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Public perceptions of the effects of nuclear energy on the environment and public health: Associations with proximity, rurality, and political ideology

by

Grace Dehner

A thesis
submitted in partial fulfillment
of the requirements for the degree of
Master of Public Health in the Department of Community and Public Health
Idaho State University
Fall 2021

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Grace Dehner find it satisfactory and recommend that it be accepted.

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Human Subjects Committee Approval

April 21, 2021

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RE: Study Number IRB-FY2021-172: Perceptions of INL and Nuclear Energy in the local Community

Dear Dr. van Woerden:

I agree that this study qualifies as exempt from review under the following guideline: Category 2: Anonymous educational tests, surveys, interviews, or observations. This letter is your approval, please, keep this document in a safe place.

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Sincerely,

Ralph Baergen, PhD, MPH, CIP Human Subjects Chair

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List of Abbreviations

AEC	Atomic Energy Commission
ARS	Acute radiation syndrome
ATR	Advanced Test Reactor
CAES	Center for Advanced Energy Studies
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
CLT	Construal Level Theory
CRI	Cutaneous radiation injury
DNA	Deoxyribonucleic acid
DOE	Department of Energy
EBR-I	Experimental Breeder Reactor-I
EPA	Environmental Protection Agency
ESRP	Eastern Snake River Plain
H1	Hypothesis 1
H2	Hypothesis 2
H3	Hypothesis 3
H4	Hypothesis 4
HAZWOPER	Hazardous Waste Operations and Emergency Response
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IQR	Interquartile range

IRB	Institutional Review Board
IRENA	International Renewable Energy Agency
ISU	Idaho State University
MWe	Megawatt energy
NEI	Nuclear Energy Institute
NICE	Nuclear Innovation: Clean Energy
NRDC	Natural Resources Defense Council
NWPA	Nuclear Waste Policy Act
OR	Odds ratio
OSHA	Occupational Safety and Health Administration
PC1	Principal component #1
PC2	Principal component #2
PC3	Principal component #3
PCA	Principal components analysis
PD	Psychological Distance
PPE	Personal protective equipment
PV	Photovoltaic
RPM	Risk Perception Model
RUCA	Rural Urban Commuting Area
SMR	Small Modular Reactor
SNF	Spent nuclear fuel
STIG	Structured Threat Intelligence Graph
TWh	Terawatt-hour

US	United States
USGS	U.S. Geological Survey
WHO	World Health Organization
WIPP	Waste isolation pilot plant
WNA	World Nuclear Association

Public perceptions of the effects of nuclear energy on the environment and public health: Associations with proximity, rurality, and political ideology

Thesis Abstract – Idaho State University (2021)

This study analyzed if individuals perceive nuclear energy as a risk to environmental and public safety and determined how proximity, rurality, and political ideology influenced that perceived risk. This was a cross-sectional study that collected data through electronically disseminated surveys. The survey was distributed in May 2021 to Idaho residents within a 50-mile radius of INL. A total of 3,524 participants were included in the final analysis. Overall, the plurality of respondents agreed that nuclear energy may lead to more environmental pollution and contamination, contamination of water supplies, and new human health issues**.** Because Idaho is at the forefront of US nuclear energy, being home to INL with proposed projects on the horizon, the importance of understanding current and local perceptions of nuclear energy is necessary and will continue to be relevant, especially with the impending risks of climate change.

Key Words: Public health, Nuclear energy, Environment, Risk perception

Chapter I – Introduction

Background

Minor daily changes in climate are constant and considered a regular occurrence of everyday life on Earth. An increase in average temperatures has been documented everywhere throughout the world and are projected to continue. Specifically, in the United States, the National Resources Defense Council (NRDC) recently produced a report that indicated an eleven degree increase in average temperature by 2100 (Constible, 2017). Environmental and public health risks become greater as temperatures rise. Risks such as floods, storms, heatwaves and droughts, wildfires, decreased air quality, and heightened disease transmission are a few examples of risks posed by increasing global temperatures. Humans are one of the leading causes of global warming, primarily due to the burning of fossil fuels and deforestation (Environmental Defense Fund, 2020). The depletion of these natural resources is directly correlated with worldwide rising temperatures, and ocean water's changing chemistry (NOAA, 2019; USGCRP, 2020; Environmental Defense Fund, 2020).

It is imperative that the United States initiate the process of transitioning from fossil fuels to alternative, reliable, clean energy sources, while at the same time accommodating for the ever-increasing energy utilization that goes along with a growing population. Though increasing the use of renewable energy sources such as wind power and solar power seems to be the most sensible course of action, in many cases, these sources are unable to take on the entire workload of the power grid they support in their current capacity (Gielen et al., 2019; World Nuclear Association, 2021b). A lack of power storage and a dependency on outside variables such as weather or time of day are the biggest barriers to renewables at this time. This means that looking into other clean yet reliable energy sources is necessary to fill the gaps. Nuclear power is considered to be a clean and reliable energy source, however, due to public opinions of high perceived risk there has been a decline of support and upkeep of nuclear power stations (Paillere & Donovan, 2021; World Nuclear Association, 2021a). As a result, there is growing interest in the determining variables that influence public perception of nuclear energy. This project will address these gaps in knowledge and will evaluate the actual and perceived risks associated with nuclear energy to the environment and public health in relation to other energy sources.

Problem Statement

The world is changing, the globe is warming at faster and faster rates, increasing the likelihood of amplified public health risks, environmental contamination, pollution levels, and water contamination. A primary cause of these negative changes, specifically the burning of fossil fuels, such as coal, natural gas, and oil, is directly interrelated to humans and how we live our lives. A major factor in decreasing the use of fossil fuels is to identify other energy sources that could take the place of harmful emitters and still produce the energy needed to safely and effectively run our communities. Due to prior nuclear incidents (e.g., Three Mile Island, Chernobyl, and Fukushima), there are beliefs that nuclear energy may lead to new human health problems, more pollution and environmental contamination, and increased risks of groundwater contamination. Nuclear energy utilization is increasing and technology may be improving in countries such as China, South Korea, India, and Russia; however, this is insignificant if local perceptions are negative in nature and the benefits are not seen to outweigh the risks. Because Idaho is home to the Idaho National Laboratory (INL) and was the location of the first US reactor to produce enough electricity to power a small town, Idaho is at the forefront of nuclear energy for the United States. Older studies have assessed public perception of nuclear energy, however, as there are new reactors planned for construction at INL, it is important to understand current and local perceptions of nuclear energy and examine how they may differ according to proximity, rurality, ideology, and other demographic factors.

Project Purpose, Specific Aims, and Hypothesis

This project will analyze if individuals perceive nuclear energy to be a risk to environmental and public safety and will determine how the level of proximity to the national laboratory, level of rurality, and political ideology influences that perceived risk. This thesis will also assess how perceptions of environmental impact of various sources of energy are associated with perceived environmental and health risks of nuclear energy. The environmental and health risks of nuclear energy to be measured include 1) pollution, contamination of the environment, 2) contamination of water supplies, and 3) new human health problems. In order to achieve this goal, this project proposes the following specific aims are proposed:

I. Describe the perceptions of the environmental and health risks of nuclear energy.
   a. H1: The majority of respondents will perceive nuclear energy as something that may lead to more environmental pollution, contamination, contamination to water supplies, and new human health issues.

II. Determine the association of level of rurality and political ideology with perceived risk of environmental and health risks from nuclear energy.
   a. H2: Perceived risk of nuclear energy to the environment and health is significantly influenced by level of rurality and political ideology, specifically those who reside in urban locations and individuals who identify as liberal will be more likely to perceive nuclear energy as a risk to the environment and to public health compared to those who live in rural locations and individuals with conservative ideologies.

III. Explore the association between the perceptions of environmental impact of energy sources and perceptions of the environmental and health risks of nuclear energy, before and after controlling for demographic variables.

a. H3: Perceptions of environmental impact of energy sources will be independently associated with perceptions of the environmental and health risks of nuclear energy.
b. H4: Those that perceive that fossil fuels have a higher environmental impact will also perceive nuclear energy as having high environmental and health risk, and those that do not perceive fossil fuels as having a high environmental impact will not perceive nuclear energy as having high environmental and health risk.

Significance

The way that we utilize natural resources for energy production has a direct connection to many adverse public health outcomes and the contamination of the environment and water supplies. While there is a growing repertoire of research on public perceptions of nuclear energy as an alternative power source, very little of this literature is specific to Idaho. Completing this project would be an essential step towards understanding how Idahoans, based off of geographic level of rurality, demographic factors, and political ideologies perceive whether or not nuclear energy may lead to new human health problems, more pollution and environmental contamination, and increased risk to water supply contamination. This project would also examine individual ratings of environmental impact of energy sources according to perceptions of the environmental and health risks of nuclear energy. From this information, areas and populations of concern will be identified. While this proposal will examine the perceptions of nuclear energy in Idaho and the surrounding states, it is anticipated that many of the findings will be generalizable to other US locations. This project may aid in bridging the gap between pro and anti-nuclear energy communities/organizations and bring awareness to perceived and actual risk of nuclear energy. Results from this project will help INL expand and implement solutions-based initiatives in local Idaho communities. This is an opportunity to identify what the public believes regarding nuclear energy as an alternative energy source. Results from this project will also provide environmental organizations data and results that will allow them to implement or address initiatives in Idaho communities.

The idea of One Health supports the concept that the choice of an individual affects, not just themselves, but their community and the environment or ecosystem that community is attached to – involving all flora and fauna. The Centers for Disease Control and Prevention (CDC) defines its model as “a collaborative, multisectoral, and transdisciplinary approach — working at the local, regional, national, and global levels — with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment” (Centers for Disease Control and Prevention, 2020). My intention is to complete this project in support of the guiding principle of One Health, to do my part in bridging the gap between environmental conservation and public health.

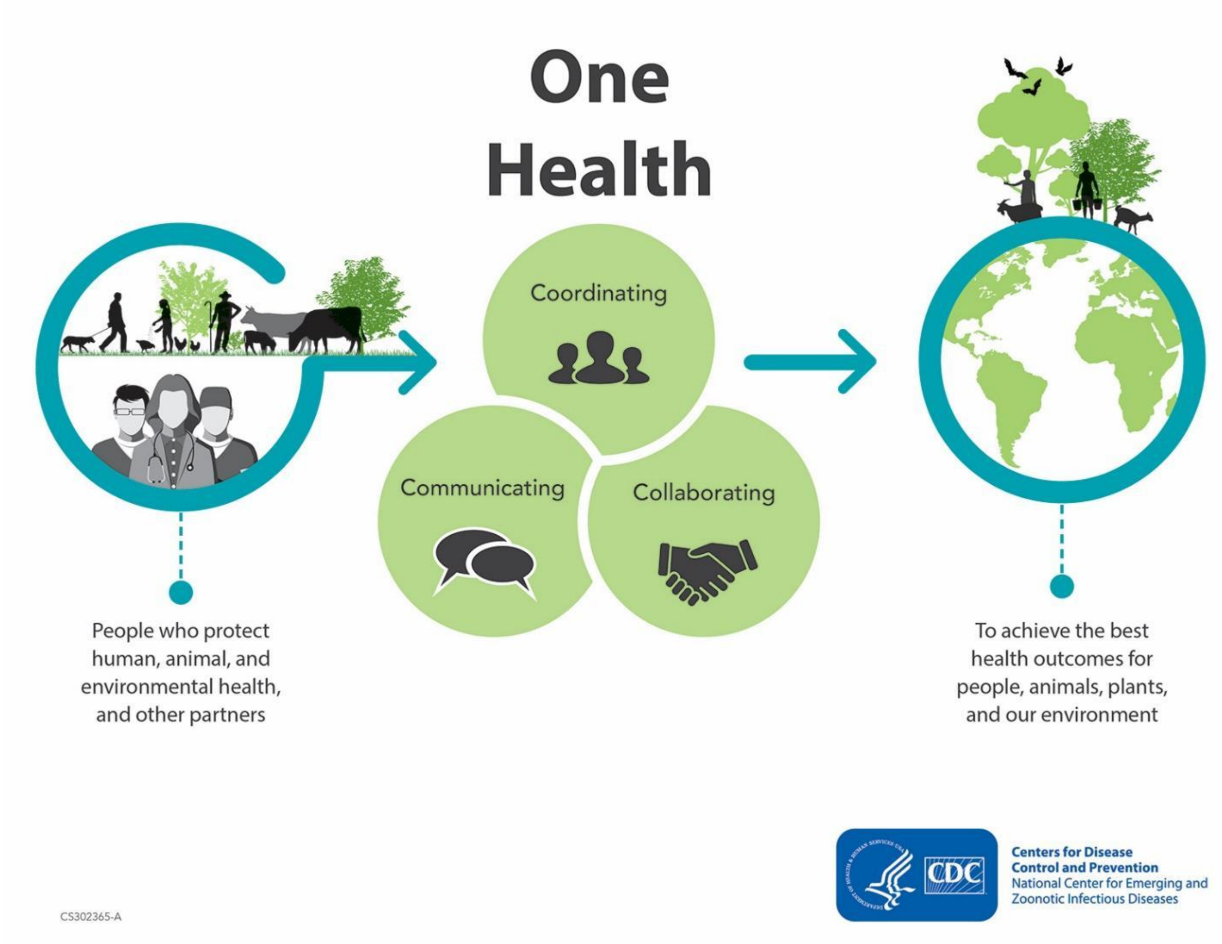

Figure 1 CDC - One Health Diagram

Chapter II – Literature Review

As of December 31, 2020, there are 441 nuclear reactors currently in use and 115 decommissioned power plants worldwide, of which, six were permanently decommissioned in 2020. There are 52 new nuclear reactors in construction and around 250 units have been proposed to be operating by 2030 (World Nuclear Association, 2016a; World Nuclear Association, 2016b). In the United States, there are currently 93 nuclear reactors in use, 40 plants decommissioned (one of which was shut down in 2020 – Indian Point), and at least 10 approved or proposed new reactors, two of which are currently under construction in Georgia State (United States Nuclear Regulatory Commission, 2020; World Nuclear Association, 2016a; World Nuclear Association, 2021c; World Nuclear Association, 2021d). In Idaho there is at least one operational reactor, which is located at INL in the Advanced Test Reactor (ATR) complex, 49 have been decommissioned, and one NuScale Small Modular Reactor (SMR) power plant has been proposed for construction at INL (Atomic Heritage Foundation, 2019; Idaho National Laboratory; 2021; U.S. Department of Energy - Office of Nuclear Energy, 2021a). In the 1950s, nuclear economics experienced rapid growth with the hope of being the new technology that would advance civilization significantly. Reasoning behind the implementation of this new technology was due to an increased electrical demand, it was promoted as a clean energy (e.g. zero-carbon or zero-emission energy) source, a new science and technology, a source of well-paying jobs, and considered the "future of energy" (Lester & Rosner, 2009; Nuclear Energy Institute, 2021a). The United States was initially a major proponent of nuclear energy; however, reduced support has resulted in a stagnation of new nuclear technology implementation. Other countries are starting to increase their nuclear fleets and are gaining on the United States in terms of per capita production of this alternative energy source. Data from 2020 shows that the United

States continues to lead the world in operator net capacity (megawatt energy (MWe)), producing 95,523 MWe, followed by France (61,370 MWe), China (49,569 MWe), Japan (31,679 MWe), Russia (28,578 MWe), and South Korea (23,150 MWe) (World Nuclear Association, 2016b). Due to its energy efficiency and reliability, availability of fuel, increased electrical demand, and clean energy production, countries like China, South Korea, India, Turkey, Russia, and the United Kingdom began increasing their nuclear power fleets and moved forward with advancing nuclear technologies (Lester & Rosner, 2009). Most nuclear reactors as of 2019 are housed in the United States (96), France (58), China (48), Russia (38), and Japan (33) (International Atomic Energy Agency, 2020).

