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Social Acceptance of Nuclear Energy Among Y and Z-Generation Hungarian Residents

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SUMMARY

Governments all over the world are trying to find the balance between the constantly increasing electricity demand of their countries' economy, while mitigating the negative effects of energy generation on the atmosphere (especially CO2 emission). Nuclear energy generation seems like a solid solution for both problems; however, the technology itself is considered as a two-edged sword by many people because of the negative effects of a possible accident. To understand people's attitude, scholars and researchers developed several behavioral and technology acceptance models such as TPB, TAM, and Risk-Benefit Concept, which they used successfully in many countries to investigate energy-related topics. This study aims to scrutinize the social acceptance of nuclear energy generation among Y and Z generation Hungarian residents to gain a deeper understanding of the factors that could support the acceptance and promotion of the technology. For this purpose, a unique theoretical framework has been developed (by mixing the above-mentioned behavioral and technology acceptance models) and tested via survey method, where the gathered data has confirmed the importance of the influencing factors of the model.

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1. INTRODUCTION

1.1. The Potential of Nuclear Energy

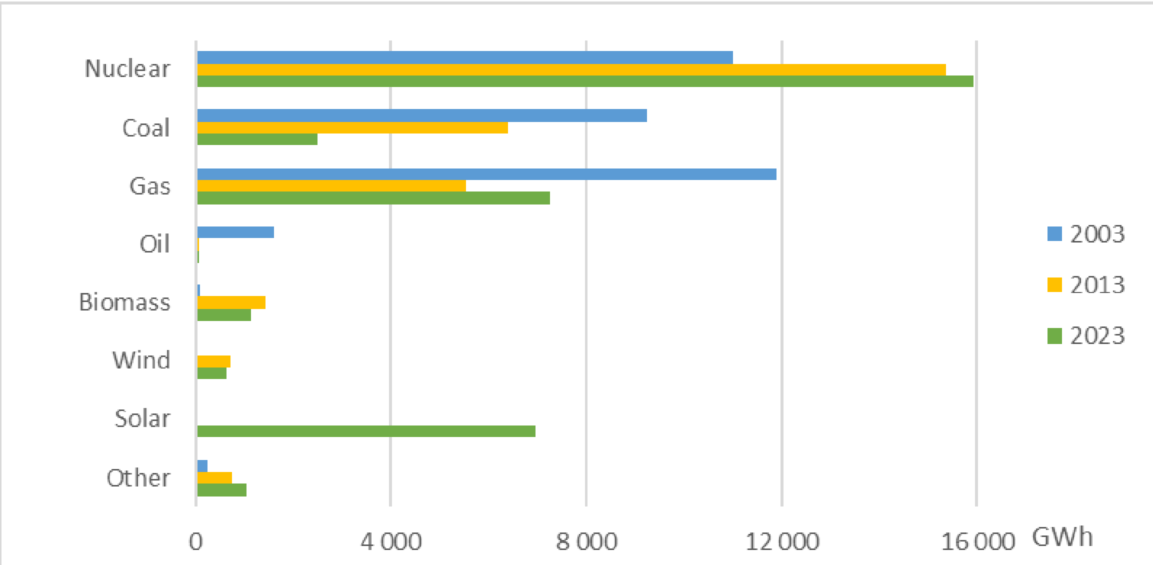
In order to decarbonize the world's economy, people tend to focus on the utilization of renewable energy sources and not give enough credit to the possibilities that lie in nuclear energy. This is so even though- based on a study by Sarkodie and Adams (2018) renewable energy investment has a competitive disadvantage compared to fossil fuel and nuclear energy systems, because for them to be attractive, fiscal incentives from governments are required to achieve development in three key areas: technology (research and development), industry (higher performance and quality) and commerce (available and accessible markets).

Nuclear power plants (NPP) could be the solution to maintain the balance between the constantly growing energy needs of the economies while offering a less harmful way of producing energy than burning fossil fuels. Throughout its lifecycle, nuclear fuel emits roughly the same amount of carbon dioxide as wind turbines, when measured per unit of energy production, and this ratio is even better (only one-third) when compared to solar panels. (Arias & Lozano, 2001; Knief, 1981; Rust, 1979) At the same time, it is also important to highlight that CO_2 emission is mostly related to the frontend processes of the nuclear fuel cycle and less to the building, operation, or back-end processes (Rashad & Hammad, 2000). From a financial point of view, building NPPs could also be a reasonable solution for meeting the constantly growing energy demand, since these facilities produce base-load electricity less expensively than many other energy sources (thanks to their low operating costs), while from an operation aspect, availability cannot be a negligible element either, since NPPs are able to generate electricity 24 hours a day. (Lau et al., 2019; Rosen & Dincer, 2007)

1.2. Hungary's electricity mix

Based on the data of the International Atomic Energy Agency and the World Nuclear Association, nuclear reactors generated a total of 2545 TWh of electricity in 2022, in 38 countries. From the total of 437 operable reactors, 413 were operating throughout the year, while only 25 were suspended (21 in Japan, mostly due to the Fukushima accident in 2011, and 4 in India) (IAEA, 2024; World Nuclear Association, 2023; Yamagata, 2024).

Hungary is one of the above-mentioned 38 countries with nuclear energy capacity. A nuclear power plant has been in operation since 1982, contributing significantly to the electricity mix of the country. (MVM, 2024)



Source: Own editing based on KSH (2024a) data

Figure 1: Gross electricity production of Hungary by source in 2003, 2013 and 2023

As can be seen in Figure 1, Hungary's electricity mix has substantially changed in the last 20 years. The usage of coal decreased by 73% compared to the data from 2003, while oil consumption had been nearly eradicated in these decades. On a positive note, solar energy became an essential component (6,960 GWh) due to the EU and government incentives (FIT, METÁR systems and other tenders such as Napenergia Plusz Program) but biomass and wind turbines are also taking their fair share from the electricity production with 1,126 GWh and 645 GWh in 2022 (Atsu et al., 2021; Szolnoki, 2022; Szőke, 2023). While the share of renewable energy sources increased substantially, nuclear energy remained the number-one contributor with 15,918 GWh, making for 45% of the overall mix in 2023 (KSH, 2024a). Since Hungary has a long-term relationship with nuclear energy, it is no wonder that the government had already started to explore the theoretical options for expanding the currently working nuclear power plant back in 2009. The project officially began in 2023, when the Hungarian government signed the construction contract for building two new units with a combined capacity of 2,000 MW, in addition to the current plant. That means that if everything goes according to the construction plan, for a couple of years nuclear energy will become even more significant in Hungary's energy and electricity mix because the old units will be operating simultaneously with the new ones (Paks 2 is expected to be ready in 2032, while the old units will be phased out from 2037) (Ablonczy, 2023; Paks 2 Zrt., 2024).

To maintain or temporarily increase the contribution of nuclear energy in the country's electricity mix seems like a reasonable idea, based on the fact that the demand has shown a slow but continuous tendency to grow in the past decade (KSH, 2024a). Studies suggest that by 2040 the yearly electricity usage could be around 66,000 GWh, which is 85% more than in 2023 (ITM, 2020).

