Nuclear Energy: Powerful Tool or Imminent Risk? Analyzing the Public Divide on the Nuclear Energy Argument using Cultural Theory.

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Sean Robinson

Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

MC Forelle, Department of Engineering and Society

TABLE OF CONTENTS

1. INTRODUCTION

Every day, we see news stories about the all of the amazing new technologies that will solve all of our energy issues and will put climate change to rest. Whether it be a breakthrough in cold fusion, or a brand-new energy storage device, people are quick to think that any day, we will find the one technology to save all of us. However, the truth is that no silver bullet solution does, or will ever exist, and thus a variety of approaches will be needed. Wind and solar energy have grown in popularity, but currently lack the grid-scale energy storage technologies capable of providing a constant power base load. On the other hand, nuclear energy is capable of providing base load power while producing almost no emissions. Since its debut in the 1950's, nuclear energy has grown significantly worldwide, currently providing around 17% of the world's energy (*Nuclear Power Today*, n.d.). Despite proving to be an effective large-scale source of low-emissions energy, an apparent strong risk bias exists against nuclear power. These risk perceptions are primarily concerned with accident potential and the management of nuclear wastes. While there are certainly valid and important criticisms of nuclear power, there is also strong evidence supporting 1) the safe implementation of nuclear energy at all stages of its life-cycle and 2) the consequences of continuing to utilize fossil fuels to support our energy needs. However, the anti-nuclear risk bias creates political and economic barriers that prevent the effective large-scale implementation of nuclear energy, leading to a larger dependence on fossil fuels.

This research aims to focus in on the discrepancy in perceived versus actual risk of nuclear energy. Through this research, cultural theory of risk is used as a framework. Here, I will argue that the deviations in the perceived risk and actual risk of nuclear energy are primarily a result of anti-authority egalitarianism, which originate from 1970's environmentalist and anti-nuclear movements. Public opinion polls detailing attitudes towards nuclear energy, as well as discourse

analysis on social media platforms, were used to gauge how supporters and opponents of nuclear reflected the cultural biases outlined by cultural theory of risk. This research highlights how the mistrust of authority and their ability to ensure the health and safety of people when it comes to nuclear power, which is sources primarily from egalitarian and individualistic belief systems, results in a public who is split on whether nuclear is a viable solution to the climate crisis. Utilizing this information, I will argue that improving access to energy education, both in higher education and primary/secondary schools, as well as federal investment in small modular reactor technology, will help expose the public more to nuclear energy technologies and reduce uncertainty surrounding its safety.

2. LITERATURE REVIEW

2.0 SOCIAL AND ECONOMIC BARRIERS TO NUCLEAR ENERGY

Fossil fuels are generally advantageous as an energy source because 1) they are plentiful and thus inexpensive to procure and 2) they are capable of providing a consistent base load of electricity to an energy grid. Renewables such as wind and solar have seen significant cost reductions in the past few decades (He et al., 2020); however, the energy they generate is intermittent. This variability creates an issue as it leads to periods where either too much or not enough energy is produced. Ideally, excess energy is stored at times of excess generation and offloaded at times of poor generation in order to keep a consistent base load. However, very few energy storage technologies are commercially viable on a grid-level scale. Available grid-scale energy storage technologies tend to be geographically limited, such as pumped-hydroelectric storage, and thus are not widely available.

In order to effectively transition away from fossil energy, energy production needs to be capable of providing base load power in addition to producing low emissions. Here, nuclear energy presents itself as a promising solution. Similarly to natural gas or coal fired power plants, nuclear power plants work by producing a high-pressure working vapor that drives a turbine to generate electricity; the main difference being that the heat comes from nuclear fission rather than combustion (Anadón et al., 2012). Since combustion is not utilized to produce heat, no carbon dioxide is released during power generation, making nuclear a low emissions source of energy. Additionally, the consistency and controllability of the fission reaction makes nuclear capable of providing base load power (Davis, 2012).

For several decades, nuclear power has proven to be a reliable and safe source of low-emissions energy; however, many countries are hesitant to pursue nuclear power as a primary energy source due to political and social stigma that surrounds it (Koerner, 2014). Nuclear is generally perceived as a high safety risk, whether due to the fear of accident (Drottz-Sjöberg & Sjoberg, 1990), the release of nuclear waste, or the proliferation of nuclear weapons (Goldston, 2011). Despite a few high-profile incidents, such as the power plant meltdowns at Three-Mile Island (1979), Chernobyl (1986) and Fukushima (2011), nuclear energy has historically been one of the safest sources of energy available. Even taking into account these accidents, nuclear power has an almost 3000x lower death per terawatt-hour of power produced when compared to natural gas and coal (Statista, 2023). Reasonably, this is due to the plethora of safety regulations that are in place to ensure the safe utilization of nuclear fuel. Additionally, many modern nuclear power plants are designed to withstand the worst of worst-case scenarios.

