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Peoples' Perception towards Nuclear Energy

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Abstract: Perception towards nuclear energy is a vital factor determining the success or failure of nuclear projects. An online survey obtained attitudes toward nuclear energy, opinions on whether benefits of nuclear energy outweigh the risks, and views of using nuclear energy as an energy source. A total of 4318 participants from across the U.S. completed the survey. Logistic regression was used to predict perceptions of nuclear energy by participant demographics and geographical location. Participants living closest to Idaho National Laboratory (INL) were more likely to have positive attitudes towards nuclear energy (aOR: 7.18, $p < 0.001$), believe the benefits were greater than the risks (aOR: 4.90, $p < 0.001$), and have positive attitudes toward using nuclear energy as an electricity source (aOR: 5.70, $p < 0.001$), compared to people living farther from INL. Males and non-Hispanic white participants were more likely to have positive perceptions of nuclear energy. Developing and implementing awareness raising campaigns for people living further away from nuclear power plants, targeting females and Hispanic whites, may be key to improving the overall perceptions of nuclear energy.

Keywords: energy; nuclear; United States; Idaho; attitudes

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1. Introduction

The United Nations' Sustainable Development Goals (SDGs) are a universal call for action to ensure a sustainable future for all [1]. The aim of SDG 7 is to ensure that everyone has access to affordable, reliable, and modern energy resources by the end of 2030 [2]. The U.S. Office of Nuclear Energy states that nuclear energy is not only affordable and reliable, but also a clean and zero carbon energy source [3]. It is proposed that nuclear energy, along with other energy sources such as solar, wind and hydro power can provide the required energy to eventually meet SDG 7 [2]. The current global energy mix relies heavily on non-sustainable fossil fuels (~75% of electricity worldwide), with only a small proportion coming from nuclear energy [4]. One reason for the limited use of nuclear energy is the public's negative perception of nuclear energy. In particular, concerns around safety and radioactive waste have impeded progress of the nuclear industry globally [5]. Negative public opinion of nuclear energy is a major barrier to the acceptance of nuclear energy technologies [4].

Globally, the United States (U.S.) is the largest producer of nuclear energy. The U.S. has 94 reactors in 28 states [6], which account for more than 30% of the global nuclear energy production, and 19% of the electricity output for the U.S. [7]. Nonetheless, the U.S. has faced considerable public opposition to the use of nuclear energy. A nuclear energy generating station 30 miles from Detroit faced strong opposition in 1957, and the project was ultimately abandoned in 1964 [8,9]. Anti-nuclear energy protests also preceded the shutdown of Shoreham, Yankee Rowe, Rancho Seco, Maine Yankee and about a dozen other nuclear power plants in the U.S. [10]. There were many anti-nuclear protests in the U.S. during the 1970s and 80s, including a large protest following the Three Mile Island accident in 1979 [11].

Demographics and geographical location have been shown to be associated with perceptions toward nuclear energy, however the direction of these associations has sometimes been inconsistent. Females have consistently been found to be more opposed to nuclear energy than males, at both the state and federal levels [12–19]. While some studies have found that increasing age leads to positive perceptions about nuclear energy [14,16], other studies have found the opposite [20]. There are also inconsistent findings with education, with some studies showing educated groups being more likely to be pro-nuclear [20,21], while other studies report opposite findings [14]. Similarly, monthly income may positively correlate with nuclear perceptions, or the effect may be insignificant. [13,14]. Findings on proximity to a nuclear reactor and perceptions of nuclear energy are also inconsistent [21]. Some studies have found a higher level of negative perceptions and concerns of nuclear energy with closer proximity to nuclear reactors [22–25]. However, other studies have found a higher proportion of favorable perceptions to nuclear energy among those living in the vicinity of nuclear power stations [26].

Idaho National Laboratory (INL) is the leading U.S. national laboratory for nuclear energy research and development [27]. There is a dearth of information highlighting the association of geographical location and proximity to INL, and socio-demographic features with the perceptions towards nuclear energy. This study seeks to bridge this important gap in the literature with the specific objectives to explore the association of (a) proximity to INL, and (b) socio-demographic characteristics, with perceptions of nuclear energy.