Current trends of increased nuclear energy production are justified by climate change, energy security, and increased demand on electrical grids, however, local politics, economics, and individual perceptions at the local level impact the growth of this industry. Since wariness of nuclear energy still lingers in the US, the continued research into new nuclear technologies, obtaining stakeholders and funding, and to begin building new reactors has been a slow-moving process that has only started to gain momentum again. Primary areas in which nuclear energy is included in energy discussions is global and local climate change initiatives such as the 2016 Paris Agreement – an international treaty on reversing climate change and to the ever-increasing global trends in energy consumption (World Nuclear News, 2020). The United States under President Obama initially endorsed the Paris Agreement in 2016, withdrew in 2020 under President Trump, and then rejoined in 2021 when President Biden came into office (Denchak, 2021). Another barrier to beginning to think about new reactors and a reason for revisiting this topic now is due to the fact that the average age of most of the reactors in the United States are around 40 years old and are beginning to either be replaced or require significant maintenance

(Energy Information Administration, 2020). Because of safety concerns, nuclear energy has become more and more regulated, which has increased the cost of nuclear energy over the last decade, inversely, the cost of natural gas and renewable energy sources has reduced significantly over that same time period (Ray, 2018). Therefore, in most recent cases of nuclear reactor shutdowns, the electricity that power plants provided to those communities was replaced by fossil fuels, primarily natural gas (Union of Concerned Scientists, 2018).

At the beginning of nuclear energy, Idaho was at the forefront. On December 20, 1951, INL, initially known as the National Reactor Testing Station, discovered that Experimental Breeder Reactor-I (EBR-I) could successfully produce useable electricity by means of atomic fission (Idaho National Laboratory, 2019a; U.S. Department of Energy - Office of Nuclear Energy, 2019). In 1953, further testing determined that EBR-I could produce sustainable electricity by producing more fuel than was needed for powering the reactor (Idaho National Laboratory, 2019a; U.S. Department of Energy - Office of Nuclear Energy, 2019). Eventually, in 1955, the Borax III reactor from the same power plant location as the EBR-I would power the small rural town of Arco, Idaho, second in providing nuclear energy to a community only to the plant located in Obninsk, Russia (Haroldsen, 2008; National Geographic Society, 2011). In the same year, EBR-I experienced a partial core meltdown during a coolant flow test; due to harmlessness of the event, this incident is not considered to be an official nuclear accident by the Atomic Energy Commission (AEC) reactor safeguard committee (Haroldsen, 2008). INL is not just a research and testing site, but also a nuclear waste storage facility that stores the partially-melted core remains of the Pennsylvania’s Three Mile Island nuclear plant (Berrios, 2017; Ridler, 2018; United States Nuclear Regulatory Commission, 2018).

Risks of Nuclear Energy

Environmental Risks

There are environmental safety risks associated with each type of energy source. These risks may have an impact on the environment, such as increasing pollution levels, or contaminating water sources, or cause new human health risks. Some sources of energy pose a risk to both the environment and public health. The Nuclear Energy Institute (NEI) and the Department of Energy (DOE) report that nuclear energy is the largest cleanest source of energy, meaning that not only is nuclear energy carbon-free, it produces more clean energy than all other sources (Nuclear Energy Institute, 2021b; Mueller, 2021). From this perspective is where proponents of nuclear energy get their argument to support nuclear energy inclusion in future energy mixes. There are, however, significant potential risks of nuclear energy that must be considered. Some risks pose more of a threat to specific locations, and others may not be as valid, but all must be considered.

Primary environmental contamination risks include, the contamination of food supplies and farms, depletion of natural resources, radiation exposure, uranium mining, nuclear waste leaks and storage, endangered species (flora and fauna), and cultural heritage, historic archaeological sites, and artifacts (Griffith & Hoiland, 2015). This list is not exhaustive, but indicates risks that are more relevant, or are of actual risk to the environment. Many of these environmental contamination risks are relevant to Idaho, however, a primary concern for the area within and surrounding INL is contamination of the Sagebrush-Steppe Ecosystem Reserve and the rehabilitation project centered around protecting the at-risk sage-grouse (Bureau of Land Management, 2018; Griffith & Hoiland, 2015).

Many conservation organizations in Idaho are concerned that potential nuclear radiation exposure and possible nuclear waste leakage are existing threats to this area. The World Nuclear Association (WNA) states that “though nuclear waste remains weakly radioactive for a few hundred-thousand years, the radioactivity from the main component of the waste which could cause health problems will have decayed to safe levels within a few hundred years” (World Nuclear Association, 2020a). Before that point, however, nuclear waste is highly radioactive and requires a multi-level storage system to address radioactive exposure to the environment and humans. This multi-level storage system involves immediate wet cooling and storage pools, secondary dry storage casks, and permanent geologic repositories (World Nuclear Association, 2020a). The United States does not have a permanent disposal facility to house high-level nuclear waste at this time (U.S. Energy Information Administration, 2020a). There is a Waste Isolation Pilot Plant (WIPP) located in New Mexico that is able to store radioactive waste in an ancient salt formation underground (U.S. Department of Energy - Office of Environment, Health, Safety & Security, 2015). However, according to the DOE report, there was an unintentional release of radioactive material in 2014 at the WIPP, indicating that the permanent geologic repository for high-level nuclear waste facility still has design and functionality issues.

Fortunately, there are other options for storing nuclear waste. Though less efficient, short-term storage facilities remain effective in containing nuclear waste, or spent nuclear fuel (SNF) and are regulated by the Nuclear Regulatory Commission under the Atomic Energy Act, as amended (P.L. 83-703). SNF is currently stored on site of commercial nuclear power plants either in wet storage pools or in dry casks underground. The United States has 80 sites nation-wide that store nuclear waste, of these storage locations, 57 of them have active reactors (Larson, 2020). INL is among the 80 active US sites (23 of which are just storage sites and 57 of which house operational reactors) that are storing nuclear waste (Larson, 2020). SNF is stored at the INL-based Idaho Nuclear Technology and Engineering Center (INTEC) and utilizes primarily dry storage technologies, but does still utilize wet storage pools (U.S. Department of Energy - Office of Environmental Management, 2021). INL is actively working to achieve a DOE determined goal of transferring all SNF from wet storage pools to dry casks by 2023 (U.S. Department of Energy - Office of Environmental Management, 2020).

Water Contamination Risks

Water contamination from nuclear waste is an area of higher perceived risk, especially after the 2011 Fukushima nuclear incident (Miao et al., 2013). Improper storage, poor mining practices, and nuclear accidents pose a risk to groundwater that not only affects environments and ecosystems, but also human health. In the early times of nuclear energy, waste was not disposed of in appropriate ways that would prevent water or environmental contamination. The problem with this is that much of the waste that was dumped in the 1940's – 60's has not been retrieved and stored in safer locations and packaging, primarily due to the high costs of nuclear site and waste remediation projects (Feldman, 2018; Institute for Energy and Environmental Research, 2014). Waste disposal since then has significantly improved and regulation of the disposal of nuclear waste has become mandatory thanks to the Nuclear Waste Policy Act (NWPA) established in 1982 (United States Environmental Protection Agency, 2013). That being said, accidents still happen and the process has not yet been perfected. Due to the unstable nature of discharged wastewater into infiltration or percolation ponds, mitigation by way of groundwater monitoring processes maintained by the DOE and the U.S. Geological Survey (USGS) is constantly ongoing and poses a significant contamination threat to the eastern Snake

River Plain (ESRP) aquifer and perched groundwater zones which happen to be beneath INL (Bartholomay, 2020; Rattray, 2019).

Water contains naturally occurring radionuclides, which is why the radioactivity of drinking water is a common and standard indicator for quality or safety of drinking water (Miao et al., 2013; National Research Council (US) Safe Drinking Water Committee, 1977). However, the potential ingestion exposure to radioactive material is a growing as a public health risk (Vergara & Kalinich, 2021). The 2013 study by Miao et al., 2013 found that radioactivity of water levels varied depending on seasons due to amount of rainfall, location or proximity to a nuclear facility, age, and source of drinking water (e.g., well or tap (city water)). Overall, this study found that all water sampled from the surrounding areas of seven Chinese nuclear facilities was considered to have safe radioactive levels, below the World Health Organization (WHO) recommended values (Miao et al., 2013). The primary risk of ingesting high levels of radionuclides in groundwater in severe instances such as Chernobyl and Fukushima, which both had significant groundwater contamination, there is an increased risk of cancers (Minnesota Department of Health, 2021); however, due to seasonal and location-based dilution, much of water contamination risk is mitigated (Bugai et al., 1996; Kratchman & Norton, 2015).

A lesser thought of risk to water contamination from nuclear energy are earthquakes. The Great East Japan Earthquake of 2011 was to blame for the explosion of Fukushima Daiichi Nuclear Power Plant (Maeda & Oe, 2015). Earthquakes are not just a risk to Japan, but also to Idaho. INL operates a seismic monitoring program that identifies the where, when, and size of earthquakes that may have an impact on the nuclear research center (Podgorney et al., 2013). Even though INL is located in the Snake River Plain, which is at lower risk of seismic risk, there are areas that are relatively close in proximity to INL that are of considerable risk. Potential earthquake sources in this area include Yellowstone, Wyoming which, according to Podgorney et al., is considered a region of higher crustal deformation. One major earthquake in that region was the Borah earthquake in 1983 which was located around 70 miles from the research center, however “no significant damage occurred” (Podgorney et al., 2013).

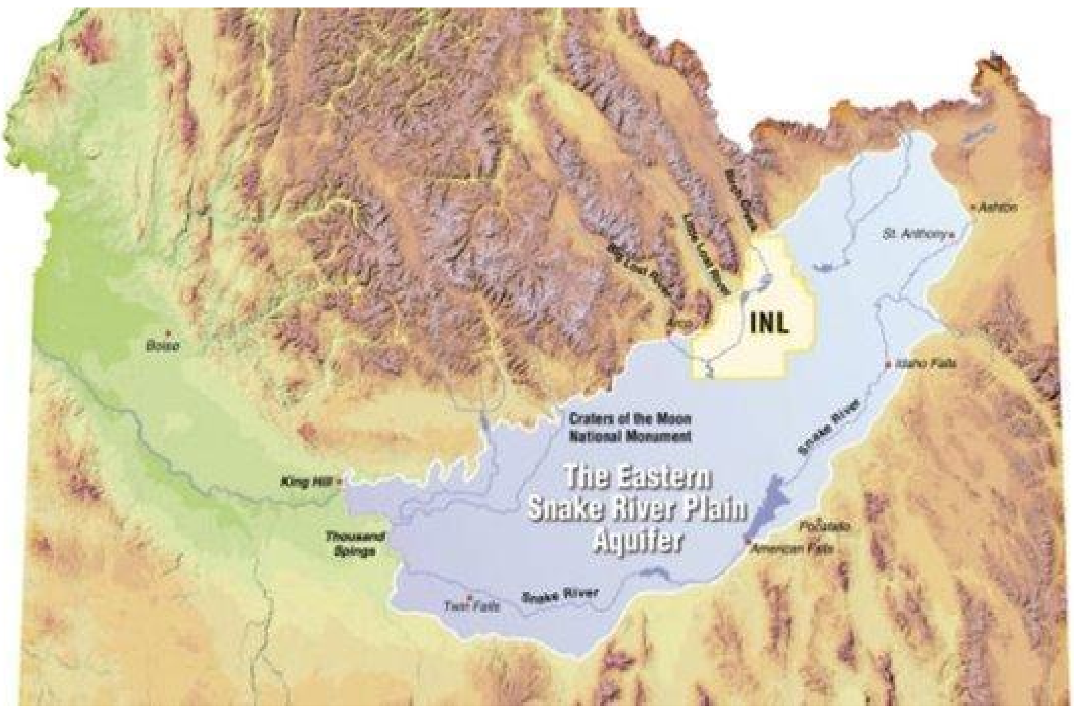

Figure 2 Location of INL in Reference to the Eastern Snake River Plain Aquifer – Image sourced from INL

Risks to Public Health

Every type of energy has its own level of risk or danger. In order to measure level of actual risk, the number of deaths per energy source is compared below. While there is high perceived environmental and public health risk associated with nuclear incidences (Bian et al., 2021; Ho et al., 2014; Huhtala & Remes, 2017), nuclear energy is among the safest sources of energy in terms of number of deaths per terawatt-hour (TWh) (Ritchie, 2020). A 2020 analysis compiles death rates from energy production per TWh from Makandya & Wilson (2007) and Sovacool et al. (2016) and indicates that deaths measured are not just directly connected to accidents, but also through invisible issues such as chronic exposure to pollution (Markandya & Wilkinson, 2007; Ritchie, 2020; Sovacool et al., 2016. This comparison of mortality rates indicates that coal has the highest mortality rate of all energy sources per TWh, followed by oil, then natural gas (coal – 24.62 deaths per TWh, oil – 18.43 deaths per TWh, gas – 2.82 deaths per TWh, nuclear – 0.07 deaths per TWh, wind – 0.04 deaths per TWh, hydropower – 0.02 deaths per TWh, and solar – 0.02 deaths per TWh) (Ritchie, 2020). Each of these is significantly higher than the death rate associated with nuclear energy, which indicates that per energy source, nuclear energy is safer than coal, natural gas, and oil by an average of 98.93% fewer deaths. According to Ritchie, these data do not include those deaths associated with the mining of uranium for fuel source. Ritchie also notes that due to the lack in data regarding death rates of renewable energy sources, these estimates may be outdated and only show a more favorable outlook for nuclear energy (Ritchie, 2020). It is difficult to calculate the number of deaths directly associated with nuclear radiation exposure due to the various possible levels of exposure – "the severity of symptoms and illness (acute radiation sickness) depends on the type and amount of radiation, how long you were exposed, and which part of the body was exposed" (National Institutes of Health, U.S. National Library of Medicine, 2016).

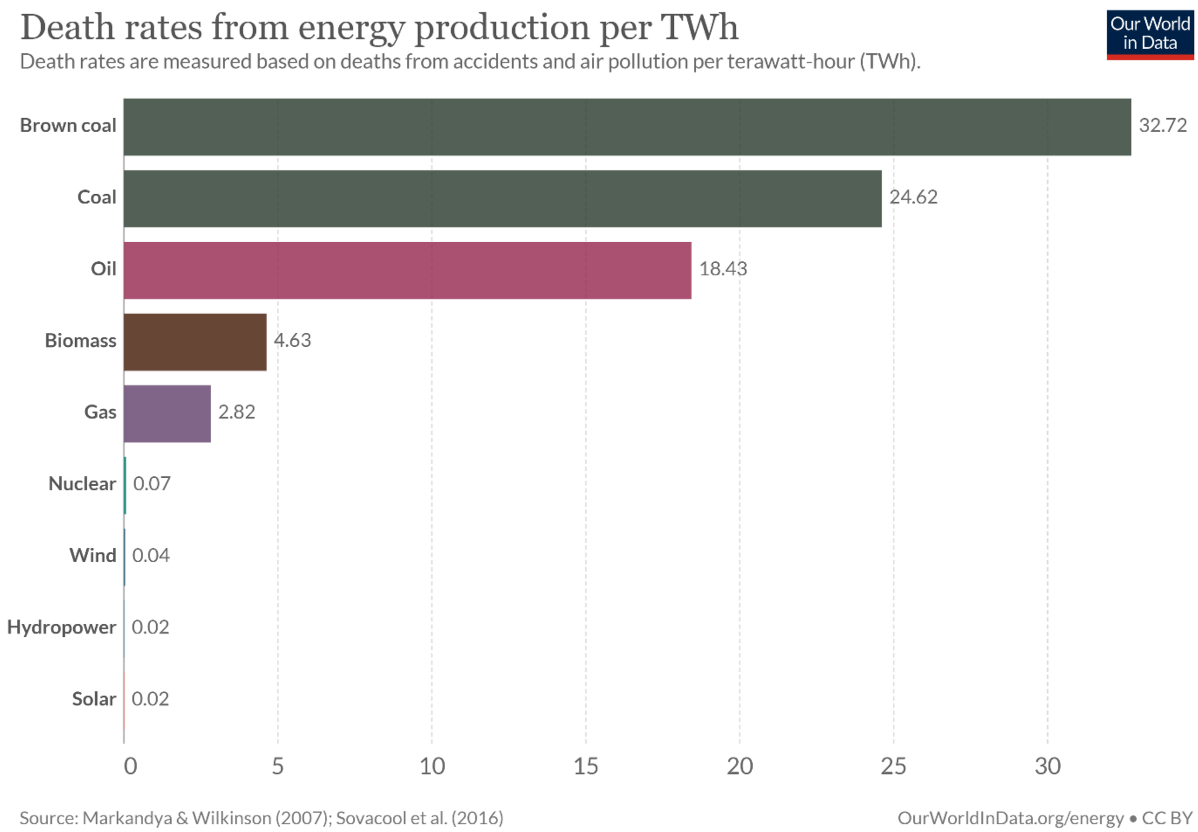

Figure 3 Death rates from energy production per TWh

Uranium mining and milling is another significant area of concern to public health. Uranium is the most common fuel source for energy produced from nuclear fission reactors (U.S. Energy Information Administration, 2021b). Radium is a production of decaying uranium, which then produces radon, a radioactive gas that poses a threat to the environment, water supplies, and public health; primarily miners and those living in close proximity to an open pit uranium milling site are at increased risk of radon exposure (United States Environmental Protection Agency, 2021; Virginia et al., 2011). According to the Environmental Protection Agency (EPA), radiation exposure from uranium mining disproportionately affects Native American lands, specifically Navajo lands, where more than half of abandoned uranium mines are located (United States Environmental Protection Agency, 2021).

