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Safety and Risk Management of Nuclear Power Plants: Is Public Opinion Relevant?

Samuel A. Oyewole, Ph.D.
Assistant Professor
Environmental Health and Safety Engineering
Department of Energy and Mineral Engineering
The Pennsylvania State University
University Park, PA 16802

Introduction

Nuclear technologies are globally employed to produce energy and are vital components to the modern, globalized economy. Nuclear power may represent a viable alternative energy source to fossil fuels and serve as a means to reduce greenhouse gas emissions. Economic barriers in the form of high capital costs, decommissioning costs, and waste management may challenge the further adoption of nuclear technologies in these difficult economic times. Environmental health and safety issues with nuclear power and radiation leaks are of great public concern, but the discourse must continue related to nuclear technologies. In this paper, the results of an experimental survey revealed that the public is willing to accept nuclear power generation on some scale, if it remains safe. In the event of a catastrophic nuclear disaster, it is most important to distribute information to the public. A dialogue of nuclear power needs to be ongoing as the global demand for energy continues to rise.

On March 9, 2011, a magnitude 9.0 earthquake occurred in Japan, leading to a tsunami and damage to the nuclear power plants northeast of Tokyo. These events caused system failure at the reactor cooling stations at four TEPCO nuclear power plants and caused radiation to be released into the local environment. In recent years, the issue of nuclear power has been heavily debated, but for the most part, is conducted by a culture that lacks the appropriate information needed to make an informed argument. In this paper, nuclear power is presented on a factual basis with the hope to provide readers with the information that is lacking from most dialogues related to the subject. A discussion of the prevalence of nuclear technologies is presented to establish nuclear power's current role in society. Information related to power generation and the possibility of nuclear power to serve as an alternative to fossil fuels will be discussed to shed light on its future potential. Economic and human health issues associated with nuclear power are considered in order to provide the necessary information in assessing nuclear power's viability into the future. An experimental survey was designed to assess the public's opinion on nuclear power, and the results from this survey will be used to encourage further work. It is the goal of this paper to provide the pertinent information necessary to make an informed argument about nuclear power, its limitations, and its future.

Literature Review

Nuclear Energy Today

Globally, 439 operational nuclear facilities generate over 372 GW (gigawatts) of energy, enough to power over 350 million U.S. households. These operational plants are found in 35 countries; several additional countries are pursuing nuclear technologies. The International Atomic Energy Agency (IAEA) projects that by 2030, between 400 and 800 gigawatts of additional nuclear energy capacity will be globally utilized (IAEA 2008). As shown in Exhibit 1, with the exception of France, nuclear energy is not a primary source of energy for the remaining thirty-four countries, which rely on a more diverse energy portfolio. In Exhibit 1, darker shades of green reflect increasing percentages of energy use generated by nuclear means. As of the end of 2011, five nuclear power plants are in the decommission stages, and thirty-three plants are under construction (World Nuclear Association 2011).

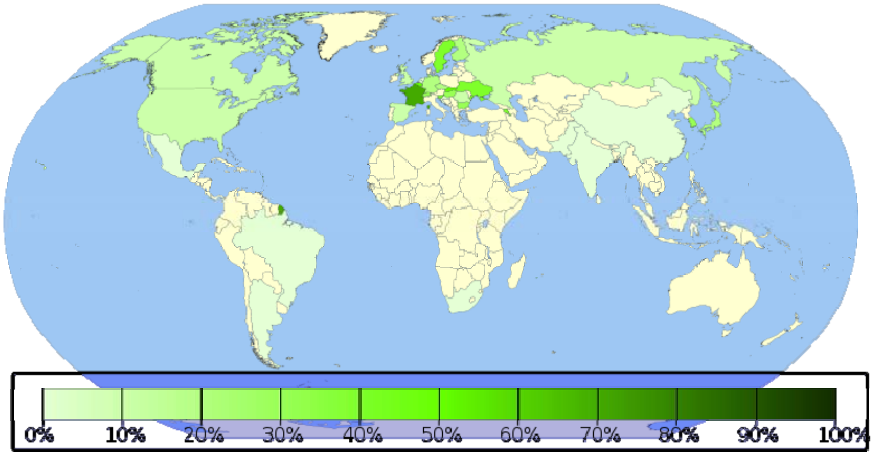


Exhibit 1. Countries that employ nuclear power plants and the relative amount of domestic energy produced by nuclear means.

