), which is slightly lower than the income levels reported by the United Nations (USD 45,909 in 2020) and the IMF (USD 50,795 in 2021). One reason for the lower income level per household among the respondents is thought to be that many residents seeking to earn additional income participate in web surveys. It can also be assumed that the respondents to this survey were low-income people who are more sensitive to increases in energy prices.

Table 1. Demographic attributes of survey participants (n = 600).

Variable	Category	Frequency	Percentage
Sex	Male	259	43.2
	Female	341	56.8
Age	18–29	195	32.5
	30–44	273	45.5
	45–60	103	17.2
	Over 60	29	4.8
	Average/SD	46.8	12.2
Children under 12		242	40.3
Household	Average/SD	2.65	1.262
Education	Primary	36	6.0
	Secondary	165	27.5
	College/Technical	191	31.8
	Undergraduate	154	25.7
	Graduate	54	9.0
Income	Less than EUR 8500	59	9.8
	EUR 8501∼51,000	320	53.3
	EUR 51,001∼94,000	157	26.2
	EUR 94,001∼137,000	64	6.8
	Over EUR 137,001	23	3.8
	Average/SD	48,621	37,329
Region	Nordrhein-Westfalen	149	24.8
	Baden-Württemberg	60	10.0
	Niedersachsen	59	9.8
	Freistaat Bayern	51	8.5
	Berlin	48	8.0
	Other	233	38.8
Occupation	Office Worker	111	18.5
	Public Employee	66	11.0
	Factory Worker	62	10.3
	Other	361	60.2

3.2. Concerns Abouts Oil, Natural Gas, and Electricity Shortages, and Support for Power Generation

The results regarding concerns about oil, natural gas, and electricity shortages, and support for power generation are shown in Figure 2.

3.3. Concerns About Oil and Natural Gas Supply Shortages

The EU has agreed to impose additional sanctions on Russia due to its ongoing invasion of Ukraine through bans on the import of Russian oil [1]. On 7 September 2022, the EU announced a proposal to place a price cap on Russian natural gas imported into the EU. As a result, President Putin intimated that gas supplies to Europe could be cut off completely [35]. These trade embargoes and the proposed price cap have increased the risk of crude oil and natural gas supply shortages, raising concerns about energy shortages around the world. Participants were asked whether they were concerned about increasing oil and natural gas prices due to the oil and natural gas supply shortages. We found that a total of 70.3% of respondents ("Strongly agree", 41.7%; "Somewhat agree", 28.7%) were concerned about a shortage in oil and natural gas supplies.

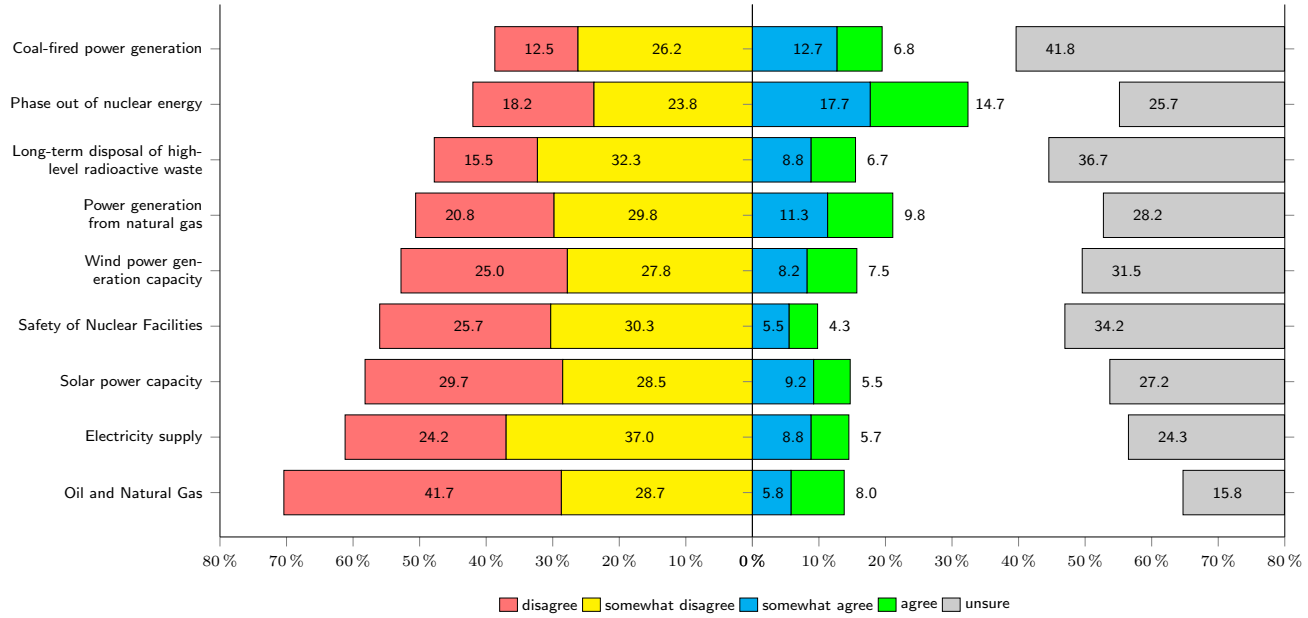


Figure 2. Concern for energy and energy-related issues (n = 600).

3.4. Concerns About Electricity Supply Shortages

On 8 June 2022, the International Energy Agency (IEA) Director-General Birol expressed the view that Europe could face an energy shortage in the winter of 2022 as a result of the worsening energy crisis [36]. Therefore, we asked participants whether they were concerned about potential electricity shortages by the end of the year. The results showed that 61.2% of respondents ("Strongly agree", 24.2%; "Somewhat agree", 37.0%) felt some concern about electricity supply shortages.

3.5. Cessation of Nuclear Power Plant Operations within the Year (2022) as Scheduled

On 8 March 2022, the German government rejected a proposal to extend the operation of nuclear power plants as a means of limiting dependence on Russian gas [37,38]. Therefore, we asked participants whether they supported shutting down nuclear power plants by the end of the year (2022) as initially planned. The results showed that the largest number of responses were "Somewhat agree" (23.8%), followed by "Strongly agree" (18.2%). However, 32.3% of respondents ("Somewhat disagree", 17.7%; "Disagree", 14.7%) were opposed to the phase-out of nuclear power as planned. On September 5, eight days after the survey date (August 28), it was announced that the Emsland nuclear power plant would cease operation at the end of 2022 as planned, while the two nuclear power plants, Isar2 and Neckarwestheim2, would maintain operational status as an emergency backup power source until April 2023 [11]. The Russian invasion of Ukraine has heightened energy concerns, with the debate focused on whether to extend the operation of the last three reactors. However, an opinion poll in August revealed that 80% of respondents supported their continued operation. The results of our survey showed a similar response in terms of public opinion, with many respondents opposed to shutting down the nuclear power plants as planned.

3.6. Support for Thermal Power Generation Using Natural Gas

On 19 June 2022, the German Minister for the Economy and Climate, Habeck, announced emergency measures to curb gas consumption in preparation for a significant reduction in natural gas supply from Russia [2], with Germany increasing the use of coal-fired power generation and introducing new measures to encourage gas conservation by industry. Therefore, we asked participants whether they were in favor of promoting thermal power generation using natural gas. The results showed that the highest percent-

age of responses fell under "Somewhat agree" (29.8%), with a significant proportion also indicating "Neither agree or disagree" (28.2%).

3.7. Promotion of Coal-Fired Power Generation by 2030

Germany aims to phase out coal as early as 2030 [39]. However, on 19 June 2022, the Minister for the Economy and Climate, Habeck, announced that the government would proceed with legal measures to expand the operation of coal-fired power generators rather than reduce the consumption of gas for electricity generation within Germany [40]. Therefore, participants were asked whether they supported the government's promotion of coal-fired power generation until 2030. The results showed that while the largest category of responses was "Neither agree or disagree" at 41.8%, a significant portion also leaned towards agreement with 26.2% responding "Somewhat agree".

3.8. Ensuring the Safety of Nuclear Power Facilities

On 24 February 2022, Russian forces occupied the previously decommissioned Chernobyl nuclear power plant [41]. This attack on the nuclear plant by Russian forces sent shockwaves through the international community [42]. While nuclear reactors are designed to withstand adverse events such as air crashes, they are not designed to withstand multiple missile strikes. We therefore asked participants whether they supported ensuring the safety of nuclear power plants. The results showed that while the largest category of responses was "Neither agree or disagree" at 41.8%, when combining those who "Strongly agree" (25.7%) and "Somewhat agree" (30.3%), a total of 56.0% of respondents believed that the safety of nuclear power facilities should be ensured.

3.9. Selection of a Final Disposal Site for High-Level Radioactive Waste

Germany must find candidate sites for burying approximately 2000 containers of high-level radioactive waste by 2031 [43]. Excluding intermediate storage facilities, radioactive waste around the world is currently stored in temporary storage facilities near nuclear power plants. We therefore asked participants whether they felt that Germany should hasten the selection of a final disposal site for radioactive waste. The results showed that the largest number of respondents (36.7%) answered "Neither agree or disagree". However, when combining those who responded with "Somewhat agree" (32.3%) and "Strongly agree" (15.5%), a total of 47.8% believed that a final disposal site should be selected.