Thorium is an alternative fuel source of public health concern. Thorium is used in nuclear technology as a molten salt reactor; however, no currently operational reactors are thorium-fueled due to its many pros and cons. Due to a lack of current thorium supported infrastructure, the costs associated with the start-up, implementation, and oversight are substantially higher than uranium technologies (Gaille, 2018). Uranium-232 is the man-made isotope that is separated from thorium through neutron radiative capture, is extremely radioactive, and produces a highly corrosive molten salt mixture which is difficult to store (Gaille, 2018; Nuclear Power, 2021). The reasoning behind some countries normalizing the utilization of thorium is because of the abundant, global availability – Thorium is available three times as much as uranium (World Nuclear Association, 2020b). Uranium-232 is not compatible with nuclear-based weapon technologies, new manufacturing technology could reduce the overall cost and availability of reactors, the waste from thorium reactors is recyclable, able to be used again for nuclear fuel, storage timeline for radioactive waste is significantly less than uranium, produces high levels of efficient energy, temperature self-regulation which reduces the risk of a reactor overheating, and thorium has less health and environmental risk associated with mining efforts due to its global availability (Gaille, 2018; International Atomic Energy Agency, 2005; Ting, 2015; World Nuclear Association, 2020b).

Health risks associated with nuclear energy tend to be dependent upon the nature in which an individual is exposed and the length of exposure. Radon decay exposure from uranium mining and processing is significantly associated with pulmonary disease (National Cancer Institute, 2011; Virginia et al., 2011). Direct contact to materials by way of inhalation, ingestion, or an open wound to may lead to ionizing radiation exposure (e.g., alpha, beta, and gamma particles), which may result in a breakdown in DNA and increasing the risk of cancer

(Occupational Safety and Health Administration, 2021; Virginia et al., 2011). Other risks from radiation exposure include birth defects, cataracts, cutaneous radiation injury (CRI), and acute radiation syndrome (ARS) (Centers for Disease Control and Prevention, 2021; National Institutes of Health, U.S. National Library of Medicine, 2016a; United States Environmental Protection Agency, 2014; World Health Organization, 2016).

According to the Occupational Safety and Health Administration (OSHA), there are strict regulations regarding ionizing radiation which indicates that exposure risks such as the ones listed above, are highly unlikely (Occupational Safety and Health Administration, 2021). There are regulations and employment protections in place, such as the Radiation Emergency Preparedness and Response guidance framework, Hazardous Waste Operations and Emergency Response (HAZWOPER), and personal protective equipment (PPE) standards that are implemented and are required to abide by existing OSHA standards to ensure worker and community safety (Occupational Safety and Health Administration, 2020). Other agencies such as the DOE, U.S. Nuclear Regulatory Commission, and the International Commission on Radiological Protection are examples of other governing bodies that regulate ionizing radiation.

A more modern, human-based risk with increased relevance to nuclear power plants is the risk of cybersecurity attacks (American Nuclear Society, 2020). Idaho plans to mitigate any future cyber risks by the implementation of a new Structured Threat Intelligence Graph (STIG) software cybersecurity tool designed to interact and protect against cyberthreats (Idaho National Laboratory, 2019). Though no commercial nuclear power plant in operation today has been the source of nuclear weapons due to the high burnup of fuel (Brook et al., 2014), another area of concern for some is the idea that a nuclear power plant could be the target of a terrorist attack. A specific example of risk associated with a terrorist attack is the story of the Indian Point Plant located in Buchanan, New York and about 25 miles north of Manhattan, New York. Though, Indian Point was a main contributor of New York State's electricity, operations were permanently stopped in 2021 (U.S. Energy Information Administration, 2021). There was opposition to the power plant from the beginning, however, the September 11, 2001 terrorist attack caused perceived risk to increase exponentially due to the announcement by President Bush in 2002 that Al Qaeda was intending to target American nuclear power plants (City of New York - Manhattan Community Board 3, 2002; Council on Foreign Relations, 2006). There were other reasons for environmental organizations such as Riverkeeper and the New York Governor's office to want to shut the plant down such as close proximity to New York City and the negative environmental impact the cooling system and waste leakage had on the fish and plants in the Hudson River (Gearino, 2021; Kennedy, 2021; Riverkeeper, 2019).

Environmental Impact of Different Energy Sources

A high-level concern of opponents to nuclear energy is regarding environmental impact, however, all sources of energy have some sort of negative effect on the environment, even those considered to be renewable and produce clean energy. It is fact that fossil fuels such as coal, natural gas, and oil have a significantly more harmful impact on the environment, water sources, and public health (Union of Concerned Scientists, 2013). Clean sources may not produce emissions while producing energy, however, there are many unseen stages that go into the overall concept of an energy source that should be considered when comparing overall environmental impact. The various stages to think of include the construction, production, processing, distribution, and disposal (e.g., what happens to a solar panel when the technology becomes outdated or needs to be replaced). Though, even without constant and appropriate early-on regulation, technological advancement, and funding, it should be mentioned that nuclear energy is the most reliable, or firm clean source of energy available (U.S. Department of Energy - Office of Nuclear Energy, 2021b). Firm or reliable energy means that the electricity produced by nuclear power is not variable and is consistently available. Renewable energy sources such as solar, wind, some hydroelectric, and geothermal power are also considered clean energy, however, these sources of energy are not considered "firm power" because they either depend on certain conditions, time of day, can only be collected in specific locations, or they have a limited source (Gromicko, 2010; U.S. Department of Energy - Wind Energy Technologies Office, 2014). Non-renewables are considered to be reliable, however, coal, natural gas, and oil are not clean energy sources (U.S. Department of Energy, 2021). Science is slowly advancing other options for clean reliable power such as long-term renewable storage and carbon capture, but these will not be available for some time (https://issues.org/stephens/).

Renewable Energy Sources (Wind, Solar, Hydropower, and Geothermal)

Wind is one of the most sustainable sources, however, there are environmental impacts that should be considered. The location of wind farms in relation to residential areas is a concern for some due to mechanical or aerodynamic noise pollution and visual interference, the disruption of wildlife habitats by way of death of birds and bats, and the alteration of migratory patterns of some animal species are examples of some (American Bird Conservancy, 2020; (Saidur et al., 2011; Union of Concerned Scientists, 2013b). Steel is a primary component of a wind turbine and is a recyclable material, however, there are negative environmental effects from the processing of steel in the production of and recycling of wind turbine components (Andersen et al., 2014). The blades of a wind turbine can be as long as 165 feet tall, make up a large part of the total turbine body (https://www.windustry.org/wind-turbine-blade) and are made primarily of fiberglass which is difficult to recycle and causes hazardous dust when destroyed (Andersen et al., 2014).

Similar to wind power, the location for many solar power plants can be the primary issue. In order to create enough energy, solar panels can take up massive amounts of space and can ruin habitats of native plant and animal species (U.S. Energy Information Administration, 2019). The US Energy Information Administration also notes that some solar power plants require large quantities of water for cleaning and power processing. The construction of solar panels is also an environmental risk as toxic chemicals are required for converting sunlight into energy and some panels require heat transfer that utilizes toxic fluids such as propylene glycol, or antifreezes, silicones, or refrigerants such as hydrochlorofluorocarbons, which if leaked may negatively impact the environment (U.S. Department of Energy, 2020; U.S. Energy Information Administration, 2019). The negative impacts of the mining of other materials, such as aluminum, concrete, copper, nickel, steel, and zinc, and silica which is critical for the construction of most solar panels and the conduction of energy (Bleiwas, 2010) should also be considered. Since this is an ever-evolving technology and the ultimate goal is to maximize efficiency and effectiveness, solar technologies become outdated at a fast rate and the disposal of solar panels is fast becoming a major environmental issue (Bates, 2020; Chowdhury et al., 2020; Maani et al., 2020; Majewski et al., 2021). The International Renewable Energy Agency (IRENA) states that only the European Union and the United Kingdom have solar photovoltaic (PV)-specific waste regulations (Weckend et al., 2016), which indicates that a large portion of solar panels will end up in landfills rather than recycling plants in the United States (Tao et al., 2020).

Hydropower is a highly contested energy source in many areas of the world because of the environmental impact. The United States is looking to increase capacity at current dams rather than construct new sites, (Union of Concerned Scientists, 2013a) which indicates a higher strain on those already in use and possible increased environmental impact for areas surrounding those power plants. in, some cases, has a significantly negative impact on many environments and ecosystems, such as the destruction of river plains from flooding above and below dam builds, dry river beds below dam sights due to increased water retention behind the dam due to drought, the prevention of migration and spawning of native fish species, destruction of forests, agricultural land, and historic cultural sites (Union of Concerned Scientists, 2013a). Increased levels of harmful substances such as methylmercury is caused by the flooding of new areas and is measured in fish, birds, human populations that rely on these waters for food, water, and survival (Calder et al., 2016). The construction and demolition of these power plants tends to produce significant levels of harmful emissions (Union of Concerned Scientists, 2013a).

Geothermal energy has many positive and negatives associated with it. The primary issue that results from geothermal power plants is from the drilling of an injection well to bring up to the surface the geothermal fluids, or greenhouse gases (e.g., carbon dioxide, hydrogen sulfide, methane, and ammonia) needed to produce steam in order to turn the turbines to produce energy (Berrizbeitia, 2014; U.S. Department of Energy - Office of Energy Efficiency & Renewable Energy, 2015). This injection process is known to be the cause of seismic events, or earthquakes (Garthwaite, 2019; Majer & Peterson, 2006; Majer et al., 2012; Martínez-Garzón et al., 2020). Other environmental impacts from geothermal power plants involve environmental and groundwater pollution, terrain alterations, and large-scale industrial activity, and while are significant, are still less than those from fossil fuels (Berrizbeitia, 2014).

Fossil Fuels (Coal, Oil, and Natural Gas)

Coal, oil, and natural gas are the three energy sources that make up fossil fuels. A fossil fuel is millions of years old animal and plant matter that has been fossilized (Denchak, 2018). The Natural Resources Defense Council (NRDC) indicates that fossil fuels have significant impacts on the environment, including land degradation, pollution of groundwater, harmful emissions such as carbon dioxide, carbon monoxide, nitrogen oxide, and sulfur dioxide, the acidification of the oceans (Denchak, 2018). Ocean acidification is the increase in oceanic water acidity level, which kills oceanic ecosystems and puts coastal communities at risk (National Oceanic and Atmospheric Administration, 2020). Coal, oil, and natural gas individually are more harmful to the environment than all other sources of energy combined, in just greenhouse gas emission alone (Ritchie, 2020). An article written by Delborne et al., in 2020 indicates that historically, fossil fuels have been thought of as “transitional fuels” used as a placeholder and means to support energy demands in the interim in order to identify other cleaner, reliable sources of energy. As the transition from heavy reliance on fossil fuels to renewable sources continues, natural gas has taken on more of the energy demand due to technological advancement in fossil fuel extraction methods (Delborne et al., 2020; Hazboun & Boudet, 2020).

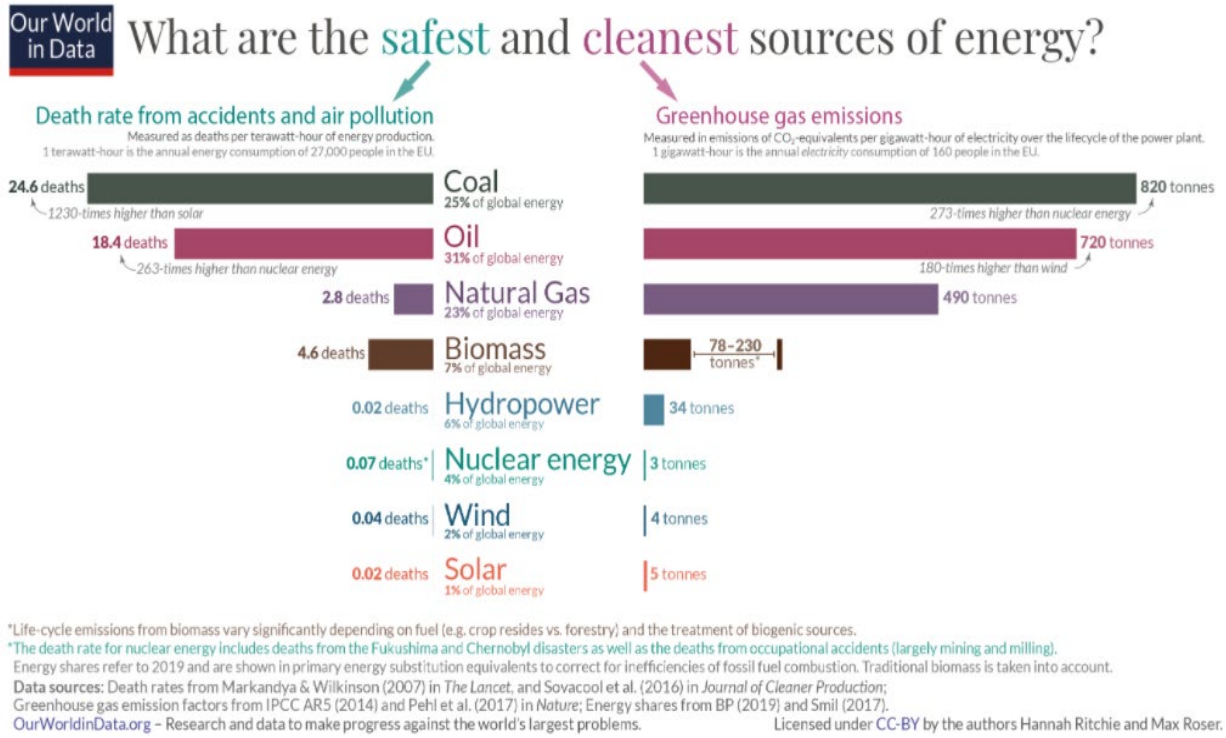

Figure 4 Safest and Cleanest Sources of Energy

Public Perception

The impact of a nuclear accident or event on US soil to American perception and acceptance of nuclear energy is significant and has varied over time but is indicated in the 50 new construction projects and rapid continuous decline of ongoing projects (Bukszpan, 2011). Currently, most risk from nuclear energy is due to a lack of sustained maintenance, funding and implementation of new technologies. Once the nuclear energy industry lost stakeholder support and funders, improvements and maintenance slowed to a rate that could not keep up with the aging technology. This leads to negative impacts to the environment and public health which increases perceived risk and increases negative perception.

Historical research has indicated a direct connection to negative public perception of nuclear energy directly following a nuclear incident (Yeo, 2014). Major incidents of note that qualified for these particular studies are Fukushima, Chernobyl, and Three-Mile Island. After these events, public perception of risk increased dramatically, however, historical Energy polls implemented by Gallup indicate perception of risk decreases and favorability of nuclear energy as a power source increases as those incidences become thought of as historical events (Gallup Inc., 2021). A study done by Bisconti Research in 2019 indicated that more awareness and more information about nuclear energy increases positive attitudes about nuclear energy.