Nuclear power plants can be classified into three categories based on the design employed. These three designs are: (1) fast reactors; (2) water-cooled reactors, such as the light-water reactors (LWR); and (3) gas-cooled reactors (IAEA 2009). Of the 439 operational nuclear power plants, 359 of these plants are water-cooled reactors, which are further categorized into pressurized water reactors (PWR) and boiling water reactors (BWR). Light-water reactors are likely to continue to be the most prevalent reactor types because of the historical success of these reactors, political support for their continued use, and the comparative ease of technological applicability (Cowan 1990). The application of nuclear technologies is often considered to progress in generational steps, with current technologies falling into the Generation III category; these plants typically produce around 1 gigawatt (GW). These technologies have been developed since the 1990s, and it is likely that any plants constructed in the next 30 years will be considered Generation III nuclear power plants (Ramana 2009).

Nuclear Energy and Climate Change

Today, a globalized economy demands significant energy resources to power ever-growing enterprises, as modernized and developing economies exchange goods and services. Industrialized nations, such as the United States of America, Canada, and Australia, heavily rely on electricity generated from coal resources and transportation networks powered by petroleum products to meet their citizens' demands. Furthermore, newly industrialized nations, including the Republic of India and the People's Republic of China, have massive population demographics that are demanding access to the latest technologies, goods, and services, requiring the increased exploitation of fossil fuel resources. The effects of burning fossil fuels, though complicated, are well understood, and it is clear that the continued use of carbon-intensive energy resources will impact future generations and the environment (Sarmiento and Gruber 2006). Alternatives to fossil fuel exploitation are available but are typically economically less competitive, and it appears that their adoption will not be undertaken as quickly as necessary. The issues associated with anthropogenic-induced climate change and greenhouse gas emissions are beyond the scope of this paper; however, electricity generated from nuclear power represents an alternative energy source that is currently employed and may be more widely developed as the issues related to climate change become more apparent (Sailor et al., 2000).

Nuclear energy has been heavily modified since is early developments in the 1940s and nuclear power has proven itself as a technology capable of supplying large quantities of energy. Proponents of energy policies that include nuclear power argue that electricity generated by nuclear means has significantly less greenhouse gas emissions than more conventional means of electricity generation like coal-fired power plants (Jacobson 2009). Opponents of this argument contend that the development of nuclear technologies is extremely energy-intensive, creating large pollutant emissions during the mining, enrichment, processing and disposal of uranium and its byproducts. Additional sources of emissions stem from the complex engineering enterprises that occur during plant design and construction. Carbon emissions related to nuclear energy utilization have been investigated by many political and scientific organizations, and emission estimates ranges exceed two orders of magnitude, highlighting the complexity in assessing the footprint of nuclear energy (Ramana 2009).

For comparative purposes, lifecycles associated with nuclear energy suggest emissions between 16 and 70 grams carbon dioxide (CO_2) per produced kilowatt hour (kWh). Coal-fired power plants typically produce between 790 and 1020 g CO_2 per kWh, and alternative energy sources, such as wind and hydroelectric power, produce between 4 and 11 and 17 to 22 g CO_2 per produced kWh, respectively (Jacobson 2009). In addition to the debate on actual greenhouse gas emissions, opponents to a nuclear energy policy cite the proliferation of nuclear terrorism, nuclear system failures, and long-term waste disposal as reasons to reject the continued use of nuclear technologies. Further evidence against nuclear policies suggests that when nations employ nuclear power, peripheral economic development creates larger carbon footprints than would otherwise be observed (Keepin and Kats 1988). The issues of nuclear safety and economics will be discussed to further highlight the associated risks of employing nuclear technologies.