3.10. Promotion of Renewable Energy after Nuclear Attacks

Germany aims to further strengthen measures to achieve its goal of over 80% of electricity consumption from renewable sources by 2030 and make domestic electricity carbon-neutral by 2035 [44]. Therefore, we asked participants whether they thought solar power generation should be promoted. The results showed that 56.0% of respondents ("Strongly agree", 29.7%; "Somewhat agree", 28.5%) supported solar power generation. Similarly, when we asked participants whether they thought wind power generation should be promoted, 47.8% of respondents ("Strongly agree", 25.0% ;"Somewhat agree", 27.8%) supported wind power generation.

3.11. Concerns About Energy Supply Shortages, Ensuring the Safety of Nuclear Facilities, Selecting a Final Disposal Site for High-Level Radioactive Waste, and the Relationship with Electricity Generation

In addition, we conducted a correspondence analysis to determine the relationship between concerns about energy supply shortages, ensuring the safety of nuclear power plant facilities, selecting a final disposal site for radioactive waste, and electricity generation. This analysis enables us to visualize the relationship between categories using a map. On this map, items located close to each have a strong relationship, while items located far from each other have a weak relationship.

Figure 3 shows the results of the correspondence analysis for estimating the relationship between concerns about energy supply shortages, ensuring the safety of nu-

clear power plant facilities, selecting a final disposal site for radioactive waste, and electricity generation.

As the vertical axis is concentrated within the range of 0.6 to −1.0, and the horizontal axis within the range of 1.0 to −0.8, the evaluations are approximate. The cumulative contribution rate is 62.0% for the first axis, and 92.7% when the second axis is included, with p-values of <1% obtained using the χ^2 test for both axes, indicating that they are statistically significant. The first axis can be interpreted as showing the pros and cons regarding nuclear power, with the second axis showing the degree of insecurity regarding the energy supply.

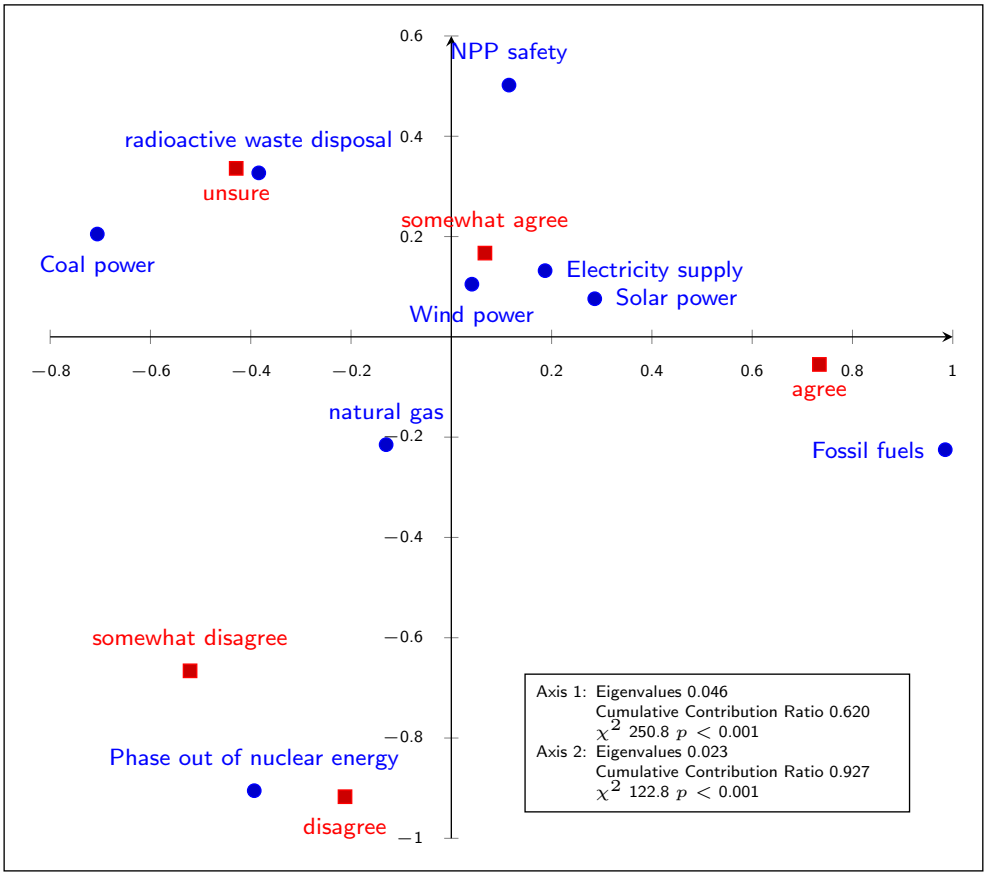


Figure 3. Concerns about energy supply shortages and ensuring the safety of nuclear power plant facilities, selection of final disposal sites for high-level radioactive waste, and their relationship to the electricity sources being supported.

In the first quadrant, there is an approximation between "Promotion of wind power generation", "Promotion of solar power generation", and "Concerns about electricity supply shortages" with "Somewhat agree". In the second quadrant, "Selection of a final disposal site for high-level radioactive waste" and "Promotion of coal-fired power generation" are approximated with "Neither agree or disagree". The third quadrant indicates that there is an approximation between "Shutdown of nuclear power plants" and "Strongly disagree", while the fourth quadrant reveals an approximation between "Concerns about shortages in oil and natural gas supply" and "Strongly agree".

Consideration of the overall results from this analysis shows that there is strong concern about the lack of supply of oil and natural gas. Further, while there is support for renewable energy, there is some concern about the energy supply. Additionally, while there were many concerns about coal-fired power generation until 2030 and selecting a final disposal site for high-level radioactive waste, there was a good deal of negativity regarding the shutting down of nuclear power plants as planned.

3.12. Ten-Point Plan to Reduce EU Dependence on Russian Natural Gas

The IEA states that imports from Russia can be reduced by more than 50% and carbon dioxide emissions also reduced by reducing the import of natural gas from Russia by one-third and adding interim measures [45]. See Appendix A for a list of the points.

Figure 4 shows the responses to the 10-point plan to reduce EU dependence on Russian natural gas.

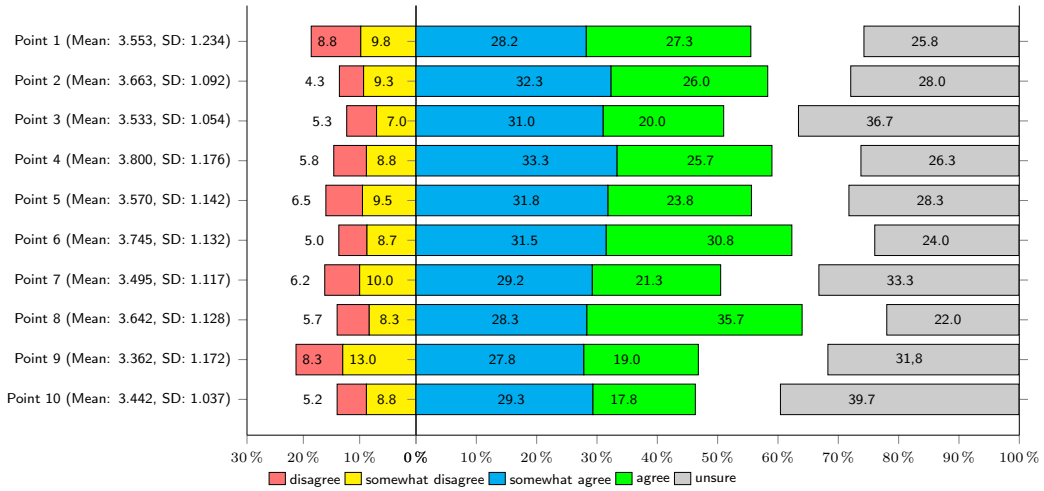


Figure 4. Responses to the EU 10-point action plan (n = 600).

3.13. Relevance of the 10-Point Plan to Reduce EU Dependence on Russian Natural Gas

Figure 5 shows the estimated results regarding the relevance of the EU's 10-point plan to reduce dependence on Russian natural gas from the correspondence analysis.