There are a wide range of perceptions of nuclear energy and its impact on the environment and human health. Opponents of nuclear energy include those that think considering nuclear power as part of the solution to growing energy needs in the United States would be detrimental to environmental and human health and that adding more nuclear energy would remove resources from renewables such as solar and wind power (Cooper, 2014; Green America, 2017; Hazboun & Boudet, 2020). Proponents of nuclear energy include those that consider nuclear power as part of the solution to growing energy needs in the United States and that nuclear energy is a zero-carbon energy source that will reduce the dependency on fossil fuels (Rhodes, 2018). Anti-nuclear organizations such as environmental agencies and pro-nuclear groups within the nuclear industry have both been known to attempt to influence perceptions of nuclear energy. Arguments surrounding authenticity of sustainability goals, containment strategies, and corporate practices are primary areas of debate (Banerjee, S.B. and Bonnefous, A.M., 2011). The Nuclear Innovation: Clean Energy (NICE) Future is an example of an initiative that supports nuclear energy becoming a significant factor of the world's energy mix that will focus on an "integrated renewable-nuclear energy system" (Clean Energy Ministerial, 2018; U.S. Department of Energy - Office of Nuclear Energy, 2018).

Public opinion of nuclear energy can change and is changing. The 2019 public opinion survey conducted by Bisconti Research and Quest Global Research determined several things regarding public opinions about nuclear energy, the main findings being that public perception of nuclear energy is becoming more positive, or favorable, especially with younger generations, and those who are considered to be more informed (Bisconti, 2019). Bisconti's research indicates that there is growing belief of significant environmental advantages of nuclear energy. Some studies have found that if posed as a solution or prevention measure or further lessening of environmental impact, individuals are more likely to "reluctantly accept" nuclear power as an energy source (Corner et al., 2011). Interpretation of the safeness of an energy source varies among the general population and is subject to personal biases, such as political affiliation, geographical location, career, exposure or personal experience (Pew Research Center, 2016).

An energy mix refers to the combination of primary sources of energy used to meet the electrical needs of an individual, community, or country (Planète Énergies, 2021). The search for a better energy mix that does not pose a threat to human health and the environment is hastening as we experience the effects of climate change and negative human health due to fossil fuels. An approach involving a careful technology development with clear and transparent documentation; unbiased scientific review and appropriate legal approvals; and clear communication of risks and benefits (which must outweigh the risks) is the roadmap that is followed by many products in the public health world (e.g. medicines or vaccines or birth control or surgeries). While INL is mentioned in most research of this nature due to it being one of the country's top nuclear research facilities, very few of these public perception surveys are targeted towards perceptions of Idaho residents. A 2013 study by Mahler and Barber surveyed 6,330 University of Idaho students over the course of 19 years on both the first and last day of their freshman environmental science class (Mahler & Barber, 2013). Similar to our study, Mahler and Barber asked students about their stance on environmental risk of nuclear energy and preference to the use of fossil fuels for energy. They found that students with more unbiased primary education were more likely to perceive nuclear energy more positively. A significant number of students who perceived nuclear energy to be a risk to the environment prior to the course did not by the end of the course (Mahler & Barber, 2013). This study was limited to freshman students at the University of Idaho attending a specific course. While this study represents perception data of environmental risk among those living in Idaho, it is difficult to generalize such findings to other Idahoans as they are college-educated and quite homogenous in age. Also, these studies did not assess perceptions of human health risk.

Political Ideology

It is common assumption that generally, political liberals are supportive of renewable, clean energy sources while political conservatives are generally more supportive of fossil fuels (Pew Research Center, 2016). Political moderates and those independent of political affiliation tend to cover a wider range of support for various energy sources, but tend to be more supportive of cleaner, energy efficient power options, which may even include nuclear energy (Funk & Hefferon, 2019). Older individuals who identify as conservatives tend to be in favor of expanding fossil fuel productions while younger political conservatives have been found to favor increasing the utilization of alternative energy sources, but overall, less favorable of greener options than those who identify as liberal or moderate (Funk & Hefferon, 2019). After the initial boom of nuclear energy and after US nuclear incidences that increased perception of risk in association with nuclear energy, political and economic support has been declining since the energy crisis in 1974 (Nivola, 2004). According to perception polls such as Bisconti's mentioned above, and a 2015 Pew Research Study, there is recent increased support for nuclear energy overall and primarily among those who view climate change as an important issue, but even more noticeable within scientist groups (Bisconti, 2021; Pew Research Center, 2015).

Previous studies have been conducted to assess political association with support or opposition to nuclear energy. A corresponding study conducted using the same nuclear energy questionnaire as this project, sought to understand how an individual's political ideology influences their perception of nuclear energy. Their findings showed that in the state of Idaho, political conservatives and moderates are more favorable of nuclear energy than those with liberal ideologies, in the US, political liberals (rather than those with conservative and moderate ideologies) are more likely to believe that the benefits of nuclear energy outweigh the risks, and those who live in Idaho have a more favorable view of nuclear energy compared to those living in the United States outside of Idaho (McBeth et al., under review).The researchers theorize that this is due to their residing and working close proximity to a nuclear power station, INL.

Rurality and Nuclear Perceptions

Communities that are classified as urban hold a distinct higher concentration of democratic or liberal voters, while rural communities hold a greater number of republican or conservative voters. This pattern of partisan structure is becoming increasingly substantial across all levels of rurality – urban, suburban, and rural (Parker et al., 2018). As mentioned previously, there is recent increased support for nuclear energy overall, but especially among political conservatives in Idaho who live near INL (McBeth et al., under review). Knowing this, the likelihood of individuals residing in a more rural location are more likely to consider themselves conservative and would have a higher likelihood of having more positive perceptions of nuclear energy. The same could be said for urban areas that tend to identify as more liberal having more negative perceptions of nuclear energy. Idaho state is considered a rural state and historically has voted republican or conservative. In the 2020 presidential election, majority (over 60%) of voters voted republican (Idaho Secretary of State, 2020), which may indicate that Idaho has a more positive perception of nuclear energy, especially since INL is centrally located. That said, a majority of nuclear power sites in the United States are located in rural and suburban areas, including waste storage and treatment sites indicating an increased perceived risk of environmental exposure and health risks by way of agriculture contamination, contamination from mining sites, radiation, and water contamination from waste leakage (Schuelke-Leech, 2013). Nuclear power plants do provide benefit to community economies by way of increased power stability, and jobs (Schuelke-Leech, 2013) indicating that those who are closer are more positively associated with nuclear energy (rural and suburban) and those with less proximity and do not recognize the economic benefits may have more negative associations with nuclear energy (urban). A study researching student's knowledge, perceptions, and attitudes toward renewable energy in Jordan determined that there was significant differences with knowledge and attitudes between students living in rural areas compared to students living in urban areas. Students in urban areas had more knowledge and positive association with renewable energy compared to students living in rural areas, who were found to favor nuclear energy (Zyadin et al., 2012).

Theoretical Framework

Prior research has indicated that perceived risk is based upon the individual's own personal experience, prior knowledge, proximity, and beliefs. The theoretical framework supporting the hypotheses of this study will be the Construal Level Theory (CLT) and Psychological Distance (PD). With the use of these concepts, the specific aims and hypotheses of this study seek to explore how people perceive risks of nuclear energy to human and environmental health and safety in terms of proximal distance. The CLT consists of four psychological distances social, temporal, experiential or physical, and hypothetical or experiential which influence behavior, interpretation, and assessment (Tan et al., 2020; Trope et al., 2007). Results from prior studies that indicate that perceived risk is both "psychologically distant and proximal in relation to different dimensions – lower psychological distance was generally associated with higher levels of concern" (Spence et al., 2012). These theories are guiding principles for how demographics that measure an aspect of distance, age, distance from INL, rurality, etc. impact perceptions and may provide reference to compare Idaho-specific data relative of perceived risk of nuclear energy to other studies. With the intention of seeing if Idaho results may differ or follow the same resulting pattern found from other studies that included these theories, due to resident's proximity to INL. We will look at the level of physical distance from the CLT, primarily due to this study's geographical location targets being centered within a fifty-mile radius of INL, the State of Idaho outside the fifty-mile radius of INL, and the entire United States outside of Idaho. One study identifies that "more knowledge-calibrated individuals have more positive attitudes toward nuclear energy" and indicates there is significance between acceptance of nuclear energy and knowledge and psychological distance (Kim & Kim, 2021). The findings from this study show that psychological distance was positively associated with risk perception

Conclusion

All energy sources come with risks and all energy sources have a potential impact on the environment, water supplies, and human health though some carry substantially more risks to certain aspects of the environment and human health than others. When assessing actual risk and perceived risk, every stage of the energy process should be assessed in order to gauge an accurate understanding of risk. When nuclear energy repositories are designed, constructed, and utilized correctly, the risk posed to the environment, water contamination, and public health is reduced significantly. However, the fact remains that nuclear processing facilities and power plants have caused significant harm to the environment and represent a significant risk to human health. INL, Hanford, Oak Ridge, etc. Significant costs are spent on cleanup projects and site remediation from these former processing facilities in order to make these areas safe and livable again. Similar can be said for power plants (e.g., Three Mile Island, Chernobyl, Fukushima, etc.), where actual impact has occurred including groundwater contamination, impact to local environments and ecosystems, and human lives lost have occurred. All of this is actual, factual health risk information that the public is acutely aware of which translates to perceived risk in all aspects of the use of nuclear fuels. These facilities that exist in the Pacific Northwest, and specifically in Idaho, have indeed impacted people's lives and health, have extensive remediation costs, and have vast, yet limited public awareness is enough to make the point that they would affect people's perception of nuclear energy and represent a mental "hurdle" for people to overcome in terms of perceived environmental and health risks. It is a fact that nuclear materials carry human health and environmental health risks as evident by these case examples. Exactly how the industry addresses these risks, through state-of-the-art technology and processes for the use, processing, manufacture, construction, operation/maintenance, monitoring, and closure throughout the lifecycle of these materials and facilities, is the key to their future safe and successful implementation or remediation. Development and implementation of these advanced practices is crucial to address and mitigate public health risk. From a public perception standpoint, transparent communication and education about those processes that safeguard these facilities and public health, along with clear identification of the risks and benefits of these facilities to the planet would also be important.

Chapter III

Methods

Study participants and sampling strategy

This study is a collaboration between the researchers at Idaho State University (ISU) and Idaho National Laboratory (INL). The primary area of geographical interest for this study focused on those who live within an approximate 50-mile radius of INL, individuals who live in Idaho outside of the approximate 50-mile radius of INL, and those who live within the United States but outside of Idaho. This categorization was done so that we could have a measure of the level of proximity to the national laboratory where the new reactor project has been proposed. As of October 2020, INL employs approximately 5,134 individuals (Idaho National Laboratory, 2020). The largest regional counties of this area are Bonneville County, with an estimated 2020 population of 113,877 (US Census Bureau, 2020a) and Bannock County, with an estimated 2020 population of 75,647 (US Census Bureau, 2020b).

This was a cross-sectional study design that collected data through electronically disseminated surveys. The survey was disseminated through two Idaho news outlets: East Idaho News and the Idaho State Journal. The study design planned for alternative participant response collection if collection sizes did not meet minimum study numbers via mail, email listserv, fliers at local businesses, and local schools, however, these alternative methods ultimately were not utilized. The response window for this survey took place from May 10, 2021 to June 25, 2021. Inclusion criteria included being of adult age (at least 18 years of age) and ability to read the survey online in English.

In order to access the survey, all participants were required to first read through the study disclaimer and provide informed consent; those who completed these preliminary tasks and finished the survey were eligible to win one of 100, $20.00 Amazon gift cards. Ethical approval for the study was obtained from the Idaho State University Institutional Review Board, (IRB-FY2021-172).

A sample size calculation was not completed for this study because of the intention to identify the sampling method(s) that were most effective in survey response collection from a large cross-section of the population identified.

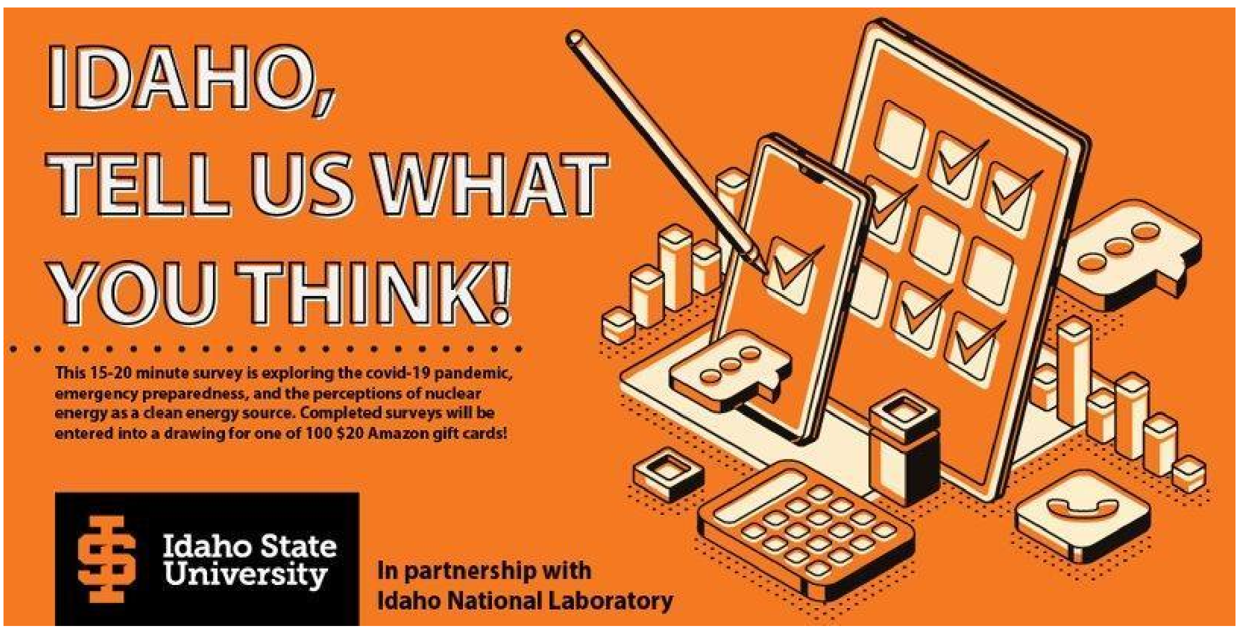

Figure 5 Marketing flyer - information regarding survey

Data Collection

In order to increase validity, accuracy, and to gauge understandability of questions asked in the survey, pilot feedback was solicited from 35 individuals not specific to Idaho State. These individuals took the questionnaire in full and submitted reactions in comments attached to the survey. Their suggestions were reviewed by the research committee as individuals and as a group then these suggestions were incorporated into the final questionnaire to improve usability. Data were collected through the online questionnaire software Qualtrics. The average respondent took approximately 14 minutes to complete the online survey (IQR = 8 minutes to 26 minutes) and was self-administered.

Measures

For the purposes of this thesis, this survey assessed the following variables in the areas of demographics and location, perceived risk of nuclear energy, and knowledge of environmental impact:

Table 1 List of variables - the three risk perception variables utilized in this analysis are from S.K. Yeo et al. in 2014, environmental impact variables utilized from a study by Poortinga et al., (2005), other variables included demographics, political ideology, and geographic location

Demographics, Location, Political Ideology	
Variable Name	**Variable Question**
Gender	Gender: How do you identify?
Age	Derived from initial age variable (What is your age?)
Education	Derived from initial education variable (What is the highest grade or level of school you have completed or the highest degree you have received?
Income	Derived from initial income variable (What is your total household income?)
Race and Ethnicity	Derived from initial ethnicity and race variables (How do you describe yourself?)
Geographical location	Idaho in 50-mile radius of INL, Idaho outside of 50-mile radius of INL, US non-Idaho
RUCA score	Derived from zip code (Please specify your current residence state and zip code)
Politics	Derived from initial politics variable (What is your political ideology on the left to right spectrum?)