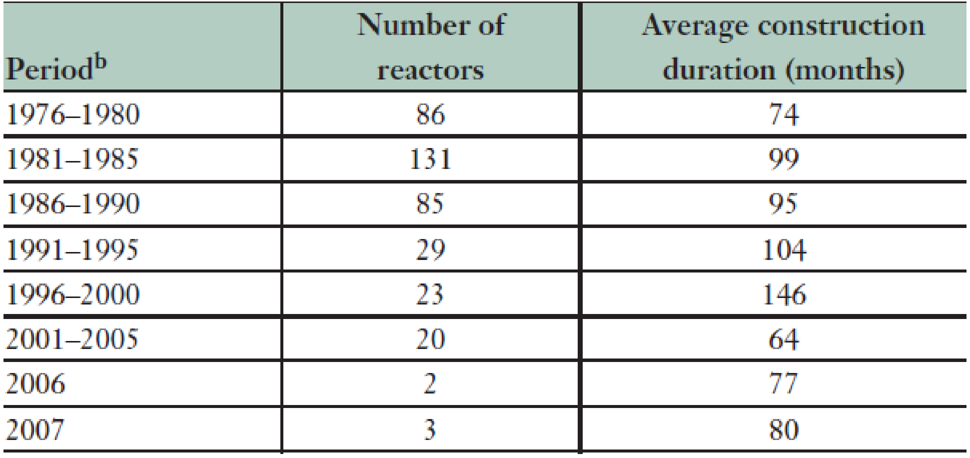
The Economics of Nuclear Power

In a world driven by economic means, financial barriers are often considered the greatest obstacle to the ongoing development of nuclear technologies. Because of the associated environmental health and safety concerns, nuclear power plants require substantial engineering of fail-safe systems and capital investments. These capital investments fall upon the actual investors, who are often hesitant to expend the necessary capital for potentially long-lasting, difficult construction projects (Deutch et al., 2003). In assessing the actual economics of any project, the concept of levelized cost is utilized in which all the future and present expenditures and revenues are compared to generate a relative cost per produced amount of electricity. With respect to nuclear power, costs arise in four areas: (1) capital construction costs, (2) operation and maintenance, (3) waste disposal, and (4) plant decommissioning (Ramana 2009).

Waste management and plant decommissioning are often difficult to assess because these events occur many years after a plant is constructed, and waste disposal is a politically contested issue. Nuclear waste and nuclear brownfield sites must meet rigorous government standards, and many people simply do not want to deal with ongoing issues associated with nuclear power plants. Operational costs have decreased with improving technologies and no longer represent a significant component of the associated costs of a nuclear power plant (Kazimi and Todreas 1999). Beyond the end-of-life costs associated with nuclear energy, construction cost investments represent the largest component of economic uncertainty with respect to nuclear power.

Capital construction costs of nuclear power plants are difficult to ascertain for several reasons. Most readily apparent is the associated construction times. Nuclear power plants require multiple levels of engineering fail-safes, regulatory guidelines must be met, and precision and constant reevaluations of the project must be undertaken. Meeting regulations on a concrete timeline can be difficult, and unforeseen events can put off the construction of a power plant for years or even decades. Political or social opposition can add additional unforeseen barriers to construction and delay projects. This is why there has been an observed slowdown of new power plant construction. As shown in Table 1, nuclear power plant construction peaked in the early 1980s. During this period, 131 new plants were constructed. By comparison, only three new facilities were constructed in 2007. Additionally shown in Table 1 is the average construction duration. Construction durations range from 64 to104 months, a substantial amount of time. These amounts of time make nuclear power plants very unattractive to investors who may never see returns on their investments. Investors may also have to pay interest on the loans they take out to fund these projects, and very few investors see it a viable strategy to pay interest on a project that may exceed eight years to complete (Ramana 2009).

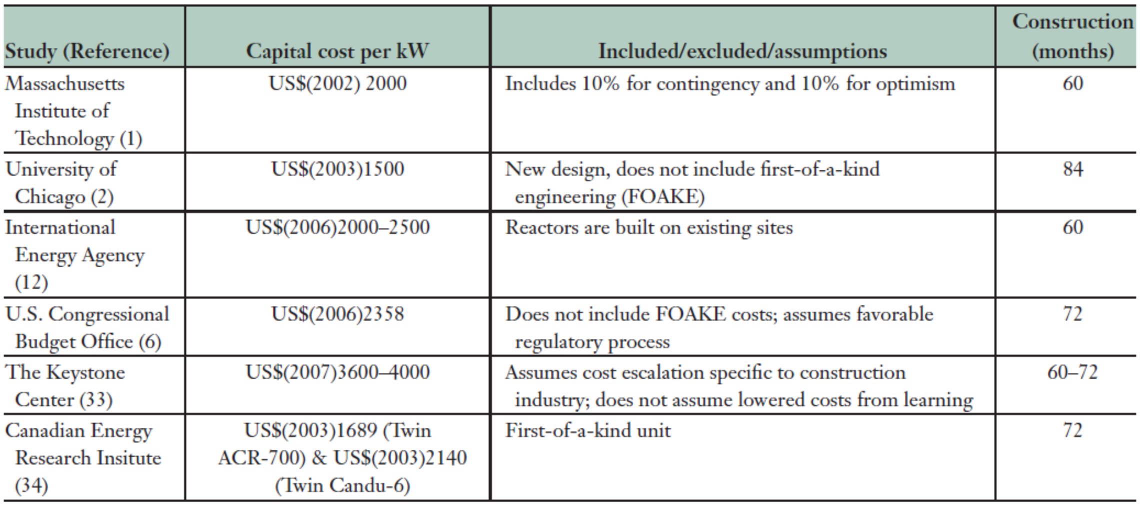
Table 1. Average construction durations for nuclear power plants (*Source:* Ramana 2009).