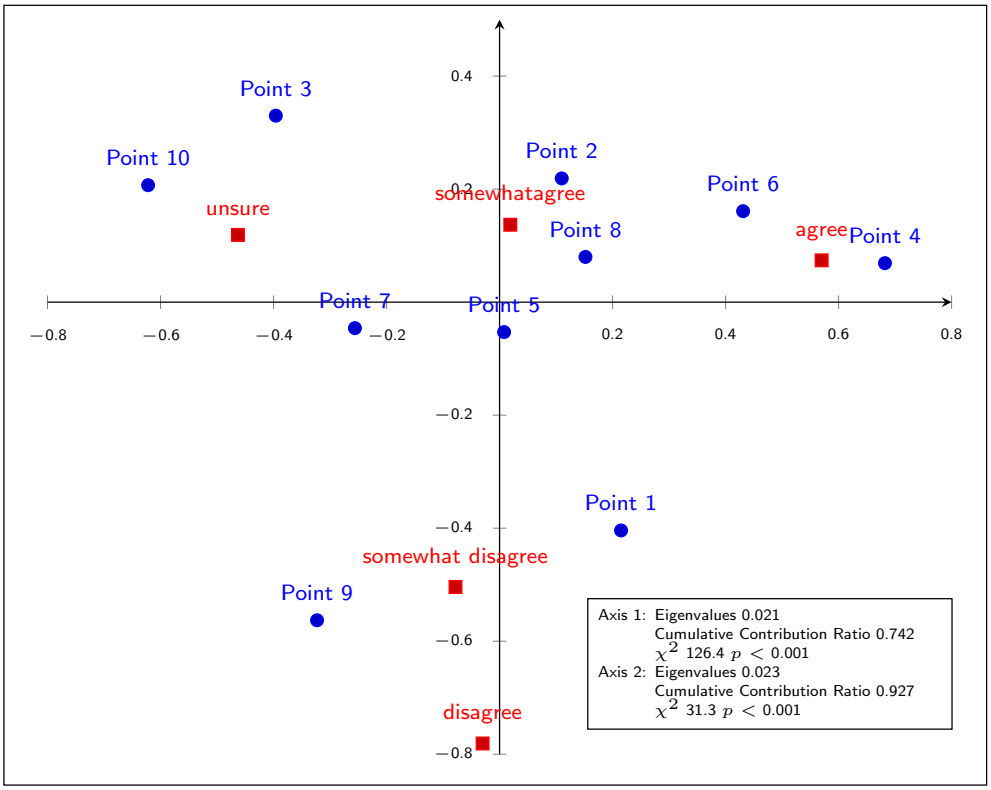


Figure 5. Relevance to the EUs 10-point plan to reduce dependence on Russian natural gas.

The vertical axis in the figure is concentrated within the range of 0.4 to −0.8, and the horizontal axis within the range of 0.7 to −0.7, so estimations are approximate. The cumulative contribution rate of each axis is 74.2% for the first axis, and 92.7% when the second axis is included, with the *p*-values of <1% obtained using the χ^2 test for both axes, indicating that they are statistically significant. The first axis can be interpreted as showing the support or lack of support for the items in the Action Plan, with the second axis showing the speed of introduction of measures related to renewable energy.

In the first quadrant, "Accelerating the introduction of new wind and solar power projects" and "Protecting vulnerable consumers against rising electricity prices" are associated with the response "Strongly agree". Additionally, "Replacing Russian gas imports to alternative sources" and "supporting energy efficiency in the building and industrial sectors" are associated with the response "Somewhat agree". The second quadrant shows that "Introducing a minimum gas storage obligation to enhance market resilience" and "Decarbonization through diversification of flexible systems and supply reduction" are associated with the response "Neither agree or disagree". In the third quadrant, "Temporary adjustments of thermostats by consumers" can be seen to be associated with the responses "Somewhat disagree" and "Strongly disagree". As outlined above, there is a general positive attitude towards plans to accelerate the introduction of new wind and solar power projects and to protect vulnerable consumers against high electricity prices. However, there is a more negative response towards passive plans, such as temporary adjustments to thermostats by consumers.

3.14. Reasons for Supporting or Not Supporting Coal-Fired Power Generation

Table 2 presents the aggregated results for the reasons for supporting or not supporting coal-fired power generation.

First, regarding the reasons for supporting coal-fired power generation, the most common opinion is "As a mix of energy sources including thermal power generation, hydropower, and renewable energy is necessary" (39.7%), followed by "As Germany and the EU are experiencing electricity shortages" (30.5%).

On the other hand, as for the reasons for not supporting coal-fired power generation, the most common reason is "As Germany should promote renewable energy instead" (36.0%), followed by reasons including "As coal-fired power generation has high CO_2 emissions and imposes a significant environmental burden during the generation process" (30.2%) and "As burning coal emits atmospheric pollutants that can lead to issues like asthma and acid rain" (29.3%).

Table 2. Reasons for supporting or opposing coal-fired power (multiple answers allowed).

	Items	Percent
Reasons for supporting	An energy mix combining thermal power, hydroelectric power and renewable energy is necessary	39.7
	Germany and the EU are experiencing electricity shortages	30.5
	Coal-fired electricity is cheaper than that produced by crude oil or natural gas	24.2
	There are coal reserves in Germany, providing a stable supply of energy	23.0
	Advances have been made in clean coal technology, significantly reducing air pollutants	12.7
	Other	1.2
	None of the above	9.5
Reasons for opposing	Germany should promote renewable energy	36.0
	Coal-fired power emits large amounts of CO_2 and has a large environmental impact	30.2
	Burning coal emits air pollutants that cause asthma, acid rain, etc	29.3
	Germany imports half of its coal from Russia, and it is necessary to reduce dependency on Russia	20.2
	Germany, as the chairing country of the G7 Climate, Energy and Environment Ministers' Meeting, is responsible for compiling a joint statement on phasing out coal-fired power generation by 2035	15.8

Table 2. *Cont.*

	Items	Percent
Reasons for opposing	Many financial institutions in the EU are reluctant to invest in coal-fired power, making it difficult to build new power plants	10.7
	Decarbonization, which is a further step forward from "low carbonization", is progressing around the world	9.5
	other	0.3
	None of the above	10.2

3.15. Reasons for Supporting or Not Supporting Solar Power Generation

Table 3 shows the aggregated results regarding reasons for supporting or not supporting solar power generation.

Table 3. Reasons for supporting or opposing solar power (multiple answers allowed).

	Items	Percent
Reasons for supporting	The power generation efficiency is constant regardless of size, and the system can be installed on small areas such as rooftops	45.7
	It can be used as an emergency power source through the use of storage batteries	35.5
	It improves the country's energy self-sufficiency and energy security	32.0
	It generates income from the sale of electricity	21.0
	Mechanical breakdowns are less likely to occur and high-performance panels are becoming cheaper year by year	14.8
	Other	0.3
	None of the above	8.2
Reasons for opposing	Solar power is dependent on the seasons and weather, therefore unstable and unreliable	30.0
	The equipment is too easily damaged by bad weather (storms, etc.)	29.3
	Solar panels can damage the environment, taking up valuable land and creating problems with reflected light	25.0
	Installation and land costs are high and the cost per unit of electricity generated is relatively high.	15.2
	There is an increased risk of heat stroke for residents in the vicinity of solar farms	11.3
	Damaged panels may lead to leaking of lead or other toxic heavy metals	11.3
	Other	0.8
	None of the above	13.0

First, regarding the reasons for supporting solar power generation, the most common reason is "As it has consistent power generation efficiency regardless of scale and can be installed in small spaces such as rooftops" (45.7%), followed by reasons including "As it can serve as an emergency power source through the use of batteries" (35.5%) and "As it improves the country's energy self-sufficiency, which is advantageous for energy security" (32.0%).

On the other hand, as for the reasons for not supporting solar power generation, the most common reason is "As solar power generation output depends on sunlight and is unstable" (30.0%), followed by "As there is the possibility for damage to the generation facilities by typhoons, earthquakes, fires, and so on" (29.3%).

3.16. Reasons for Supporting or Not Supporting Wind Power Generation

Table 4 presents the aggregated results regarding reasons for supporting and not supporting wind power generation.

First, regarding the reasons for supporting wind power generation, the most common reason is "As it does not emit greenhouse gases during electricity generation" (36.3%), followed by reasons that include "As it improves the country's energy self-sufficiency and can be used as an independent power source, even in remote islands" (32.7%), "As no fuel is required for operation, resulting in lower generation costs and relatively easy

commercialization" (29.8%), and "As it can convert energy into electricity more efficiently than other renewable energy sources" (28.3%).

On the other hand, as for the reasons for not supporting wind power generation, the most common reason is "As strong winds and other factors can lead to damage to wind turbines" (30.2%), followed by "As there is a potential to damage the natural landscape" (27.5%).

3.17. Reasons for Supporting or Not Supporting Wind Power Generation

Table 4 presents the aggregated results regarding reasons for supporting or not supporting wind power generation.

Table 4. Reasons for supporting or opposing wind power (multiple answers allowed).

	Items	Percent
Reasons for supporting	It improves the country's energy self-sufficiency and energy security, particularly in remote areas	32.7
	It does not emit greenhouse gases during power generation	36.3
	No fuel is needed for operation, the cost of power generation is low and commercialization is relatively easy	29.8
	Energy can be converted into electricity with higher efficiency than other renewable energies	28.3
	Wherever the wind blows constantly, power can be generated at any time of day or night	19.8
	Germany is said to be one of the best places for wind power	10.2
	Other	0.5
	None of the above	7.7
Reasons for opposing	Strong winds (storms, etc.) may cause damage to wind turbines	30.2
	There is a possibility of damaging the natural landscape	27.5
	Fluctuations in wind speed cause fluctuations in voltage and power factor, which can result in unstable and inconsistent energy supply	23.3
	There is a high risk of birds being killed or injured by collisions with rotating wind turbines	21.8
	It may cause noise damage and health hazards due to ultrasound in the surrounding area	16.5
	The inspection and repair costs of wind turbines are increasing year by year	8.7
	Other	0.5
	None of the above	13.7

4. Regression Analysis Results

In this section, we present the results based on analysis methods including ordinal logistic models and binomial logistic models. Table 5 shows the estimated results regarding energy choices in Germany.