Today's policymakers must take into consideration not just the previous trends but also prepare the electricity system for the upcoming structural changes in Hungary's economy. A series of articles published in recent years indicate that the government's idea is to make the country into a battery-producing superpower, which is a highly electricity-intensive sector (HIPA, 2022; McCormack, 2023; Simon, 2023). To fulfill that role, a steady energy supply is essential for the country, and nuclear energy meets this objective.

1.3. Nuclear energy as a divisive issue: social dilemmas

Although many scholars (Naser, 2015; Uche et al., 2023; Wang et al., 2023; Yue et al., 2022) have argued that countries should promote the development of nuclear energy, the downside of this technology should not be forgotten. The greatest public concern about using nuclear power is that a major incident can happen, which could have severe consequences for the environment or for the local population (McCombie & Jefferson, 2016). These events (for example the Three Mile Island accident in the USA, the Chernobyl accident in Ukraine, or the Fukushima accident in Japan) are usually accompanied by dread and fear of the unknown or also called "radiation phobia" which can influence how different generations perceive benefits and risks by operating an NPP (Ayoub & Sornette, 2023). Another concern of laypeople regarding the usage of nuclear energy is the disposal of the wastes produced by the process. A survey carried out by Flynn et al. (1990) in the USA revealed that citizens would like to have a median distance of 320 kilometers from a nuclear waste facility. This mentality can be described as the NIMBY phenomenon (which refers to "Not in My Back Yard") and it indicates that people are willing to support a cause as long as they are not directly affected by it, otherwise they (actively) oppose it (Bell et al., 2005; Bonev et al., 2024; Hu & Han, 2023).

For these reasons, nuclear energy can be considered a two-edged sword, and many scholars, such as Goodfellow et al. (2011), argue that policymakers must acknowledge the fact that public perception is an important factor, and without winning the public's opinion, such developments cannot be successfully carried out. When governments are thinking about promoting nuclear energy, it is necessary to persuade the citizens that the perceived benefits outweigh the perceived risks, thus gaining a social license to operate (Hall et al., 2015; Moffat & Zhang, 2014). In this study I focus on the social acceptance of nuclear energy among Y and Z generation citizens of hungarians because they represent 37.4% (KSH, 2024b) of the population, they have not been affected by any serious nuclear accident in their lifetimes, and due to technological advancement they have wide access to information and data about anything that they care about, including energy generation, energy dependency, and even the operational risks and benefits of a nuclear reactor.

2. Literature review

Forecasting citizens' perceptions associated with new technologies is a popular topic in both academic and business environments; thus, several theories have come to light in the last four decades.

To understand the motives behind people's decisions, the Theory of Planned Behavior (TPB) model (which is an extension of the theory of reasoned action model) was introduced by Icek Ajzen in 1991. It was designed to predict and explain human behavior in specific contexts. The model describes that people's behavior in a given situation depends on their intention (aggregated motivational factors), which indicates how much effort they are planning to exert in order to engage in a behavior (Ajzen, 1991).

This intention can be described as the aggregation of the following factors:

- Attitude towards the behavior, which means that people constantly evaluate the outcome of a particular behavior based on the assumption, that it will carry out positive or negative personal value for them (Ajzen, 1991).
- Subjective norms are in a broader sense the equivalent of the expected behavior set by the society or relevant others (family, friends, or just important people in our environment such as colleagues, doctors, personal trainers, and so on) (Fishbein & Ajzen, 1975; Nickerson, 2023).
- Perceived Behavioral Control based on Bandura (1982) determines an individual's beliefs about whether they can carry out a given task or not. When people encounter difficulties, those who have serious doubts regarding their capabilities tend to slacken their efforts or completely give up on overcoming the challenges, while those who believe in their own strong self-efficacy tend to exert greater effort in order to complete the task at hand (Bandura & Schunk, 1981; Schunk, 1984; Schunk, 1991).

In order to better explain human behavior in technology-related topics, the Technology Acceptance Model, which was introduced by Davis in 1985, is often used in an extended form with the TPB model (Chang, 2023; Chen, 2016; Ong et al., 2022; Tang & Jiang, 2024; Wong et al., 2024).

According to the model, technology acceptance is a three-stage process, where different External Factors (design features) can trigger Cognitive Responses (perceived ease of use and perceived usefulness) in the potential user, which form an Emotional Response (attitude toward using technology) influencing the Behavioral Response, thus determining whether someone is willing to use the given technology or not (Davis, 1985). In the model, Perceived Usefulness is defined as the potential user's belief that the use of a certain technology will improve his/her performance and Perceived Ease of Use refers to the effort that the potential user has to make (whether is it mental or physical) in order to use the technology (Davis, 1989; Innovation Acceptance Lab, 2024). While the above-mentioned factors are permanent in the model, the number of external factors can vary. In previous studies, many factors have been identified, that had a significant impact on public acceptance, but the most often used and confirmed one was Knowledge (Alzahrani et al., 2023; Jang & Park, 2020; Ong et al., 2022; Zhu et al., 2016).

Another popular approach especially in nuclear energy topics for analyzing the acceptance of the population is the risk-benefit concept (Guo & Ren, 2017; Ho et al., 2019; Mah et al., 2014; Wang et al., 2019). As Heider (1958) highlights, seeking benefits is part of our daily life, and even in our relations, we tend to like those people who benefit us. Wang et al. (2022 p. 5) defined perceived benefit as "the perceived likelihood that taking a recommended course of action will lead to a positive outcome" even if it is shown only in psychological terms such as reduced risk or reduced worry. In this research, perceived benefit is defined as the individual's belief that either he or the whole society will benefit from developing and or utilizing nuclear energy technologies.

According to Jacobs and Worthley (1999 p. 231), "risk can be defined by the probability of an event and magnitude of its consequences". Nuclear energy production is widely perceived as a dangerous technology compared to the usage of other renewable sources because in case of an accident (malfunctioning, leakage, improper waste management) the consequences can be severe for the economy, for the environment, and even for the individual's health (Cha, 2000; Keller et al., 2012; Parkhill et al., 2010). For this reason, based on Wang et al. (2019), perceived risk will be defined in this study as the extent to which the public believes that they may be exposed to certain risks or hazards arising from the usage of nuclear energy production.

In this research I combine the above-mentioned behavioral models- as other researchers did in other countries- in order to identify the social acceptance of the Hungarian Y and Z generation related to nuclear energy generation, while trying to keep my model as simple as possible so that even a limited number of survey respondents could support my hypotheses.

3. Theoretical framework

Many scholars in different countries have confirmed that knowledge is an important psychological factor that can influence risk and benefit perception in both ways. Insufficient knowledge can hinder not just the development of nuclear energy but even the development of the less controversial renewable energy sources; therefore, it is crucial to pay attention to this factor in case governments want to promote nuclear power plants on a wider scale (Frederiks et al., 2015; Kardooni et al., 2016). Wang et al. (2019) in their survey of Chinese residents also found a significant positive effect between knowledge and perceived benefit, while Huang et al. (2013) examined how the Fukushima accident affected the risk perception of residents living near a nuclear power plant in China. Alzahrani et al. (2023) also argue that as people gain more information about the principles of nuclear energy generation, they will worry less as the advantages start to outweigh the disadvantages; at the same time, faith is replaced in their mindset by facts (Wallquist et al., 2010). As a result, I propose the following hypotheses:

H1: Knowledge about nuclear energy has a significant effect on Risk Perception
H2: Knowledge about nuclear energy has a significant effect on Benefit Perception

Creating knowledge and influencing public opinion is not a subject of this research but based on Elmustapha et al. (2018) and Kiss (2023) mass media and gamification methods can be useful intermediary tools for this purpose, while Yamagata (2024) emphasizes that young people obtain more information from the internet and they trust it more than they trust information from older generations; thus, providing sufficient data on this channel could be a useful way to increase their awareness.