Period[b]	Number of reactors	Average construction duration (months)
1976–1980	86	74
1981–1985	131	99
1986–1990	85	95
1991–1995	29	104
1996–2000	23	146
2001–2005	20	64
2006	2	77
2007	3	80

Acquiring specific construction data has also been a challenge to analysts because, in recent years, not that many nuclear power plants have been constructed, and specific plant details are sometimes maintained as confidential. Additional challenges in quantifying construction costs arise from what Ramana (2009) refers to as first-of-a-kind engineering (FOAKE) because new projects employ newly developed, power-plant-specific technologies that may or may not be proven as completely feasible. Table 2 conveys a comparison of capital costs associated with nuclear power.

Table 2. – Construction capital costs (*Source:* Ramana 2009).



Study (Reference)	Capital cost per kW	Included/excluded/assumptions	Construction (months)
Massachusetts Institute of Technology (1)	US$(2002) 2000	Includes 10% for contingency and 10% for optimism	60
University of Chicago (2)	US$(2003)1500	New design, does not include first-of-a-kind engineering (FOAKE)	84
International Energy Agency (12)	US$(2006)2000–2500	Reactors are built on existing sites	60
U.S. Congressional Budget Office (6)	US$(2006)2358	Does not include FOAKE costs; assumes favorable regulatory process	72
The Keystone Center (33)	US$(2007)3600–4000	Assumes cost escalation specific to construction industry; does not assume lowered costs from learning	60–72
Canadian Energy Research Insitute (34)	US$(2003)1689 (Twin ACR-700) & US$(2003)2140 (Twin Candu-6)	First-of-a-kind unit	72

As shown in Table 2, capital costs per kilowatt-hour range from $2000 to $4000 per kilowatt. While this range may seem insignificant (being on the same order of magnitude), associated construction cost uncertainties play a huge role in investor thinking, and hesitation to invest in nuclear power plants is rampant. To encourage investment in nuclear technologies, in the United States, the Energy Policy Act of 2005 offered incentives to nuclear power investors in the form of loan guarantees, tax credits, researching funding, and financial offsets for incurred costs on interest loans that stem from construction delays (Ramana 2009).

Two additional economic factors associated with nuclear power plants will be discussed: decommissioning costs and nuclear waste management. Overall, there is very little information in the literature associated with nuclear power plant decommissioning for several reasons. First and foremost, very few nuclear power plants have actually been decommissioned. As previously stated, the capital investments for nuclear power plants are substantial, and countries that utilize nuclear power are more likely to retrofit existing plants rather than decommission them and build new facilities. In other words, operators of nuclear power plants attempt to maximize the utility of their respective plants by extending the originally intended lifetime of the plant by adding new technologies to preexisting structures. According to the World Nuclear Association (WNA), nuclear power plant decommission costs could range anywhere between nine and fifteen percent of the capital investment costs (WNA 2008). Analysis of two nuclear plants: the 1240 megawatt Superhenix in France, which operated between 1985 and 1998, and the 14 megawatt Demonstration Fast Reactor (DFR), which operated in the United Kingdom between 1959 and 1977, suggest that decommissioning costs may exceed $1.2 billion (NEA 2003).

Spent nuclear fuel can be dealt with by either reprocessing or storing it in long-term repositories. No country to date has succeeded in constructing a long-term repository, which would most likely be some geologic formation that was surveyed to prevent contaminant leaking. In the United States, there have been decade-long debates of using a facility in Yucca Mountain in a remote location in the southwestern United States. Political opposition has plagued the discussion of this issue, and it does appear to be moving anywhere quickly. It has been estimated that the construction of a long-term, geologic repository could cost as much as $8.5 billion (Ramana and Suchitra 2007). Interim storage is currently the United States' strategy in which spent nuclear fuel is kept onsite in secure storage facilities.

Reprocessing, though expensive, can produce returned revenue as plutonium is processed out of depleted uranium. Costs stem from the high capital costs associated with constructing reprocessing facilities, which require many of the same safety engineering systems found in nuclear power plants. This plutonium can be reused in more modern nuclear facilities or in the construction of nuclear weapons. Unfortunately, reprocessing creates highly radioactive waste materials, which must be dealt with. The many associated costs of nuclear power make these projects unappealing to many investors and without substantial government subsidies, the construction of new facilities occur extremely slowly. These challenges stem from public fears of associated health hazards and the potential dangers associated with radiation.