2. Material and Methods

2.1. Study Design

This study is part of a larger project to assess the perceptions of the local community of Idaho to nuclear energy and determine their preparedness to potential disasters [28]. A structured online survey was distributed through two local news outlets (East Idaho News and Idaho State Journal) from 10 May to 25 June 2021. A monetary incentive to complete the survey was provided, with participants entered in a draw to win one of one hundred USD 20 Amazon gift cards upon completing the survey. The electronic survey took approximately 14 min to complete (IQR = 8 min to 26 min) and was self-administered. All participants older than 18 years of age who were willing to participate in the study were deemed eligible. Ethical approval for the study was obtained from the Idaho State University Institutional Review Board.

The response rate to the survey was much higher than expected. The survey was online, and became shared with a wide audience—a total of 6151 participants across the U.S. completed at least one question in the survey. A total of 496 participants with incomplete socio-demographic, state/ZIP code, and perceptions of nuclear energy responses were excluded from the study. To limit bias from other nuclear facilities in the US, an additional 732 participants living within a 50-mile radius of another nuclear facility were also excluded. Finally, 121 participants reporting a non-female or male gender, 95 participants who exited the survey before reporting their INL employment status, and 396 participants who stated they did not know if they had been employed by INL were also removed, reducing the final dataset to n = 4318 observations.

2.2. Measurements

2.2.1. Attitudes and Opinions toward the Use of Nuclear Energy

Attitudes and opinions toward the use of nuclear energy were measured by three items, which have been previously used and validated in a study conducted in the United Kingdom in 2011 [16]. To capture *feelings toward nuclear energy*, participants were asked "On a purely emotional level, how do you feel about nuclear energy?" with the response options on a five-point Likert scale of "very positive" to "very negative." Responses were dichotomized to "positive" (positive or very positive) and "negative/neutral" (very negative, negative or neutral). To determine *attitudes toward using nuclear energy as a source of electricity provision*, participants were asked "Please select the option that best describes

your position on the use of nuclear energy as one of the ways to provide electricity in the United States" with response options on a four-point Likert scale of "strongly oppose" to "strongly favor." Responses were dichotomized to "oppose" (strongly oppose or oppose) and "favor" (strongly favor or favor). To determine the *opinion of people regarding benefits and risks* of nuclear power, participants were asked "From what you know or have heard about nuclear power and Idaho National Laboratory (INL), in general, which of these statements, if any, most closely reflects your own opinion?" with the response options on a five-point Likert scale of "benefits far outweigh risks" to "risks far outweigh benefits." Responses were dichotomized to "benefits outweigh risks" (benefits far outweigh risks or benefits slightly outweigh risks) and "risks outweigh benefits'" (same, risks slightly outweigh benefits or risks far outweigh benefits).

Geographical location was obtained by ZIP code and state of participants. Idaho participants' were categorized as "Idaho: living within 50-mile radius of INL" and "Idaho: Living outside 50-mile radius of INL" based on zip code. All non-Idaho participants were classified as "US: non-Idaho".

2.2.2. Socio-Demographics

Participants reported their age, gender, race, ethnicity, educational status and income. Based on the distribution of responses, participant race/ethnicity was classified as "non-Hispanic white", "Hispanic" and other. Participants were also asked, "Have you previously been employed in INL?" with response options of "Yes", "No", Don't know" and "Not Applicable". The "Don't know" option was included as INL has numerous subcontractors who work closely with the laboratory, resulting in some participants being unclear if they had previously been employed at INL or not.

The face validity of the questions was established by pre-testing the questionnaire and administering it to 18 individuals, selected by the research team based on feasibility. The individuals provided constructive feedback which was incorporated to refine the questions. The detailed study questionnaire is provided in Supplementary Table S1.