Currently, the main barrier to nuclear energy is not safety, but cost. The operating cost of a nuclear power plant is typically lower than that of a natural gas powerplant because nuclear fuel has a much higher power density and thus power plants do not require a constant input of fuel to generate energy (NEI, n.d.). However, in the U.S., the average nuclear powerplant takes 5-6 years or more to construct (Moreira et al., 2013). This is not due to any complexities in the construction process, rather the intense regulatory barriers that slow down the process significantly. The high construction cost of nuclear power plants results in a higher electricity cost once finished as it takes a long time for the lower operating cost of the power plant to offset the extremely high cost of construction (EIA, 2021). This creates an enormous cost of entry barrier that, to many potential investors, makes nuclear too risky to place their dollars on. The investment risk is further perpetuated by the variability of policy; it is difficult to convince someone to invest in a decade-

long construction of a nuclear power plant if the regulations in a couple years could result in higher expenses. (Nam et al., 2021). While heavy regulation has contributed to the high level of safety associated with nuclear, some might say that is has been unfairly targeted compared to the immense safety and environmental issues that come with fossil energy. In essence, the perceived risk of nuclear energy is not reflective of the actual risk.

2.1 CULTURAL THEORY OF RISK APPLIED TO NUCLEAR ENERGY

Cultural theory argues that trends in risk perceptions are caused by relative associations with the four "cultural biases" (Rippl, 2002):

- Individualism – the values, goals, and rights of the individual should have precedence over the state or a social group
- Egalitarianism - all people are fundamentally equal and should be accorded exactly equal rights.
- Fatalism - people have no power to influence the outcome of the future with their own actions.
- Hierarchicalism – people should be organized in society based on corporate groups

Each of these cultural biases are based on how one associates themselves within a hierarchical and social group structure. For example, both individualist and egalitarians value less social hierarchy. However, egalitarians value group structure (such as governments), while individualists do not. As an analogy, individualists would likely belong to libertarian political groups, while egalitarians would likely belong to socialist political groups. Alignment with the cultural biases is measured based on one's "myths of nature", or systems of beliefs that are shaped and internalized by persons. Several studies have been done on nuclear energy in the context of cultural theory, some of which

have shown that there is generally no tradeoff between the perceived risk of nuclear energy and the perceived risk of climate change (Bian et al., 2021; McNeeley & Lazrus, 2014) in groups that value less social order (i.e., individualists and egalitarians).

3. METHODS

Through this research, methods of discourse analysis, public opinion polls, and policy analysis are utilized. To facilitate discourse analysis, data was obtained from Gupta et al. (2022). Here, researchers used Twitter, a major social media network, to analyze arguments pertaining to nuclear energy across major coalitions. Additionally, public opinion polls conducted by NPR and the Pew Research Center pertaining to views on nuclear energy in the United States were investigated. The findings from these polls and the discourse analysis were corresponded to the four cultural biases outlined by cultural theory of risk in order to rationalize the cultural origins of groups opposing and supporting nuclear energy. The combined results of the discourse and public opinion analyses were used to suggest how current nuclear energy policy could be changed in order to better appeal to groups with cultural biases that oppose expanding nuclear power, while not sacrificing safety standards.

4. DISCUSSION

4.0 DISCOURSE ANALYSIS AND PUBLIC OPNION ANALYSIS

The first question we want to address is "How do the cultural biases of the groups in support or in opposition to nuclear energy inform us about how these groups perceive risk?" Here, I will argue that hierarchicalists, which appeal to authority and societal structure, tend to accommodate pro-nuclear arguments, while egalitarians and individualists tend to accommodate opposing arguments. Hierarchicalists arguments in support of nuclear energy focus on the technological benefits and tend to dismiss social impacts. These arguments focus on things like operating cost, low carbon emissions, safety statistics, and energy security (van de Graaff, 2016). Hierarchicalists appeal to scientific evidence and logical reasoning, and believe that any roadblocks can be solved with some sort of authoritative oversight, such as government regulation. They have faith that authority figures of nuclear energy are capable of effective implementing it, so long as they are given adequate resources. Major incidents are treated as "anomalies" and as a mistake of people, not inherent limitations of nuclear energy itself. This leads to a highly data driven perspective which can be seen as dismissive or narrow-minded by other cultural groups, particularly egalitarians.