Nuclear Power Plant Health and Safety

Safety is the key issue when it comes to nuclear energy. Substantial investments have been made in plant design, safety redundancies, and nuclear power plant security, but despite these investments, issues persist. Beyond the 2011 events in Japan, issues at the Three Mile Island Nuclear Power Plant in the United States in 1979 and Chernobyl Nuclear Power Plant in the Ukraine in 1986 have turned off many members of the public towards nuclear energy (Mynatt 1982). Despite the complications of these reactors, the information attained from these events has been extremely valuable in designing later systems. With respect to nuclear safety, three factors exist: organizational factors, human factors, and technological factors. With respect to technological factors, engineering achievements have proven that it is possible to design safe plants, but the public still insists that, despite these designs, nuclear power plants are still not safe. Again, the recent events in Japan point to this. In this case, these plants have only been moderately successful in dealing with the devastation that occurred. Organizational and human factors include evacuation plans and strategies to deal with a problem should one occur.

Environmental health and safety engineering principles can be incorporated into a nuclear power plant in two ways. The first way is to design a plant so that, in an event of failure, it automatically or deliberately shuts down to contain any potential release of radioactive materials. The second method is to design a plant with certain engineering redundancies that limit or contain the failing system. To accomplish this, plants are designed with many levels of fail-safes to reduce the likelihood of any catastrophic scenario. For total system failure, all of the engineered redundancies must fail for further regional damage to occur. This is what actually occurred in Japan and, despite the many levels of fail-safes, the combination of earthquake, tsunami, and subsequent fires and explosions caused the reactor cooling systems to completely fail and release radioactive materials into the environment.

Plants are usually designed with three levels of fail-safe, redundancy systems. The first level is related to the actual design of the reactor. This can be viewed as a sort of hardware design system, where the failure might actually occur. These systems can be active or passive in design, with the former requiring human operators and the latter requiring computer systems to come online in the event of a problem. Passive systems are often more favored than active systems because they do not require any action by an operator and tend to be less expensive. The second level is a design level, in which if a problem was to occur, systems would come online to contain the actual failing component. This level is akin to a sprinkler system designed to come online and contain a fire in confined area. The third level is a mitigation level, designed to contain any spreading or ongoing issues. An example of this would be the operation of fire doors in a building to reduce the spread of a fire from one room to the next (Ramana 2009). Newer plants are considered a great deal safer than their predecessors, and ongoing research will only improve current designs.

Safety and health research related to nuclear power has been conducted since the event at the Three Mile Island Plant and has most focused on engineering safety models. Probabilistic safety analysis or probabilistic risk assessments are methodologies endorsed by the United States Nuclear Regulatory Commission (NRC) to systemically review nuclear power plant designs and safety protocols. These models, though still widely employed, have been criticized because they are not always successful in incorporating uncertainty analysis. With respect to nuclear power, levels of uncertainty are most often found in human actions, structural limitations, and computer software. Human action is extremely difficult to model because humans are inherently complex and unpredictable. Structural limitations are easier to quantify but most of the systems are designed to an engineered limit, where it is almost impossible to test these limitations unless a real disaster event actually occurs. Computer software uncertainty exists because failure events are non-linear and often unpredictable and, though nuclear software is designed to cope with a range of variables, events are unpredictable, and computer systems may be overwhelmed or left without power.

The events that occurred at Three Mile Island have since been described as failures due to structural elements, which include both operations and design elements in nuclear technologies. Investigations of Three Mile Island have led to the development of a concept known as the *normal accident theory* (NAT), which describes two characteristics associated with catastrophic failures in nuclear technologies: tight coupling and interactive complexity. *Tight coupling* is described as a time-dependent linking of different components. *Interactive complexity* is described as the interaction of subsystems in different, unpredictable ways. These issues persist because the engineering complexity that goes into designing a nuclear power plant can often produce unforeseen outcomes or series of events. The redundancy systems that go into these designs are often so complex that their actual successes at reducing failure may be hindered by their own complex designs. A criticism of NAT and these complex redundancies is that they are often employed when more simply designed alternatives exist; however, technological advances have encouraged the use of more complex redundancy systems. A fatal flaw of engineers is their reliance on technology and complexity to cope with problems (Ramana 2009 and Sagan 2004).

Additional concern arises from human factors and safety culture (Mynatt 1984). Nuclear systems are designed to include human capabilities within a disaster event scenario. These systems are designed with a man-machine system to be enacted in which humans can interact with the system from a safe distance. Humans can be flexible in decision making, but because there is the possibility for them to make errors, organizational hierarchical protocols exist to ensure that decision makers make the best decision with the best available information. In this way, nuclear power plant safety system designs have included research related to human cognition and decision making in order to reduce the flaws of humans and enhance their capabilities. Despite these concrete system protocols, humans often fail to adhere to the prescribed chain of command and follow procedure. This is an additional reason why power plant systems so heavily rely on passive, computer-based safety management systems.