Table 5. Results for ordinal logistic regression analysis for energy choice and food security.

Variable	Support for Natural Gas											
	Evaluation		**Strongly Disagree**		**Somewhat Disagree**		**Neither**		**Somewhat Agree**		**Strongly Agree**	
	Coef	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**
NPP × Male	−0.368 ***	0.116	0.072 ***	0.026	0.043 ***	0.014	0.030 ***	0.008	−0.051 ***	0.019	−0.094 ***	0.027
NPP × Children	0.231 **	0.113	−0.035 **	0.016	−0.027 **	0.013	−0.029 *	0.016	0.022 **	0.009	0.069 *	0.036
Age	−0.323 **	0.134	0.054 **	0.023	0.038 **	0.017	0.036 **	0.016	−0.037 **	0.016	−0.092 **	0.038
cut1 to cut4	−2.485	0.487	−1.981	0.484	−1.182	0.481	−0.343	0.480				
Likelihood ratio	−844.9		AIC	1818.2		χ^2	14.7		Pseudo R^2	0.009		
Variable	Support for coal-fired power											
	Evaluation		strongly disagree		somewhat disagree		neither		somewhat agree		strongly agree	
	Coef	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE
Male	0.179 **	0.087	−0.023 **	0.011	−0.026 **	0.013	−0.020 *	0.011	0.032 **	0.016	0.037 **	0.018
Household	0.285 **	0.085	−0.037 **	0.012	−0.041 **	0.013	−0.031 **	0.011	0.051 **	0.016	0.057 **	0.017
cut1 to cut4	−1.185	0.111	−0.553	0.099	0.611	0.099	1.489	0.111				
Likelihood ratio	−859.3		AIC	1701.8		χ^2	22.4		Pseudo R^2	0.013		
Variable	Support for solar power											
	Evaluation		strongly disagree		somewhat disagree		neither		somewhat agree		strongly agree	
	Coef	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE
NPP Location	0.771 ***	0.247	−0.081 ***	0.028	−0.086 ***	0.028	−0.124 ***	0.038	0.027 **	0.011	0.264 ***	0.083
Income	0.118 **	0.048	−0.012 **	0.005	−0.014 **	0.006	−0.020 **	0.008	0.005 **	0.003	0.040 **	0.016
NPP × Education	−0.533 **	0.222	0.057 **	0.025	0.063 **	0.027	0.089 **	0.038	−0.025 **	0.013	−0.183 **	0.076
Education	0.378 ***	0.145	−0.040 **	0.016	−0.044 **	0.018	−0.063 **	0.025	0.018 **	0.008	0.130 ***	0.050
cut1 to cut4	−0.990	0.173	−0.439	0.165	0.425	0.164	1.185	0.168				
Likelihood ratio	−876.0		AIC	1734.6		χ^2	6.4		Pseudo R^2	0.004		

Variable	Support for Natural Gas											
	Evaluation		**Strongly Disagree**		**Somewhat Disagree**		**Neither**		**Somewhat Agree**		**Strongly Agree**	
	Coef	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**	**dy/dx**	**SE**
Variable	Support for wind power											
	Evaluation		strongly disagree		somewhat disagree		neither		somewhat agree		strongly agree	
	Coef	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE
Income	0.116 **	0.046	−0.016 **	0.007	−0.011 **	0.005	−0.018 **	0.008	0.009 **	0.004	0.037 **	0.015
cut1 to cut4	−1.305	0.093	−0.871	0.083	0.073	0.077	0.823	0.081				
Likelihood ratio	−876.0		AIC	1762.0		χ^2	6.4		Pseudo R^2	0.004		

note1 = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. note2 = Pseudo R^2 denotes McFadden Pseudo R^2. note3 = Backward stepwise selection was used to remove explanatory variables above the 20% significance level, so that only variables that were significant at the 1–10% significance level remained, until optimal estimation results were obtained. Therefore, the estimation results in the table show only the explanatory variables that were significant. note4 = cut represents multiple responses; cut1 shows the thresholds for "strongly disagree" and "somewhat disagree", cut2 shows the thresholds for "somewhat disagree" and "neither agree nor disagree", cut3 shows the thresholds for "neither agree nor disagree" and "somewhat agree" thresholds, and cut4 indicates "somewhat agree" and "strongly agree" thresholds. note5 = Households, education, age, and income are logarithmically transformed.

4.1. Ordinal Logistic Regression Analysis

4.1.1. Logistic Regression Results for "Thermal Power Generation Using Natural Gas"

An examination of the regression coefficients reveals that the coefficient for NPP state × Children (0.231) is positive, whereas the coefficients for NPP state × Male (−0.368) and NPP state × Age (−0.323) are negative. As the estimation parameters of the ordinal logistic model cannot be compared directly, they are interpreted in terms of marginal effects.

First, for NPP state × Children, the marginal effect is the largest for "Strongly Agree" (0.069). On the other hand, for NPP state × Male and "NPP state × Age", the marginal effects are significant for "Strongly Disagree" (0.072 and 0.054, respectively). In other words, individuals with children in NPP states tend to support thermal power generation using inexpensive natural gas, whereas males and older individuals living in NPP states tend not to support power generation dependent on Russia.

4.1.2. Logistic Regression Results for "Coal-fired Power Generation"

An examination of the regression coefficients shows that those for Male and Age (0.179 and 0.285, respectively) are positive.

When looking at the marginal effects for males, we see that the largest marginal effects are for "Strongly agree" (0.057) and "Somewhat agree" (0.051). Similarly, for older individuals, significant marginal effects are observed for "Strongly agree" (0.037) and "Somewhat agree" (0.032). In 1985, Germany was the world's second-largest electricity producer behind the US, supplying 312.88 TWh of electricity from coal (according to BP statistics). This fact explains why males and older individuals tended to support coal-fired power generation.

4.1.3. Logistic Regression Results for "Solar Power Generation"

The regression coefficients here show that the coefficients for "NPP state", "Income", and "Education" are positive (0.771, 0.118, and 0.378, respectively). On the other hand, the coefficient for NPP state × Education is negative (−0.533). When we examine the effect of education on NPP state, the coefficient value is 0.378 + (−0.533) = −0.155. In other words, more educated individuals in NPP states tend not to support solar power generation.

An examination of the marginal effects shows that residents of NPP states have the largest marginal effect for "Strongly agree" (0.264). This is the highest value among all estimation effects and indicates that residents of NPP states, in particular, are strongly supportive of enhancing Germany's electricity supply through solar power generation. Furthermore, the marginal effects for individuals with higher education and income levels are large for "Strongly agree" (0.130 and 0.040, respectively). Conversely, among residents of NPP states with higher education levels, there are substantial marginal effects for "Strongly disagree" (0.057) and "Somewhat disagree" (0.063). In other words, residents of NPP states tend to support solar power generation, but more educated individuals living in these states are less supportive of solar power generation.

4.1.4. Logistic Regression Results for "Wind Power Generation"

An examination of the regression coefficients shows that the coefficient for "Income" is positive (0.116). When we look at the marginal effects, individuals with higher incomes have a large marginal effect for "Strongly agree" (0.037). In other words, individuals with higher incomes in Germany are more supportive of wind power generation, even if electricity costs are high.

4.2. Results from the Binomial Logistic Regression Analysis

Results for the 10-Point Plan to Reduce EU Dependence on Russian Natural Gas

Table 6 shows the results for the 10-point plan to reduce EU dependence on Russian natural gas. Note that the results for Item 9 have been omitted as no significant results were obtained for the explanatory variables.

The results for Item 1 showed that the coefficient for Male (−0.203) was negative, while the coefficients for NPP state × Income (0.124) and NPP state × Age (0.328) were positive. In other words, females and higher income or older individuals in states with nuclear power plants did not support entering into new gas supply agreements with Russia.

In the results for Item 2, higher income individuals (0.031) and more educated individuals in NPP states (0.178) were in favor of importing natural gas from sources other than Russia.

In the results for Item 4, it was found that females (−0.189), individuals with fewer household members (−0.196), and higher income individuals (0.175) are in favor of accelerating the introduction of new wind and solar power projects.

In the results for Item 5, it was found that males (0.207) and higher income individuals (0.157) support maximizing the use of existing dispatchable resources with lower emissions, such as bioenergy and nuclear power. Additionally, the coefficient for Age is 0.736, and the coefficient for NPP state × Age is −0.743. Therefore, in NPP states, the overall effect is −0.007, indicating that there is a tendency for older individuals in such states to oppose maximizing the use of existing electricity resources, although this tendency is minimal. On the other hand, regarding children, the coefficient for NPP state is 0.436, indicating that individuals with children in such states are in favor of maximizing the use of existing electricity resources.