Researchers from the University of Oklahoma performed a discourse network analysis and narrative policy framework on Twitter to analyze arguments across multiple major coalitions. Many of the groups in favor of nuclear energy consisted of large, government-based organizations, or energy companies, such as Dominion Energy and the Nuclear Energy Institute (Gupta et al., 2022). These groups would certainly fall under hierarchical cultural beliefs as they are highly organized and subscribe to expertise. The arguments of these groups were highly cohesive and

primarily advocate for the development of new nuclear technologies as well as sustaining older nuclear technologies.

Egalitarian arguments against nuclear energy primarily focus on the environmental and safety risks, and the mistrust policy makers to effectively and consistently uphold preventative measures (van de Graaff, 2016). Egalitarians tend to be highly organized, similar to hierarchicalists; however, they do not favor an authoritative structure. They believe there is not enough scientific consensus to ensure accidents will not happen. This perspective has roots in the Green Party movement, which began in the 1970s. These groups have continuously gained momentum after major nuclear disasters, such as Chernobyl and Fukushima. For example, in 2012, the US Green Party advocated for a complete phase-out of nuclear power because "all processes associated with nuclear power are dangerous" (Green Party US, 2010).

Individualist arguments against nuclear energy tend to focus on the financial aspect of it. Individualists are in favor of market freedom and thus are not tied down to a specific energy source (van de Graaff, 2016). So long as energy needs are satisfied, an individualist is satisfied, whether it comes from nuclear or natural gas. For them, the primary deciding factor is "how much will it cost?". Because nuclear power plants frequently exceed original cost estimations, it is likely that individualists would be in opposition (Ross & Staw, 1993). However, this also implies that if the conditions were right and nuclear power plants could be competitive with other energy sources (without excessive government subsidization), and individualist could be in support of nuclear energy.

Next, we want to address how the cultural beliefs of nuclear energy supporters negatively impact its implementation. Here, I will argue that improper communication as well dismissal of actual risks among hierarchicalists results in alienation of potential supporters of nuclear energy,

resulting in an unbalanced perception in the risk that is rooted in mistrust. The one thing hierarchicalists and egalitarians both argue for is alternative energy sources in an effort to fight climate change. However, there is a split among these groups on the role of nuclear energy in solving climate change. As shown before, egalitarians are generally against nuclear because of the perceived safety risks and potential for disaster, while hierarchicalists see nuclear as a strong source of low carbon energy. Some states, such as Virginia, have been utilizing nuclear energy for several decades, while other states such as California have begun to shut down their nuclear power plants in favor of renewables, so there has yet to be a consensus on how to approach the issue (Harris, 2013). This is reflected in public opinion polls conducted on U.S. adults that show the general populace is much more split when it comes to nuclear energy vs. other sources of energy. Among U.S. adults, 50% were shown to favor expanding more nuclear power plants, while 47% were shown to oppose expansion (Leppert, n.d.). Other public opinion polls conducted by Gallup showed that college educated people support nuclear energy development significantly more than non-college educated people (60 % vs. 37 %) (Inc, 2019).

Even in the U.S., there has been history of mishandling and misuse of nuclear material that has resulted in harm. For example, researchers at the National Cancer Institute found an excess of cancer rates in the New Mexico comminutes of Guadalupe, Lincoln, San Miguel, Socorro, and Torrance as a result of the Trinity Nuclear Tests in the 1940's (Simon, 2020). The legacy of the Cold War and its association with nuclear weapons have certainly contributed to the fear and mistrust of anything associated with nuclear. With the tendency of hierarchal ideals to dismiss historical examples of harm as human errors rather than technological errors, it leads to an appearance of a dismissive attitude from authority, which simply sows even more distrust in an already skeptical populace. So, despite the clear and proven benefits of nuclear energy, as well as

the proven safety record, the majority of the general populace has yet to be convinced that harm can be avoided.