Attitude in the TPB model pertains to the mindset when people decide about their point of view or about their future behavior related to an important topic, based on the assumption that it will carry out positive or negative value for them (Ajzen, 1991). Previous studies, such as Ryu et al. (2018), have confirmed that there is a negative relationship between perceived risk and public attitudes in the case of nuclear energy technologies; thus, if the perceived risks outweigh the perceived benefits, people will not support this type of energy source. When people do not take any action for or against a technology, that means that they simply tolerate it (Huijts et al., 2012). While not supporting a case is an easy decision, taking action against it is quite another. Sadly, in the case of nuclear energy generation, there is no middle ground, which means that if there is no public support, then usually there is active public resistance (Huang et al., 2018). Huhtala and Remes (2017) concluded that if the risk perception of the residents is high, then it directly results in lower public acceptance and larger social expenses. Siegrist et al. (2014) found that attitudes toward nuclear energy can change over the course of time, and in case of a serious accident this can happen abruptly, especially if it is close to the individual's living environment (change of the attitude of Japanese people towards nuclear energy after Fukushima), therefore permanent attention is required to maintain public support. Interestingly, there is a gender difference between the influencing factors of attitude, according to Choi et al. (1998), benefit perception is more dominant in male participants' attitudes toward nuclear energy, while female participants give more importance to perceived risks. As a result, I propose the following hypotheses for the theoretical framework:

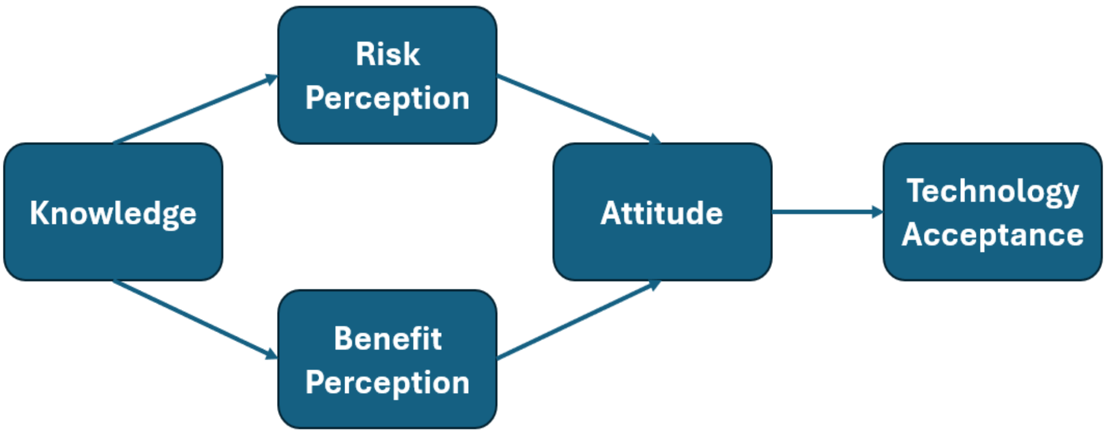
H3: Risk Perception has a significant effect on Attitude
H4: Benefit Perception has a significant effect on Attitude

Technology acceptance refers to the state where people accept the presence of a new technology in their daily lives, which is usually later manifested in actual system usage. Technology acceptance derives from different and complex motivational factors, such as public perception, or from social, cultural, and historical factors (Liu et al., 2008), but many scholars have proved that one of the key elements of this factor is attitude (which can also be an accumulated factor) (Jang & Park, 2020).

As Savari and Gharechaee (2020) implied, aggregated motivational factors can determine technology acceptance in both ways. Conducting research amongst Iranian farmers, they confirmed that attitude has a significant effect on technology acceptance and influencing the antecedent factors can lead even to technology rejection if it is desired. Lim et al. (2017) found that residents close to a future nuclear-related facility may strongly oppose its construction, even if it would be beneficial for the majority of the population. This statement was supported by Xiao et al. (2017), who also confirmed that without gaining the trust of local communities, there is no way to successfully expand the use of nuclear energy. For this reason, governments have to make more efforts to persuade local residents than those who farther away from the construction site. At the same time, it is also important to note that the influencing factors of technology acceptance may vary over the course of time. Park and Ohm (2014) found that after the Fukushima earthquake and accident, the main factor that determines technology acceptance shifted from perceived costs to public attitudes. As a result, I propose the following hypothesis:

H5: Attitude has a significant impact on Technology Acceptance

In alignment with the above-presented models and studies, Figure 2 depicts the theoretical framework of the study. This illustrates the various factors that were considered for the extended Technology Acceptance Model, which focuses on the acceptance of nuclear energy among Y and Z generation people in Hungary.



Source: Own editing based on TAM, TPB and Risk-Benefit concept models

Figure 2: Conceptual framework of the study

4. Methodology

4.1. Sample selection

The aim of this study is to scrutinize the nuclear energy acceptance of Y and Z generation people in Hungary. The time periods of the different generations are identified variously in the literature (Gen Y from 1980-1982 to 1994-2000) and there is no one common classification accepted by everyone (BBC, 2024; Laor & Galily, 2022; Seaman et al., 2018; Vafaei-Zadah et al., 2022). Due to this reason, the separation between Gen Y and Gen Z was made by the presumed economic status at the time of the study:

- Gen Y: 1980-1998, who is probably economically active and already has a family therefore cares more about the future.
- Gen Z: 1999-2010, those who are probably still studying and are not yet supporting themselves.

This classification was also considered when setting the ranges for the age question in the questionnaire.

At the beginning of the questionnaire, the respondents were asked to accept the data policy, confirming that the survey information they submitted would be used for research purposes only and anonymously. A consent statement was provided in the preface section of the questionnaire, and respondents were asked to confirm their agreement with a checkbox before proceeding with the questionnaire items (if they did not accept the terms, the questionnaire jumped to the last page without recording any information).

The Hungarian-language survey was sent out to 1,200 students of the University of Miskolc who were studying economics at that time or in the previous three years at the university. At the same time, it was also shared in a Hungarian Facebook group specialized in research questionnaires where young researchers can mutually fill out each other's forms. For this reason, the survey cannot be considered representative of the Y and Z generation of Hungarian residents; however, the high number of the respondents lays the foundations of the research. The survey was available online from the beginning of May 2024 till the end of May 2024. In that period, 232 people answered the questions: about 90% of the answers came from university students and about 10% from the Facebook group. From this data pool, 3 potential participants were excluded because they did not accept the data policy, and another 13 people were excluded at the end because based on their age, they were not part of Generation Y or Z. As a result, the final table contained the data from 216 participants.

4.2. Sample

At the beginning of the survey, four demographic questions were asked: Gender, Age, Residence, Education.

From the 216 respondents who are within the age range, the majority are considered Generation Z, which seems reasonable because the survey was sent out mostly to undergraduate students who are usually starting their college education after high school at age 18 or 19. Consequently, the remaining 72 respondents were from Gen Y (49 respondents were in the 25-34 age group, while 23 respondents were in the category of 35-44 years old).

