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Nuclear reactor at home? Public acceptance of small nuclear reactors in the neighborhood

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Small Nuclear Reactors (SNR) can provide climate-neutral, stable electricity and heating if located in people's neighborhoods close to people's dwellings. The extensive use of SNR would reduce capacity requirements for energy transmission systems and increase the overall stability of energy grids. However, the public fear location of SNR close to their homes. This paper hypothesizes that the public acceptance of SNR in the neighborhood is contingent upon knowledge of technology, fear of nuclear energy (NE), trust in the government, the expected increase of future electricity needs and the expected ability of renewables to cover these needs, environmental and climate concerns, and media exposure. We rely upon representative survey data from the Czech Republic (N = 1,013, 51.2% female, aged 18–91, M $\pm$ SD: 47.7 $\pm$ 17.6; 19.6% with higher education). Methodologically we conduct exploratory Principal Component Analysis and a series of ordinal regressions. The results suggest that the knowledge of technology, trust in the government, the preference for NE expansion, and media exposure increased the acceptance of SNR, while fear of NE decreased SNR acceptance. The perceived replaceability of conventional energy sources with renewables decreased acceptance of SNR in most cases. Surprisingly, worries about climate change reduced the support for SNR. Women accept fewer SNRs located close to their residence compared to men. More educational effort is needed in the specifics of SNR technology and the environmental effects of SNR. Media proved to be an excellent way to start.

KEYWORDS

small nuclear reactors, public preferences, location, climate change, nuclear energy, shared capacities

1 Introduction

The evident energy crisis of 2020th, suppression of non-renewable, and instability of renewable energy sources reopened the issue of producing energy from nuclear power (Chakraborty et al., 2021; Singh, 2021; IEA, 2022; McWilliams et al., 2022). Nuclear power plants seem to offer the ways to produce stable, low-carbon energy in sufficient quantities (Siqueira et al., 2019; Makhijani and Ramana, 2021; Muellner et al., 2021). Contrary to traditional power plants, Small Nuclear Reactors (SNR) provide a number of benefits such as lower initial investments, fewer requirements for site selection and preparation, standardized design and construction, lower capacities of transmission systems and energy grids, the ability to be tuned to local needs, lower need of expertise in operation, ability to produce heat as a side product of electricity production (Ingersoll, 2009;

Shropshire, 2011; Carlsson et al., 2012; Lokhov et al., 2013; Carter, 2016; OECD, 2021). These benefits can be utilized most if SNRs are located close to people's residences. However, the accidents in power plants (Three Mile Island, Chornobyl, and Fukushima) and the adverse health effects of radioactivity made people fear the Nuclear Power Plants located near their homes (Bird et al., 2014; Guo and Ren, 2017). For example, people in China were willing to pay up to US$ 116.6 per year to avoid building a nuclear power plant in the neighborhood (Sun and Zhu, 2014). This paper aims to study the factors that can reduce this fear and increase the support of SNRs located near people's dwellings.

The literature on public perceptions of nuclear power is vast and comprehensive. It generally suggests that public opinion is affected by the perceived benefits, costs, risks, and the perceived ability of governments to reduce these risks (Stoutenborough et al., 2013). In the case of nuclear energy, the benefits include the stable, climate-neutral energy source for a reasonable price (Bird et al., 2014), while the risks encompass all the fears of radiation and other effects coming from nuclear accidents (Bird et al., 2014; Guo and Ren, 2017).

However, the perceived benefits, costs, and risks studied in the literature primarily concerned traditional power stations. This paper argues that the benefits and risks of Small Power Stations are somewhat different. Moreover, the technology on SNR is still on the stage of the prototype; thus, the requested public support for the placement of SNR is still hypothetical, with no existing evidence of the reactors already in place. Yet, public support is indispensable for the future location of SNR close to the people's homes. To our knowledge, the literature on the factors affecting public perceptions of SNR is lacking.

The perceived benefits, costs, and risks of new technologies are impacted by knowledge about the subject, cognitive abilities, and education (Soares, 2009; Čábelková et al., 2021; Hande et al., 2022). In addition, public attitude is often affected by values, which are heavily influenced by the mass media, such as traditional (TV, Radio, Printed newspapers, and magazines) and new (social networks, online news sources, online and off-line discussions; Mulder, 2012; Kim and Kim, 2014; Koerner, 2014).

This paper studies the factors predicting the public acceptance of SNR in locations closer than 10 km from residence, more than 50 km from residence, in the city, in and out of the current nuclear power stations. We hypothesize that the acceptability of SNR in various locations is affected by the knowledge of technology (both of nuclear energy and SNR), attitude to nuclear energy (fear, the trust in the government in NE), environmental concerns, the perception of electricity needs in the future (increase, can be replaced by renewables), sources of information (mass media, other), and socio-demographic characteristics including age, gender, and education. Methodologically we rely on a Principal component analysis and a set of ordinal logit analyses performed on representative survey data in the Czech Republic (N = 1,013, 51.2% female, aged 15–91, M ± SD: 47.7 ± 17.6; 19.6% with higher education).

The paper is structured as follows. The next sections present the benefits, costs, and risks of small nuclear reactors as opposed to traditional ones. The following section summarizes the literature on the factors affecting the public acceptance of nuclear technologies and defines the hypotheses. The following sections describe the data, methodology, and results. The last sections discuss the results and conclusions.

2 Small nuclear reactors (SNR) as an alternative to conventional reactors

Historically, nuclear power in advanced economies was responsible for around 50% of all low-carbon electricity, i.e., over ten times more than the combined contribution of wind and solar power (1971–2018, IEA, 2019). In EU countries, nuclear power contributed around 25% of total energy generation, with shares less than 5% in the Netherlands up to more than 50% in the countries implementing policies to support nuclear power like the Czech Republic or Hungary (ibid). Besides effective energy production, the nuclear power stations are considered to be Green House Gasses neutral, thus reducing the speed of Global warming (Coleman et al., 2012; Lenzen and Schaeffer, 2012; Kharecha and Hansen, 2013; Pata and Kartal, 2022).

The major challenges to the widespread use of nuclear power reactors are relatively large investment costs, inflexible electricity provision, and extensive requirements for safety and security (Mignacca et al., 2020). The first two limitations can be largely avoided by Very Small (under about 15 MWe) to Small (under 300 MWe) Nuclear Reactors (SNR) located close to people's residences. These reactors can provide stable electricity sources close to the customers, thus making it independent from large electricity grid systems, eliminating transmission of electric energy to long distances, and reducing capital costs. Besides electricity, they could also provide a heat source for heating systems of homes and enterprises. The power of small or very small reactors could be tuned to the particular needs of consumers, be it industrial enterprises, cities, or particular families. (World Nuclear Association, 2022).

The idea of Small Nuclear Reactors (under 300 MWe, International Atomic Energy Agency) goes back to the times after World War II. Though the first reactors were relatively small, the development prioritized large Nuclear Power Stations (NPS, Ingersoll, 2009). The revival of small modular technologies for power stations occurred at the beginning of the 21st century. Nowadays, various technologies exist, and several reactors are already operating (see Table 1). Many other reactors are planned, licensed, or built (World Nuclear Association, 2022).

The operating cost effectiveness, low carbon generation, simpler design, and job creation make SNRs one of the alternatives for the future (Shropshire, 2011; Carlsson et al., 2012; Lokhov et al., 2013; OECD, 2021). The enormous potential of SMRs rests on the factors summarized can be seen in Table 2.

The operating cost effectiveness, low carbon generation, simpler design, and job creation make SNRs one of the viable alternatives for the future (Shropshire, 2011; Carlsson et al., 2012; Lokhov et al., 2013; OECD, 2021).

Despite all benefits of SNRs, the adverse health effects of radioactivity and the accidents on powerplants (Three Mile Island, Chornobyl, and Fukushima) made people fear the Nuclear Power Plants and made them unacceptable close to their place of residence (Emanuel, 2021; Wu and Huang, 2021).