4.1 DEVELOPING POLICY THAT APPEALS TO THE OPPOSITION

Lastly, we want to determine how nuclear energy policy be changed to better appeal to opposing cultural biases. Here, I will argue that small modular reactors (SMRs) are highly promising as they are community oriented, lower safety risk, and lower financial risk. SMRs are essentially "mini" version of a full-scale nuclear reactor, producing less power (100 MW for SMR vs. 1 - 2 GW for a normal reactor). The concept behind SMRs is that they can be used to power smaller communities rather than entire regions of states (Liou, 2021). These reactors could be easily introduced into communities similar to how the Lake Anna reactor in Virginia operates. This in effect transforms nuclear power from something associated with state-run authority into community driven, clean energy that appeals to egalitarian ideals. Small modular reactors also greatly benefit energy security as they enable communities to generate their own power, which appeals to hierarchicalists ideals. Additional benefits of investment into small modular reactors are their ease of production and lower capital investment. Researchers from MIT argue that the ability to manufacture SMRs in a factory setting rather than completely on-site helps standardize the construction process, helping to lower costs (MIT, n.d.). The result is reactors that can made cheaper and faster, further reducing risk of cost overruns. This would appeal to an individualist perspective as it reduces the financial risk that is typically associated with constructing nuclear power plants in the west.

One of the arguments against small modular reactors is that their safety has not been proven. In 2013, the Union of Concerned Scientists, an organization known for holding an anti-nuclear stance, stated that SMRs are designed to be less robust and with less security features,

increasing the risk of accidents and potential proliferation (UoCS, 2013). The Office of Nuclear Energy, which oversees federal investments and research into nuclear power, states that SMRs will be designed to "withstand design basis aircraft crash scenarios and other specific threats" (ONE, n.d.). Additionally, because SMRs operate more efficiently, they require less refueling which reduces risk of sabotage compared to large reactors. Overall, they anticipate SMRs being safer than large reactors. Finally, the safety of SMRs reactors has been proven in much more precarious conditions for several decades already – on submarines and aircraft carriers. Many people view SMRs as a new technology, however the U.S. navy, as well as other countries' military forces, have been using SMRs to power their large ships for several decades without incident. Therefore, it seems unlikely that the safety risk of SMRs would change much from large reactors, which already have incredibly low safety risk under current practices.

Beyond practical implementations, there needs to be a culture shift surrounding nuclear energy. Reframing the pro-nuclear argument as a friend of renewable energy rather than competition is essential as the end goal is to fight climate change. Emphasis on the need for diverse solutions is needed as it is impossible for a single technology to solve the energy crisis. In general, there is a need to increase the available education surrounding climate change (Cho, 2023). A 2020 study found that only 16% of secondary schools in middle and high income countries studied climate change (Cordero et al., 2020). Furthermore, only a handful of universities in the U.S. offer comprehensive education surrounding nuclear energy and nuclear engineering. The climate crisis and energy sciences are married together, and thus we need a higher emphasis on educating the public on the science of these issues, as well as increasing the availability of higher education programs that encourage students to pursue careers in energy science.

5. CONCLUSION

Using cultural theory of risk as a framework, public opinion polls and social media discourse were analyzed in order to discover the cultural origins of why nuclear energy is perceived as a high risk. The primary supporters of nuclear energy tend to be hierarchicalists, scientific organization that's view nuclear energy as a low-carbon, secure source of energy. On the other hand, opposers of nuclear energy tend to be egalitarian and individualistic communities that lack faith in the government and companies to ensure the safety of the public. The result is a general public who is extremely divided on whether or not nuclear is good or not. In order to utilize nuclear energy to its fullest potential, this gap between cultural biases needs to be closed to create a more cohesive public opinion. Federal and state investments into small modular reactors will help create nuclear communities as well as expose the public to typically unseen energy technologies. Ideally this could help improve public opinion about nuclear energy by helping educate the public.

This paper is targeted towards policy makers, particularly those involved in energy policy. It is important for policy makers to know how to properly communicate information with their substituents, particularly when you are dealing with an audience with a diverse set of beliefs and biases. The information discussed here can be helpful in helping policy makers adjust their approach when it comes to nuclear energy, with the goal of making it a more accessible and open topic to the public. Future researchers should dive into energy education, particularly in primary and secondary school. The idea of including energy sciences in K-12 education is a relatively new idea that has seen some resistance due to its political nature. However, it is important that people have a basic understanding of how their society functions, and energy is an important part of that. Researchers should look at how energy education can fit into today's system and what curriculum should be covered. Nuclear energy is a technology that has a complicated history and a mixed

reputation; however, it is a powerful tool in humanity's energy toolbox and will continue to have an important place in our future societies.

ACKNOLWDGEMENTS

I'd like to thank Prof. MC Forelle of the University of Virginia Department of Engineering and Society for their guidance through writing this research paper.