As can be seen from Table 1, almost two-thirds of the respondents were women, which is probably due to the fact that women usually tend to fill out surveys on a higher scale than men (Smith, 2008), and additionally, the survey was sent out mostly to economics students, where the balance also shifts in favor of women.

The University of Miskolc is a prestigious school located away from the capital; therefore, 85% of the respondents are currently living in villages, cities, or in cities that are county seats. Since Miskolc is located close to the country's borders, Hungarians who are living abroad but studying at the university also filled out the survey (since the language of the survey was Hungarian it is unlikely that any of the respondents were international student).

The distribution of the educational attainment also reflects the characteristics of the sample. The majority of the respondents had only a high school degree or post-secondary educational degree, probably due to their young age, with only one-fourth of them holding a degree.

Table 1

Descriptive statistics of the sample

Sample characteristics	*Frequency*	*Percent*
Gender		
Men	84	38.9
Women	132	61.1
Age		
18-24	144	66.7
25-34	49	22.7
35-44	23	10.6
Residence		
Abroad	4	1.9
Village	56	25.9
City	69	31.9
County seat	60	27.8
Capital city	27	12.5
Education		
Secondary School	140	64.8
Post-secondary vocational education	23	10.7
College or University Degree	53	24.5

N = 216

Source: Own editing based on the survey data

4.3. Measurement

In this investigation the questions for the questionnaire of the study were carefully selected, with the purpose of gathering important data about the perception of the Hungarian residents related to the usage of nuclear energy as an alternative energy source to fossil fuels.

Based on the conceptual framework, presented theories, and the received feedback, the questionnaire is divided into five sections (in addition to the demographic section). Survey questions in the same topic by other researchers were considered (see Appendix 1) when developing my own structure. The questions were divided into the following categories:

- Knowledge (4 items)
- Risk Perception (3 items)
- Benefit Perception (3 items)
- Attitude (3 items)
- Technology Acceptance (3 items)

To assess the validity and reliability of the survey instruments and questionnaire contents, two researchers from the University of Miskolc were contacted through e-mail and invited to evaluate the questionnaire and look for double-barreled, perplexing, or leading queries, which they are examples of errors. The researchers were selected based on their expertise in nuclear science, energy transition, and survey methodology, which is a requirement for content validation (Taherdoost, 2016).

The survey utilized a 5-point Likert scale to evaluate the perception of participants related to the latent variables, and the questionnaire was provided in Hungarian as it is the official language of the country. (Appendix 2)

For analyzing the technical variables, first Cronbach's α was calculated in order to check the reliability of the data; results can be seen in Table 2.

Table 2

Unidimensional reliability of the analyzed variables

Variable	Cronbach's α	CI = 95%
Knowledge	.78	[.72; .82]
Risk Perception	.66	[.57; .73]
Benefit Perception	.75	[.69; .81]
Attitude	.77	[.71; .82]
Technology Acceptance	.89	[.86; .91]

Source: Own editing based on the survey data

Based on the data in Table 2, the reliability is considered acceptable for all factors as the lowest Cronbach's α in the table is still above α = .65 (for Risk Perception), while most of the factors are above α = .75 (Zeller, 2005).

Due to the decent reliability results, the scale scores were created by averaging; thus, the values range from 1 to 5.

5. Statistical Analysis

5.1. Descriptive statistic

I started by reviewing the descriptive statistics of the variables included in the study. As can be seen from Table 3, the skewness value is close to 0 regarding all variables, which indicates that the dataset is symmetrically distributed.

Further analyzing the dataset, it can be seen that the kurtosis values are negative, which indicates that the distribution has slightly lighter tails and a flatter peak than the normal distribution (platykurtic kurtosis), and responses also occur towards the edges of the mean, therefore covering the whole range relatively well (see Appendix 3). Based on the skewness and kurtosis values, which are both relatively close to 0, the dataset is considered to be normally distributed.

After that, I used a t-test to examine the difference between the Risk and Benefit Perception measures and how they are affected by the different demographic factors. Since the data gathered by the questionnaire for the demographic factors were ordinal, this analysis was performed with the Spearman correlation, while the correlations between the factors of the theoretical framework were analyzed with the Pearson correlation. Unfortunately, the number of respondents did not allow the investigation of the model as a whole, so to tackle that issue, a decision was made to separate the framework into two different models. For the first part, parallel mediation analysis was performed in order to test the mediating role of Risk and Benefit Perception between Knowledge and Attitude, while for the second part, linear regression was used in order to test how well the different factors can predict Technology Acceptance.

To perform the above-mentioned analyses, the software JASP was utilized, which is an open-source statistical tool developed by the University of Amsterdam.

5.2. Results

In order to get a deeper understanding of the data, descriptive statistics were performed and the results are presented in Table 3.

In the questionnaire, two variables were used to obtain the respondents' perceptions about the effects of nuclear energy generation. Positive perception about nuclear energy generation was identified with Benefit Perception, while negative perception was identified with Risk Perception factor. Using a paired samples t-test, a significant difference was found between the magnitude of Risk and Benefit Perception, $t\,(215) = -4.86$ $p < .001$ Cohen's $d = -0.33$, which means that respondents of the survey perceived the benefits larger.

Table 3

Skewness and kurtosis of the analyzed variables

Variable	Mean	Std. Deviation	Skewness	Kurtosis
Knowledge	2.98	0.88	0.06	-0.50
Risk Perception	3.09	0.91	-0.11	-0.54
Benefit Perception	3.57	0.87	-0.20	-0.30
Attitude	3.19	0.89	0.00	-0.22
Technological Acceptance	2.66	1.07	0.21	-0.57

Source: Own editing based on the survey data

After that, I examined whether nuclear energy scales show a correlation with demographic indicators. The four demographic factors considered in the questionnaire were gender, age, education, and place of residence. In order to test the possibility of any gender difference, an independent samples t-test was used on the dataset.

In Table 4 it can be seen that for the factors Knowledge, Benefit Perception, Attitude, and Technological Acceptance there is a positive significant difference, which means that men give higher ratings to these variables than women do, while for Risk Perception the significant difference remains, but with a negative direction, which means that in this case women perceive the risks associated with nuclear energy generation as being higher than men do.

Table 4

Independent samples t-test

	Mean		Std. Deviation		t	p	Cohen's d
	Men	Women	Men	Women			
Knowledge	3.35	2.75	0.83	0.83	5.24	< .001	0.73
Risk Perception	2.71	3.33	0.92	0.81	-5.15	< .001	-0.72
Benefit Perception	4.01	3.30	0.78	0.82	6.36	< .001	0.89
Attitude	3.64	2.91	0.86	0.80	6.29	< .001	0.88
Technological Acceptance	3.10	2.38	1.07	0.97	5.11	< .001	0.71

Men: N = 84; Women: N = 132

Source: Own editing based on the survey data

Based on the conceptual framework of the study, correlations of the demographic variables is investigated, which can be seen in Table 5.

The results show that the Age factor is related to the Education factor with a positive strong correlation, so as people become older, they usually become more qualified, as they have more time to educate themselves. I think this is especially true of this database, as many participants, at 18-24 years old, literally did not have time to gain a higher qualification than finishing their high school studies. Related to that, there is a positive weak correlation between Age and Knowledge also.