TABLE 1 Small nuclear reactors operating.

Name	Capacity (MWe)	Type	Developer
CNP-300	300	PWR	SNERDI/CNNC, Pakistan and China
PHWR-220	220	PHWR	NPCIL, India
EGP-6	11	LWGR	at Bilibino, Siberia (cogen, soon to retire)
KLT-40S	35	PWR	OKBM, Russia
RITM-200	50	Integral PWR, civil marine	OKBM, Russia

Source: World Nuclear Association (2022).

TABLE 2 Benefits of small nuclear reactors (SNR) as compared to large nuclear power stations (LNPS).

Groupe	Large nuclear power stations (LNPS)	Small nuclear reactors (SNR)
Initial investments	The LNPS requires considerable initial investments. However, once constructed, their electricity is relatively cheap and stable (Gu, 2018; Rothwell, 2018; Haas, et al., 2019; Wu et al., 2019)	The initial investments are relatively low, especially if the reactors are standardized and economies of scale are explored (Ingersoll, 2009)
Site selection and preparation	The site choice, preparation, initial infrastructure, and all permissions are complicated and generally long-term (Baskurt and Aydin, 2018)	Given the size and the modular structure, the requirements for the locality are less demanding. The decreased amount of radioactive particles present in the center of a reactor, which might be released into the environment, renders them suitable for use near residential sites and allows their heat output to be harnessed for heating. (Ingersoll, 2009)
Design and construction	The design and construction are largely complicated, requiring considerable expertise and a large set of sub-contractors, and must be tailored to a particular locality. This produced considerable delays in the construction of new reactors and increased construction costs time fold. Under the condition of everchanging legislation, these projects became rather risky (Gu, 2018; Portugal-Pereira et al., 2018; IEA, 2019; Matsuo and Nei, 2019; Wu et al., 2019)	The design and construction can be standardized, enabling economies of scale and reducing the number of sub-contractors, construction risks, and costs. The reactors can be built in a controlled factory setting and installed in chosen locality module by module (Shropshire, 2011; Carlsson et al., 2012; Lokhov et al., 2013; Carter, 2016; OECD, 2021)
Transmission systems and energy grids	Large investments in the transmission systems are required, as, given the size, the reactors are located far away from consumers (Gu, 2018; Wu et al., 2019)	The transmission of electricity over long distances is largely eliminated, thus reducing capital costs and pressure on energy grids (World Nuclear Association, 2022)
Safety	The additional safety requirements enacted after each nuclear accident made it difficult to design safe, easy-to-operate, cost-efficient, and reliable nuclear reactors (Gu, 2018; Wu et al., 2019)	The safety requirements, though equally binding, could be met in a standardized setting by exploiting economies of scale. Moreover as (Ingersoll, 2009)
Time flexibility of energy production	Low flexibility of the reactor in energy production related to the time schedule of energy needs, though good practices for increasing this flexibility exist (Cany et al., 2018; Morilhat et al., 2019)	Low flexibility of the reactor in energy production for related to the time schedule of energy needs. However, this flexibility can be increased if combined with an energy storage system (Nian and Zhong, 2020)
Ability to be tuned to locality needs	Low ability to tune the reactor changing energy needs of a particular locality	The reactors can provide a stable energy source tuned to particular customers' needs independently of large electricity grids (World Nuclear Association, 2022)
Need of expertise in operation	The operation of a power station requires considerable expertise in Nuclear processes and energy systems	The expertise requirements are less strict. The SNRs are a viable alternative for localities with small grids and less experience with NE due to their small size and passive safety features (World Nuclear Association, 2022)

Source: own compilation of literature sources.

3 The factors affecting public acceptance of nuclear technologies in the literature

Public perceptions of new technologies are generally affected by perceived benefits, costs, risks, and the perceived ability of governments to reduce these risks (Stoutenborough et al., 2013). All these are influenced by knowledge about the subject, cognitive abilities, and education (Soares, 2009; Hande et al., 2022). Public perceptions are, in most cases, heavily influenced by the mass media, either traditional (TV, Radio, Printed newspapers, and magazines) or new ones (social networks, online news sources, online and off-line discussions; Mulder, 2012; Kim and Kim, 2014; Koerner, 2014).

3.1 Knowledge of technology

In Korea, despite numerous scientific analyses and all the efforts taken to promote nuclear power as an environmentally friendly energy source, nuclear power is in jeopardy. According to Lee and Roh (2022), this can result from the Korean public's insufficient knowledge of nuclear power.

However, important factors for decreasing public concerns about nuclear power include comprehensive knowledge and improving the transparency of nuclear power regulations Guo and Ren (2017) also noticed that the local acceptance of nuclear power plants in China depends on perceived benefits and risks. However, contrary to the findings by Sun and Zhu (2014) or evidence from the US delivered by Stoutenborough et al. (2013), Guo and Ren (2017) pointed out that the public's perception of nuclear power is influenced by emotional identification and social trust rather than knowledge.

Huang et al. (2018), just like Sun and Zhu (2014), found a positive relationship between knowledge and nuclear risk acceptance. An analogous relationship was also observed between trust and risk acceptance. The latter relationship has been previously proved by Liu et al. (2008). In turn, Kim et al. (2014), based on their analysis of 19 countries, indicated that knowledge of nuclear inspection is a more effective factor than trust in inspection authorities in enhancing the public's acceptance of nuclear power in countries with relatively strong opposition to nuclear power. Huang et al. (2018) showed that before the Fukushima accident, perceived benefits had a stronger impact on nuclear power acceptance than perceived risks, while after the nuclear accident, the importance of benefits decreased, and risks were more and more decisive to the public's acceptance.

Thus, we hypothesize that:

Hypothesis 1 The public acceptability of Small Nuclear Reactors is impacted by the knowledge of technology (both the technology of NE and SNR; H1.1, H1.2).

3.2 Attitude to nuclear energy. The role of nuclear accidents

The public's perception of nuclear power is affected by nuclear accidents, including the Fukushima disaster (Guo and Ren, 2017). The Australian public's acceptance of nuclear power in relation to climate change and the Fukushima disaster has been assessed, e.g., by Bird et al. (2014). As results from their study, in 2010 (before the Fukushima accident), 42% of Australians were willing to accept nuclear power if it would help combat climate change, while in 2012 (after the Fukushima disaster) the public support for building nuclear power plants has decreased (34.4% of Australians supported that idea). In 2012 an increased proportion of respondents believed that the risks associated with nuclear power outweighed the possible benefits related to the extensive use of cleaner and more efficient source of energy than coal (Bird et al., 2014).

Similarly, to Bird et al. (2014) as well as Ho and Chuah (2021), who focused on five Southeast Asian countries including Indonesia, Malaysia, Singapore, Thailand, and Vietnam, Huang et al. (2013), Huang et al. (2018) identified a decreasing public acceptance of nuclear power after the Fukushima accident. Risk acceptance declined most among women, people over the age of 35, respondents not in public service, those with lower income or higher level of education, and living near nuclear power plants (Huang et al., 2013).

Those results concur with the Switzerland study by Visschers and Siegrist (2013) and Siegrist et al. (2014). However, in China, perceived risks have become a stronger predictor of acceptance than benefits (Huang et al., 2018). Due to the greater awareness of the risks of nuclear power before the nuclear accident, this was not the case in Switzerland (Visschers and Siegrist, 2013). In that country, economic benefit perception has remained a more important driver for nuclear power acceptance than risk perception (Visschers et al., 2011). Perceived benefits were also of key importance in determining the public's acceptance of nuclear power plants in Korea (Jang and Park, 2020).

Thus, we hypothesize that:

Hypothesis 2 The public acceptability of Small Nuclear Reactors is impacted by the attitude to nuclear energy—fear of NE, trust in the government in dealing with NE, and perception that the share of NE should increase (H2.1, H2.2, H2.3).