REFERENCES

Anadón, L. D., Bosetti, V., Bunn, M., Catenacci, M., & Lee, A. (2012). Expert judgments about RD&D and the future of nuclear energy. Environmental Science & Technology, 46(21), 11497–11504. https://doi.org/10.1021/es300612c

Cho, R. (2023, February 9). Climate Education in the U.S.: Where It Stands, and Why It Matters. *State of the Planet*. https://news.climate.columbia.edu/2023/02/09/climate-education-in-the-u-s-where-it-stands-and-why-it-matters/

Cordero, E. C., Centeno, D., & Todd, A. M. (2020). The role of climate change education on individual lifetime carbon emissions. *PLOS ONE*, *15*(2), e0206266. https://doi.org/10.1371/journal.pone.0206266

Davis, L. W. (2012). Prospects for Nuclear Power. Journal of Economic Perspectives, 26(1), 49–66. https://doi.org/10.1257/jep.26.1.49

Death rate globally by energy source. (n.d.). Statista. Retrieved February 15, 2023, from https://www.statista.com/statistics/494425/death-rate-worldwide-by-energy-source/

Frequently Asked Questions (FAQs)—U.S. Energy Information Administration (EIA). (n.d.). Retrieved February 15, 2023, from https://www.eia.gov/tools/faqs/faq.php

He, G., Lin, J., Sifuentes, F., Liu, X., Abhyankar, N., & Phadke, A. (2020). Rapid cost decrease of renewables and storage accelerates the decarbonization of China's power system. Nature Communications, 11(1), Article 1. https://doi.org/10.1038/s41467-020-16184-x

Green Party US. (2010). *Green Party of the United States—National Committee Voting—Proposal Details*. https://gp.org/cgi-bin/vote/propdetail?pid=519

Gupta, K., Ripberger, J., Fox, A., Jenkins-Smith, H., & Silva, C. (2022). *Chapter 2: Discourse Network Analysis of Nuclear Narratives*. https://doi.org/10.15788/npf2

Harris, R. (2013, December 17). Environmentalists Split Over Need For Nuclear Power. *NPR*. https://www.npr.org/2013/12/17/251781788/environmentalists-split-over-need-for-nuclear-power

Leppert, R. (n.d.). Americans continue to express mixed views about nuclear power. *Pew Research Center*. Retrieved March 5, 2023, from https://www.pewresearch.org/fact-tank/2022/03/23/americans-continue-to-express-mixed-views-about-nuclear-power/

Liou, J. (2021, November 4). *What are Small Modular Reactors (SMRs)?* [Text]. IAEA. https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

MIT. (n.d.). *The Future of Nuclear Energy in a Carbon-Constrained World*. Main. Retrieved March 5, 2023, from https://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/

Nuclear Fuel. (n.d.). Nuclear Energy Institute. Retrieved February 15, 2023, from https://www.nei.org/fundamentals/nuclear-fuel

Nuclear Power Economics | Nuclear Energy Costs—World Nuclear Association. (n.d.). Retrieved February 15, 2023, from https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx

ONE. (n.d.). *Benefits of Small Modular Reactors (SMRs)*. Energy.Gov. Retrieved March 5, 2023, from https://www.energy.gov/ne/benefits-small-modular-reactors-smrs

Rippl, S. (2002). Cultural theory and risk perception: A proposal for a better measurement. Journal of Risk Research, 5(2), 147–165. https://doi.org/10.1080/13669870110042598

Ross, J., & Staw, B. M. (1993). Organizational Escalation and Exit: Lessons From the Shoreham Nuclear Power Plant. *Academy of Management Journal*, *36*(4), 701–732. https://doi.org/10.5465/256756

Simon, S. (2020, August 31). *Trinity Nuclear Test Study Summary—NCI* (nciglobal,ncienterprise) [CgvArticle]. https://dceg.cancer.gov/research/how-we-study/exposure-assessment/community-summary

UoCS. (2013). *Small Modular Reactors | Union of Concerned Scientists*. https://www.ucsusa.org/resources/small-modular-reactors

U.S. Energy Information Administration—EIA - Independent Statistics and Analysis. (n.d.). Retrieved February 15, 2023, from https://www.eia.gov/state/?sid=VA

van de Graaff, S. (2016). Understanding the nuclear controversy: An application of cultural theory. *Energy Policy*, *97*, 50–59. https://doi.org/10.1016/j.enpol.2016.07.007