Education also has a link with Knowledge; presumably those who are more educated have more knowledge about nuclear energy generation, while based on the data there is a negative and weak connection between Education and Risk Perception, therefore more educated people usually evaluate Risk Perception, at a lower level than those who have a lower educational background.

Table 5

Spearman’s Correlation between the different variables

Variable	Age	Residence	Education
Age	—		
Residence	.077	—	
Education	.51***	.10	—
Knowledge	.17*	.02	.22**
Risk Perception	-.11	-.13	-.15*
Benefit Perception	-.06	.09	.03
Attitude	-.02	.11	.06
Technological Acceptance	-.08	-.02	.04

* p < .05, ** p < .01, *** p < .001

Source: Own editing based on the survey data

Table 6

Pearson’s Correlation between the different variables

Variable	Knowledge	Risk Perception	Benefit Perception	Attitude	Technological Acceptance
Knowledge	—				
Risk Perception	-.37***	—			
Benefit Perception	.56***	-.37***	—		
Attitude	.51***	-.43***	.66***	—	
Technological Acceptance	.43***	-.47***	.59***	.73***	—

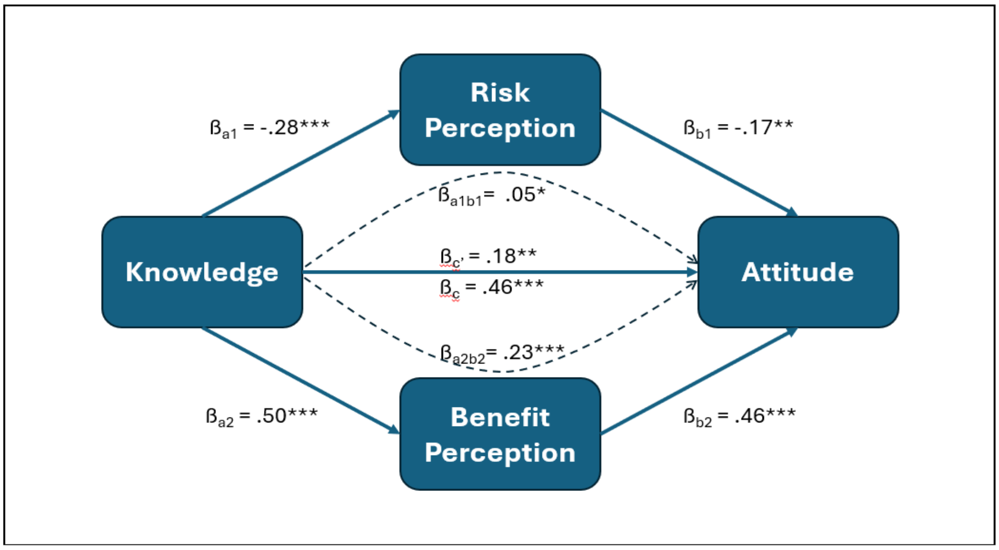
Source: Own editing based on the survey data

As can be seen from Table 6, there is a positive strong connection between Knowledge and Benefit Perception, which means that people who dig deeper into the literature on nuclear power generation tend to rate the benefits coming from the usage of the technology higher than others, while at the same time, they devalue the risks (negative medium link between the two factors).

The same dichotomy can be discovered when the correlation is measured between Attitude and Risk and Benefit Perception variables. Simply put, if Benefit Perception increases, it has a positive strong correlation with Attitude while evaluating the risks highly, usually resulting in lower Attitude towards the technology (negative medium correlation).

Interestingly, the strongest relation is between Attitude and Technology Acceptance (0.730), which means that if people have a strong positive attitude towards the technology, then they are open to supporting the spread of it.

To analyze the direct and indirect effects of the factors of the model, mediation analysis was performed on the data of the survey; however, because of the limited data availability (N = 216) the conceptual framework was divided into two different analyses. Throughout the analysis, background confounders were used (Gender, Education, Residence, Age) and the values represented in Table 7 are modified by these factors, therefore, the effects of the direct and indirect paths are independent from the demographical aspects of the survey.



Note: * p < .05, ** p < .01, *** p < .001
The model has been controlled for demographic indicators and the ß values are unstandardized
Source: Own editing based on the survey data

Figure 3: Parallel mediation analyzing the relationship between knowledge and attitude mediated by RP and BP

As can be seen in Figure 3, Risk Perception and Benefit Perception are both considered mediating factors between Knowledge and Attitude. The total explanatory effect is $ß_c$ = .457, while the direct effect is $ß_{c'}$ = .181, which means that Knowledge by itself is significantly responsible for shaping people's Attitude toward nuclear energy generation. At the same time, the total indirect effect ($ß_{ab} = ß_{a1b1} + ß_{a2b2}$) is also significant ($ß_{ab}$ = .276), but it is divided between the two perception factors. Risk Perception accounts for $ß_{ab1}$ = .046 and $ß_{ab2}$ = .230. It is also important to note that there is a negative relationship between the Knowledge → Risk Perception → Attitude path, which also proves that acquiring more information about nuclear energy technology, will result in a decreasing risk perception, and this lower perception value will have an opposing effect on the Attitude (with decreasing Risk Perception, Attitude will increase). Based on the analysis results in Table 7, all effects presented in Figure 3 are considered significant.

Table 7

Mediation analysis of Knowledge, Perception, and Attitude factors

					Estimate	Std. Error	p
Path coefficients							
$ß_{b1}$ - Risk Perception		→		Attitude	-.17	.06	0.005
$ß_{b2}$ - Benefit Perception		→		Attitude	.46	.07	< .001
$ß_{c'}$ - Knowledge		→		Attitude	.18	.06	.003
$ß_{a1}$ - Knowledge		→		Risk Perception	-.28	.07	< .001
$ß_{a2}$ - Knowledge		→		Benefit Perception	.50	.06	< .001
Total effects							
$ß_c$ - Knowledge		→		Attitude	.46	.06	< .001
Direct Effects							
$ß_{c'}$ - Knowledge		→		Attitude	.18	.06	.003
Indirect Effects							
$ß_{a1b1}$ - Knowledge	→	Risk Perception	→	Attitude	.05	.02	.033
$ß_{a2b2}$ - Knowledge	→	Benefit Perception	→	Attitude	.23	.05	< .001

Note: The model has been controlled for demographic indicators and the ß values are unstandardized
Source: Own editing based on the survey data

Now that the mediation model is considered for the first part of the model, I will analyze the factors influencing Technology Acceptance by building a hierarchical regression model.

Table 8

Hierarchical regression model of Technology Acceptance

Model	R^2	F	p
M_0	.13	7.74	< .001
M_1	.25	13.68	< .001
M_2	.44	23.67	< .001
M_3	.59	37.70	< .001

Note: M_0 includes Gender, Age, Residence, Education
M_1 includes Gender, Age, Residence, Education, Knowledge
M_2 includes Gender, Age, Residence, Education, Knowledge, Risk Perception, Benefit Perception
M_3 includes Gender, Age, Residence, Education, Knowledge, Risk Perception, Benefit Perception, Attitude
Source: Own editing based on the survey data

As can be seen in Table 8, the demographical factors explain Technology Acceptance only in 13%, while the M_3 regression model extended with the professional factors is responsible for 59%. This is a good result, because based on the literature review, basic behavioral models (mixed or extended TPB and TAM models) tend to have 40-50% explanatory power (Aziz et al., 2020).