3.3 Climate change and environmental concerns

However, a more recent study by Uji et al. (2021) showed that climate change concerns do not drive the acceptance of nuclear power, possibly because the benefits of climate mitigation are not clearly visible and immediate. Nonetheless, climate change mitigation appears to be a significant factor boosting nuclear power acceptance in the United Kingdom, Finland, and France (Bickerstaff et al., 2008; Pidgeon et al., 2008; Teräväinen et al., 2011), i.e., in countries that have experienced nuclear power generation. At the same time, Lee and Roh (2022) revealed the negative relationship between greenhouse gas concerns and nuclear power acceptance in South Korea. Hence, it can be concluded that empirical evidence is ambiguous in the case of those impacts).

Thus, we hypothesize that:

Hypothesis 3 The public acceptability of Small Nuclear Reactors is impacted by the concerns about the environment—both the current environment and climate change (H3.1, H3.3).

3.4 Future electricity needs and the possibility of replacing conventional energy sources with renewables

The future electricity needs of the world are predicted to increase significantly due to population and economic growth, urbanization, and the increased electrification of transport and heating. According to the International Energy Agency (IEA), global electricity demand is set to double by 2050 (IEA, 2022). This increase in demand will be driven by rising incomes, population growth, and the electrification of transport and heating, as well as the need to decarbonize electricity generation to meet climate change targets (ibid).

Renewable sources of energy were sought to have the potential to accommodate these new electricity needs and to replace

traditional energy sources due to their abundance, sustainability, and environmental friendliness. However, the instability of energy production and the excess pressure on electricity grids in the peaks of production cast certain doubts on the ability to replace the traditional energy sources. Some authors suggest that renewables should be used together with the conventional sources of energy (Bekirsky, et al., 2022).

Thus, we hypothesize that:

Hypothesis 4 The public acceptability of Small Nuclear Reactors is impacted by the perception of electricity needs in the future (increase/decrease, H4.1) and the possibility of replacing conventional energy sources with renewables (H.4.2).

3.5 The effect of distance from the plant

On the other hand, Guo and Ren (2017) found that the public perception of nuclear power plants is affected by the distance to the plant sites. People who live closer to them are usually less willing to accept it than those who live further. On the one hand, this is consistent with the observations by Huang et al. (2013), but on the other hand, this has not been confirmed by Uji et al. (2021) when evaluating the public support for nuclear power in Japan.

We do not formulate the hypothesis on the distance from the plant; however, we take it into account in the formulation of the dependent variable.

3.6 The effect of income, gender and education

Many analyses on the acceptance of nuclear power plants in the post-Fukushima period offer evidence from China. Sun and Zhu (2014) focused on nuclear power plants at the preliminary planning stage and showed that people in China are willing to pay up to US$ 116.6 per year to avoid building a nuclear power plant in the neighborhood. It was also indicated that the higher the annual income, the higher amount of willingness to pay.

Stehlik (2010) found that older Australians are more likely to support nuclear power than younger people. The same applies to men compared to women, who are usually more concerned about climate change (McCright, 2010) and perceive risks to be higher (Leiserowitz, 2006). Stronger support for nuclear power from men than women was also found by Arikawa et al. (2014), who examined Japanese attitudes toward nuclear power after the Fukushima accident. Unlike in Australia, the older Japanese showed less support for nuclear power. Opponents of nuclear power were also identified as those who use electronic devices less intensively and reveal energy-saving behavior to a greater extent than nuclear power advocates.

3.7 The aim of the paper

The aim of the paper is to assess the factors affecting the acceptability of Small Nuclear Reactors, such as knowledge of technology, attitude to nuclear energy, concerns about the environment, and the perspective of electricity needs in the future (increase/decrease).

3.8 Hypotheses, recapitulation

The public acceptability of Small Nuclear Reactors is related to:

1. Knowledge of technology (both the technology of NE and SNR; H1.1, H1.2)
2. Attitude to Nuclear Energy—fear of NE, trust in the government in NE, and perception that the share of NE should increase (H2.1, H2.2, H2.3)
3. Concerns about the environment—both the current environment and climate change (H3.1, H3.3)
4. The perception of electricity needs in the future (increase/decrease, H4.1) and the possibility of replacing conventional energy sources with renewables (H.4.2)

4 Data and methodology

4.1 The data

The data were collected by the Czech Institute of Sociology in the project Our society (Nase spolecnost, Sociologický ústav, 2020). One thousand thirteen persons representing the population of the Czech Republic aged 15 and over were interviewed voluntarily and anonymously (N = 1,013, 51.2% female, aged 15–91, $M\pm SD$: 47.7 ± 17.6; 19.6% with higher education). The representativeness of the collection was ensured by quotas derived from the real distribution of the required characteristics in the population of the Czech Republic. The monitored quotas were that of gender, age (6 categories), and education (4 categories) of the respondent. Other monitored quota features were also the region (14 categories), size of place of residence (5 categories), economic status (6 categories), and internet use (3 categories, ibid.). The data are available for non-commercial use upon signing up the corresponding contracts with the depositor of the data. The data should not be used for commercial purposes or transmitted to third parties.

4.2 The indicators

4.2.1 Indicators for public acceptability of small nuclear reactors

One of the main benefits of small nuclear reactors is the ability to be close to the electricity consumers, thus avoiding much of the financial, environmental, and land-related costs of long electricity transmission networks. However, the direct proximity of Small Nuclear Reactors (SNR) to the customers might be unacceptable to many of them. Thus, the indicators of public support study the acceptance of SNR in direct proximity to the public. The answers to the following questions were employed:

1. *"How acceptable or unacceptable would the construction of a small nuclear reactor be for you?" Tell me your opinion on these options:*
   a) A small nuclear reactor would be built closer than 10 km from your home

b) A small nuclear reactor would be built more than 50 km from your home
c) A small nuclear reactor would be built on the site of some of the existing nuclear power plants in the Czech Republic
d) A small nuclear reactor would be built outside the existing nuclear power plants in the Czech Republic.

2. *Unlike large nuclear reactors, which are being built outside the city, the possibility of building a small nuclear reactor directly in the city and using it as a heating plant supplying heat is being considered. Would you agree with a small nuclear reactor built in the city and serving as a heating plant?"* (Sociologický ústav, 2020).

The distributions of the respondents are presented in Table 3.

From Table 3 follows that for a little over 50% of the respondents, the construction of the SNR directly in their city or up to 10 km from their home is (definitely or rather) unacceptable. The location of SNR in the area of the current NPS is much more acceptable—for 65% of respondents, it is definitely or rather acceptable. However, in this case, the main benefit of SNR - the possibility of locating close to the customers—is difficult to achieve. On the other hand, it is possible to use the existing electricity distribution system if the capacity is sufficient.

The acceptability of SNR further than 50 km from the respondents' home and out of the area of current NPS is approximately similar—approximately a third of the respondents find these two options unacceptable (definitely or rather), and 45%–50% of the respondents agree or rather agree with this option. A significant share of the respondents (15%–20%) did not have an opinion on the acceptability of SNR.

4.2.2 Indicators for knowledge of technology

The knowledge of technology firstly implies the knowledge of Nuclear Energy (NE) principles, and secondly, some knowledge of the technological principles of Small Nuclear Reactors (SNR). Two indicators were employed to study these aspects according to the answers to the following questions:

1. *"At your own discretion, try to say what is the level of your knowledge in the field of physical and technical principles of nuclear power plant operation:"* no or almost no knowledge (37,4%), basic knowledge (45.7%), advanced knowledge (9.7%), knowledge almost or completely at the level of an expert (1.4%), no opinion (5,8%) (Sociologický ústav, 2020).
2. *"The possibility of using the technology of so-called small nuclear or modular reactors to produce energy from nuclear power is currently being investigated. Have you ever heard of small nuclear or modular reactor technology?"* Yes (18.1%), No (72.3%), Do not know (9.6%) (ibid).