In terms of actual human and environmental safety, the issue of radiation is the most prevalent issue associated with nuclear energy. Radiation events can occur from actual system failures or routine, accidental exposure. Radiation issues are most apparent in the increased rates of cancer development among those exposed to radiated materials. Thyroid cancer and leukemia are the most prevalently diagnosed health issues associated with radiation exposure. Estimates from the reactor failure of the Chernobyl incident suggest that anywhere between 4,000 and 600,000 people experienced increased rates of cancer development from released radiation (Ramana 2009). Beyond cancer concerns are the psychological ailments that occur from catastrophic events or even from close habitation to nuclear facilities. Land that has formerly housed radioactive material is often considered contaminated for many years into the future, and people are often forced to relocate from these sites. Routine exposure is heavily regulated by governing bodies and is often limited to 1 milliSievert per person per year, which is an exposure dose that raises the risk of cancer by 0.005% per year. Routine exposure may result from working at a facility or living in close proximity to a nuclear power plant. Despite these stringent regulatory restrictions, a comprehensive study conducted in France, the United States, Canada, Germany, the United Kingdom, and Spain observed increased leukemia rates in children living around nuclear power plants (Spix et al., 2008).

Experimental Design

After considering the aforementioned economic, health and safety, prevalence of nuclear technologies today, and its potential impact on climate change, a survey was conducted to ascertain how the public feels about nuclear technologies. For the experimental design component of this research, a series of eleven questions were drafted, based on brainstorming and the author's knowledge of nuclear power plant information and what may be considered potentially important to those surveyed. These questions were presented to respondents via email. They were told that all answers would be kept confidential and anonymous, and that no prior knowledge of nuclear energy was necessary. A phone interview was randomly conducted for a total of 180 individuals, age 18 years and above (N =180, male = 87; female = 93), United States residents from all 50 states. The participants were asked to rank their responses on 1 to 10 scales. A response of 1 was described as representing a stance of total opposition to the question or no knowledge of the posed question, when appropriate. A response of 10 was described as either totally supportive of or highly knowledgeable about the respective question. A response of 5 was described as being neither opposed to, nor supportive of or only moderately knowledgeable, when appropriate. The eleven posed questions are presented in Table 3.

Table 3. Survey questions

1.	You understand the costs/benefits of nuclear power?	2.	Nuclear power is a good idea?
3.	Nuclear power is safe and effective?	4.	You would support the construction of a nuclear power plant within 10 miles of you?
5.	You would support the construction of a nuclear power plant within 100 miles of you?	6.	The events in Japan have altered your opinion about nuclear power?
7.	The risks of nuclear power outweigh the risks of climate change?	8.	You think every country has the right to access power generated by nuclear means?
9.	Politics is the greatest barrier to nuclear power?	10.	Environmental/human health issues are the greatest barriers to nuclear power?
11.	If you had more information to make an informed opinion about nuclear power, you would take the time to understand it better?		

Results

The respondents were randomly selected and no age, race or gender information was obtained. The majority of respondents had no issues answering the questions, but two specific questions raised conflict with three of the respondents. Question 3, “Nuclear power is safe and effective?” was considered a poor question by two respondents because they made the argument that nuclear power is extremely effective but immensely dangerous. Question 9, “Politics is the greatest barrier to nuclear power?” also raised issues with respondents because they considered politics to be a generalized term, and they felt that there was greater complexity to the question. Despite these hesitations, all 18 participants responded to the previously posed questions. Values labeled as NA represent a respondent’s unwillingness to respond. Respondents’ answers are presented in Table 4.

Table 4. Ranking of answers provided by respondents.

Question	1	2	3	4	5	6	7	8	9	10	11
Respondents’ Average	6.8	7.3	6.9	2.7	6.6	3.3	4.7	4.9	6.4	6.1	8.7

Participants were not asked to seek out any information before the survey and were told to feel free to answer all questions if they felt they were capable of doing so. Additionally, before the interview was conducted, each participant was asked to indicate their willingness to complete or not complete, or participate in the survey. An informed consent was read to all participants, and no monetary compensation was paid to any of the respondents. In Question 1, no individual respondent considered himself or herself poorly versed in the associated costs and benefits of employing nuclear power. Twenty-four participants (13.3%) indicated that they might not have a great appreciation of the costs and benefits associated with nuclear power plant operations.