Table 9

Detailed hierarchical regression model of Technology Acceptance

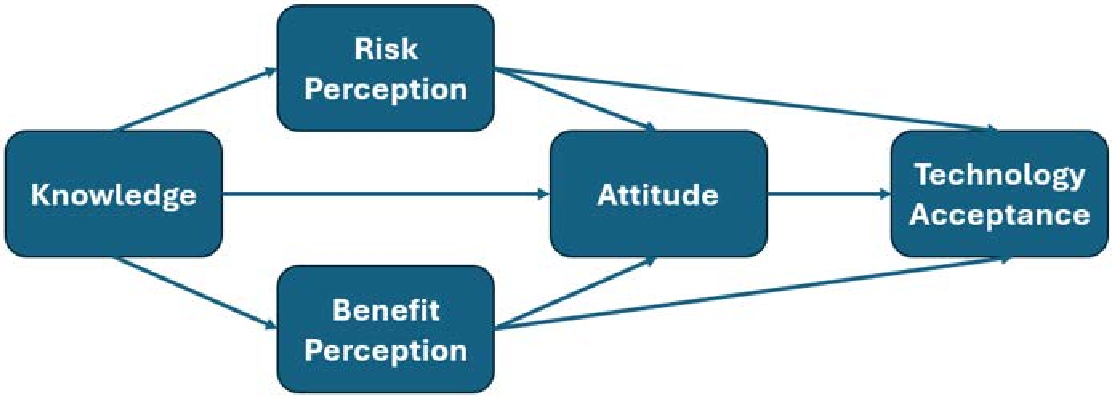
Model	Standardized	p
M_0		
Gender	- .33	< .001
Age	- .14	.061
Residence	- .04	.587
Education	.13	.087
M_1		
Gender	- .21	.001
Age	- .17	.016
Residence	- .03	.612
Education	.06	.393
Knowledge	.38	< .001
M_2		
Gender	- .05	.432
Age	- .10	.101
Residence	- .09	.107
Education	.03	.556
Knowledge	.09	.187
Risk Perception	- .28	< .001
Benefit Perception	.42	< .001
M_3		
Gender	.01	.840
Age	- .06	.274
Residence	- .11	.018

Education	.04	.487
Knowledge	- .01	.858
Risk Perception	- .19	< .001
Benefit Perception	.17	.008
Attitude	.55	< .001

Source: Own editing based on the survey data

When thoroughly analyzing the M_3 model (Table 9), it can be seen that most of the demographic factors and Knowledge only affect Technology Acceptance through the antecedents (Figure 3), while Risk Perception and Benefit Perception have an impact on TA through Attitude, but also exert their effect directly to Technology Acceptance. Interestingly, the Residence factor is the only demographic parameter that has a significant negative effect on Technology acceptance; those who live in bigger towns accept nuclear energy less than those who live in smaller settlements.

Based on the statistical studies carried out above, the hypotheses of the study can be approved, while the final conceptual framework of the research is presented in Figure 4.



Source: Own editing based on the survey data

Figure 4: Final theoretical framework of the research, based on the statistical analyses

The hypotheses of the base model had been confirmed, while other significant effects were also identified between the factors, such as Knowledge on Attitude, Risk Perception on Technology Acceptance, and Benefit Perception on Technology Acceptance.

6. Discussion

In this research, social acceptance of nuclear energy generation was analyzed using a mixed framework of behavioral models (TPB, TAM, Risk-benefit concept) among generation Y and Z citizens of Hungary. Through an online survey 232 responses were gathered, and from them, 216 were considered in the study (others were excluded because respondents either did not accept the data policy or they were not Generation Y or Z). The considered factors of the theoretical framework were Knowledge, Risk Perception (RP), Benefit Perception (BP), Attitude, and Technology Acceptance, while throughout the analysis, I extended my model with demographic attributes such as Gender, Age, Residence, and Education. With the paired samples t-test, I found that Y and Z generation people rate the Perceived Benefits more highly, than they rate the Perceived Risks. This finding is interesting, given the fact that two-thirds of the respondents were women, and women usually tend to focus on the negative effects of nuclear power plants (Choi et al. 1998). Based on the results of the survey, surprisingly, women evaluated the RP and BP factors at almost the same level (RP=3.33; BP=3.30), while men showed a huge difference in their ratings (RP=2.71; BP=4.01), which can be considered a normal deviation based on the literature (Hitchcock, 2001; Islam et al., 2023; Rasmussen et al., 2020). The close values of RP and BP for women may come from their age, as they have not experienced any nuclear crisis in their lives, or also from the fact that the country has a working nuclear reactor; thus, they may have become used to the idea that such a facility can safely produce energy without any malfunction.

Correlation in the demographical data obviously indicated the links between Age to Education and Age to Knowledge, while Education had a significant effect on both Knowledge and Risk Perception. It is interesting that the Residence factor had no significant effect on other demographic factors, nor on the factors of the theoretical framework. I think this is the result of globalization, because with the rapid development of convenient services (such as internet connections), distances have shrunk (especially for the Y and Z-generation residents), and a vast amount of data is available to everyone on every topic they are interested for (in 2023, 92.7% of Hungarian households had internet access, and 96.6% of the population used the internet daily), regardless of where they live (Statista, 2025; KSH, 2025). Analyzing the correlation between the professional factors of the model, it can be seen that the selected features indeed have an impact on each other; therefore, the validity of the theoretical framework is proved.

In the base model, Risk and Benefit Perception were considered as an intermediary factor, but the mediation analysis showed that there is also a direct effect between Knowledge and Attitude ($ß_{c'}$ = .181). This means that people who gather more expertise about nuclear energy generation generally have a more positive attitude towards the technology because they feel more familiar with the principles of its operation. In other fields, this concept was proved by Wei et al. (2016), however, in nuclear energy research, this idea is not often analyzed. From the open-access studies available for this research (Appendix 1) only Zhu et al. (2016) examined the effect of Knowledge on Behavioral Intention, and this hypothesis was also accepted in his paper.

The same effect can be observed in the hierarchical regression model, where Attitude cannot fully capture the explanatory power of Risk and Benefit Perception to Technology Acceptance; therefore, there is a significant direct effect between these factors. This concept is often hypothesized in the literature (Alzahrani et al., 2023; Contu et al., 2016; Islam et al., 2023; Roh & Geong, 2021), and the reason why fellow researchers leave out the intermediary factor is probably that nuclear energy generation and an operating NPP can affect people life on such a wide scale (especially in case of malfunctioning), that these perceptions (if already arisen) are strong enough on their own to have an effect on the acceptance or on the rejection of the technology. Although based on my statistical analyses, leaving out the intermediary factor (Attitude) does not seem like a reasonable idea because the explanatory power is presented on the Perception-Attitude-Technology Acceptance path too.

While the hypothesized effects were identified for the dataset, it is important to note that the survey data was not representative of Hungarian Y and Z-generation residents; therefore, it would be useful to extend the data-gathering process in a later study to support the current findings.