2.3. Data Analysis

Pearson chi-square tests were run to examine the bivariate association between perceptions of nuclear energy and participant geographical location and socio-demographic features. Three multivariate binary logistic regression models predicting the three perceptions of nuclear energy by geographical location and sociodemographic characteristics. As those who work at INL were anticipated to have more positive attitudes and opinions about nuclear energy, all models were controlled for any prior or current INL employment. As INL workers living further than "driving distance" to INL (outside the 50-mile radius) may indicate the participant no longer works at INL, an interaction term for INL workers and geographical location was included in the model. Statistical significance was defined as a $p < 0.01$. All analyses were performed using R (version 4.1.1).

3. Results

The majority of participants in this study were less than 35 years of age (60%), with at least an undergraduate degree (60%), not working at INL (57%), and from outside of Idaho (57%) (Table 1). Notably, while 22% of participants stated they were previously or currently employed at INL, another 13% of participants chose not to answer this question. The majority of the study participants reported a positive emotional response toward nuclear energy (54%), considered the benefits of nuclear energy to outweigh the risks (58%), and favored the use of nuclear energy as a means of providing electricity in the U.S. (76%).

Table 1. Socio-demographic characteristics and perceptions towards nuclear energy of the study participants (N = 4318).

	Total	**ID in 50 Miles**	**ID out 50 Miles**	**US Non-ID**
	N = 4318	N = 1158 (27%)	N = 803 (19%)	N = 2357 (55%)
Age n (%)				
Less than 35 years	2590 (60)	466 (40)	448 (56)	1676 (71)
35 years or older	1728 (40)	692 (60)	355 (44)	681 (29)
Gender, n (%)				
Female	1881 (44)	504 (44)	294 (37)	1083 (46)
Male	2437 (56)	654 (56)	509 (63)	1274 (54)
Race/ethnicity, n (%)				
Non-Hispanic white	1878 (43)	959 (83)	281 (35)	638 (27)
Hispanic	1640 (38)	103 (9)	355 (44)	1182 (50)
Other/Unknown	800 (19)	96 (8)	167 (21)	537 (23)
Education, n (%)				
Less than High school/GED	593 (14)	33 (3)	73 (9)	487 (21)
High school	1155 (27)	352 (30)	229 (29)	574 (24)
Undergraduate degree	1673 (39)	540 (47)	384 (48)	749 (32)
Graduate degree	897 (21)	233 (20)	117 (15)	547 (23)
Income, n (%)				
USD 60,000 or less	1437 (33)	416 (36)	250 (31)	771 (33)
USD 60,001 to USD 80,000	1077 (25)	209 (18)	158 (20)	710 (30)
over USD 80,000	1804 (42)	533 (46)	395 (49)	876 (37)
Have you currently or previously been employed at INL? n (%)				
No	2696 (62)	873 (75)	613 (76)	1210 (51)
Deliberate skip	600 (14)	81 (7)	79 (10)	440 (19)
Yes	1022 (24)	204 (18)	111 (14)	707 (30)
On a purely emotional level, how do we feel about nuclear energy? n (%)				
Positive	2383 (55)	950 (82)	472 (59)	961 (41)
Neutral/Negative	1935 (45)	208 (18)	331 (41)	1396 (59)
From what you know or have heard about nuclear power and Idaho National Laboratory (INL), in general, which of these statements, if any, most closely reflects your own opinion? n (%)				
Benefits outweigh risks	2561 (59)	968 (84)	501 (62)	1092 (46)
Same or Risks outweigh benefits	1757 (41)	190 (16)	302 (38)	1265 (54)
Please select the option that best describes your position on the use of nuclear energy as one of the ways to provide electricity in the United States. n (%)				
Favor	3327 (77)	1088 (94)	641 (80)	1598 (68)
Oppose	991 (23)	70 (6)	162 (20)	759 (32)

Significant differences by geographical location were found for all socio-demographic variables, as well as for all three measures of perceptions of nuclear energy (all $p < 0.001$).