Perceived Risk of Nuclear Energy	
Variable Name	**Variable Question**
Environmental contamination	Nuclear power may lead to more pollution and environmental contamination (Disagree/neutral/agree/don't know)
Water contamination	Nuclear power may lead to contamination of water supplies (Disagree/neutral/agree/don't know)
New health problems	Nuclear power may lead to new human health problems (Strongly agree/agree/neither agree nor disagree/disagree/strongly disagree/don't know)
Knowledge of Environmental Impact	
Variable Name	**Variable Question**
Environmental impact of coal	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of gas	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of geothermal	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of hydroelectric	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of nuclear	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of oil	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of solar	Rate this source of energy from least environmental impact to most environmental impact
Environmental impact of wind	Rate this source of energy from least environmental impact to most environmental impact

To clean the data set, all variables with missing responses were removed. The final sample size of those with complete data for all variables was N = 3,524 (2,627 participants excluded due to missing data (e.g., participants who responded "prefer not to say", "unknown" "don't know", intentionally skipped the question, and no response). For the logistic regression, in order to better summarize or visualize data by group, demographic variables, location variables, and perception variables were re-grouped by combining neutral and don't know responses – the perception variables *environmental contamination* and *water contamination* were re-categorized as [*agree*, *disagree*, *neutral* (*neutral* + *don't know*)]. The perception variable *new human health problems* was re-categorized as [*agree* (*strongly agree* + *agree*), *disagree* (*disagree* + *strongly disagree*), *neutral* (*neither agree nor disagree* + *don't know*)]. The association [*risk perception of nuclear energy* and *demographics*] and [*risk perception of nuclear energy* and *environmental impact of energy sources*] were determined by applying logistic regression to determine adjusted odds ratios, 99.9% confidence intervals, and p-values.

Dependent Variables

The dependent variables for this thesis were perceptions of risk. *Risk perception* was initially measured for two of the dependent variables using a 4-point Likert scale (disagree/neutral/agree/don't know) and the third variable using a 6-point Likert scale (Strongly agree/agree/neither agree nor disagree/disagree/strongly disagree/don't know). In order to better summarize data by group, risk perception variables were re-grouped by combining the neutral response with the lower of the percentages of the agree or disagree responses. negative and neutral responses – the perception variables: *environmental contamination* and *water contamination* were re-categorized as [*agree* and *disagree* (*disagree* + *neutral* + *don't know*)]. The variable *new human health problems* was re-categorized as [*agree* (*agree* + *strongly agree*) and *disagree* (*disagree* + *neither agree nor disagree* + *strongly disagree*)].

These questions asked participants to assess their level of perceived risk regarding nuclear energy by how much they agreed with the following three statements related to nuclear power:

I. "Nuclear power may lead to more pollution and environmental contamination,"

II. "Nuclear power may lead to contamination of water supplies,"

III. "Nuclear power may lead to new human health problems"

The three risk perception variables used for this study and thesis were obtained from a previously done study by S.K. Yeo et al. in 2014 that assessed the amplification of perceived risk of nuclear energy specifically relating to the Fukushima disaster.

Independent Variables

The independent variables of this thesis include demographics, location, political ideology and environmental impact of different sources of energy.

Demographics such as age, gender, education, income, race and ethnicity, and zip code to determine geographical location based on level of rurality were included to control for demographic influences on the three dependent variables. *Age* was measured as a dichotomous measure (less than 35-years and 35-years or older). *Gender* was measured as a dichotomous measure (male or female) and the proportion of male-to-female respondents was (39% Female and 61% Male). Ethnicity was measured dichotomously (Hispanic or non-Hispanic – yes/no). *Education* (less than a high school degree + high school, undergraduate degree, or graduate degree), *income* ($60,000 or less, $60,001 to $80,000, or over $80,000), and *zip code* were measured categorically. Zip code data was measured by way of Rural Urban Commuting Area (RUCA) rating and was collected from the USDA Economic Research Service (USDA 2020) and is a calculated variable. Traditionally, RUCA scores are classified by a score from 1-10 (1=urban; 10=rural). For this analysis RUCA scores were reclassified into three main categories: urban (scores 1, 2, and 3), middle (scores 4, 5, and 6), and rural (scores 7, 8, 9, and 10). Urban n=2,706, middle n=433, and rural n=385.

The *politics* variable assessing political ideology was measured by asking "What is your political ideology on the left to right spectrum?" and was measured categorically (Strong conservative, conservative, moderate, no opinion, liberal, Strong liberal, Other (please specify)). For the purposes of this study and to better visualize data by group politics variables were re-grouped by combining conservative responses together, neutral and moderate responses together, and liberal responses together. Politics was re-categorized as a trichotomous or nominal variable [*Conservativ*e (*Strong conservative* + C*onservative*), *Moderate no opinion* (*Moderate + no opinion*), and *Liberal* (*Liberal + strong liberal*)].

Knowledge of environmental impact was assessed by a rating scale by asking respondents to rate the environmental impact of the following sources of energy (least environmental impact to most environmental impact). Questions relating to environmental impact stemmed from a 2005 study done by Poortinga et al., regarding perceptions of nuclear power, climate change, and energy options in Britain. Poortinga et al. compared responses to three types of energy sources while this study asked participants to rank eight different types of energy sources (coal, natural gas, geothermal, hydroelectric power, nuclear power, oil, sun/solar power, and wind power).

Statistical Analysis

Survey findings were summarized by descriptive statistics; categorical data were summarized with proportions and counts, and continuous data were described by the calculations of mean and standard distribution or median and interquartile range. Kruskal Wallis T-tests and Chi-square tests were used to show differences between those that agreed, were neutral, or disagreed with statements regarding the environmental or human health impact of nuclear energy. Principal components (PC) analysis were run as the preliminary step to use the environmental variables for the section on environmental impact where respondents were asked to rate their perception of environmental impact from different sources of energy by least impact to most impact. The three PC groupings (PC1, PC2, PC3) were as follows (Table 2): PC1 indicated perceived high negative impact to the environment for all energy sources, especially solar, wind, geothermal, and gas; PC2 contrast coal and oil (and gas to a lesser extent) with solar and wind (and hydroelectric to a lesser extent); and PC3 contrast solar, wind, and gas with geothermal and significantly nuclear.

Table 2 Principal component analysis of ratings of environmental impact of various energy sources

Variable	PC1	PC2	PC3
Environmental Impact of Solar	-0.43	0.31	-0.18
Environmental Impact of Wind	-0.43	0.27	-0.25
Environmental Impact of Geothermal	-0.40	0.09	0.28
Environmental Impact of Hydroelectric	-0.44	0.14	-0.11
Environmental Impact of Nuclear	-0.21	0.05	0.89
Environmental Impact of Gas	-0.38	-0.28	-0.15
Environmental Impact of Coal	-0.20	-0.61	-0.07
Environmental Impact of Oil	-0.22	-0.59	0.01

Proportions and 99.9% CI were presented for each of the responses. The results were stratified by zip code to determine geographical variation. To further assess how the belief that nuclear energy may lead to more environmental pollution, contamination, and new human health issues and demographics are associated, a logistic regression predicting environmental contamination, water contamination, new human health problems by level of rurality and political ideology was done. Logistic regression also included environmental impact of different energy sources variables and their association with the belief that nuclear energy may lead to more environmental pollution, contamination, and new human health issues, while controlling for demographics to test for association with perceptions. The statistical software R (v 4.1.1) was used and statistical significance was set at $P<0.001$ for all analysis.

Acknowledgement

The study was funded by the State of Idaho and in part by the Center for Advanced Energy Studies (CAES) through the CAES Summer Visiting Faculty Program. CAES is a research and education consortium that involves INL, Boise State University, Idaho State University, the University of Idaho, and the University of Wyoming. An INL liaison reviewed the survey before it was administered. The data and results were not reviewed or influenced in any way by INL or CAES prior to the analysis and dissemination of the thesis; findings and outcomes of this study are entirely those of the researcher.

Chapter IV

Results

Sample demographics

This thesis used a sample of 3,524, 697 (20%) of which lived within fifty miles of INL headquarters, 678 (19%) lived outside fifty miles of INL headquarters within Idaho, and 2,149 (61%) lived in the United States outside of Idaho. A total of 6,151 participants were included in the dataset initially, but after 2,627 participants with missing data were excluded (e.g., participants who responded “prefer not to say”, “unknown” “don’t know”, intentionally skipped the question, and those who did not see the question), a total of 3,524 participants (57% younger than 35 years, 40% female; 33% Hispanic) were included in the final analysis (Table 3). The majority of respondents (61%) were from the non-Idaho US; 678 of the participants were from Idaho outside of the 50-mile radius of INL, while 697 (20%) were within the 50-mile radius of INL. 77% of participants were considered to be urban based on the re-classified RUCA scores, 12% of participants were considered to be moderate or had no political affiliation (no opinion), while 11% of respondents were considered to be rural. When asked about political ideology, 38% responded conservative, 33% liberal, and 29% were moderate or no opinion.

Perception of environmental contamination due to nuclear energy

When asked about perception of environmental safety and nuclear energy, specifically, nuclear power may lead to more pollution and environmental contamination, 38% of respondents agreed, 36% were neutral, and 916 (26%) disagreed. Of those who agreed that nuclear energy may lead to more environmental contamination, participants were predominantly younger than 35-years of age (61%), Hispanic (39%), earned an undergraduate degree (43%), considered themselves to be liberal (39%), were considered to live in an urban area (77%), and lived in the United States outside of Idaho (66%). The proportion of respondents that were less than 35-years that agreed with the statement “nuclear energy may cause increased pollution and environmental contamination” was 61% (compared to 46% younger than 35-years that disagreed; *P*<.001). The proportion of respondents that were Hispanic that agreed with the statement “nuclear energy may cause increased pollution and environmental contamination” was 36% (compared to 16% of Hispanics that disagreed; *P*<.001). The proportion of participants who had an undergraduate degree who agreed that nuclear energy may cause increased environmental contamination was 43% (compared to 34% that disagreed; *P*<.001). Of those who consider themselves to be conservative, 33% agreed (compared to 48% that disagreed; *P*<.001) that nuclear energy may cause more environmental contamination. The proportion of participants who lived in the United States outside of Idaho that agreed nuclear energy may negatively affect the environment was 66% (compared to 47% that disagreed; *P*<.001). There were not significant differences in the proportions that agreed or disagreed in gender, income, and RUCA score variables.

There were significant differences in the median rankings of the impact of geothermal energy, nuclear energy, natural gas, coal, and oil on the environment and level of agreement that nuclear power may lead to more pollution and environmental contamination. For nuclear energy and geothermal energy, the median ranking of the environmental impact of each respective energy source was higher among those that agreed or were neutral compared to the ranking of those that disagreed that nuclear power may lead to more pollution and environmental contamination (*P*<.001for each). For natural gas, coal, and oil, the median ranking of the environmental impact of coal and oil was lower among those that agreed or were neutral compared to the ranking of those that disagreed that nuclear power may lead to more pollution and environmental contamination (*P*<.001for each). There were no significant differences in the median rankings of the environmental impact of hydroelectric, wind, or solar, among those that agreed/neutral/disagreed with the statement "nuclear power may lead to more pollution and environmental contamination" (*P*>.001).

Hispanic participants were more likely to agree that nuclear power may lead to more pollution and environmental contamination (OR=1.68, 99.9% CI=1.10, 2.60, *P*<.001) compared to non-Hispanic White respondents. Compared to those living in urban areas, individuals living in rural areas had lower odds of believing that nuclear energy may lead to increased pollution and environmental contamination (*P*=.002). Those who identify as moderate or no political opinion were not more likely or less likely than those who consider themselves conservative to agreed that nuclear power may lead to more pollution and environmental contamination (*P*=.002). However, those who identify as liberal were more likely to agree that nuclear power may lead to more pollution and environmental contamination (OR=1.66, 99.9% CI=1.12, 2.47, *P*<.001) than political conservatives. Compared to participants within a 50-mile radius of INL, participants living in Idaho but outside the 50-mile radius (OR=5.03, 99.9% CI=2.85, 9.00) and participants living in the US outside of Idaho (OR=3.53, 99.9% CI=2.20, 5.72) had higher odds of agreeing that nuclear power may lead to more pollution and environmental contamination (*P*<.001 for each). The logistic regression indicated that age, gender, education, income, and level of rurality were not more or less likely to agree that nuclear power may lead to more pollution and environmental contamination.

After controlling for demographic variables, the first principal component was not independently associated with the perception that nuclear power may lead to more pollution and environmental contamination (*P*=.052). PC2 was independently associated with higher odds of agreeing that nuclear energy may lead to increased pollution and environmental contamination was indicated. As the perceived environmental impact of coal and oil increased and the perceived environmental impact of wind and solar decreased, the score on PC2 also increased (OR=1.20, 99.9% CI=1.04, 1.37, *P*<.001). This suggested that participants who were favorable to wind and solar energy, and who were unfavorable to other energy sources (especially those who were unfavorable of coal and oil) had higher odds of agreeing that nuclear power may lead to more pollution and environmental contamination. The third principal component was independently associated with the perception that nuclear power may lead to increased pollution and environmental contamination (*P*<.001), indicating that as PC3 increases, the odds of concern regarding risk to the environment also increases (OR=1.74, 99.9% CI=1.47, 2.07, *P*<.001). PC3 suggests that high environmental concerns around nuclear equals high concerns around environment and pollution risks from nuclear energy. Race/ethnicity, political ideology, geographical location, and PC3 were independently associated with thinking that nuclear energy may lead to more pollution and environmental contamination. Level of rurality was not independently associated, however, individuals in rural locations had lower odds of believing nuclear energy lead to more environmental contamination. Age gender, education, income, and PC1 were not independently associated with thinking that nuclear energy may lead to increased environmental contamination.

Perception of contamination of water supplies due to nuclear energy

When asked about perception of environmental safety and nuclear energy, specifically, nuclear power may lead to more contamination of water supplies, 40% of respondents agreed, 36% were neutral, and 850 (24%) disagreed. Of those who agreed that nuclear energy may lead to more water supply contamination, the majority of participants were younger than 35-years of age

(61%), male (57%), Hispanic (38%), had an undergraduate degree (43%), held an income over $80,000 (39%), considered themselves to be liberal (39%), considered to live in an urban area (77%), and lived in the US outside of Idaho (66%). The proportion of respondents that were less than 35-years that agreed with the statement "nuclear energy may cause increased water contamination" was 61% (compared to 46% younger than 35-years that disagreed; $P<.001$).The proportion of respondents that were non-Hispanic White that agreed with the statement "nuclear energy may cause increased groundwater contamination" was 35% (compared to 58% non-Hispanic White that disagreed; $P<.001$). The proportion of participants who had a graduate degree who agreed that nuclear energy may cause increased water supply contamination was 26% (compared to 39% that disagreed; $P<.001$). Of those who consider themselves to be conservative, 35% agreed (compared to 46% that disagreed; $P<.001$) that nuclear energy may cause more water supply contamination. The proportion of participants who lived in the United States outside of Idaho that agreed nuclear energy may negatively affect groundwater supplies was 66% (compared to 47% that disagreed; $P<.001$). There were not significant differences in the proportions that agreed or disagreed in gender, income, and RUCA score variables.

There were significant differences in the median rankings of the impact of geothermal energy, nuclear power, coal, and oil on the environment and level of agreement that nuclear power may lead to more water contamination. For nuclear energy and geothermal energy, the median ranking of the environmental impact of each respective energy source was higher among those that agreed or were neutral compared to the ranking of those that disagreed that nuclear power may lead to more groundwater contamination ($P<.001$ for each). For coal and oil, the median ranking of the environmental impact of coal and oil was lower among those that agreed or were neutral compared to the ranking of those that disagreed that nuclear power may lead to more pollution and environmental contamination (*P*<.001for each). There were no significant differences in the median rankings of the environmental impact of natural gas, hydroelectric, wind, or solar among those that agreed/neutral/disagreed with the statement “nuclear power may lead to contamination of water supplies” (*P*>.001).