The distribution of the respondents above presents a very bleak picture of the knowledge of the population of Nuclear principles and technologies. Almost 40% of the respondents reported no knowledge of nuclear energy principles, which is surprising as these principles should be explained in secondary schools. Despite that, only 45% of the respondents acknowledged at least basic knowledge. Similarly, only 18% of the respondents acknowledged that they had heard about Small Nuclear Reactors (SNR). The overall level of knowledge thus seems to be very low.

4.2.3 Attitude to NE

Though not many respondents revealed some level of knowledge on principles of NE, we expected that there is some emotional attitude to NE, possibly formed by the last Nuclear incidents, discussion on the expansion of Temelin or Dukovany Power Stations, and the recent Energy policy of EU and Czech Government. Three indicators were used to study these attitudes:

1. *"Do you yourself feel concerned about the use of nuclear energy in our country?"* Major concern (8.3%), medium concerns (22.1%), small concerns (38.3%), no concerns (27.0%), No opinion (4.2%), (Sociologický ústav, 2020),
2. *"Do you trust the government of the Czech Republic to make the right decisions about the development of nuclear energy in our country?"* Definitely yes (8.7%), rather yes (43.2%), rather not (25.1%), definitely not (10.5%), no opinion (12.5%) (ibid).
3. *"Do you think that the share of nuclear energy in the production of electricity in our country should increase in the future, remain at the current level, or should decrease? "* Should definitely increase (8.8%), rather should increase (23.6%), should remain at the current level of (36.7%), should rather decrease (16.1%), should definitely decrease (4.0%), no opinion (10.8%) (ibid).

Understandably, in light of the Nuclear Incidents in Chornobyl and Fukushima, almost 70% of the respondents had some (small or big) concerns about the use of nuclear energy in the Czech Republic. However, a little above 50% trust the government in the decisions about nuclear energy. But the most surprising was the support for Nuclear energy. Almost a third of the respondents believe that the share of nuclear energy in electricity production in the Czech Republic should increase. Another third of the respondents (36,7%) stated that the share of energy should remain the same.

4.2.4 Electricity needs in the future

Electric usage is likely to go up in the near future. The replacement of gasoline-powered vehicles with electric equivalents will result in a surge of electricity demand, and this energy must be generated without harming the environment; yet there are still doubts that this can be done. The next indicators reveal public opinions:

1. *"Do you think that our electricity consumption will increase, remain at its current level, or decrease in the future?"* It will definitely increase (30.3%), will rather increase (43.6%), will remain at the current level (16.8%), will rather decrease (4.0%), will definitely decrease (0.4%), no opinion (4.8%), (Sociologický ústav, 2020),
2. *"Do you think that it is possible to replace the production of electricity from conventional sources (such as thermal power plants burning coal or gas, nuclear power plants, or large dam hydropower plants) with the production of electricity from wind, solar radiation, and biomass combustion?"* It can definitely be replaced (8.7%), rather it is possible to replace (35.5%), rather it is not possible to replace (33.2%), certainly cannot be replaced (12.2%), no opinion (10.4%), (ibid).

Above 70% of the respondents believe that in the future, electricity consumption will (definitely or rather) increase in the Czech Republic, while 45% of the respondents believe that it is not possible to replace the production of electricity from conventional

TABLE 3 The acceptability of small nuclear reactors. The distribution of the respondents (%).

	Definitely unacceptable	Rather unacceptable	Rather acceptable	Definitely acceptable	No opinion
SNR up to 10 km, (%)	28,2	26,7	22	5,4	17,7
SNR further than 50 km, (%)	13,9	19,4	35,5	15,9	15,2
SNR in the area of current NPS, (%)	6,5	10,5	39,6	26	17,5
SNR out of the area of current NPS, (%)	11,5	19,4	33,8	12,6	22,7
SNR directly in the city, (%)	25,2	25,7	23,2	5,4	20,5

Note: SNR, Small Nuclear Reactor; NPS, Nuclear Power Station. the respondents with no opinion were excluded from further analysis.

sources with the production from renewable sources. Thus, it seems that nuclear power will still have its place.

4.2.5 Environmental concerns

The production of electricity, including the production from Nuclear energy, has some impact on the environment. In this paper, we monitor two indicators—the level of satisfaction with the current state of the environment in the Czech Republic and the fear of climate change:

1. *"How satisfied or dissatisfied are you with the environment in our republic?"* Very satisfied, (5.1%), rather satisfied (50.5%), rather dissatisfied (36.1%), very dissatisfied (4.7%), no opinion (3.7%), (Sociologický ústav, 2020),
2. *"How much are you worried about the effects of climate change?"* Very worried (17.2%), more worried (48.6%), rather not worried (24.1%), definitely not worried (6.5%), no opinion (3.6%), (ibid).

4.2.6 Sources of information

We considered seven possible sources of information: TV, printed magazines and newspapers, radio, news servers on the internet, discussion and blogs on the internet, social networks, and discussions outside the internet. The distribution of the respondents is presented in Table 4.

The indicators of sources of information were then transformed into two categories - Traditional media and New media, as presented in the section Data transformation.

4.2.7 Socio-demographic characteristics

We consider the following socio-demographic and other characteristics of the respondents: age In years), gender (as self-reported by the respondent, male = 1), education (basic = 1, secondary w/o state exam = 2, secondary with state exam = 3, higher = 4 included into further analysis as factor variable), economic activity (active = 1/non-active = 0), subjective size of the municipality the respondent lives in (large city, suburb of a large city, medium-sized city, small town, large village, small village, solitude), political orientation (left-right, 11 point scale), life satisfaction (definitely satisfied = 1, rather satisfied = 2, neither satisfied nor dissatisfied = 3, rather dissatisfied = 4, definitely dissatisfied = 5, 5 point scale).

4.3 Data transformations

In order to reduce the dimensionality of the model we applied the Principle Componenta Analysis (with VARIMAX rotation and Kaiser Normalization) to six variables representing the sources of information (Table 5). Two components were extracted, which can be tentatively named as old media and new media. The regression-based factor scores were saved for all the observations. These scores served as indicators for sources of information (New media and Traditional media) in the further analysis.

The two extracted components explained 61% of the variability of the original variables.

All the respondents who had chosen "no opinion" in any of the questions were excluded from the further analysis.

4.4 The model

We rely on a set of ordinal regression analyses in the following form (formula 1):

$$\begin{aligned} SNR\,acceptability_i = logit\big(&a_0 + a_{1-2}Technology + a_{3-5}Attitude \\ &+ a_{6-7}Electricity + a_{8-9}Environment + a_{9-10}Info \\ &+ a_{11}Age + a_{12}Gender + a_{13-15}Education \\ &+ a_{16}Economic\,activity + a_{17-21}Municipality \\ &+ a_{22}Political\,orientation + a_{23}Life\,Satisfaction + e\_ \end{aligned} \quad (1)$$

where

SNR acceptability—five indicators of acceptability subsequently (SNR up to 10 km, SNR further than 50 km, SNR in the area of current NPS, SNR out of the area of current NPS, SNR directly in the city, Table 3).

Technology—two indicators of Knowledge of Nuclear technology (knowledge of principles of NE, knowledge of technology for SNR, see section Indicators for knowledge of technology).

Attitude—three indicators mapping Attitude to Nuclear Energy (Fear of NE, trust to the government in NE, the belief that share of NE should increase, see section Attitude to NE).

Electricity—two indicators on the perception of electricity needs in the future (the belief that electricity consumption will increase in the future, the perception on whether conventional electricity replacement is possible (see section Electricity needs in the future).

Environment—two indicators for environmental concerns (satisfaction with the environment in the Czech Republic, fear of climate change, see section Environmental concerns).

Info—two indicators for sources of information (new media, old media, see section Sources of information).

TABLE 4 Indicators—exposition to mass media and social discussion platforms concerning following social life. Frequency table (%).