While 82% of participants within a 50-mile radius of INL felt positive about nuclear energy, only 59% of Idaho participants outside the 50-mile radius and 41% of non-Idaho U.S. participants reported positive attitudes. This decreasing positive trend of nuclear perceptions as the distance from INL increased was also observed for believing the benefits of nuclear energy outweigh the risks (84%, 63%, 46%), and favoring the use of nuclear energy as an electricity source (94%, 80% and 68%). For a summary of perceptions of nuclear energy by State, see Supplementary Table S1.

In the logistic regression, geographical location remained a significant predictor of attitudes and opinions towards the use of nuclear energy (Table 2). Participants who lived further away from INL had lower odds of positive perceptions of nuclear energy. Compared to participants within 50 miles of INL, participants within Idaho living further than 50 miles from INL had significantly lower odds of a positive emotional response toward nuclear energy (OR = 0.46, 99% CI = 0.33, 0.63), of considering that the benefits of nuclear energy outweighed the risks (OR = 0.37, 99% CI = 0.27, 0.52), and of favoring the use of nuclear energy as a way to provide electricity in the U.S. (OR = 0.24, 99% CI = 0.15, 0.38). For non-Idaho U.S. participants, the odds were even lower (0.16, 0.32, and 0.24, respectively).

Table 2. Logistic regression results showing the association of geographical location and socio-demographics with nuclear energy perceptions (n = 4318).

	Positive Response to Nuclear Energy at the Emotional Level [a]			**Considers That the Benefits of Nuclear Energy Outweigh the Risks [b]**			**Favors the Use of Nuclear Energy as One of the Ways to Provide Electricity in the United States [c]**		
EMOTION	**OR**	**99% CI**	***p*-Value**	**OR**	**99% CI**	***p*-Value**	**OR**	**99% CI**	***p*-Value**
Location									
ID in 50 miles	(ref)			(ref)			(ref)		
ID out 50 miles	0.46	0.33, 0.63	**<0.001**	0.37	0.27, 0.52	**<0.001**	0.24	0.15, 0.38	**<0.001**
US non-ID	0.16	0.12, 0.22	**<0.001**	0.32	0.24, 0.43	**<0.001**	0.24	0.16, 0.36	**<0.001**
Age									
Less than 35 years	(ref)			(ref)			(ref)		
35 years or older	0.99	0.81, 1.20	0.878	0.87	0.72, 1.05	0.061	0.78	0.62, 0.98	**0.005**
Gender									
Female	(ref)			(ref)			(ref)		
Male	1.20	1.00, 1.45	0.011	1.64	1.37, 1.98	**<0.001**	1.90	1.52, 2.36	**<0.001**
Race/ethnicity									
non-Hispanic white	(ref)			(ref)			(ref)		
Hispanic	0.59	0.47, 0.74	**<0.001**	0.88	0.70, 1.10	0.140	0.99	0.74, 1.32	0.905
Other/Unknown	0.47	0.36, 0.60	**<0.001**	0.77	0.60, 1.00	**0.009**	0.51	0.38, 0.69	**<0.001**
Education									
Less than HS or GED	(ref)			(ref)			(ref)		
High School	0.49	0.36, 0.67	**<0.001**	0.97	0.70, 1.33	0.793	3.05	2.14, 4.35	**<0.001**
Undergraduate degree	0.68	0.50, 0.92	**<0.001**	1.13	0.83, 1.54	0.300	3.03	2.17, 4.25	**<0.001**
Graduate degree	0.54	0.39, 0.77	**<0.001**	1.17	0.83, 1.66	0.237	1.81	1.25, 2.63	**<0.001**
Income									
USD 60,000 or less	(ref)			(ref)			(ref)		
USD 60,001 to USD 80,000	1.89	1.48, 2.40	**<0.001**	0.61	0.48, 0.77	**<0.001**	0.49	0.38, 0.64	**<0.001**
over USD 80,000	1.03	0.84, 1.27	0.730	1.03	0.83, 1.26	0.760	1.49	1.14, 1.94	**<0.001**
INL employment									
No	(ref)			(ref)			(ref)		
Deliberate skip	1.30	0.61, 3.07	0.403	0.83	0.40, 1.88	0.536	0.67	0.25, 2.35	0.353
Yes	4.30	2.06, 10.5	<0.001	2.42	1.22, 5.41	**0.002**	2.78	0.87, 14.9	0.053
INL employment: Location									
Deliberate skip: ID out 50 miles	0.47	0.16, 1.27	0.058	1.03	0.37, 2.74	0.934	2.90	0.65, 11.6	0.052