The results for Item 6 demonstrate that females (−0.287), more educated individuals (0.381), and residents with more household members in NPP states (0.310) or those without children (−0.419) are in favor of protecting low-income vulnerable consumers and socially disadvantaged individuals against high electricity prices.

In the results for Item 7, it was found that more educated individuals (0.447) are in favor of accelerating the switch from gas boilers to heat pumps.

The results for Item 8 suggest that females (−0.215) and individuals with higher incomes (0.319) are in favor of supporting energy efficiency in the building and industrial sectors.

The results for Item 10 indicate that younger individuals (−0.605) and individuals with no children in NPP states (−0.340) are in favor of decarbonization through the diversification of electricity system to be more flexible in response to electricity demands and reducing natural gas supplies. Here, the coefficient for Age (−0.605) is negative, while the coefficient for NPP State × Age (0.154) is positive. Thus, in NPP states, the result is −0.605 + 0.154 = −0.451, indicating that, in such states, there is a tendency for individuals to support the reduction of natural gas supplies in order to achieve decarbonization as they age.

4.3. Results for Supporting or Not Supporting Coal-Fired Power Generation

Table 7 shows the results regarding the reasons for supporting and not supporting coal-fired power generation. First, we present the results for the reasons for supporting coal-fired power generation.

Table 6. Results of binomial regression analysis for the EU's 10-point plan to reduce dependence on Russian gas.

Point 1: No New Contracts			**Point 2: Alternative Sources**			**Point 3: Minimum Storage Requirements**		
Variable	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**
Male	−0.203 *	0.113	Income	0.031 **	0.014	NPP × Children	−0.316 *	0.182
NPP × Income	0.124 **	0.062	NPP × Education	0.178 **	0.090	Children	0.377 ***	0.141
Age	0.328 *	0.172						
Constant	−1.784 ***	0.619	Constant	−0.620 ***	0.095	Constant	−0.975 ***	0.079
Likelihood ratio	−342.0 ***		Likelihood ratio	−384.3 ***		Likelihood ratio	−289.6 **	
χ^2	12.0		χ^2	9.56		χ^2	7.15	
Pseudo R^2	0.017		Pseudo R^2	0.012		Pseudo R^2	0.012	
Point 4: New wind & solar projects			Point 5: Expand bio & nuclear energy			Point 6: protect vulnerable consumers		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
Male	−0.189 *	0.109	Male	0.207 *	0.122	Male	−0.287 **	0.145
Income	0.175 ***	0.061	NPP × Age	−0.743 **	0.378	Education	0.381 **	0.187
Household Size	−0.196 *	0.109	Age	0.736 ***	0.262	NPP × Children	−0.419 *	0.245
			NPP location	2.634 *	0.175	NPP × Household	0.310 *	0.165
			NPP × Children	0.436 **	0.175			
			Income	0.157 **	0.068			
Constant	−0413 ***	0.126	Constant	−3.858 ***	0.951	Constant	−1.588 ***	0.229
Likelihood ratio	−375.3 ***		Likelihood ratio	−286.3 ***		Likelihood ratio	−200.0 ***	
χ^2	11.7		χ^2	25.0		χ^2	11.7	
Pseudo R^2	0.015		Pseudo R^2	0.042		Pseudo R^2	0.028	
Point 7: Accelerate heat pump installation			Point 8: Accelerate energy efficiency programs			Point 9: Accelerate decarbonization and efficiency programs		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
Education	0.447 ***	0.162	Male	−0.215 *	0.128	NPP × Children	−0.340 *	0.185
			Income	0.319 ***	0.076	NPP × Age	0.154 ***	0.042
						Age	−0.605 ***	0.212
						Education	−0.353 **	0.172
Constant	−1.401 ***	0.186	Constant	−1.308 ***	0.130	Constant	0.469	0.755
Likelihood ratio	−277.3 ***		Likelihood ratio	−261.4 ***		Likelihood ratio	−233.5 ***	
χ^2	8.0		χ^2	21.2		χ^2	22.5	
Pseudo R^2	0.014		Pseudo R^2	0.039		Pseudo R^2	0.046	

note1 = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. note2 = Where necessary, "NPP location" has been shortened to "NPP" for brevity.

First, the results for "Germany and the EU are experiencing electricity shortages" show that elderly people in NPP states (0.049) are likely to support coal-fired power generation due to electricity shortages in Germany and the EU.

Second, regarding "An energy mix combining thermal power, hydroelectric power, and renewable energy is necessary", young people (−0.255) and higher income individuals (0.136) in NPP states support coal-fired power generation as they believe in the need for an energy mix.

Third, regarding "Coal-fired electricity is cheaper than that produced by crude oil or natural gas", younger individuals (−0.302), males (0.366), higher income individuals (0.221) living in NPP states, and those with smaller household members (−0.341) support coal-fired power generation as it can generate electricity economically and cheaply. Furthermore, younger individuals in NPP states (−0.108) are even more supportive.

Fourth, regarding "There are coal reserves in Germany, providing a stable supply of energy", the coefficients for NPP state × Education (0.405) and NPP state × Household size (0.302) show positive values. This means that NPP states with a higher proportion of more educated individuals and larger household sizes tend to support coal-fired power generation as coal offers a stable energy supply. Furthermore, the coefficient for Age (0.411) is positive, while the coefficient for NPP states × Age (−0.224) is negative. Therefore, in NPP states, the sum of these coefficients, 0.411 + (−0.224), gives 0.187, indicating that there is a tendency for the support for coal-fired power generation to decrease with age, even though a stable supply can be expected, in such states.

Fifth, regarding "Advances have been made in clean coal technology, significantly reducing air pollutants", higher income individuals (0.167) living in NPP states tend to support coal-fired power generation due to the recent significant reductions in air pollutants from coal-fired power plants. However, the coefficient for the Number of children (0.393) is positive, while the coefficient for NPP states × Number of children (−0.488) is negative. Therefore, in NPP states, the coefficient is 0.393+(−0.488) = −0.095,

indicating that individuals with children in NPP states tend not to support coal-fired power generation, even if air pollutants are significantly reduced, although this tendency is small.

Table 7. Results of binomial regression analysis for perception of coal-fired power.

Reasons for Supporting								
Electricity Shortages			**Energy Mix is Necessary**			**Clean Coal Technology**		
Variable	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**
NPP × Age	0.049 *	0.030	NPP × Age	−0.255 *	0.141	NPP × Income	0.167 **	0.085
			Income	0.136 **	0.057	Children	0.393 **	0.167
						NPP × Children	−0.488 ***	0.236
Constant	−0.593 ***	0.074	Constant	−0.390 ***	0.090	Constant	−1.325 ***	0.106
Likelihood ratio	−367.7 *		Likelihood ratio	−398.8 **		Likelihood ratio	−224.4 *	
χ^2	9.5		χ^2	8.44		χ^2	7.3	
Pseudo R^2	0.004		Pseudo R^2	0.011		Pseudo R^2	0.016	
Reasons for supporting						Reasons for opposing		
Coal reserves			Cheaper than other fossil fuels			Germany should support RE		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
NPP × Age	−0.224 **	0.087	NPP × Age	−0.108 *	0.062	NPP × Household	−0.217 *	0.129
NPP × Education	0.405 *	0.230	NPP × Household	−0.341 *	0.180	NPP × Income	0.224 ***	0.078
Age	0.411 **	0.188	Age	−0.302 *	0.181			
NPP × Household	0.302 *	0.177	NPP × Income	0.221 **	0.107			
			NPP × Male	0.366 **	0.178			
Constant	−2.158 ***	0.671	Constant	0.465	0.639	Constant	−0.408 ***	0.066
Likelihood ratio	−318.8 **		Likelihood ratio	−322.4 ***		Likelihood ratio	−387.8 **	
χ^2	9.5		χ^2	18.8		χ^2	8.4	
Pseudo R^2	0.015		Pseudo R^2	0.028		Pseudo R^2	0.011	
Reasons for opposing								
EU reluctance to invest in coal			CO_2 and environmental impact			Reduce dependence on Russia		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
Education	0.544 ***	0.201	Education	0.489 ***	0.143	NPP × Male	−0.313 *	0.181
NPP × Age	−0.770**	0.323	NPP location	1.734 *	0.949	NPP × Household	−0.368 **	0.163
NPP location	2.956 ***	1.139	NPP × Age	−0.475 *	0.257	Age	0.308 *	0.184
			NPP × Household	−0.292 *	0.165	Age	0.308 *	0.184
						Education −0.371 **	0.169	
						Income	0.132 *	0.067
Constant	−1.962 ***	0.248	Constant	−0.950 ***	0.169	Constant	−1.733 **	0.683
Likelihood ratio	−195.1 ***		Likelihood ratio	−356/9 ***		Likelihood ratio	−293.5 **	
χ^2	17.1		χ^2	20.9		χ^2	16.3	
Pseudo R^2	0.042		Pseudo R^2	0.028		Pseudo R^2	0.027	
Reasons for opposing								
Coal emits pollutants			decarbonization is progressing globally			Germany has a leadership role		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
Education	0.320 **	0.140	Income	0.144 *	0.086	Education	0.499 ***	0.167
			Education	0.639 ***	0.222			
Constant	−0.882 ***	0.159	Constant	−2.216 ***	0.265	Constant	−1.540 ***	0.195
Likelihood ratio	−360.4 **		Likelihood ratio	−180.3 ***		Likelihood ratio	−257.5 ***	
χ^2	5.3		χ^2	16.1		χ^2	9.4	
Pseudo R^2	0.007		Pseudo R^2	0.043		Pseudo R^2	0.018	

note1 = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. note2 = Where necessary, "NPP location" has been shortened to "NPP" for brevity.