7. Conclusion

Hungary is one of the 38 countries that have an operational nuclear power plant in its territory, and policymakers are actively working on increasing its capacities, but building new sites has also not been ruled out yet.

The perception of nuclear energy production as well as the optimal transition to alternative energy sources are hot topics in today's societies; therefore, gaining citizen support is a must-have for this type of endeavor. The aim of this research was to analyze the social acceptance of nuclear energy generation among Generation Y and Z citizens of Hungary in order to get an insight about their ideas for the future electricity mix of the country.

For this purpose, a theoretical framework was built from the social acceptance models available in the literature, such as TPB, TAM, or the Risk-Benefit concept, while trying to minimize the number of factors in order to keep the survey as short as possible. For this purpose, the factors Knowledge, Risk Perception, and Benefit Perception were selected, which theoretically exert their effect through Attitude to Technology Acceptance. After performing a hierarchical regression, it was clear that these factors (with the additional demographic parameters) can predict Technology Acceptance with 59% accuracy, which is a decent value considering the low number of External Factors used in the theoretical framework. At the same time, there is still room to improve the model, perhaps by adding other factors, because a wide range of external factors have been tested for similar studies in other countries. This investigation may serve as a basis for future research in Hungary utilizing a wider scale of psychological factors.

Through the analyses, it was proved that there is a significant effect between the factors of the model, therefore, the basic hypotheses of the theoretical framework were approved, while other significant effects arose, such as the direct effect of Knowledge on Attitude and the direct effect of Perceptions to Technology Acceptance. Based on this information, it is clear that policymakers have to tackle Knowledge, Risk Perception, and Benefit Perception factors if they want to increase the share of nuclear energy in the country's electricity mix. For this purpose, educational materials or campaigns should be more widely available, not just for the younger generations but also for the whole society, especially if increasing the share of nuclear energy generation in Hungary's electricity mix is under discussion.

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Data availability statement

Data available on request due to privacy, from the author: **Péter Bihari** bpeti7@gmail.com

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Appendix

Appendix 1: Nuclear energy acceptance researches used as a baseline for the questionnaire

Title	Author	Year	Journal
The acceptance of nuclear energy as an alternative source of energy among Generation Z in the Philippines: An extended theory of planned behavior approach	Belmonte et al.	2023	Nuclear Engineering and Technology
Who is willing to participate? Examining public participation intention concerning decommissioning of nuclear power plants in Belgium	Hoti et al.	2021	Energy Policy
Social acceptance of nuclear power plants in Korea: The role of public perceptions following the Fukushima accident	Jang and Park	2020	Renewable and Sustainable Energy Reviews
A framework of examining the factors affecting public acceptance of nuclear power plant: Case study in Saudi Arabia	Alzahrani et al.	2023	Nuclear Engineering and Technology
Public perceptions and acceptance of nuclear energy in China: The role of public knowledge, perceived benefit, perceived risk and public engagement	Wang et al.	2019	Energy Policy
Modeling individual preferences for energy sources: The case of IV generation nuclear energy in Italy	Contu et al.	2016	Ecological Economics
An empirical study of the risk-benefit perceptions between the nuclear and non-nuclear groups towards the nuclear power plant in Bangladesh	Islam et al.	2023	Nuclear Engineering and Technology
Public Perception of the Nuclear Research Reactor in Thailand	Tantitaechochart et al.	2018	2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)
Predicting unsafe behaviors at nuclear power plants: An integration of Theory of Planned Behavior and Technology Acceptance Model	Zhang et al.	2020	International Journal of Industrial Ergonomics
Effects of information strategies on public acceptance of nuclear energy	Hu et al.	2021	Energy
When it is unfamiliar to me: Local acceptance of planned nuclear power plants in China in the post-fukushima era	Guo and Tao	2017	Energy Policy
Anti-nuclear behavioral intentions: The role of perceived knowledge, information processing, and risk perception	Zhu et al.	2016	Energy Policy
How and when does information publicity affect public acceptance of nuclear energy?	Wang et al.	2020	Energy
Investigating the acceptance of the reopening Bataan nuclear power plant: Integrating protection motivation theory and extended theory of planned behavior	Ong et al.	2022	Nuclear Engineering and Technology
Residents' acceptance of using desalinated water in China based on the theory of planned behaviour (TPB)	Lili et al.	2021	Marine Policy
A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies	Venkatesh and Davis	2000	Management Science

Predicting intention to improve household energy efficiency: The role of value-belief-norm theory, normative and informational influence, and specific attitude	Fornara et al.	2016	Journal of Environmental Psychology
What affects college students' acceptance of nuclear energy? Evidence from China	Hao et al.	2019	Journal of Cleaner Production

Appendix 2: Survey form English translation

Dear Participant,
My name is Péter Bihari, I am a final-year PhD student at the Faculty of Economics, University of Miskolc. My research topic is the social acceptance of different energy sources.
In this questionnaire, I aim to assess public attitudes toward nuclear energy. Please support my professional work by completing the following survey.

The questionnaire contains no open-ended questions, only items rated on a 1-to-5 Likert scale, and takes only 4–6 minutes to complete.
Your data will be handled strictly confidentially and anonymously. Submitted responses will become part of a larger database and will not be traceable to individuals.
Thank you for contributing to my scientific work by completing the survey!

*** Required question**
By completing this questionnaire, I consent to the use of my data for research purposes as described in the information notice. *
1. Gender
   - Male
   - Female

2. Age
   - Under 24
   - 25–34
   - 35–44
   - 45–60
   - Over 61

3. Place of residence
   - Village/Small town
   - Town
   - County seat
   - Budapest
   - Abroad
   - Other:

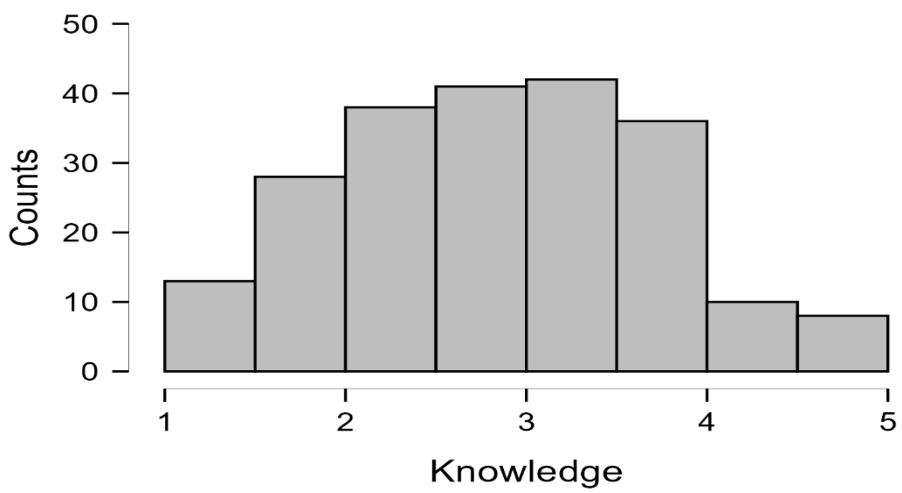
4. What is your highest level of education?
   - Secondary school diploma
   - Higher education vocational training
   - College or university degree
   - Ph.D.
   - Other:

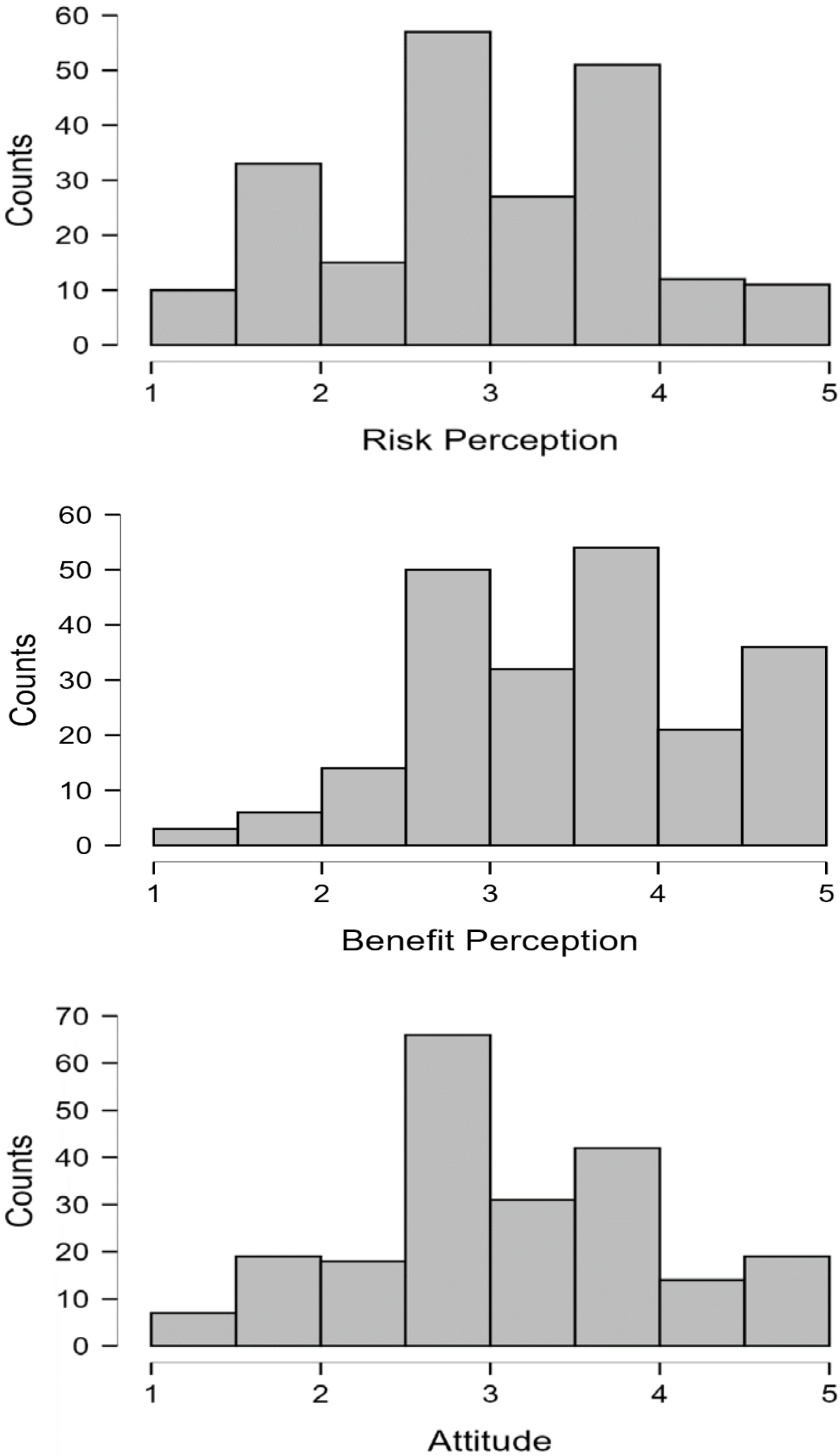
Questions related to nuclear energy
(Please rate the extent to which you agree with the following statements, 1 = Strongly disagree, 5 = Strongly agree):

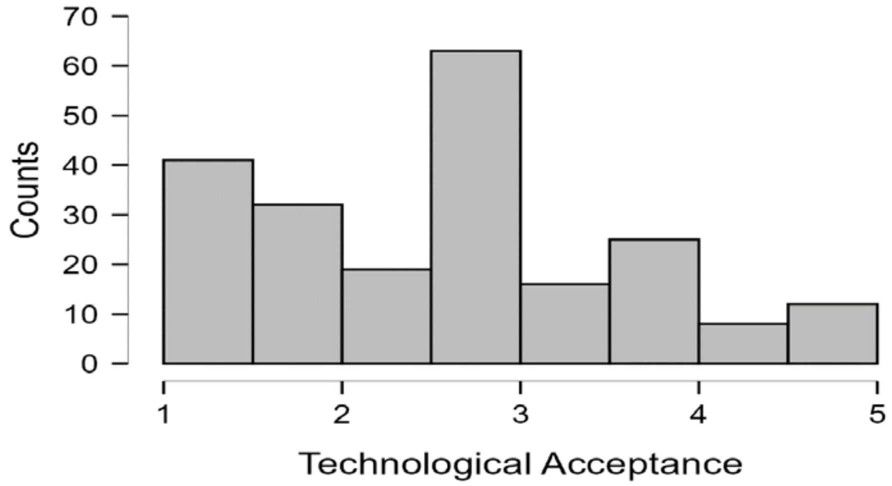
5. I understand the scientific principles behind nuclear energy and know how a nuclear power plant operates.
6. I am aware of the effects of nuclear radiation on the environment and human health.
7. I am familiar with news and major events related to nuclear energy, as well as their background.
8. The risks associated with building and operating nuclear power plants are decreasing thanks to technological advancements.
9. The construction or operation of a nuclear power plant causes serious environmental damage to its immediate surroundings.
10. Operating nuclear power plants negatively affects human health.
11. Today’s nuclear power plants are not capable of withstanding extreme natural events (e.g. earthquakes, droughts) or other unforeseen incidents (e.g. terrorist attacks), which could lead to unforeseeable consequences.
12. Nuclear power plants help mitigate climate change by emitting significantly less carbon dioxide than other fossil fuels (coal, oil, natural gas).
13. Operating nuclear power plants significantly contributes to energy security and cheaper electricity production in a given country.
14. Operating a nuclear power plant can be beneficial for a country due to job creation and technological development.
15. Overall, the advantages of using nuclear energy outweigh the disadvantages.
16. Due to Hungary's geographical and geopolitical position, the operation of a nuclear power plant does not involve any extra risk.
17. Electricity produced in nuclear power plants is a suitable alternative to fossil fuels.
18. I support the construction of more nuclear power plants in the EU.
19. I support the maintenance/expansion of nuclear energy use in electricity generation in Hungary.
20. I support nuclear energy projects even near my place of residence (research, development, plant construction, or fuel repository).

Thank you for supporting my work with your feedback!

Appendix 3: Distribution plots for technical variables




Counts
60
50
40
30
20
10
0
1
2
3
4
5
Risk Perception
Counts
60
50
40
30
20
10
0
1
2
3
4
5
Benefit Perception
Counts
70
60
50
40
30
20
10
0
1
2
3
4
5
Attitude



Counts
70
60
50
40
30
20
10
0
1
2
3
4
5
Technological Acceptance