Table 2. *Cont.*

	Positive Response to Nuclear Energy at the Emotional Level [a]			Considers That the Benefits of Nuclear Energy Outweigh the Risks [b]			Favors the Use of Nuclear Energy as One of the Ways to Provide Electricity in the United States [c]		
EMOTION	**OR**	**99% CI**	***p*-Value**	**OR**	**99% CI**	***p*-Value**	**OR**	**99% CI**	***p*-Value**
Yes: ID out 50 miles	0.33	0.12, 0.84	**0.003**	0.39	0.15, 0.96	**0.009**	0.58	0.09, 2.49	0.374
Deliberate skip: US non ID	0.99	0.40, 2.24	0.986	0.78	0.33, 1.71	0.435	1.38	0.38, 4.00	0.467
Yes: US non ID	0.40	0.16, 0.88	**0.005**	0.11	0.05, 0.22	**<0.001**	0.21	0.04, 0.70	**0.004**

[a] Predicting a "positive" (vs. "negative + neutral") response to the question "On a purely emotional level, how do we feel about nuclear energy? [b] Predicting a "Benefits outweigh risks (benefits far outweigh risks, benefits slightly outweigh risks)" vs. a "Same or Risks outweigh benefits (Same, risks slightly outweigh benefits, risks far outweigh benefits)" to the question "From what you know or have heard about nuclear power and Idaho National Laboratory (INL), in general, which of these statements, if any, most closely reflects your own opinion?" [c] Predicting a "favor" (vs. "oppose") response to the question "Please select the option that best describes your position on the use of nuclear energy as one of the ways to provide electricity in the United States".

Compared to participants less than 35 years of age, participants 35 years or older had lower odds of favoring the use of nuclear energy as a way to provide electricity in the U.S. As expected, compared to females, males had higher odds of positive perceptions of nuclear energy on all three measures (OR = 1.20, 1.64, 1.90). Compared to participants who were non-Hispanic white, participants who were Hispanic had lower odds of a positive emotional response to nuclear energy (OR = 0.59, 99% CI = 0.47, 0.74); no significant difference between Hispanic and non-Hispanic white participants was found for considering that the benefits of nuclear energy outweighed the risks ($p = 0.140$) or for favoring the use of nuclear energy in the United States ($p = 0.905$). Compared to participants with an education level less than high school or a GED, participants with at least a high school education had lower odds of a positive emotional response to nuclear energy (OR = 0.49, 0.68, 0.54; $p < 0.001$) and higher odds of favoring the use of nuclear energy in the U.S. (OR = 3.05, 3.03, 1.81; $p < 0.001$).

INL employment was associated with higher odds of a positive emotional response to nuclear energy (OR = 4.3, 99% CI = 2.06, 10.5), and higher odds of considering that the benefits of nuclear energy outweighed the risks (OR = 2.42, 99% CI = 1.22, 5.41; Table 2). However, the interaction term showed that INL employees outside of the 50-mile radius of INL had, in general, significantly lower odds of positive perceptions of nuclear energy.

4. Discussion

This study examined how geographical proximity to INL and socio-demographics were associated with perceptions of nuclear energy. Participants who lived within 50 miles of INL had more positive perceptions of nuclear energy than participants who lived further away. Males were more favorable towards nuclear energy than females, while the findings for education and income were mixed. Working at INL was associated with more positive perceptions of nuclear energy; however, INL workers who lived further than 50 miles from INL had significantly lower odds of positive perceptions of nuclear energy.