Hispanic participants were more likely to agree that nuclear power may lead to more pollution and environmental contamination (OR=2.02, 99.9% CI=1.30, 3.17, *P*<.001) compared to non-Hispanic White respondents. Individuals with an undergraduate degree were not more likely or less likely than those with less than a college degree to agree that nuclear power may lead to the contamination of water supplies (*P*=.012). However, those with a graduate degree were less likely to agree that nuclear power may lead to groundwater contamination (OR=0.62, 99.9% CI=0.39, 1.00, *P*<.001) than those with less than a college degree. Compared to participants within a 50-mile radius of INL, participants living in Idaho but outside the 50-mile and participants living in the US outside of Idaho had higher odds of agreeing that nuclear power may lead to more pollution and environmental contamination (*P*<.001 for each). The logistic regression indicated that age, gender, income, political ideology, and level of rurality were not more or less likely to agree that nuclear power may lead to radius had higher odds of agreeing that nuclear power may lead to more contamination of water supplies.

After controlling for other demographic variables, the second principal component was not independently associated with the perception that nuclear power may lead to contamination of water supplies (*P*=0.101). However, participants had lower odds of agreeing that nuclear power may lead to contamination of water supplies if they scored higher on the first principal component (OR=0.92, 99.9% CI=0.83, 1.02, *P*=.008). The third principal component was also independently associated with the perception that nuclear power may lead to increased groundwater contamination (*P*<.001), indicating that as PC3 increases, the odds of concern regarding water supply contamination also increases (OR=1.78, 99.9% CI=1.50, 2.13). This suggests that high environmental concerns around nuclear energy equals high concerns around contamination of groundwater risks from nuclear energy. Race/ethnicity, education, geographical location, PC1, and PC3 were independently associated with thinking that nuclear energy may lead to more water supply contamination. Age, gender, income, political ideology, level of rurality, and those who considered PC2 to be lower risk to the environment were not independently associated with thinking that nuclear energy may lead to increased groundwater contamination.

Perception of new human health problems due to nuclear energy

When asked about perception of environmental safety and nuclear energy, specifically, nuclear power may lead to new human health problems, 47% of respondents agreed, 29% were neutral, and 834 (24%) disagreed. Of those who agreed that nuclear energy may lead to new human health problems, majority of participants were younger than 35-years of age (63%), male (59%), Hispanic (39%), had an undergraduate degree (40%), held an income over $80,000 (40%), considered themselves to be liberal (41%), considered to live in an urban area (78%), and lived in the US outside of Idaho (67%). The proportion of respondents that were less than 35-years that agreed with the statement “nuclear energy may cause new human health problems” was 63% (compared to 44% younger than 35-years that disagreed; *P*<.001). The proportion of respondents that were non-Hispanic White that agreed with the statement “nuclear energy may cause new human health problems” was 34% (compared to 62% non-Hispanic White that disagreed; *P*<.001). The proportion of participants who had an income of over $80,000 who agreed that nuclear energy may cause increased risk to public health was 40% (compared to 46%

that disagreed; *P*<.001). Of those who consider themselves to be conservative, 34% agreed (compared to 47% that disagreed; *P*<.001) that nuclear energy may cause more new human health issues. The proportion of participants who lived in the State of Idaho and inside the 50-mile radius of INL that agreed nuclear energy may negatively affect the environment was 8.7% (compared to 46% that disagreed; *P*<.001). There were not significant differences in the proportions that agreed or disagreed in gender, education, and RUCA score variables.

There were significant differences in the median rankings of the impact of geothermal energy, nuclear energy, natural gas, coal, and oil on the environment and level of agreement that nuclear power may lead to new human health issues. For nuclear energy and geothermal energy, the median ranking of the environmental impact of each respective energy source was higher among those that agreed or were neutral compared to the ranking of those that disagreed that nuclear power may lead to increased public health risk (*P*<.001for each). For natural gas, coal, and oil, the median ranking of the environmental impact of coal and oil was lower among those that agreed or were neutral compared to the ranking of those that disagreed that nuclear power may lead to new human health issues (*P*<.001 for each). There were no significant differences in the median rankings of the environmental impact of hydroelectric, wind, or solar among those that agreed/neutral/disagreed with the statement "nuclear power may lead to new human health problems" (*P*<.001). There were no significant differences in the median rankings of the environmental impact of hydroelectric, wind, or solar, among those that agreed/neutral/disagreed with the statement "nuclear power may lead to new human health problems" (*P*>.001).

Individuals aged 35-years or older were less likely to agree that nuclear power may lead to new human health problems (OR=0.76, 99.9% CI=0.59, 0.97, *P*<.001) than participants younger than 35-years. Compared to participants who identify as non-Hispanic White, individuals who identify as "other" were not more likely or less likely to agree that nuclear power may lead to new human health problems (OR=1.25, 99.9% CI=0.90, 1.74, *P*=.025). However, participants who identify as Hispanic (OR=1.31, 99.9% CI=0.98, 1.77, *P*=.002) had higher odds than participants who identify as non-Hispanic White of agreeing that nuclear power may lead to new human health problems. Those who identify as moderate or no political opinion were not more likely or less likely than conservatives to agree that nuclear power may lead to new human health problems (p=0.922). However, those who identify as liberal were more likely to agree that nuclear power may lead to new human health problems (OR=1.62, 99.9% CI=1.21, 2.16, *P*<.001) than those with conservative ideology. Compared to participants within a 50-mile radius of INL, participants living in Idaho but outside the 50-mile radius and participants living in the US outside of Idaho, both had higher odds of agreeing that nuclear power may lead to new human health problems (*P*<.001for each). The logistic regression indicated that age, gender, race/ethnicity, education, income, and level of rurality were not more or less likely to agree that nuclear power may lead to new human health problems.

After controlling for other demographic variables, the first principal component was not independently associated with the perception that nuclear power may lead to new human health problems (*P*=.952). The second principal component was also not independently associated with the health risk perception variable (*P*=.019). The third principal component was, however, independently associated with the perception that nuclear power may lead to new human health problems (*P*<.001), indicating that as PC3 increases, the odds of concern regarding new human health problems also increases (OR=1.52, 99.9% CI=1.33, 1.73); suggesting that high environmental concerns around nuclear equals high concerns around health risks from nuclear energy. Age, race/ethnicity, political ideology, geographical location, and PC3 were independently associated with thinking that nuclear energy may lead to new human health problems. Gender, education, income. Level of rurality, PC1, and PC2 were not independently associated with thinking that nuclear energy may lead to increased risk to public health.

Table 3 Study completed in 2021; overall sample size N = 3,524; differences in demographic and environmental impact ratings according to level of agreement of the impact of nuclear energy on environmental contamination, water supply contamination, and new human health problems.

Characteristic	Overall, N = 3,524[1]	***Environmental Contamination***				***Water Contamination***				***New Human Health Issues***			
		Agree	**Neutral**	**Disagree**	p-value[2]	**Agree**	**Neutral**	**Disagree**	p-value[2]	**Agree**	**Neither agree nor disagree**	**Disagree**	p-value[2]
		N = 1329 (38%)[1]	N = 1279 (36%)[1]	N = 916 (26%)[1]		N = 1404 (40%)[1]	N = 1270 (36%)[1]	N = 850 (24%)[1]		N = 1660 (47%)[1]	N = 1030 (29%)[1]	N = 834 (24%)[1]	
Age					**<0.001**				**<0.001**				**<0.001**
Less than 35	2,016 (57%)	814 (61%)	782 (61%)	420 (46%)		852 (61%)	771 (61%)	393 (46%)		1,046 (63%)	601 (58%)	369 (44%)	
35 or older	1,508 (43%)	515 (39%)	497 (39%)	496 (54%)		552 (39%)	499 (39%)	457 (54%)		614 (37%)	429 (42%)	465 (56%)	
Gender					0.071				0.046				0.036
Female	1,415 (40%)	554 (42%)	522 (41%)	339 (37%)		599 (43%)	487 (38%)	329 (39%)		685 (41%)	427 (41%)	303 (36%)	
Male	2,109 (60%)	775 (58%)	757 (59%)	577 (63%)		805 (57%)	783 (62%)	521 (61%)		975 (59%)	603 (59%)	531 (64%)	
Race/Ethnicity					**<0.001**				**<0.001**				**<0.001**
non-Hispanic White	1,487 (42%)	481 (36%)	481 (38%)	525 (57%)		494 (35%)	498 (39%)	495 (58%)		557 (34%)	415 (40%)	515 (62%)	
Hispanic	1,169 (33%)	514 (39%)	505 (39%)	150 (16%)		537 (38%)	504 (40%)	128 (15%)		648 (39%)	386 (37%)	135 (16%)	
Other	868 (25%)	334 (25%)	293 (23%)	241 (26%)		373 (27%)	268 (21%)	227 (27%)		455 (27%)	229 (22%)	184 (22%)	
Education					**<0.001**				**<0.001**				0.015
Less than a College Degree	1,043 (30%)	392 (29%)	397 (31%)	254 (28%)		438 (31%)	369 (29%)	236 (28%)		499 (30%)	321 (31%)	223 (27%)	
Undergraduate degree	1,439 (41%)	565 (43%)	563 (44%)	311 (34%)		600 (43%)	556 (44%)	283 (33%)		664 (40%)	426 (41%)	349 (42%)	

Graduate degree	1,042 (30%)	372 (28%)	319 (25%)	351 (38%)		366 (26%)	345 (27%)	331 (39%)		497 (30%)	283 (27%)	262 (31%)	
Income					0.400				0.006				**<0.001**
60000 or less	1,324 (38%)	504 (38%)	483 (38%)	337 (37%)		523 (37%)	486 (38%)	315 (37%)		611 (37%)	428 (42%)	285 (34%)	
60001 to 80000	793 (23%)	292 (22%)	307 (24%)	194 (21%)		339 (24%)	297 (23%)	157 (18%)		391 (24%)	233 (23%)	169 (20%)	
over 80000	1,407 (40%)	533 (40%)	489 (38%)	385 (42%)		542 (39%)	487 (38%)	378 (44%)		658 (40%)	369 (36%)	380 (46%)	
Political Ideology					**<0.001**				**<0.001**				**<0.001**
Conservative	1,353 (38%)	442 (33%)	470 (37%)	441 (48%)		488 (35%)	477 (38%)	388 (46%)		565 (34%)	398 (39%)	390 (47%)	
Moderate no opinion	1,012 (29%)	365 (27%)	401 (31%)	246 (27%)		370 (26%)	412 (32%)	230 (27%)		421 (25%)	345 (33%)	246 (29%)	
Liberal	1,159 (33%)	522 (39%)	408 (32%)	229 (25%)		546 (39%)	381 (30%)	232 (27%)		674 (41%)	287 (28%)	198 (24%)	
RUCA Score					0.090				0.026				0.036
Urban.123	2,706 (77%)	1,035 (78%)	995 (78%)	676 (74%)		1,082 (77%)	1,002 (79%)	622 (73%)		1,298 (78%)	798 (77%)	610 (73%)	
Middle.456	433 (12%)	165 (12%)	145 (11%)	123 (13%)		169 (12%)	136 (11%)	128 (15%)		187 (11%)	119 (12%)	127 (15%)	
Rural.78910	385 (11%)	129 (9.7%)	139 (11%)	117 (13%)		153 (11%)	132 (10%)	100 (12%)		175 (11%)	113 (11%)	97 (12%)	
Geographical Location					**<0.001**				**<0.001**				**<0.001**
ID in 50-mile	697 (20%)	140 (11%)	168 (13%)	389 (42%)		155 (11%)	180 (14%)	362 (43%)		144 (8.7%)	168 (16%)	385 (46%)	
ID out 50-mile	678 (19%)	317 (24%)	263 (21%)	98 (11%)		316 (23%)	272 (21%)	90 (11%)		404 (24%)	167 (16%)	107 (13%)	
US non-ID	2,149 (61%)	872 (66%)	848 (66%)	429 (47%)		933 (66%)	818 (64%)	398 (47%)		1,112 (67%)	695 (67%)	342 (41%)	
Environmental Impact of Solar	33 (14, 57)	34 (13, 58)	33 (15, 56)	32 (14, 57)	>0.900	33 (13, 59)	33 (15, 55)	32 (14, 57)	>0.900	31 (13, 58)	35 (14, 56)	33 (15, 57)	0.200
Environmental Impact of Wind	36 (15, 61)	38 (14, 64)	35 (15, 58)	36 (16, 61)	0.140	35 (14, 62)	36 (15, 58)	37 (16, 65)	0.035	35 (13, 61)	37 (15, 59)	38 (18, 63)	0.007
Environmental Impact of Geothermal	38 (20, 57)	40 (23, 60)	40 (21, 57)	31 (16, 52)	**<0.001**	41 (23, 60)	38 (21, 57)	31 (16, 52)	**<0.001**	40 (23, 60)	38 (20, 56)	32 (16, 53)	**<0.001**

Environmental Impact of Hydroelectric	37 (17, 57)	39 (17, 59)	37 (18, 56)	34 (15, 56)	0.130	39 (17, 59)	37 (19, 56)	32 (15, 56)	0.062	37 (16, 59)	36 (18, 55)	38 (18, 56)	0.800
Environmental Impact of Nuclear	44 (22, 66)	54 (33, 74)	43 (24, 63)	29 (12, 51)	**<0.001**	54 (33, 73)	43 (25, 61)	28 (11, 49)	**<0.001**	51 (30, 72)	45 (26, 63)	27 (11, 51)	**<0.001**
Environmental Impact of Gas	45 (26, 65)	44 (25, 63)	44 (26, 63)	50 (29, 69)	**<0.001**	44 (25, 64)	45 (26, 63)	48 (26, 67)	0.130	44 (23, 63)	44 (28, 62)	50 (31, 70)	**<0.001**
Environmental Impact of Coal	55 (34, 77)	53 (33, 72)	51 (32, 74)	66 (40, 87)	**<0.001**	53 (33, 73)	53 (33, 73)	66 (38, 88)	**<0.001**	52 (32, 72)	52 (33, 75)	69 (45, 88)	**<0.001**
Environmental Impact of Oil	55 (34, 76)	55 (34, 74)	50 (31, 72)	63 (39, 84)	**<0.001**	54 (34, 74)	51 (32, 73)	64 (36, 84)	**<0.001**	53 (32, 74)	50 (32, 71)	65 (42, 85)	**<0.001**

Table 3 [1]n (%); Median (IQR) / [2]Pearson's Chi-squared test; Kruskal-Wallis rank sum test