How often do you follow social life via	At least once a day, %	Several times a week, %	Once a week, %	Less than once a week, %	Never, %
TV	50,2	29,7	8,1	7,3	4,4
Printed newspapers and magazines	12,4	22,3	21,1	22,5	21,3
Radio	23,5	29,9	14,4	13,2	18,6
News webs on internet	25,2	29,8	14,3	10,6	19,7
Internet discussions and blogs	7,8	14,7	15,1	17,7	44,1
Social networks (for example, Facebook, Twitter, or Instagram)	13,2	15,4	11,7	14,2	45
Discussions outside of internet	6,5	24,3	24,6	21,4	21,5

Source: Data from (Sociologický ústav, 2020), own processing.

TABLE 5 Rotated component matrix and total variance explained.

Factors		Component factor loadings		Rotation sums of squared loadings		
		I	II	1	2	3
New media	Internet-based blogs, discussions	0,857	−0,063	2,384	34,054	34,054
	Social networks	0,83	−0,145			
	Online news servers	0,79	0,028			
	Discussions outside internet	0,568	0,27			
Traditional media	Printed newspapers, magazines	0,068	0,82	1,931	27,58	61,634
	Radio	0,025	0,792			
	TV	−0,062	0,73			

Note: Extraction method: principal component analysis. Rotation method: varimax with kaiser normalization. 1—Total; 2—% of variance, 3—Cumulative %.

Age, Gender, and *Education*—age, gender, and education (basic, secondary w/o state exam, secondary with state exam, higher).
Economic activity—active/non-active.
Municipality—the subjective size of a municipality (large city, a suburb of a large city, medium-sized city, small town, a large village, small village, solitude.
Political orientation—political orientation on 11-point scale.
Life satisfaction – subjective life satisfaction.

5 Results and discussion

The results of ordinal regression analyses (formula 1) are presented in Tables 6, 7.

5.1 Knowledge of technologies (H1.1, H1.2)

From Tables 6, 7 follow that knowledge of principles of NE is statistically significant predictor of SNR acceptability in four out of five indicators (SNR up to 10 km, SNR further than 50 km, SNR out of the area of current NPS, SNR directly in the city). The more knowledge of NE technology the respondent reports, the more acceptable SNR is up to 10 km from his residence, SNR further than 50 km from his residence, SNR out of the area of current NPS, and SNR directly in the city. The indicator of SNR in the area of current NPS was not statistically related to the subjective level of knowledge of NE. This may be because SNR's location in the current NPS area does not significantly change the perceived threat of nuclear energy.

In addition, the perceived knowledge of SNR technology increases the acceptability of SNR according to the following indicators: SNR up to 10 km, SNR in the area of current NPS, and SNR directly in the city.

5.2 Attitude to NE (H2.1, H2.2, H2.3)

Attitude to NE also proved to be highly related to public acceptability. The more the respondent is concerned about the use of NE in the Czech Republic, the less acceptable is the use of NE in all the five indicators (SNR up to 10 km, SNR further than 50 km, SNR out of the area of current NPS, SNR in the area of current NPS, SNR directly in the city). The more respondents trust the government about NE in the country, the more acceptable SNR are according to the four (out of five) following indicators: SNR up to 10 km, SNR further than 50 km, SNR in the area of current NPS, SNR out of the area of current NPS). The more respondents believe that the share of NE in the production of electricity in the Czech Republic should increase, the more he accepts SNR up to 10 km from their residence, further than 50 km from their

TABLE 6 Predicting the acceptance of small nuclear reactors. The results of original regression analyses I.

	SNR up to 10 km		SNR further than 50 km		SNR in the area of current NPS	
	Estimate	Sig	Estimate	Sig	Estimate	Sig
Threshold = 1	−0,921	0,371	−0,309	0,760	−2,540*	0,014
Threshold = 2	0,912	0,376	1,358	0,181	−1,21	0,24
Threshold = 3	3,485**	0,001	3,772***	0,000	1,197	0,245
Knowledge of technology						
Knowledge of principles of NE	0,535***	0,000	0,304*	0,036	−0,022	0,881
Knowledge of SNR technology	−0,524*	0,017	−0,293	0,183	−0,505*	0,023
Attitude to NE						
Fear of NE	0,718***	0,000	0,763***	0,000	0,438***	0,000
Trust to the government in NE	−0,299*	0,027	−0,476***	0,000	−0,394**	0,003
Share of NE should increase	−0,404***	0,000	−0,278**	0,006	−0,079	0,447
Electricity needs in the future						
Electricity consumption increase	0,315**	0,006	−0,057	0,607	−0,305**	0,008
Conventional electricity replacement possible	0,283*	0,010	0,513***	0,000	0,432***	0,000
Environment concerns						
Environment satisfaction	−0,327*	0,023	−0,055	0,682	−0,160	0,241
Fear of climate change	0,126	0,291	0,400**	0,001	0,387**	0,001
Sources of information						
New media	−0,274*	0,010	−0,190	0,070	0,010	0,924
Old media	−0,216*	0,032	−0,224*	0,022	−0,197	0,053
Socio-demographic variables						
Age	−0,014*	0,036	−0,005	0,430	−0,004	0,508
Gender	0,532**	0,005	0,111	0,546	0,111	0,550
Education—basic	0,146	0,695	0,381	0,284	0,169	0,644
Education—secondary w/o exam	0,272	0,291	0,435	0,083	0,389	0,125
Education—secondary with exam	0,273	0,250	0,433	0,061	0,230	0,325
Economic activity—non-active	0,312	0,118	0,238	0,221	0,042	0,829
Subjective size of municipality						
large city	−0,128	0,734	0,285	0,44	0,557	0,128
suburb of a large city	−1,060	0,106	−0,643	0,312	0,280	0,672
medium-sized city	−0,681	0,065	−0,774*	0,031	−0,131	0,714
small town	−0,049	0,889	−0,114	0,741	0,260	0,449
large village	0,406	0,382	−0,138	0,763	0,591	0,219
Political orientation	−0,057	0,197	−0,016	0,714	0,022	0,606
Life satisfaction	−0,119	0,301	−0,051	0,633	−0,079	0,464
Model Fitting Information (Sig.)		0,000		0,000		0,000
Pseudo R-Square						
Cox and Snell	0,391		0,385		0,241	
Nagelkerke	0,423		0,415		0,265	

(Continued on the following page)

TABLE 6 (*Continued*) **Predicting the acceptance of small nuclear reactors. The results of original regression analyses I.**

	SNR up to 10 km		SNR further than 50 km		SNR in the area of current NPS	
McFadden	0,191		0,184		0,116	
N	514		534		523	

Notes: SNR, Small Nuclear Reactors; NE, Nuclear Energy, Reference variables: gender—women, education—higher, economic activity—active, size of settlement—small village, settlement, solitude. Link function: Logit. ***-significant on 0,1% level. **—significant on 1% level, *—significant on 5% level. Thresholds indicate the cutoffs between categories on an ordered scale. Thresholds are determined by finding the point at which the probability of belonging to a particular category (e.g., high-moderate-low) changes.

residence, out of the area of current NPS, and directly in the city.

5.3 Future electricity needs and the possibility of replacing traditional energy sources with renewables (H3.1, H3.2)

A greater belief that the electricity needs in the future will increase was associated with less acceptance of SNR up to 10 km from the residence and directly in the city and more acceptance of SNR in the area of currents NPS.

The belief that it is possible to replace conventional electricity sources with renewables was associated with less acceptance of SNR in four out of five cases - up to 10 km for residence, further than 50 km from the residence, in and out of the area of current NPS.

5.4 Environmental concerns (H4.1, H4.2)

The more the respondents are satisfied with the environment in the Czech Republic, the more they accept SNR up to 10 km from their residence.

The more the respondents are worried about climate change, the less acceptable for them is SNR further than 50 km from their residence, in and out of the area of current NPS.

5.5 Sources of information

The role of the mass media, both old (printed newspapers, magazines, radio, TV) and new (internet-based blogs, discussions, social networks, internet news, discussions outside the internet), was generally positive. The more respondent exposes himself to new and old media, the more he accepts SNR up to 10 km from the residence. Old media also support the acceptance of SNR further than 50 km and out of the area of current NPS.