Next, we present the results regarding the reasons for not supporting coal-fired power generation.

First, the results for "Germany should promote renewable energy" indicate that individuals with higher incomes (0.224) and those with fewer household members in NPP states (−0.217) do not support coal-fired power generation, as they feel that Germany should instead promote renewable energy.

Second, regarding "Burning coal emits air pollutants that cause asthma, acid rain, and so on", individuals with higher levels of education (0.320) do not support coal-fired power generation as burning coal emits air pollutants that can lead to conditions such as asthma and acid rain.

Third, regarding "Coal-fired power generation emits large amounts of CO_2 and has a large environmental impact", individuals from NPP states (1.734) and those with higher levels of education (0.489) do not support coal-fired power generation due to its significant environmental impact. Within NPP states, the coefficients for Household Size and Age of

−0.292 and −0.475, respectively, were observed. In such states, households with a larger number of members and older individuals show support.

Fourth, with regard to "Germany imports half of its coal from Russia, and it is necessary to reduce dependency on Russia", older individuals (0.308) and those with higher incomes (0.132), as well as females (−0.313) and individuals with smaller households (−0.368) living in NPP states, do not support coal-fired power generation as it is necessary for Germany to reduce its dependency on Russia. Furthermore, the coefficient for Education (−0.371) is negative, while the coefficient for NPP state × Education (0.418) is positive. Therefore, in NPP state, the combined coefficient is −0.371 + 0.418 = 0.047. For this reason, as educational standards rise in NPP states, there is a tendency for greater support for coal-fired power generation in order to promote "de-Russianization", but this tendency is small.

Fifth, regarding "Many financial institutions in the EU are reluctant to invest in coal-fired power generation, making it difficult to build new power plants", individuals with higher levels of education (0.544) do not support coal-fired power generation because many financial institutions in the EU do not providing funding for coal-fired power generation, making it difficult to establish new power plants. Additionally, the coefficient for NPP state (2.956) is a positive value, and the coefficient for NPP state × Age (−0.770) is a negative value. Therefore, residents in NPP states tend not to promote coal-fired power generation because it is difficult to build new thermal power plants, but residents in NPP states tend to show greater support for coal-fired power generation with age.

Sixth, regarding "Decarbonization, which is a further step forward from low carbonization", individuals with higher incomes (0.144) and those with higher levels of education (0.639) do not support coal-fired power generation as decarbonization is advancing on a global level.

Seventh, regarding "Germany, as the chairing country of the G7 Climate, Energy and Environment Ministers Meeting, is responsible for compiling a joint statement on phasing out coal-fired power generation by 2035", individuals with higher levels of education (0.499) do not support coal-fired power generation as Germany has the responsibility, as chair of the G7, to coordinate a joint statement on the phasing out of coal-fired power generation.

4.3.1. Results Regarding Reasons for Supporting or Not Supporting Solar Power Generation

Table 8 presents the results regarding the reasons for supporting and not supporting solar power generation. First, we show the results for the reasons to promote solar power generation. We also analyzed "It generates income from the sale of electricity", but no significant results were obtained with the explanatory variables, so we omitted it.

First, regarding "It improves the country's energy self-sufficiency and energy security", older individuals (0.285) and those with higher levels of education (0.295), as well as individuals with fewer household members in NPP states (−0.287) support solar power generation as it enhances national energy self-sufficiency and is advantageous for energy security. Additionally, the coefficient for Number of children (−0.316) is negative, while the coefficient for NPP state × Children (0.505) is positive. Therefore, the coefficient in NPP states is −0.316 + 0.505 = 0.189. Thus, a positive effect was observed for individuals with children in NPP states as solar power generation is considered more advantageous for energy security and is thus supported to a greater extent.

Second, with regard to "The power generation efficiency is constant regardless of size, and the system can be installed on small areas such as rooftops", individuals with higher incomes (0.128) and younger individuals (−0.457) were found to support solar power generation as it can be installed in small spaces such as rooftops.

Third, regarding "It can be used as an emergency power source through the use of storage batteries", individuals with higher incomes (0.194) and older individuals (0.154) in NPP states, as well as those without children (−0.377), support solar power generation as solar power can serve as an emergency power source when coupled with the use of storage

batteries. However, females in NPP states show a negative value (−0.376). Additionally, the coefficient for Income (0.194) is a positive value, whereas the coefficient for the NPP state × Income (−0.248) is a negative value. Therefore, in NPP states the coefficient is 0.194 + (−0.248) = −0.054, indicating that in NPP states, as incomes rise, there is a tendency for residents not to support nuclear power plants, even though they could be used as an emergency power source, but this tendency is small.

Table 8. Results of binomial regression analysis for perception of solar power.

Reasons for Supporting								
National Energy Security			**Scaleable Technology**			**Emergency Power when Combined with Batteries**		
Variable	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**
NPP × Children	0.505 **	0.249	Age	−0.467 ***	0.163	NPP × Male	−0.376 **	0.166
Children	−0.316 **	0.143	Income	0.128 **	0.056	NPP × Children	−0.377 **	0.162
Age	0.285 *	0.167				Income	0.194 **	0.077
NPP × Household	−0.287 *	0.150				NPP × Income	−0.248 **	0.116
Education	0.295 **	0.136			b	NPP × Age	0.154 ***	0.054
Constant	−1.650 ***	0.622	Constant	1.388 **	0.577	Constant	−0.596 ***	0.121
Likelihood ratio	−369.0 **		Likelihood ratio	−407.4 ***		Likelihood ratio	−381.4 ***	
χ^2	14.3		χ^2	12.4		χ^2	17.7	
Pseudo R^2	0.019		Pseudo R^2	0.015		Pseudo R^2	0.023	
Reasons for supporting						Reasons for opposing		
Less maintenance & cheaper supplies			Dependent on weather & seasons			unit costs are relatively high		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
NPP × Children	−0.319 *	0.179	NPP location	0.183 *	0.108	Education	−0.411 **	0.168
Education	0.615 ***	0.179				Children	−0.221 *	0.131
Constant	−1.662 ***	0.210	Constant	−0.610 ***	0.074	Constant	−1.386 ***	0.197
Likelihood ratio	−244.1 ***		Likelihood ratio	−365.1 *		Likelihood ratio	−251.0 **	
χ^2	15.7		χ^2	2.9		χ^2	8.67	
Pseudo R^2	0.031		Pseudo R^2	0.004		Pseudo R^2	0.017	
Reasons for opposing								
environmental impact of installations			risk of heat stroke			easily damaged by storms, etc		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
NPP × Children	−0.356 *	0.216	NPP × Income	−0.198 **	0.085	NPP × Household	−0.375 *	0.212
Children	0.260 *	0.150				NPP × Age	−0.958***	0.274
NPP × Education	0.243 **	0.117				NPP location	3.160 ***	0.984
						NPP × Children	0.513 **	0.208
						NPP × Income	0.232 **	0.098
Constant	−0.836 ***	0.095	Constant	−1.112 **	0.077	Constant	−0.529 ***	0.073
Likelihood	−334.7		Likelihood ratio	−209.2 **		Likelihood ratio	−352.0 ***	
χ^2	5.3		χ^2	5.74		χ^2	22.1	
Pseudo R^2	0.008		Pseudo R^2	0.014		Pseudo R^2	0.030	

note1 = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. note2 = Where necessary, "NPP location" has been shortened to "NPP" for brevity.

Fourth, concerning "Mechanical breakdowns are less likely to occur and high-performance panels are becoming cheaper year by year", individuals with higher levels of education (0.615) and those without children (−0.319) in NPP state support solar power generation as high-performance panels are becoming more affordable.

Next, we present the results regarding the reasons for not supporting solar power generation.

First, concerning "Solar power is dependent on the seasons and weather, therefore unstable and unreliable", the coefficient for residents in NPP state (0.183) is positive. This means that residents in such states do not support solar power generation as they perceive it as providing unstable power generation output.

Second, regarding "The equipment is too easily damaged by bad weather", the coefficients for NPP state are as follows: 3.160 for NPP state, −0.375 for NPP state × Household Size, −0.958 for NPP state × Age, 0.513 for NPP state × Children, and 0.232 for NPP state × Income. Therefore, it was observed that only in NPP state, the effects were observed for Number of household members, Age, Children, and Income. In NPP state, individuals with children or higher incomes do not support solar power generation, but those with larger households or older individuals tend to support it.

Third, regarding "There is an increased risk of heat stroke for residents in the vicinity of solar farms", individuals with lower incomes in NPP state (−0.198) do not support solar power generation due to the increased risk of heat stroke.