Additionally, majority of respondents (77.2%) would be willing to investigate nuclear energy further if they had access to more information. Despite some respondents considering themselves as not well versed in nuclear power, they were not very willing to comprehend any available information to make a more informed opinion. Questions 1 and 11 were designed to assess a respondent's present knowledge and contrast their confidence by seeing if they had more information, could they make a better, more informed response at another time. While this does not suggest that respondents were more confident in their knowledge of nuclear power than they actually were, it does however suggest that they could improve their response with access to greater information.

For Question 2, respondents were mostly supportive of nuclear energy, and this support could only be based of their belief that they understood the costs and benefits of nuclear power. Of the 180 respondents, 28 (15.6%) were very supportive of nuclear power and only nine (5%) were moderately opposed to it. Additionally, 42 respondents (23.3%) found Question 3 (about nuclear energy being safe and effective) to be a flawed question. Despite these hesitations (with two respondents refusing to answer this question), the majority of respondents,75.5% (median = 136) found nuclear power to be quite safe and effective.

Questions 4 and 5 (related to the proximity of a nuclear power plant to one's home) were designed to exemplify the concept of "not in my backyard" or NIMBY. NIMBY conveys the idea that people are willing to accept something considered potentially dangerous (in this case nuclear power) only if it does not affect them on a day-to-day basis. NIMBY is often linked with the concept of environmental justice in which, most often, poor and underrepresented communities must bear the brunt of potentially harmful environmental components like railyards, power plants, waste sites, and so on. Question 4 highlights this fact, with all respondents opposed to having a nuclear power plant within 10 miles of their home. For Question 5, 125 of the 180 respondents (69.4%) were willing to support a nuclear power plant within 100 miles of their homes. While the negative effects of nuclear power can be spatially expansive, responses to these questions suggest that people become more tolerable of nuclear power the farther it is away from them.

Due to the recent events in Japan, a question that involved Japan was merited. Despite excessive media coverage about the devastation at several nuclear reactors during the weeks since the earthquake and tsunami, the events in Japan only affected the opinions of 16 (8.9%) of the respondents. Suggestions can only be offered as to why this occurred, but most likely it was the nature of the disaster that people considered. In Japan's case, a massive earthquake and tsunami were responsible for the failure of four nuclear reactor cooling systems. It is possible that the respondents do not see these same events transpiring in the United States and, despite the potentially long-lasting radiation issues in Japan, respondents' opinions were not affected by the events in Japan.

Question 7 was designed to assess if the respondent would be more willing to accept the effects of nuclear power over a continued use of fossil fuels. Not surprisingly, 69 (38.3%) respondents considered the effects of climate change as a more pertinent issue than the possible effects of nuclear power. This may be due to the vast amounts of available information related to climate change and its prevalence as a global issue. Respondents who felt the effects of nuclear power are more significant than climate change may not fully believe in the concept of climate change. In the author's opinion, this may be due to the temporal scale of each of this issue. Climate change is often considered a difficult concept for some people to grasp, and the associated uncertainties make it difficult for some people to subscribe to the concept. Because of the associated uncertainties, these respondents may see the immediate effects of the dangers associated with nuclear power and, in their opinion, issues like radiation could occur on a shorter temporal scale and more immediately affect them.

Question 8 was designed to assess a respondent's opinion of free access for all countries to nuclear power. Because of recent media attention associated with countries determined to be "non-friendly" with the United States, and the fears associated with nuclear terrorism, the response to this question indicated that 168 (93.3%) of the respondents were hesitant in allowing any nation access to nuclear power. Questions 9 and 10 were designed to assess what the respondents' opinions were on barriers to a wider application of nuclear power. Most respondents (60.5%) found politics to be a greater barrier to nuclear power than the environmental or health barriers. These questions may have been flawed because it was argued that environmental and health issues are often included in the discourse of politics. It is further likely that nuclear terrorism played into a respondent's mind frame while answering these questions.

To further assess respondents' concerns associated with nuclear power, a second series of questions was presented to all respondents. Only 147 (81.7%) of the original 180 participants chose to provide their opinions on next series of questions. Respondents were asked: In the event of a local nuclear disaster, which of the following attributes is most significant to you?

1. Information associated with the disaster
2. Access to potable water and clean food
3. Reclamation of property
4. Medical attention

Respondents were told to rank the four above-mentioned attributes. A value of 4 meant that the attribute was most important to the respondent and a response of 1 meant an attribute was least important to a respondent, respectively. The results of this set of questions are shown in Table 5.