5.6 Socio-demographic variables

Except for the modular technology, the main advantage of SNR is the ability to locate this reactor close to consumers, as it can also serve as a heating plant. Thus, it seemed reasonable to assume that the size of the city would be a significant predictor of the acceptability of SNR would be dependent on the size of the city of the respondent. However, the statistical significance of relevant indicators was low. Respondents living in medium-sized towns accept less SNR further than 50 km. People living in large cities are more accepting of SNRs out of the area of current NPS.

Older respondents and women accept less SNR located close to their residence (SNR up to 10 km from residence and directly in the city).

5.7 Summary of the results and discussion

The use of SNR presents several interrelated and controversial contexts in the population's minds. First, there is a widespread belief that future electricity needs will increase (70% of the respondents). These needs can be satisfied by conventional sources and renewables. However, the population presents high distrust for renewables' ability even to replace the production of energy from conventional sources (45% of the respondents), not to mention the potential of renewables to increase overall energy production. Apart from renewables, and in light of high environmental concerns (almost 70% of the respondents are worried about the effects of climate change), nuclear energy presents one of the viable emission-free alternatives. Despite the nuclear accidents, the majority (65%) of the respondent have only small or no concerns about the use of nuclear energy in the Czech Republic, which presents a large opportunity to utilize NE for energy production in the future. Almost 70% of the sample believe that the future use of nuclear power for electricity production should stay the same or even increase.

In this respect, SNRs present an auspicious direction for energy production compared to Large Nuclear power Plants (Table 2). One of the biggest advantages of SNR is that if located close to a place of residence, they can produce both the electricity (tuned to the local electricity needs and largely independently from global electricity grids) and heat for the heating systems. However, the respondents showed little acceptance of SNR close to their residence (above 50% of the respondents perceived SNR unacceptable up to 10 from their homes or directly in the city). SNRs are more acceptable further than 50 km from the residence (above 50% of the respondents), and ideally, they should be located in the area of current nuclear power plants (almost 70% acceptance). Interestingly, almost one-quarter of the respondents (15%–22%) could not define their level of acceptance of SNR in various locations.

This fact is linked with the relatively low education in nuclear energy principles (85% report no or just basic knowledge of NE principles) and little information about SNR (18% of respondents only report some knowledge about SNR).

We hypothesized that the public acceptance of SNR is contingent upon knowledge of technology, attitude to NE in general, a perceived increase of future electricity needs, perceived substitutability of traditional energy sources with renewables, the attitudes to the

TABLE 7 Predicting the acceptance of small nuclear reactors. The results of original regression analyses II.

	SNR out of the area of current NPS		SNR directly in the city	
	Estimate	Sig	Estimate	Sig
Threshold = 1	−0,693	0,499	−1,185	0,238
Threshold = 2	0,982	0,338	0,483	0,63
Threshold = 3	3,425**	0,001	2,763**	0,006
Knowledge of technology				
Knowledge of principles of NE	0,455**	0,002	0,303*	0,034
Knowledge of SNR technology	−0,041	0,849	−0,530*	0,013
Attitude to NE				
Fear of NE	0,573***	0,000	0,503***	0,000
Trust to the government in NE	−0,358**	0,006	0,006	0,963
Share of NE should increase	−0,258*	0,013	−0,328**	0,001
Electricity needs in the future				
Electricity consumption increase	−0,128	0,260	0,220*	0,048
Conventional electricity replacement possible	0,254*	0,021	0,080	0,450
Environment concerns				
Environment satisfaction	−0,241	0,080	−0,260	0,053
Fear of climate change	0,288*	0,016	0,130	0,252
Sources of information				
New media	0,029	0,783	−0,066	0,519
Old media	−0,309**	0,003	−0,155	0,112
Sociodemographic				
Age	−0,011	0,089	−0,015*	0,017
Gender	0,200	0,282	0,500**	0,006
Education—basic	0,089	0,811	0,572	0,121
Education—secondary w/o exam	0,431	0,087	0,120	0,627
Education—secondary with exam	0,315	0,173	0,157	0,489
Economic activity—non-active	0,248	0,208	0,207	0,289
Subjective size of municipality				
large city	0,829*	0,030	−0,081	0,825
suburb of large city	−0,113	0,861	0,016	0,982
medium-sized city	−0,095	0,799	−0,125	0,727
small town	0,391	0,275	0,065	0,853
Large village	0,409	0,400	0,225	0,624
Political orientation	−0,010	0,817	−0,028	0,513
Life satisfaction	−0,015	0,887	−0,089	0,407
Model Fitting Information (Sig.)		0,000		0,000
Pseudo R-Square				
Cox and Snell	0,280		0,231	
Nagelkerke	0,303		0,250	

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TABLE 7 (*Continued*) **Predicting the acceptance of small nuclear reactors. The results of original regression analyses II.**

	SNR out of the area of current NPS		SNR directly in the city	
McFadden	0,127		0,102	
N	499		509	

Notes: SNR, Small Nuclear Reactors; NE, Nuclear Energy. Reference variables: gender—women, education—higher, economic activity—active, size of settlement—small village, settlement, solitude. Link function: Logit. ***—significant on 0,1% level. **—significant on 1% level, *—significant on 5% level. Thresholds indicate the cutoffs between categories on an ordered scale. Thresholds are determined by finding the point at which the probability of belonging to a particular category (e.g., high-moderate-low) changes.

environment, and we controlled for the sources of information and socio-demographic characteristics. Except for socio-demographic characteristics, all the other factors proved to be statistically significant.

The results suggest that knowledge of technology (both the NE in general and SNR in particular) increases the acceptance of SNR (H1.1 and H1.2. was supported in most cases, similar to Huang et al., 2018; Sun and Zhu, 2014). Fear of NE expectedly decreases the acceptability of SNR (similar to Bird et al., 2014; Ho and Chuah, 2021), while trust in the government (similar to Stoutenborough et al., 2013) and the perception that the share of NE should increase in the future makes the SNR more acceptable (H2.1, H2.2, H2.3 was supported in most cases). The expected future increase of electricity needs was ambivalent to the overall support of SNR - it decreased the acceptance of SNR located up to 10 km from residence and increased support for SNR in the area of current NPS (H3.1 was supported partly). In most cases, the perceived replaceability of conventional energy sources with renewables decreased acceptance of SNR (H3.2 was supported partly).

Environmental attitudes proved to be related to the support of SNR. The concern of climate change led to less acceptance of SNR in 3 out of 5 cases (H4.1 was supported partly), though the literature suggests that nuclear power is one of the ways to mitigate climate change (Siqueira et al., 2019; Makhijani, and Ramana, 2021; Muellner et al., 2021). The level of satisfaction with the environment proved to be unrelated to SNR acceptance in 4 out of 5 indicators (H4.2 was not supported in most cases). In the fifth one, satisfaction with the environment supported the acceptance of SNR located up to 10 km from their residence.

In general, the factors affecting the acceptance of SNR showed to be similar to those affecting public acceptance of Nuclear Energy, though the location of SRN close to the homes showed to be problematic. The media apparently does a good job presenting SNR (people more exposed to the media present more acceptance), though it does a bad job in propagating SNR (18% of respondents only report some knowledge about SNR).

6 Conclusion and policy implications

Nuclear energy, in general, and SNR, in particular, present one of the promising ways to solve the increasing energy needs and mitigate climate change, as they are generally climate neutral (Siqueira et al., 2019; Makhijani, and Ramana, 2021; Muellner et al., 2021). Moreover, if located close to people's residences, SRN can be used for heating systems. However, the location of SRN close to people requires their acceptance. We studied this acceptance on the representative sample from the Czech Republic (N = 1,013, 51.2% female, aged 18–91, $M\pm SD$: 47.7 ± 17.6; 19.6% with higher education).