Fourth, with regard to "Installation and land costs are high, and the cost per unit of electricity generated is relatively high", individuals without children (−0.211) and those with higher levels of education (0.411) do not support solar power generation because of the high initial costs and relatively high cost per unit of electricity generated.

4.3.2. Results Regarding Reasons for Supporting or Not Supporting Wind Power Generation

Table 9 presents the results for the reasons to promote and not wind power generation. To begin, we show the results for the reasons to promote wind power generation.

First, concerning "It improves the country's energy self-sufficiency and energy security, particularly in remote areas", individuals with higher incomes (0.166) support wind power generation as it enhances domestic energy self-sufficiency and can serve as an independent power source, particularly in remote areas such as islands. Additionally, it should be noted that the coefficient for NPP state (2.150) is positive, while the coefficient for NPP state × Age (−0.584) is negative. Thus, in NPP states, wind power generation is supported as it can serve as an independent power source, particularly in remote areas like islands, with younger individuals also supporting wind power generation.

Second, with regard to "It does not emit greenhouse gases during power generation", females (−0.282) and older individuals (0.133) in NPP states support wind power generation as it does not emit greenhouse gasses during power generation. Additionally, the coefficient for Income (0.203) is positive, while the coefficient for NPP state × Income (−0.284) is negative. Therefore, in NPP states, the coefficient is −0.081 (−0.284 + 0.203 = −0.081). In these states, there is a tendency to support wind power generation as income increases, regardless of greenhouse gas emissions, but this tendency is small.

Third, regarding "No fuel is needed for operation, the cost of power generation is low, and commercialization is relatively easy", individuals with higher incomes (0.112) support wind power generation because of its low generation cost and relative ease of commercialization.

Fourth, regarding "Energy can be converted into electricity with higher efficiency than other renewable energies", individuals with higher incomes (0.164) and those without children (−0.254) support wind power generation because wind power has higher efficiency in converting energy into electricity compared to other renewable energy sources. On the other hand, the coefficient for NPP state (0.411) is positive, with the coefficient for NPP state × Household Size (−0.412) also positive. In such states, wind power generation is supported because of its high efficiency in converting energy into electricity, even among individuals with fewer household members.

Fifth, regarding "Wherever the wind blows constantly, power can be generated at any time of day or night", individuals with higher incomes (0.620) and those without children (−0.212) support wind power generation as wind power can generate electricity at any time, including during the night, as long as there is a constant wind supply.

Sixth, with regard to "Germany is said to be one of the best places for wind power", women (−0.292) support wind power generation because Germany is the most appropriate place for wind power generation.

Next, we present the results regarding the reasons for not supporting wind power generation.

First, with regard to "Fluctuations in wind speed cause fluctuations in voltage and power factor, which can result in unstable and inconsistent energy supply", individuals with higher levels of education (0.240) do not support wind power generation because they believe that fluctuations in wind speed may lead to variations in voltage and power, potentially resulting in unstable and inconsistent energy supply.

Second, regarding "Strong winds may cause damage to wind turbines", high-income individuals in NPP states (0.197) do not support wind power generation as they perceive the risk of wind turbines being damaged by strong winds.

Table 9. Results of binomial regression analysis for perception of wind power.

Reasons for Supporting								
National Energy Security			**No GHG Emissions**			**Efficient Compared to other RE**		
Variable	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**	**Variable**	**Coef.**	**SE**
NPP × Age	−0.584 **	0.246	NPP × Income	−0.284 **	0.116	Income	0.164 ***	0.062
NPP location	2.150 **	0.881	Income	0.203 **	0.079	Children	−0.254 **	0.123
Income	0.166 ***	0.059	NPP × Male	−0.282 *	0.163	NPP location	0.411 **	0.180
			NPP × Age	0.133 **	0.052	NPP × Household	−0.412	0.175
Constant	−0.693 ***	0.105	Constant	−0.612 ***	0.123	Constant	−0.719 ***	0.117
Likelihood ratio	−372.4 ***		Likelihood ratio	−387.5 ***		Likelihood ratio	−347.3 ***	
χ^2	13.3		χ^2	11.3		χ^2	20.6	
Pseudo R^2	0.018		Pseudo R^2	0.014		Pseudo R^2	0.029	
Reasons for supporting								
no fuel necessary, easily commercialised			24 h power generation			Germany is an ideal location		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
Income	0.112 *	0.059	Education	0.620 ***	0.165	Male	−0.292 **	0.146
			Children	−0.212 *	0.123			
Constant	−0.671 ***	0.092	Constant	−1.438 ***	0.194	Constant	−1.159 ***	0.087
Likelihood ratio	−363.8 *		Likelihood ratio	−290.2 ***		Likelihood ratio	−195.2 ***	
χ^2	3.71		χ^2	17.32		χ^2	4.12	
Pseudo R^2	0.005		Pseudo R^2	0.0029		Pseudo R^2	0.010	
Reasons for opposing								
reliant on wind			strong winds can cause damage			an eyesore		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
Education	0.240 *	0.141	NPP × Income	0.197 *	0.106	Income	0.138 **	0.062
						NPP × Household	−0.450 ***	0.162
						Age	−0.306 *	0.179
						NPP × Age	0.126 ***	0.048
Constant	−0.981 ***	0.160	Constant	−0.690 ***	0.107	Constant	0.276	0.627
Likelihood ratio	−342.5 *		Likelihood ratio	−324.5 *		Likelihood ratio	−346.6 ***	
χ^2	2.9		χ^2	2.9		χ^2	12.54	
Pseudo R^2	0.005		Pseudo R^2	0.005		Pseudo R^2	0.018	
Reasons for opposing								
Ultrasound health concerns			bird collisions			Inspection & increasing repair costs		
Variable	Coef.	SE	Variable	Coef.	SE	Variable	Coef.	SE
NPP × Household	−0.235 *	0.120	Age	−0.318 *	0.183	NPP × Education	0.691 **	0.302
Education	0.707 ***	0.174	Education	0.306 **	0.149	NPP × Age	−0.196 *	0.105
Constant	−1.662 ***	0.209	Constant	0.024	0.667	Constant	−1.395 ***	0.100
Likelihood ratio	−257.9 ***		Likelihood ratio	−311.2 **		Likelihood ratio	−173.9 *	
χ^2	21.7		χ^2	7.36		χ^2	5.86	
Pseudo R^2	0.040		Pseudo R^2	0.012		Pseudo R^2	0.017	

note1 = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. note2 = Where necessary, "NPP location" has been shortened to "NPP" for brevity.

Third, with regard to "There is a possibility of damaging the natural landscape", individuals with higher incomes (0.138) and those with fewer household members in NPP states (−0.450) do not support wind power generation due to the potential for harm to the natural landscape. Additionally, the coefficient for Age (−0.306) is negative, while the coefficient for NPP state × Age (0.126) is positive. Therefore, in NPP states, the combined coefficient is −0.180 (−0.306 + 0.126 = −0.180). For this reason, in the NPP states, individuals tend not to support wind power generation with increasing age as it damages the natural landscape.

Fourth, regarding "It may cause noise damage and health hazards due to ultrasound in the surrounding area", individuals with higher levels of education (0.707) and those with fewer household members in NPP states (−0.235) do not support wind power generation due to the perceived potential health risk.

Fifth, with regard to "There is a high risk of birds being killed or injured by collisions with rotating wind turbines", younger individuals (−0.318) and those with higher levels of education (0.707) do not support wind power generation because of the increased risk of birds colliding with the rotating wind turbines.

Sixth, regarding "The inspection and repair costs of wind turbines are increasing year by year", younger individuals in NPP states (−0.196) and those with higher levels of education (0.691) do not support wind power generation because they expect the inspection and repair costs of wind turbines will increase year by year.

5. Discussion

Verification of Hypotheses

In this section, prior to any discussion of the results, we will verify two hypotheses based on the estimation results from the ordinal logistic regression and binomial logistic regression analyses.

First, the null hypothesis H_0 "There are no differences in energy choices among Germans based on individual attributes" was rejected as the explanatory variables related to personal attributes were significant for the two equations for coal-fired power generation and wind power generation.

Second, the null hypothesis H_0 "There are no differences in energy choices among Germans based on whether they live in an NPP state or not" was rejected as the interaction terms related to NPP states were significant for the two equations for natural-gas-fired power generation and solar power generation.

Third, regarding the null hypothesis H_0 "There are no differences in the reasons for supporting or not supporting electricity power generation among Germans based on individual attributes" was generally rejected as the explanatory variables related to personal attributes were significant in (i) all 9 equations related to plans to reduce dependence on Russian natural gas, (ii) 9 of 12 equations related to coal-fired power generation (4 equations in favor, 5 equations against), (iii) 5 of 8 equations related to solar power generation (4 equations in favor, 1 equation against), and (iv) 10 of 12 equations related to wind power generation (6 equations in favor, 4 equation against).