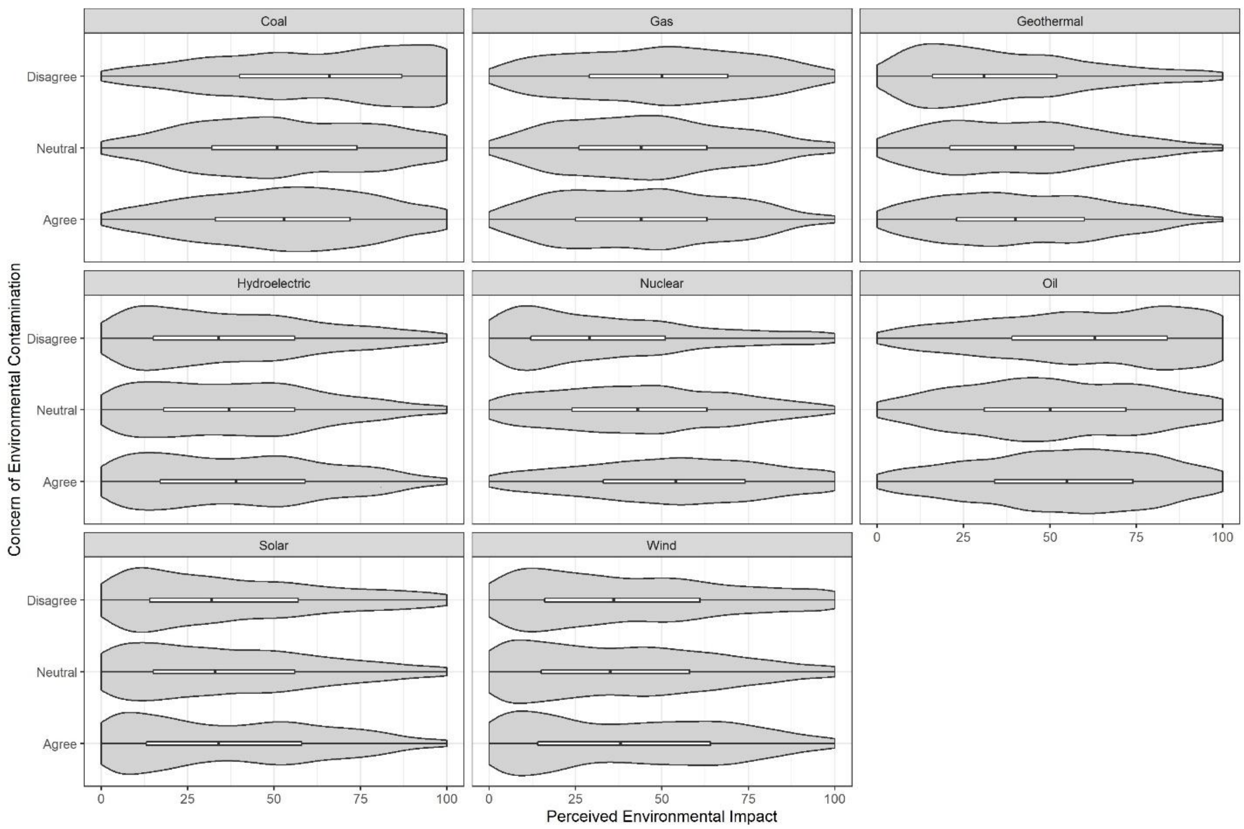

Figure 6 Geometric violin boxplot: x-axis = "perceived environmental impact", y-axis = "concern of environmental contamination (per each energy source)

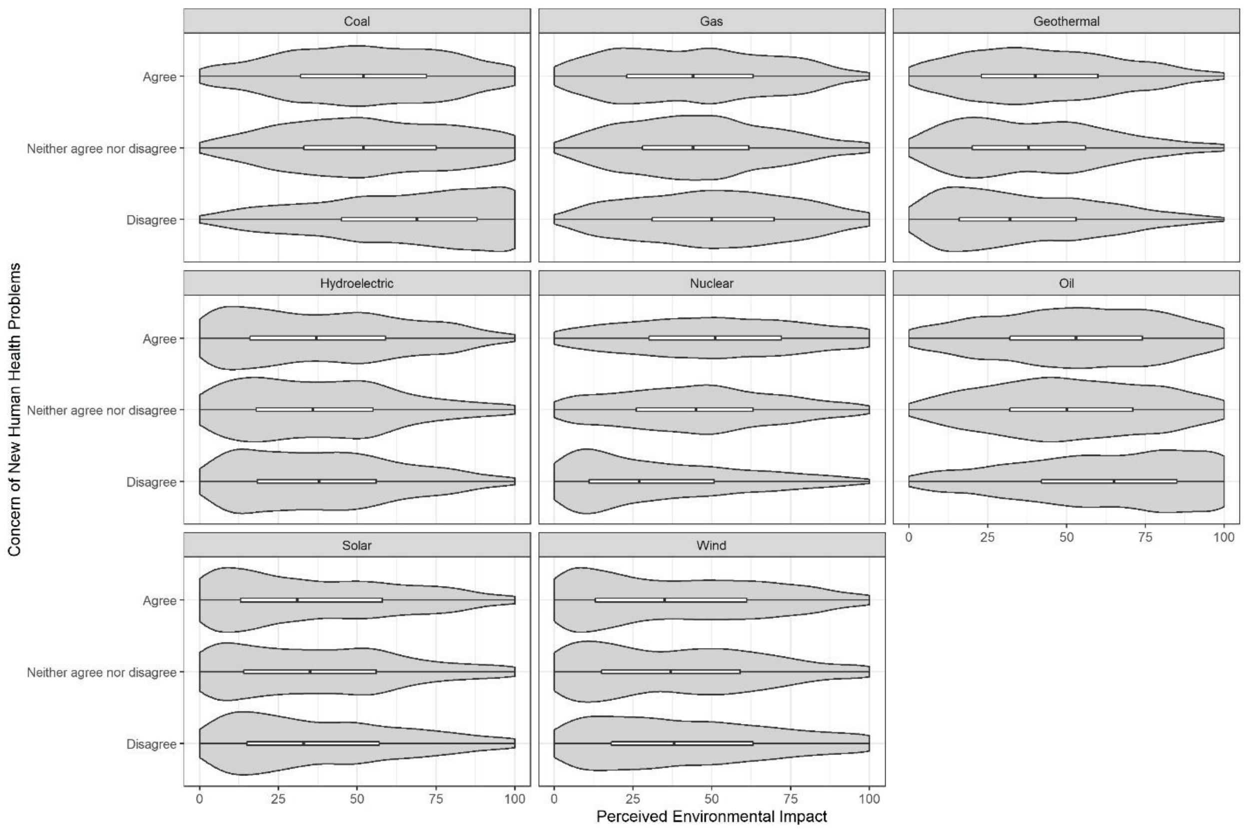

Figure 7 Geometric violin boxplot: x-axis = "perceived environmental impact", y-axis = "concern of water contamination (per each energy source)

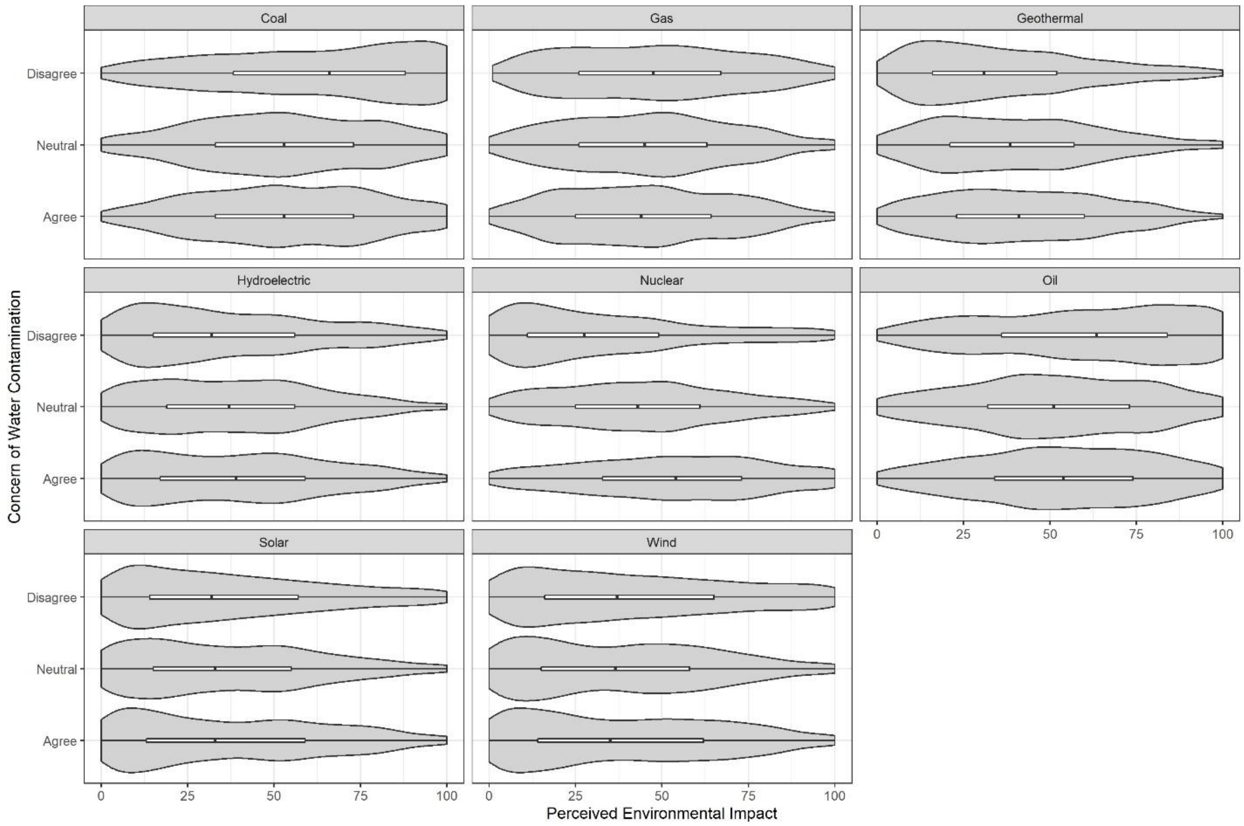

Figure 8 Geometric violin boxplot: x-axis = "perceived environmental impact", y-axis = "concern of new human health problems (per each energy source)

Table 4 Adjusted logistic regression analysis of the impact of nuclear energy on pollution, environmental contamination, water source contamination, and new human health problems, Age (less than 35-years, 35-years or older), Gender (male or female), Education (less than college degree, undergraduate degree, graduate degree), Income ($60,000 or less, $60,001 to $80,000, >$80,000), Political Ideology (conservative, moderate or no opinion, liberal), RUCA scores classified into three categories urban (1, 2, 3 scores), middle (4, 5, 6 scores), and rural (7, 8, 9, 10 scores), geographic location (</> 50-miles of INL and U.S. non-Idaho). Total sample size for this analysis is smaller (N=2245) as all neutrals have been removed.

	Environmental Contamination			**Water Contamination**			**New Human Health Problems**		
Characteristic	OR[1]	99.9% CI[1]	p-value	OR[1]	99.9% CI[1]	p-value	OR[1]	99.9% CI[1]	p-value
Age									
Less than 35	—	—		—	—		—	—	
35 or older	0.82	0.58, 1.16	0.059	0.85	0.60, 1.20	0.117	0.76	0.59, 0.97	**<0.001**
Gender									
Female	—	—		—	—		—	—	
Male	0.89	0.63, 1.24	0.233	0.92	0.66, 1.29	0.429	0.97	0.76, 1.24	0.665
Race/Ethnicity									

non-Hispanic White	—	—		—	—		—	—	
Hispanic	1.68	1.10, 2.60	**<0.001**	2.02	1.30, 3.17	**<0.001**	1.31	0.98, 1.77	**0.002**
Other	0.90	0.58, 1.38	0.407	1.10	0.71, 1.69	0.490	1.25	0.90, 1.74	0.025
Education									
Less than college degree	—	—		—	—		—	—	
Undergraduate degree	1.40	0.92, 2.14	**0.008**	1.38	0.91, 2.12	0.012	1.00	0.75, 1.35	0.961
Graduate degree	0.78	0.49, 1.24	0.080	0.62	0.39, 1.00	**<0.001**	1.11	0.79, 1.58	0.304
Income									
60000 or less	—	—		—	—		—	—	
60001 to 80000	0.98	0.64, 1.52	0.893	1.27	0.82, 2.00	0.077	1.14	0.83, 1.56	0.176
over 80000	1.08	0.73, 1.60	0.497	0.91	0.61, 1.34	0.407	1.08	0.81, 1.43	0.396
Political Ideology									
Conservative	—	—		—	—		—	—	
Moderate no opinion	1.46	0.97, 2.20	**0.002**	1.19	0.78, 1.81	0.173	0.99	0.74, 1.33	0.922
Liberal	1.66	1.12, 2.47	**<0.001**	1.27	0.85, 1.89	0.050	1.62	1.21, 2.16	**<0.001**
RUCA Score									
Urban.123	—	—		—	—		—	—	
Middle.456	1.23	0.75, 2.03	0.173	0.97	0.60, 1.60	0.857	0.97	0.66, 1.41	0.760
Rural.78910	0.62	0.37, 1.03	**0.002**	0.87	0.52, 1.47	0.378	0.83	0.57, 1.23	0.122
Geographical Location									
ID in 50-mile	—	—		—	—		—	—	
ID out 50-mile	5.03	2.85, 9.00	**<0.001**	4.33	2.45, 7.79	**<0.001**	3.55	2.29, 5.57	**<0.001**
US non-ID	3.53	2.20, 5.72	**<0.001**	3.72	2.31, 6.03	**<0.001**	2.45	1.67, 3.64	**<0.001**
PC1	0.94	0.85, 1.04	0.052	0.92	0.83, 1.02	**0.008**	1.00	0.93, 1.07	0.952
PC2	1.20	1.04, 1.37	**<0.001**	1.07	0.93, 1.23	0.101	1.08	0.97, 1.20	0.019
PC3	1.74	1.47, 2.07	**<0.001**	1.78	1.50, 2.13	**<0.001**	1.52	1.33, 1.73	**<0.001**

Table 4 [1]OR = Odds Ratio, [1]CI = Confidence Interval 99.9% Environmental impact of different energy source (coal, solar, geothermal…etc.) shown as Principal Components: PC1 = negative for all, especially solar, wind, geothermal, and natural gas, PC2 = contrasts coal and oil (and natural gas to a lesser extent) with solar and wind, PC3 = contrasts solar, wind, natural gas, with geothermal and significantly nuclear energy

Results of Hypotheses

This section summarizes this study's six hypotheses below:

H1: the majority of respondents will perceive nuclear energy as something that may lead to more environmental pollution, contamination, contamination to water supplies, and new human health issues.

Overall, the plurality of respondents agree that nuclear energy may lead to more environmental pollution and contamination, contamination of water supplies, and new human health issues (Table 4) (environmental contamination = **agreed 38%**, neutral 36%, disagreed 26%; water contamination = **agreed 40%**, neutral 36%, disagreed 24%; new human health problems = **agreed 47%**, neutral 29%, disagreed 24%).

We accept hypothesis one.

Table 5 Overall public perceptions that nuclear energy may lead to more environmental pollution, the contamination, contamination to water supplies, and new human health issues.

N = 3,524	***Environmental Contamination***	***Water Contamination***	***New Human Health Problems***
Agree	1,329 (38%)	1,404 (40%)	1,660 (47%)
Neutral	1,279 (36%)	1,270 (36%)	1,030 (29%)
Disagree	916 (26%)	850 (24%)	834 (24%)

H2: Perceived risk of nuclear energy to the environment and health is significantly influenced by level of rurality and political ideology, specifically those who reside in urban locations and individuals who identify as conservative will be more likely to perceive nuclear energy as a risk to the environment and to public health compared to those who live in rural locations and individuals with conservative ideologies.

Overall, the three categories of environmental contamination, contamination of water sources, and public health were not independently associated with level of rurality (Table 3). For the full United States sample, significant (P<.001) differences between participant political ideology and the belief that nuclear energy may lead to more environmental pollution, the contamination, contamination to water supplies, and new human health issues at the multivariate level were found (Table 3). Participants with liberal views agreed that nuclear energy may have negative effects on the environment, increase water contamination, and cause new human health issues. However, for all three indicators, a greater percentage of respondents with conservative ideologies disagreed than those with liberal views agreed.

After controlling for demographics, the logistic regression results were consistent to the bivariate results (Table 4). Compared to participants with conservative views, higher odds of agreeing that nuclear energy caused increased environmental contamination and cause new human health issues were found for participants with liberal views (environmental contamination: OR=1.66, 99.9% CI=1.12, 2.47; new human health problems: OR=1.62, 99.9% CI=1.21, 2.16).

Political ideology was independently associated with two of the three risk categories environmental contamination and public health, but was not independently associated with water contamination. Level of rurality was not significantly associated with the three categories, however those living in rural areas had lower odds of believing nuclear energy was an environmental contamination risk. Thus, we can accept the part of the hypothesis dealing with political ideology and reject the part of the hypothesis regarding the level of rurality.

H3: perceptions of environmental impact of energy sources will be independently associated with perceptions of the environmental and health risks of nuclear energy.