Table 5. Respondents' average ranking of most important attribute associated with a disaster.

Respondent's Ranking	Information associated with the disaster	Access to potable water and clean food	Reclamation of property	Medical attention
A	4	3	1	2
B	3	2	1	4
C	3	2	1	4
D	4	2	1	3
E	4	3	1	2
F	4	3	1	2
Sum	22	15	6	17

From this ranking process, it was concluded that respondents had the following attribute preferences: Access to information > Medical attention > Access to food or water > Reclamation of property

These results suggest that information associated with the disaster was the most important attribute, and reclamation of property was the least important. Medical attention was slightly favored over access to clean food and water. Because information appeared to be the most significant factor associated with a nuclear disaster, these five respondents were then asked to rank the quality of where the information would come from. Respondents were asked: In the event of a nuclear disaster, which source of information would you prefer?

Sources of Information:

1. Nuclear power company
2. Federal governing body
3. Media (example, CNN, Fox News, etc.)
4. Local governing body
5. Third-party body (example, independent nuclear watchdog)

Respondents were told to rank the four above-mentioned sources of information. A value of 5 meant that the source of information was most important to the respondent, and a response of 1 meant that source of information was least important to a respondent, respectively. The results of this series of questions are presented in Table 6.

Table 6. Respondents' average ranking of sources of information.

Respondent's Ranking	Power Company	Federal Government	Media	Local Government	Third-party source
A	3	4	5	2	1
B	3	5	4	1	2
C	3	5	2	1	4
D	4	5	3	1	2
E	4	5	3	2	1
F	4	5	2	3	1
Sum	21	29	19	10	11

From this series of questions, it was concluded that respondents had the following source of information preferences: Federal Government > Nuclear Power Company > Media > 3rd Party Source > Local Government

These results suggests that a federal governing body was considered the most valuable source of information associated with a disaster, and a local governing body was the least valuable source of information, respectively. It is speculated that the federal government would be the greatest source of information for the associated disaster because it has the most experience and greatest resource base for dealing with disasters of this magnitude. It is surprising that the local governing body was the least favorable source of information. It is quite difficult to determine whether personal biases of respondents may have played a role in their respective thought processes, and it is likely that they felt that local governments were incapable of dealing with large-scale disasters. Information directly from the nuclear power company was slightly favored over information from the media.

These results were similar to those expected; however, the media was more likely to serve as a greater source of information than the nuclear power company. It is believed that because respondents viewed the power company as a potentially biased source of information, since the power company would likely try to maintain order and could potentially withhold certain information from the public. It is likely that the independent, third-party source of information was not highly favored because respondents probably had difficulty in making a connection to this concept and viewed this source as unfamiliar and, therefore, not likely valuable.

Conclusion

Increasing global demands for power will force communities to seek out new sources of energy to cope with the demand. Nuclear power is widely employed as a source to generate energy and, although there has been a recent slowdown in its use, heightened demand and interest in shying away from fossil fuels may again increase its deployment. While there may be associated emissions from construction and uranium acquisition, nuclear power generation on its own produces little greenhouse gases and may be favored as means to reduce international carbon emissions. High capital costs, complex plant designs, plant decommissioning, and waste management and disposal represent financial barriers to ongoing developments in nuclear power plant construction.

If government subsidies are available and political discourse demands alternatives to carbon-rich fossil fuels, these costs may become more acceptable to investors, and a new era of nuclear power generation may occur. In addition to the economic barriers, social stigmas against nuclear power stemming from environmental and human health concerns may further impede any progress towards future power plant construction. Recent events in Japan may further challenge any commitment to employing nuclear technologies. A survey of public opinion related to nuclear energy revealed that there is support for these technologies if they can be safely enacted, and the effects of nuclear power generation are not immediately felt. Further analysis concludes that, in the event of a disaster, information is the most important attribute to the public, and there would be a heavy reliance on a federal governing body to disseminate that information. While this paper’s intent was not to suggest nuclear power is either good or bad, through this research it was concluded that these technologies can successfully operate when properly engineered. Additionally, when good information is available, a better dialogue can ensue. This discourse will be necessary into the future as the global population continues to rise and there is a greater demand for energy.

Overall, part of the future work will include a refinement of the posed questions and greater surveying depth. A better framework of questions would produce better results. Information should be provided to survey respondents so that can make better, more informed opinions about the questions posed. Additionally, future work should include analysis of the events in Japan, which will certainly provide invaluable information about nuclear safety and environmental impacts. Finally, it is recommended that a greater contrast of survey respondents should be conducted to garner a better grasp of global opinions on nuclear energy.

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