The results presented in this paper suggest that the population is well aware of the increasing energy needs and is worried about the effects of climate change. Despite the nuclear accidents, the majority of the respondents report only small, if any, concerns with the use of nuclear energy in the Czech Republic and generally support the use of nuclear energy in the future. However, they fear the location of SNR close to their homes or directly in their cities and would rather prefer to locate the SNR in the areas of existing nuclear power stations.

The major problem was the level of information and the knowledge of technologies, which was very low. On the other hand, the knowledge proved to increase the acceptance of SNR. In this respect, the media proved to do a good job in increasing SNR acceptance; though, more work needs to be done.

However, people associate the SNR with climate change in a negative way. The respondents worried about the effects of climate change are less accepting of SNR. This result is contradictory as SNRs are generally climate neutral and, if used instead of electricity plants using fossil fuels, can mitigate climate change while increasing energy production.

The results suggest that more public education is needed in the areas of the technology of SNR and the relation of SNR to environmental and climate change issues. The media efforts in this direction may increase support for SNR close to people's dwellings, which will have positive effects both on the satisfaction of increasing electricity needs and combatting climate change.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The data available from the data collecting agency upon signing an agreement. Requests to access these datasets should be directed to Archiv, archiv@soc.cas.cz.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethical committee of the Faculty of Economics and Management, Czech University of Life Sciences. The patients/participants provided their written informed consent to participate in this study.

Author contributions

IC, LS, and MH contributed to the conception and design of the study. MH organized the database. IC and MH performed the statistical analysis. KP wrote the theoretical sections. IC, LS, and MH wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Arikawa, H., Cao, Y., and Matsumoto, S. (2014). Attitudes toward nuclear power and energy-saving behavior among Japanese households. *Energy Res. Soc. Sci.* 2, 12–20. doi:10.1016/j.erss.2014.04.002

Baskurt, Z. M., and Aydin, C. C. (2018). Nuclear power plant site selection by Weighted Linear Combination in GIS environment, Edirne, Turkey. *Prog. Nucl. Energy* 104, 85–101. doi:10.1016/j.pnucene.2017.09.004

Bekirsky, N., Hoicka, C. E., Brisbois, M. C., and Camargo, L. R. (2022). Many actors amongst multiple renewables: A systematic review of actor involvement in complementarity of renewable energy sources. *Renew. Sustain. Energy Rev.* 161, 112368. doi:10.1016/j.rser.2022.112368

Bickerstaff, K., Lorenzoni, I., Pidgeon, N. F., Poortinga, W., and Simmons, P. (2008). Reframing nuclear power in the UK energy debate: Nuclear power, climate change mitigation and radioactive waste. *Public Underst. Sci.* 17 (2), 145–169. doi:10.1177/0963662506066719

Bird, D. K., Haynes, K., van den Honert, R., McAneney, J., and Poortinga, W. (2014). Nuclear power in Australia: A comparative analysis of public opinion regarding climate change and the fukushima disaster. *Energy Policy* 65, 644–653. doi:10.1016/j.enpol.2013.09.047

Čábelková, I., Strielkowski, W., Streimikiene, D., Cavallaro, F., and Streimikis, J. (2021). The social acceptance of nuclear fusion for decision making towards carbon free circular economy: Evidence from Czech Republic. *Technol. Forecast. Soc. Change* 163, 120477. doi:10.1016/j.techfore.2020.120477

Cany, C., Mansilla, C., Mathonnière, G., and Da Costa, P. (2018). Nuclear power supply: Going against the misconceptions. Evidence of nuclear flexibility from the French experience. *Energy* 151, 289–296. doi:10.1016/j.energy.2018.03.064

Carlsson, J., Shropshire, D. E., van Heek, A., and Fütterer, M. A. (2012). Economic viability of small nuclear reactors in future European cogeneration markets. *Energy Policy* 43, 396–406. doi:10.1016/j.enpol.2012.01.020

Carter, J. (2016). Small modular reactor deployment: Learning from the past and the present. *Electr. J.* 29 (8), 1–8. doi:10.1016/j.tej.2016.09.011

Chakraborty, S., Li, J., and Bhattacharya, P. (2021). The solution to the global energy crisis with new materials, and sustainability. *J. Phase Change Mater.* 1 (2). doi:10.58256/jpcm.v1i2.17

Coleman, N. M., Abramson, L. R., and Coleman, F. A. B. (2012). Estimated lag time in global carbon emissions and CO2 concentrations produced by commercial nuclear power through 2009 with projections through 2030. *Health Phys.* 102 (3), 326–334. doi:10.1097/hp.0b013e3182364a73

Emanuel, K. (2021). Nuclear fear: The irrational obstacle to real climate action. *Bull. Atomic Sci.* 77 (6), 285–289. doi:10.1080/00963402.2021.1989192

Gu, Z. (2018). History review of nuclear reactor safety. *Ann. Nucl. Energy* 120, 682–690. doi:10.1016/j.anucene.2018.06.023

Guo, Y., and Ren, T. (2017). When it is unfamiliar to me: Local acceptance of planned nuclear power plants in China in the post-fukushima era. *Energy Policy* 100 (C), 113–125. doi:10.1016/j.enpol.2016.10.002

Haas, R., Thomas, S., and Ajanovic, A. (2019). "The historical development of the costs of nuclear power," in *The technological and economic future of nuclear power* (Wiesbaden: Springer VS), 97–115.

Hande, V., Prathaban, K., and Hande, M. P. (2022). Educational dialogue on public perception of nuclear radiation. *Int. J. Radiat. Biol.* 98 (2), 158–172. doi:10.1080/09553002.2022.2009147

Ho, S. S., and Chuah, A. S. F. (2021). Why support nuclear energy? The roles of citizen knowledge, trust, media use, and perceptions across five Southeast Asian countries. *Energy Res. Soc. Sci.* 79, 102155. doi:10.1016/j.erss.2021.102155

Huang, L., He, R., Yang, Q., Chen, J., Zhou, Y., Hammit, J. K., et al. (2018). The changing risk perception towards nuclear power in China after the Fukushima nuclear accident in Japan. *Energy Policy* 120, 294–301. doi:10.1016/j.enpol.2018.05.007

Huang, L., Zhou, Y., Han, Y., Hammitt, J. K., Bi, J., and Liu, Y. (2013). Effect of the Fukushima nuclear accident on the risk perception of residents near a nuclear power plant in China. *Proc. Natl. Acad. Sci.* 110 (49), 19742–19747. doi:10.1073/pnas.1313825110

IEA (2019). *Nuclear power in a clean energy system*. Paris: International Energy Agency.

IEA (2022). *World energy outlook 2022*. License: CC BY 4.0 (report); CC BY NC SA 4.0. Paris: IEA. [Online], Available: https://www.iea.org/reports/world-energy-outlook-2022 (Accessed March 30, 2022).

Ingersoll, D. T. (2009). Deliberately small reactors and the second nuclear era. *Prog. Nucl. energy* 51 (4-5), 589–603. doi:10.1016/j.pnucene.2009.01.003

Jang, Y., and Park, E. (2020). Social acceptance of nuclear power plants in Korea: The role of public perceptions following the Fukushima accident. *Renew. Sustain. Energy Rev.* 128, 109894. doi:10.1016/j.rser.2020.109894

Kharecha, P. A., and Hansen, J. E. (2013). Prevented mortality and greenhouse gas emissions from historical and projected nuclear power. *Environ. Sci. Technol.* 47, 4889–4895. doi:10.1021/es3051197

Kim, D. S., and Kim, J. W. (2014). Public opinion sensing and trend analysis on social media: A study on nuclear power on twitter. *Int. J. Multimedia Ubiquitous Eng.* 9 (11), 373–384. doi:10.14257/ijmue.2014.9.11.36

Kim, Y., Kim, W., and Kim, M. (2014). An international comparative analysis of public acceptance of nuclear energy. *Energy Policy* 66, 475–483. doi:10.1016/j.enpol.2013.11.039