This study found positive perceptions of nuclear energy among participants living near INL. Potentially, participants living near INL had been exposed to more positive interactions with nuclear energy (e.g., school tours, scholarships, benefits to the economy and donations from INL), and thus had a more positive attitude. This finding of more positive perceptions to nuclear energy among participants living near INL are consistent with the "reverse NIMBY" concept. The term "NIMBY syndrome" (not-in-my-backyard syndrome) was coined in the 1980s by social scientists to describe the resistance of communities to the construction of controversial facilities in their vicinity [29]. However, substantial evidence currently exists showing the "reverse NIMBY" for nuclear energy, highlighting the positive perceptions of people living in close proximity to nuclear power plants [30–33]. For instance,

a similar study carried out in the U.K. in 2011 (n = 1326) reported a decrease in perceived risk and a positive attitude of people in proximity to the nuclear power stations at Oldbury and Hinkley Point [34]. Similarly, other evidence from the U.S. suggests that people living in proximity to nuclear reactors are less likely to perceive greater risk [35]. However, researchers from Japan found that proximity to the Fukushima nuclear power plant had no impact on public support for nuclear energy after the 2011 tsunami and nuclear incident [30]. This study provides further evidence that decreased proximity to nuclear power plants is associated with improved perceptions of nuclear energy.

As anticipated, males were more favorable to nuclear energy than females. Similar findings, showing higher opposition to nuclear energy by females, have been found in other studies carried out in the U.S. and other parts of the world [36–38]. Participants with higher education were less positive to nuclear energy at the emotional level but had higher odds of favoring the use of nuclear energy in the U.S. Prior studies have shown that higher education leads to positive perceptions towards nuclear energy [20,21]. Other studies have shown that people who have greater knowledge of nuclear energy are more supportive of the use of nuclear energy [39].

Working at INL was associated with more positive perceptions of nuclear energy; however, INL workers who lived further than 50 miles from INL were significantly less favorable to nuclear energy than INL workers living near INL. While this study did not differentiate between current and prior INL work, this finding may indicate that prior INL workers (who likely live further from INL) are not as positive towards nuclear energy as those currently working there. INL workers are typically thought to be ambassadors for nuclear energy, and are potentially a trusted source of information for the general public. Understanding the underlying reasons for positive and negative perceptions of nuclear energy among employees of the nuclear industry may identify key areas that need to be addressed.

To the best of the authors' knowledge, this is the largest study to explore perceptions of nuclear energy, and the first study to examine those living in the vicinity of INL. Strengths of this study include the use of validated questions, the large sample size of the study, and the range of responses by geographical location. However, the study does not come without limitations. Participants were recruited online, were offered a monetary incentive to complete the study, and a purposive nonprobability sampling technique was applied, all of which may have resulted in a biased sample. While a large number of participants were included in the study, the number of responses is still low in comparison to the population of the U.S., and there are a limited number of responses from other states. The question regarding working at INL was not validated, and while we excluded participants near other nuclear facilities, we also did not control for employment by other nuclear-related organizations. Future studies should also examine the use of more advanced statistical analyses.

5. Conclusions and Implications

The findings from this study suggest the reverse NIMBY syndrome is occurring with INL. Participants living within the 50-mile radius of INL form a unique group of people, and they reported more positive perceptions toward nuclear energy than participants who lived further away. The study also indicated that prior INL workers held poorer perceptions of nuclear energy, and additional research should confirm this and then examine the underlying reasons for this. Determining why differences in favorability towards nuclear energy occur is the first step in increasing (or decreasing) the level of favorability towards nuclear energy. History shows that people's perceptions of nuclear energy play an integral role in the success or failure of nuclear power plants. People living within the vicinity of nuclear facilities such as INL can serve as ambassadors of creating positive awareness about nuclear energy among the public. Door-to-door or other outreach campaigns specifically targeted towards the high-risk groups including but not limited to females and non-Hispanic whites living further away from nuclear facilities could be designed and implemented and result

in increased favorability to nuclear energy. For nuclear energy to be included in a clean energy future, the current perceptions of nuclear energy will likely need to change.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/en15124397/s1, Table S1: Perceptions of nuclear energy by State.

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