Age, race/ethnicity, geographical location, and PC3 were independently associated with thinking that nuclear energy may lead to increased pollution, environmental contamination, water contamination, and new human health problems. Political ideology was independently associated with the belief that nuclear energy may lead to more environmental contamination and new human health problems, but was not independently associated with the belief that nuclear energy may cause increased groundwater contamination. Gender, income, and level of rurality were not independently associated with thinking that nuclear energy may lead to higher levels of pollution, environmental contamination, water contamination, and public health. Education was not independently associated with environmental contamination and public health, however, those with a graduate degree were less likely to believe nuclear energy would cause increased groundwater contamination. Education was also independently associated with at least one of the three risk perception variables. PC1 had lower odds of believing that nuclear energy may lead to increased groundwater contamination, but was not associated with environmental contamination and new human health problems. PC2 had higher odds of believing that nuclear energy may lead to increased environmental contamination, but was not associated with water contamination and new human health problems.

From the results of this study, we can accept hypothesis three.

H4: Those that perceive that fossil fuels have a higher environmental impact will also perceive nuclear energy as having high environmental and health risk, and those that do not perceive fossil fuels as having a high environmental impact will not perceive nuclear energy as having high environmental and health risk.

Results from the logistic regression indicated that those who favor solar/wind and do not favor coal/oil were more likely to believe that nuclear energy leads to more pollution and environmental contamination which supports the first part of hypothesis four. Those who think that all energy sources negatively impact the environment were more likely to believe that nuclear energy leads to more water contamination, which may or may not support the hypothesis. Individuals were not more likely or less likely to believe that nuclear energy may lead to new human health issues based on their rating of environmental impact of different energy sources, which does not support the second portion of the fourth hypothesis.

From the results of the study, we were unable to conclusively accept or reject hypothesis four.

Chapter V

Discussion

This study explored public risk perceptions of nuclear energy, specifically if individuals perceive nuclear energy to be a risk to environment and public health. This project looked to determine how level of proximity to INL, level of rurality, and political ideology influences that perceived risk. This thesis was also interested in exploring how perceptions of environmental impact of various sources of energy were associated with perceived environmental and health risks of nuclear energy. The environmental and health risks of nuclear energy measured included 1) pollution, contamination of the environment, 2) contamination of water supplies, and 3) new human health problems. This study provides important contributions to the literature. Primarily, this is one of the only studies to assess risk perceptions toward nuclear energy and its effects on the environment and public health in the State of Idaho.

H1: Public Perceptions of Nuclear Energy

Results from the study's full sample size indicated that overall, the plurality of respondents agreed that nuclear energy may lead to more environmental pollution and contamination, contamination to water supplies, and new human health issues (Table 4). These findings met our expectations and support the hypothesis that the majority of respondents will perceive nuclear energy as something that may lead to more environmental pollution, contamination, contamination to water supplies, and new human health issues. These findings also align with previous research. According to a 2019 Gallup poll, though positive perception of nuclear energy is on the rise, the plurality of individuals in the United States do not support nuclear energy as a power source (Reinhart, 2019). Similar to this study the Gallup poll also indicated that conservatives, those with college degrees were more supportive of nuclear energy compared to liberals and those without college degree (Reinhart, 2019). This study also supports the findings of Poortinga that nuclear energy is still considered to be a perceived risk to the environment and public health. This study and Poortinga's results concluded that individuals agree that nuclear energy causes increased contamination and increased human health problems (Poortinga et al., 2006).

H2: Level of Rurality and Political Ideology

This study's findings also supported part of the second hypothesis that perceived risk of nuclear energy to the environment and health is significantly influenced by political ideology. This result met our expectations and indicated that those who were politically liberal believed that nuclear energy does cause increased environmental contamination and pollution and new human health problems compared to more moderate and conservative respondents across all samples. Perceived risk of nuclear energy to groundwater is not significantly influenced by political ideology. It is also important to note that a higher number of those with conservative views did not believe that nuclear energy was a risk than those with liberal views who believed that nuclear energy was a risk to the environment or public health. This finding regarding liberals and negative associations with nuclear energy is consistent with other studies that also found less liberal support for nuclear energy. This study obtained written permission from the authors of Yeo et al., to utilize three of their primary research questions (i) "Nuclear power may lead to more pollution and environmental contamination," (ii) "Nuclear power may lead to contamination of water supplies," (iii) "Nuclear power may lead to new human health problems." The primary intention of this study was to explore how risk perceptions changed based off various populations following the Fukushima disaster. Findings from this study indicated that political ideology has a significant impact on risk perception of nuclear energy. This study also aligns with Yeo et al., McBeth et al., and the Pew Research Center in finding that those who identify as liberals perceive higher risk from nuclear energy when compared to individuals with moderate and especially conservative views (Pew Research Center, 2016). This result was opposite of another study's findings that indicated those with a liberal ideology had a much lower risk perception of nuclear energy when compared to those with conservative ideology (Bian et al., 2021).

This study's findings did not support part of the second hypothesis that perceived risk of nuclear energy to the environment and health is significantly influenced by level of rurality, however, respondents residing in rural areas had lower odds of believing nuclear energy may lead to increased pollution and environmental contamination. Instead, proximity and geographical location proved to be significant. Of the individuals who agreed that nuclear energy does cause increased environmental contamination and pollution, water contamination, and new human health problems, a high percentage of individuals lived in the United States, but outside of Idaho. Very few participants living within the fifty-mile radius were among those who agreed that nuclear energy posed a risk to the environment, water supplies, and public health. Those living in Idaho, but outside of the fifty-mile radius of INL and those who live in the United States outside of Idaho were both more likely to agree that nuclear energy poses a risk to the environment, water supplies, and public health than those living within the fifty-mile radius of INL, or those living outside of Idaho. The fact that those within Idaho, not within 50 miles of INL perceive nuclear risks to the environment at higher levels than those residing out of Idaho is an interesting finding, indicating potential regional differences in attitudes. This all indicates that proximity does play a factor in public risk perceptions of nuclear energy and aligns with the study findings (Venables et al., 2012) that level of perceived risk is significantly associated with residential proximity, meaning that the closer an individual lives to a nuclear power plant, the less risk is perceived. One theory as to why individuals who live within the fifty-mile radius of INL have less perceived risk associated with nuclear energy is because those living closer may have more knowledge of nuclear energy. Which would relate to the study by Kim and Kim that found that knowledge of nuclear energy was associated with having more positive attitudes toward nuclear energy (Kim & Kim, 2021). We initially hypothesized that level of rurality would be an indicator of participant responses, however results were not significant. Contrary to the hypothesized association, rurality identified through RUCA score was not independently associated with increased risk of environmental contamination, water contamination, and new human health issues. Political ideology may be a stronger indicator of perceptions than RUCA score, as both were in the model and only political ideology resulted in a significant association. The outcome that proximity was overshadowed by political ideology indicates that an alternative theoretical framework would be better suited to explain public risk perception.

H3 & H4: Environmental Impact of Various Energy Sources

Results from the study indicated that perceptions of other sources of energy and perceptions of nuclear energy were correlated. The plurality of respondents who believe fossil fuels to be an increased risk to the environment and cause more environmental harm would also believe that nuclear energy had increased risk (Table 4). These findings met our expectations and support the hypothesis that perceptions of environmental impact of energy sources will be independently associated with perceptions of the environmental and health risks of nuclear energy. Outcomes of this study also support prior studies that indicate perceptions of nuclear energy are improving when compared to other sources of energy, specifically some fossil fuels such as coal and oil (Poortinga et al., 2006).

Hypothesis four of this study predicted that those that perceive that fossil fuels have a higher environmental impact will also perceive nuclear energy as having high environmental and health risk, and those that do not perceive fossil fuels as having a high environmental impact will not perceive nuclear energy as having high environmental and health risk. Findings indicated that the plurality of respondents who believe fossil fuels to be an increased risk to the environment and cause more environmental harm would also believe that nuclear energy had increased risk (Table 5). However, due to the variability of natural gas, which is also a fossil fuel and the inconsistency of that correlation, these results were not as expected and did not in entirety support the hypothesis.

Findings from both hypothesis three and four support prior research. We know from prior study that overall, renewable energy sources hold more favorability when compared to fossil fuels and also when compared to nuclear energy (Hazboun & Boudet, 2020; Poortinga et al., 2006). Conversely to the results from Poortinga's study where nuclear energy was ranked lowest in terms of 'favorableness', nuclear energy was viewed more positively than coal and oil. Findings from this thesis indicated the variability of environmental impact rankings of natural gas and nuclear energy. It is interesting that the plurality of respondents correlated natural gas with renewable energy sources rather than fossil fuels. This finding also reinforces prior research by Delborne et al. and Hazboun & Boudet, which showcases the increased reliance of natural gas in the energy mix and the uncertainty of nuclear energy as the transition to renewable sources continues.

Theoretical Framework

The framework selected to guide this thesis was the Construal Level Theory (CLT) and Psychological Distance (PD). These theoretical models were chosen because they support the theory that perceived risk is based upon the individual's own personal experience, prior knowledge, proximity, and beliefs, which supported the primary intention of exploring how people perceive risks of nuclear energy to human and environmental health in terms of proximal distance, level of rurality (in the form of RUCA score), and political ideology. For this study, we were not able to measure all levels of psychological distance, only proximity and beliefs. Hypothesis two of this study predicted that perceived risk of nuclear energy would be associated with level of rurality. Surprisingly, the results from our analysis determined that this was not the case across all geographical locations surveyed. There was, however, significance found between political ideology and perceived risk. The Risk Perception Model (RPM) may allow for better indicators of who fears what and why as well as connecting the political ideology piece. Three main measurements of risk: cognitive factors (e.g., knowledge), experiential processing (e.g., emotion and personal experience) and socio-cultural influences (e.g., social norms and values). The framework may be effectively adopted for many issues, such as the perceptions of the environmental and health risks of nuclear energy by examining how exposure, beliefs, and proximity were related. The RPM encompasses psychological and predictor variables as well as measure similar main measurements of risk: cognitive factors (e.g., knowledge), experiential processing (e.g., emotion and personal experience) and socio-cultural influences (e.g., social norms and values). This adjusted model also includes the role of trust which would encompass sources of information (e.g., INL and political ideologies). Socio-demographics were also incorporated into the model to indicate differences between individuals who perceive various levels of risk from nuclear energy (e.g. race/ethnicity, gender, age, education, etc.) (van der Linden, 2015). Those that identified as Hispanic had higher perceived risks from nuclear energy compared to non-Hispanic Whites, as did those with an undergraduate degree compared to those less than a college degree. Those older than 35 years of age and those with a graduate degree had lower perceptions of risk from nuclear energy in some categories that we examined. The adjusted framework may better aid in the analysis of the relationships between the measurements of risk within this model and to explore how they relate to the perceptions of environmental and public health impacts of nuclear energy (Bickerstaff et al., 2008). Other possible considerations future research would be how other studies utilized or implemented RUCA scores into their studies to better relate to chosen frameworks.

Limitations

An interesting outcome of this research is the number of neutral or no opinion responses to the three main research questions. 36% (N=1279) of responses were neutral for the question "nuclear power may lead to more pollution and environmental contamination," 36% (N=1270) of total responses were neutral for the question "nuclear power may lead to contamination of water supplies," and 29% (N=1030) of total responses were neither agree nor disagree for the question "nuclear power may lead to new human health problems." These responses were not considered in the final analysis as they were too significant in quantity to add to either agree or disagree as they would skew the category they were added in to. These responses were also not added into a different category due to the fact that we were unable to identify if these neutral responses held more positive or negative connotations. Though this was an unforeseen result, the findings from just the agree and disagree responses without including neutral responses were significant enough to identify reliable and confirming results. This would be an area that may need to be looked into further to understand the reasoning for the large quantity of neutrality in respondents. A theory as to why participants responded as neutral in these questions is due to not wanting to align directly with nuclear energy in a positive way, but also not fully agreeing with the thought that nuclear energy is a risk to the environment and public health indicating that they were in the middle of this decision and do not want to have to make this decision (DeMars & Erwin, 2005). This is an area that should be researched further to determine if the neutrals represent a neutral response (in between agree and disagree) or if they represent "I don't know" responses. The complication is that such a significant portion of the respondents selected this neutral ground this may have skewed the results of this study. That study indicates that many people do not like to say that they do not know enough about the topic so they choose the option that is not a definitive choice as a way out of making a concrete decision. For future studies, survey questions could be limited by not allowing respondents a "neutral" option and ask intentionally if they "agreed/disagreed/don't know" specifically. Those who responded "don't know" to the survey may represent an outreach and educational opportunity for INL to increase awareness and promote transparency of current and future developments and research – since more education leads to increased positive public perception. This would be in the areas that were outside of the 50-mile radius within Idaho and also the within 50-mile radius.

Another limitation of this study is the ties to the economy, such as family and friends working at INL which may skew the data possibly for respondents in Idaho. As INL and collaborating companies employ over 5,000 individuals, it is the largest employer in eastern Idaho, specifically Idaho Falls (City of Idaho Falls, 2020). However, this is not a surprising finding as this is consistent with other studies that looked into this as well.

Finally, due to time restrictions and implications from the COVID-19 pandemic, survey advertising was adjusted to remote, online distribution. Because the survey was only disseminated through two Idaho news outlets: East Idaho News and the Idaho State Journal there was a risk of sampling bias limiting the generalizability of findings. Future studies should consider advertising through a varied grouping of sources.

Strengths

Several strengths were associated with this project. Such as the data captures a specific point in time, a wide range of demographics were represented, and the results may be used to prove and/or disprove assumptions. A large sample size achieved from a semi-rural to rural areas, within and outside of the State of Idaho was another strength of this research project. A low statistical significance level set for analysis of this study's dataset assured that reporting associations by chance was less likely. Many findings and outcomes from this project may be analyzed to create new studies, in-depth research projects for a wide range of subject areas.

Conclusion

We answered our primary research question concerning whether or not individuals perceive nuclear energy to be a risk to environmental and public safety. We conclusively found that overall, individuals do perceive nuclear energy to be a risk to the environment, water contamination, and public health. The secondary research question was also answered by the results of this thesis, concerning how the level of proximity to the national laboratory (INL), level of rurality, and political ideology influences that perceived risk of nuclear energy. We found support, in the way that we expected, that political ideology does influence perceived risk of nuclear energy. Those who consider themselves to be political liberals have increased perceived risk of nuclear energy when compared to those who self-identify as political conservatives. In regards to level of proximity to INL and level of rurality, only proximity to INL was shown to have significant influence on perceived risk of nuclear energy. It was surprising that level of rurality was not an indication of risk as political ideology tends to be correlated to rurality. Overall, this study found that those who lived in the United States but outside of the state of Idaho have significant increased perceived risk of nuclear energy and believe that it will increase environmental contamination, groundwater contamination, and cause new human health problems. We also answered the third exploratory research question concerning how perceptions of environmental impact of various sources of energy were associated with perceived environmental and health risks of nuclear energy. We found support that perception of other energy sources matters, but not as significantly as initially hypothesized. Those who rate other sources of energy as high environmental impact, specifically of fossil fuels were also likely to have higher perceived risk of nuclear energy. However, it was interesting that the plurality of respondents correlated natural gas with renewable energy sources rather than fossil fuels. An area of future research may be to explore how rooted these perspectives of nuclear energy are specific to various regions and level of proximity to power stations then to determine what extent they are modifiable; in terms of the methods in which an individual receives information, what sources, people, to individuals trust most (politicians, public health officials, INL or energy industry professionals, news outlets, scientists or researchers, etc.).

Because Idaho is home to the Idaho National Laboratory (INL) and is at the forefront of nuclear energy for the United States with proposed projects on the horizon, the importance of understanding current and local perceptions of nuclear energy is necessary and will continue to be relevant, especially with the impending risks of climate change. Success of the proposed programs may depend on local perceptions and the use of this project may aid in increasing transparency of technology goals, data, and supporting public health officials to accurately assess risk. More research is needed to determine if and how nuclear energy could be included in future energy mixes to mitigate climate change. The findings of this thesis have significant implications for risk communicators such as public health officials, National energy agencies, and stakeholders of the energy industry that may aid in bridging the gap between pro and anti-nuclear energy communities/organizations and bring awareness to perceived and actual risk of nuclear energy.

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