Koerner, C. L. (2014). Media, fear, and nuclear energy: A case study. *Soc. Sci. J.* 51 (2), 240–249. doi:10.1016/j.soscij.2013.07.011

Lee, J. W., and Roh, S. (2022). Nuclear power in jeopardy: The negative relationships between greenhouse gas/fine dust concerns and nuclear power acceptance in South Korea. *Nucl. Eng. Technol.* 54 (10), 3695–3702. doi:10.1016/j.net.2022.05.032

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Clim. Change* 77, 45–72. doi:10.1007/s10584-006-9059-9

Lenzen, M., and Schaeffer, R. (2012). Historical and potential future contributions of power technologies to global warming. *Clim. Change* 112, 601–632. doi:10.1007/s10584-011-0270-y

Liu, C., Zhang, Z., and Kidd, S. (2008). Establishing an objective system for the assessment of public acceptance of nuclear power in China. *Nucl. Eng. Des.* 238 (10), 2834–2838. doi:10.1016/j.nucengdes.2008.04.001

Lokhov, A., Cameron, R., and Sozoniuk, V. (2013). OECD/NEA study on the economics and market of small reactors. *Nucl. Eng. Technol.* 45 (6), 701–706. doi:10.5516/NET.02.2013.517

Makhijani, A., and Ramana, M. V. (2021). Can small modular reactors help mitigate climate change? *Bull. Atomic Sci.* 77 (4), 207–214. doi:10.1080/00963402.2021.1941600

Matsuo, Y., and Nei, H. (2019). An analysis of the historical trends in nuclear power plant construction costs: The Japanese experience. *Energy policy* 124, 180–198. doi:10.1016/j.enpol.2018.08.067

McCright, A. M. (2010). The effects of gender on climate change knowledge and concern in the American public. *Popul. Environ.* 32 (1), 66–87. doi:10.1007/S11111-010-0113-1

McWilliams, B., Sgaravatti, G., Tagliapietra, S., and Zachmann, G. (2022). *A grand bargain to steer through the European Union's energy crisis. Bruegel Policy Contribution Issue, (14/22)*. Pittsburgh: University of Pittsburgh.

Mignacca, B., Locatelli, G., and Sainati, T. (2020). Deeds not words: Barriers and remedies for small modular nuclear reactors. *Energy* 206, 118137. doi:10.1016/j.energy.2020.118137

Morilhat, P., Feutry, S., Lemaitre, C., and Favennec, J. M. (2019). Nuclear power plant flexibility at EDF. *VGB PowerTech* 99 (5), 32–41.

Muellner, N., Arnold, N., Gufler, K., Kromp, W., Renneberg, W., and Liebert, W. (2021). Nuclear energy-The solution to climate change? *Energy Policy* 155, 112363. doi:10.1016/j.enpol.2021.112363

Mulder, K. (2012). The dynamics of public opinion on nuclear power. Interpreting an experiment in The Netherlands. *Technol. Forecast. Soc. Change* 79 (8), 1513–1524. doi:10.1016/j.techfore.2012.04.018

Nian, V., and Zhong, S. (2020). Economic feasibility of flexible energy productions by small modular reactors from the perspective of integrated planning. *Prog. Nucl. Energy* 118, 103106. doi:10.1016/j.pnucene.2019.103106

OECD (2021). *Small modular reactors: Challenges and opportunities.* Paris: OECD. NEA No. 7560.

Pata, U. K., and Kartal, M. T. (2022). Impact of nuclear and renewable energy sources on environment quality: Testing the EKC and LCC hypotheses for South Korea. *Nucl. Eng. Technol.* 55 (2), 587–594. doi:10.1016/j.net.2022.10.027

Pidgeon, N. F., Lorenzoni, I., and Poortinga, W. (2008). Climate change or nuclear power—No thanks! A quantitative study of public perceptions and risk framing in Britain. *Glob. Environ. Change* 18 (1), 69–85. doi:10.1016/j.gloenvcha.2007.09.005

Portugal-Pereira, J., Ferreira, P., Cunha, J., Szklo, A., Schaeffer, R., and Araújo, M. (2018). Better late than never, but never late is better: Risk assessment of nuclear power construction projects. *Energy Policy* 120, 158–166. doi:10.1016/j.enpol.2018.05.041

Rothwell, G. (2018). *Economics of nuclear power*. Oxfordshire: Routledge.

Shropshire, D. (2011). Economic viability of small to medium-sized reactors deployed in future European energy markets. *Prog. Nucl. Energy* 53 (4), 299–307. doi:10.1016/j.pnucene.2010.12.004

Siegrist, M., Sütterlin, B., and Keller, C. (2014). Why have some people changed their attitudes toward nuclear power after the accident in Fukushima? *Energy Policy* 69, 356–363. doi:10.1016/j.enpol.2014.02.026

Singh, S. (2021). Energy crisis and climate change: Global concerns and their solutions. *Energy Crises* 2021, 1–17. doi:10.1002/9781119741503.ch1

Siqueira, D. S., de Almeida Meystre, J., Hilário, M. Q., Rocha, D. H. D., Menon, G. J., and da Silva, R. J. (2019). Current perspectives on nuclear energy as a global climate change mitigation option. *Mitig. Adapt. Strategies Glob. Change* 24 (5), 749–777. doi:10.1007/s11027-018-9829-5

Soares, W. A. (2009). "The value of communication in changing public perception on nuclear technology: An experience with college students," in International Nuclear Atlantic Conference - INAC 2009, Rio de Janeiro, Brazi, 27 to October 2, 2009. Brasileira De Energia N Unclear - Aben.

Sociologický ústav (2020). *Nase spolecnost 2020 – červen*. doi:10.14473/V2006B

Stehlik, D. (2010). *Understanding the formation of attitudes to nuclear power in Australia*. Melbourne: National Academies Forum.

Stoutenborough, J. W., Sturgess, S. G., and Vedlitz, A. (2013). Knowledge, risk, and policy support: Public perceptions of nuclear power. *Energy Policy* 62, 176–184. doi:10.1016/j.enpol.2013.06.098

Sun, C., and Zhu, X. (2014). Evaluating the public perceptions of nuclear power in China: Evidence from a contingent valuation survey. *Energy Policy* 69, 397–405. doi:10.1016/j.enpol.2014.03.011

Teräväinen, T., Lehtonen, M., and Martiskainen, M. (2011). Climate change, energy security, and risk—Debating nuclear new build in Finland, France and the UK. *Energy Policy* 39 (6), 3434–3442. doi:10.1016/j.enpol.2011.03.041

Uji, A., Prakash, A., and Song, J. (2021). Does the "NIMBY syndrome" undermine public support for nuclear power in Japan? *Energy Policy* 148 (A), 111944. doi:10.1016/j.enpol.2020.111944

Visschers, V. H. M., Keller, C., and Siegrist, M. (2011). Climate change benefits and energy supply benefits as determinants of acceptance of nuclear power stations: Investigating an explanatory model. *Energy Policy* 39 (6), 3621–3629. doi:10.1016/j.enpol.2011.03.064

Visschers, V. H. M., and Siegrist, M. (2013). How a nuclear power plant accident influences acceptance of nuclear power: Results of a longitudinal study before and after the fukushima disaster. *Risk Anal.* 33 (2), 333–347. doi:10.1111/j.1539-6924.2012.01861.x

World Nuclear Association (2022). Small nuclear power reactors. [Online], Available: https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx.

Wu, H., Huang, L., Yuan, L., Wang, D. W., and Wang, S. (2021). Young Chinese people's perceptions of nuclear power: Connection with enthusiasm for information, perceptions of nuclear reactor technology and NIMBY. *Prog. Nucl. Energy* 138, 103964. doi:10.1016/j.pnucene.2021.103964

Wu, Y., Chen, Z., Wang, Z., Chen, S., Ge, D., Chen, C., et al. (2019). Nuclear safety in the unexpected second nuclear era. *Proc. Natl. Acad. Sci.* 116 (36), 17673–17682. doi:10.1073/pnas.1820007116