Fourth, the null hypothesis H_0 "There are no differences in energy choices among Germans based on whether they live in an NPP state or not" was generally rejected as interaction terms related to NPP state were significant in (i) 6 of 9 equations related to plans to reduce dependence on Russian natural gas, (ii) 9 of 12 equations related to coal-fired power generation (5 equations in favor, 4 equations against), (iii) 6 of 8 equations related to solar power generation (3 equations in favor, 3 equations against), and (iv) 7 of 12 equations related to wind power generation (3 equations in favor, 4 equations against).

While there are significant differences observed between individuals living in NPP states and those in states without nuclear power plants in commission or decommissioned states, these effects are generally small. However, in NPP states: (1) there is a tendency for individuals to support a reduction of the natural gas supply and pursue decarbonization with age, but not necessarily support coal-fired power generation, even when a stable supply is expected; (2) higher education does not necessarily lead to support for solar power generation, although it is seen as advantageous for energy security among those with children, prompting their support; and (3) older individuals may not support wind power generation due to concerns about its impact on natural landscapes, among other factors. In NPP states, there are cases where statistically significant differences are observed compared to states without nuclear power plants in commission or states where they have been decommissioned. It seems that in NPP states, there is a greater understanding of the advantages and disadvantages of reducing natural gas and coal-fired power generation, as well as a focus on efficient energy choices, particularly in terms of support for solar and wind power generation.

6. Conclusions

In this paper, we have examined the impact of Russia's invasion of Ukraine on Germany's energy choices, revealing the following key points.

First, after the Russian invasion of Ukraine, approximately 70% of Germans expressed concerns about the shortage of oil and natural gas supplies, and around 60% were anxious about potential electricity shortages. Moreover, more than 50% of the population was found to be in favor of renewable energy sources such as solar and wind power, while approximately 50% supported natural-gas-fired power generation, and 40% supported coal-fired power generation. Germany has been transitioning away from nuclear power, but over 30% of the respondents opposed the shutdown of nuclear power plants. On the

other hand, roughly 50% of the respondents believed that the safety of nuclear power facilities should be ensured, and final disposal sites for high-level radioactive waste should be selected.

In Germany, as part of the action plan to reduce dependence on Russian natural gas, approximately 60% of the population supported acceleration of the introduction of new wind and solar power projects. They also supported measures to protect vulnerable consumers from electricity price spikes and to switch to natural gas importation from countries other than Russia. Regarding the reasons for supporting coal-fired power generation, some respondents cited the need for a diverse energy mix and concerns about electricity shortages. On the other hand, reasons against supporting coal-fired power generation included the belief that renewable energy sources would be sufficient and concerns about the environmental impact during the power generation process. For those in favor of supporting solar power generation, reasons included the flexibility of installation on rooftops and its potential as an emergency power source. Reasons against were related to its dependence on sunlight and its instability as a source. As for wind power generation, reasons for its support included its ability to generate electricity without greenhouse gas emissions, while the reasons against included concerns about potential damage to wind turbines in strong winds and other factors.

Based on the results from the ordinal logistic regression analysis, younger individuals and those residing in states with nuclear power plants were inclined to support a reduction in dependence on Russian natural gas. Additionally, males and older individuals tended to support coal-fired power generation, while higher income individuals supported solar and wind power generation. Residents in states with nuclear power plants in commission or states where they had been decommissioned expressed strong support for solar power generation, while those with a higher education level in such states did not readily support solar power generation due to environmental considerations.

The results of the binomial logistic regression analysis indicated that older individuals, those with a higher education level, and those with a higher income are inclined to support a reduction in dependence on Russian natural gas, and this is particularly true among the more affluent and more highly educated residents in states with decommissioned nuclear power plants. Additionally, wealthier individuals, older individuals, and those with children are more likely to support coal-fired power generation, but the more highly educated population did not endorse coal-fired power generation. Residents in NPP states varied in their preferences, with some supporting coal-fired power generation and others opposed. Furthermore, individuals without children, wealthier individuals, and the more highly educated population tended to support solar power generation. However, even within these demographics, some were aware of the failings of solar power and chose not to support it. Additionally, wealthier individuals were inclined to support wind power generation, but among the more highly educated population, there were those who were aware of the shortcomings of wind power and did not support it. Overall, even among the residents in NPP states, demographic-based differences in responses were observed regarding support for solar and wind power generation.

In sum, it is also true that Russia's invasion of Ukraine has led many people in Germany to support the use of existing power plants, including nuclear and coal-fired plants, if the alternative is dependence on Russian natural gas. Obrenovic et al. [46] argue that industrial performance can be maintained despite resource supply lines being damaged by crises with a combination of technological, organizational, and infrastructural innovation and diversification.

Three nuclear reactors that were operating in Germany were shut down on 15 April 2023. Given the energy crisis, the immediate dismantling of nuclear power plants has been controversial. Supporters of nuclear power argue that wind and solar power alone will not be enough to meet demand, and that the country will eventually have to revert to nuclear power[47]. However, as Steffen [15] notes, the crisis has led more and more people to try to reduce their dependence on Russian natural gas and give their support to policies

that accelerate and support the introduction of renewable energy. Hansen et al. [47] argue that it is possible for Germany to implement its goal of transitioning its energy system to 100% renewable energy in a cost-effective manner. While the average German wants to maximize the use of nuclear and coal-fired generation to compensate for the vulnerability of renewables during an energy crisis, it is not surprising that NPP states would want to reduce and decarbonize their natural gas and coal-fired generation. Understanding the pros and cons of solar and wind power will enable Germany to move forward with its energy mix and make efficient energy choices in accordance with the goals of the Energiewende.

In summary, it is true that the Russian invasion of Ukraine has led many people in Germany to support maximizing the use of existing power plants, including nuclear and coal-fired power plants, in order to be less reliant on Russian natural gas and coal-fired power generation.

Although Germany is used as a case study in this paper, one would expect that the energy crisis triggered by Russia's invasion of Ukraine would have resulted in higher energy prices around the world and a tendency to revert to nuclear and coal-fired power generation. However, as the results of the survey of German NPP states show, there are many proponents of decarbonization around the world. It seems that policy makers and stakeholders around the world, including Germany, should work towards an energy mix that takes decarbonization into account.

Future Challenges

In this research, we have closely analyzed the impact of the Russian invasion of Ukraine on Germany's energy choices. Finally, we will discuss future challenges. Since January 2023, electricity prices in Germany have doubled compared to those in November 2022. Subsequently, on 15 April 2023, there was a shutdown of nuclear power plants, after which electricity prices surged. In addition, as discussed, the German people have voiced both support and opposition to the complete elimination of nuclear power plants in the midst of the energy crisis, saying that it may be premature. As stated above, the survey sample size was the minimum required for the analysis to be performed, given budgetary constraints This can, however, lead to the possibility of heterogeneity of variance. In other words, among the statistical errors, we may have misjudged the type I error (rejection of the null hypothesis even though it is true). Given this, the model is not as rigorous as it could be. In the future, it would be preferable to increase the sample size in order to create a more robust model. Future research along similar lines should include a web survey of residents after the shutdown of nuclear plants to investigate which personal attributes among individuals lead them to support fossil fuels or renewable energy.

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Abbreviations

The following abbreviations are used in this manuscript:

NPP Nuclear power plant

Appendix A

Appendix A.1

Table A1. List of binomial dependent variables.

Ten-point plan to reduce EU dependence on Russian natural gas
Point 1: No new contracts
Point 2: Alternative sources
Point 3: Minimum storage requirements
Point 4: New wind and solar projects
Point 5: Expand bio and nuclear energy
Point 6: Protect vulnerable consumers
Point 7: Accelerate heat pump installation
Point 8: Accelerate energy efficiency programs
Point 10: Accelerate decarbonization and efficiency programs
Perception of solar power
National energy security scaleable technology
Emergency power when combined with batteries
Less maintenance & cheaper supplies
Dependent on weather & seasons
Unit costs are relatively high
Environmental impact of installations
Risk of heat stroke
Easily damaged by storms, etc.
Perception of coal-fired power
Electricity shortages
Energy mix is necessary
Clean coal technology
Coal reserves
Cheaper than other fossil fuels
Germany should support RE
EU reluctance to invest in coal
CO_2 and environmental impact
Reduce dependence on Russia
Coal emits pollutants
Decarbonization is progressing globally
Germany has a leadership role
Perception of wind power
National energy security
No GHG emissions
Efficient compared to other RE
No fuel necessary, easily commercialised
24 h power generation
Germany is an ideal location
Reliant on wind
Strong winds can cause damage
An eyesore
Ultrasound health concerns
Bird collisions
Inspection and increasing repair costs

Appendix A.2

Table A2. List of ordinal logistic dependent variables.

Support for natural gas
Support for coal-fired power
Support for solar power
Support for wind power

Appendix A.3

Table A3. List of independent variables.

Dummy variables	
Sex (male = 1)	
Children (children under 12 years old)	
NPP state	
Continuous variables	
Age	log(Age)
Household	log(Household Size)
Education	log(Education)
Income	log(Income)
Intersection variables	
NPP Location × Male	
NPP Location × Children	
NPP Location × Age	
NPP Location × Household	
NPP Location × Education	
NPP Location × Income	

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