Nuclear Fusion: Learning from Nuclear Fission's Mistakes to Reach Closure

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

John Fitzgerald

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

Nuclear energy can be the solution to our clean renewable energy needs if it can overcome the fears and beliefs that it will lead to humanity's downfall. As fossil fuels are being completely phased out, as their consumption has had significant environmental consequences, environmentally friendly energy sources must be adopted to succeed them. Consequently, clean energy sources are competing for viability to be adopted and utilized on a larger scale by governments looking to supplant their coal, oil, and natural gas sources with renewable energy. Nuclear energy – despite the numerous benefits it possesses – has a large spectrum of opinions and a divisive history surrounding it; therefore, it can be hard for governments and companies to consider adopting it as an energy source due to the varied public opinion. Even with these drawbacks, nuclear energy stands apart due to its ability to fill a gap that most clean energy cannot easily manage – demand. Most renewable energy sources have "not been able to catch up with the demand for new electricity" globally (Kurzgesagt, 2021) leading to many seeing nuclear energy as a "major component of our rescue" from the ongoing climate crisis (Rhodes, 2018). The United States' wind and solar installations have been growing, but their output has been highly variable resulting in doubts surrounding their ability to generate sufficient electric power to supply the necessary demand; therefore, energy-dense, environmentally friendly energy sources are needed.

Nuclear power offers a promising source of low-emissions energy, but before it can meet a greater share of the energy demand in the U.S., the distrust and fears about nuclear fission energy must be better understood and mitigated. Americans do not trust nuclear power as a viable means of producing energy due to a variety of reasons ranging from previous nuclear accidents, film depictions, government policies, and misconceptions, which all greatly hinder nuclear energy's ability to be a dominant and respected clean energy source. With the recent developments in nuclear fusion energy production methods proving its feasibility, nuclear fusion has the potential to stand apart and truly become the energy source that nuclear fission dreamed of becoming as fusion becomes a more attainable and less theoretical energy production method. Although without proper care and communication, nuclear fusion could hit the same roadblocks resulting in the same negative public opinions that nuclear fission energy is shackled by.

By analyzing nuclear fission as an energy source, as well as the issues, conflicts, and setbacks experienced, I present a summary of why nuclear fission is so distrusted. Using this information, I suggest some ways that nuclear fusion can promote itself to overcome future anticipated difficulties with public opposition as it becomes less of a dream and more of an attainable energy source. I begin with an explanation of nuclear fission and nuclear fusion, how each process works, and what separates them with regard to process and safety. I present numerous setbacks that the nuclear energy industry has faced from its creation until now, and argue for ways that nuclear fusion can avoid these issues in the hopes of it becoming a less controversial energy source. First, I review the literature on nuclear fission and fusion to present the current landscape for each technology, and explain why fusion has the potential to become a less contentious clean energy source than fission despite both being nuclear energy sources. Then I detail the framework used: Pinch and Bijker's social construction of technology framework (SCOT) (Pinch & Bijker, 1984), explain the necessary concepts surrounding SCOT, and why the SCOT framework was chosen to discuss nuclear fusion's advent. Following, analysis is present looking at the problems surrounding nuclear energy, the reasons why fission has not had the same success that other sources of clean energy have had, and how fusion can use these lessons to navigate the energy landscape to become a less divisive source of clean energy. Finally, the paper concludes with some recommendations and courses of action for nuclear fusion and its public perception to allow nuclear fusion to emerge as a leading source of clean renewable energy in the coming years.

Literature Review

Due to nuclear fission's long and tumultuous history, there has been a wide array of research covering many aspects of the technology. For this paper, the focus is on nuclear energy's acceptance – or lack thereof – development, and public perception. To start, using the sociotechnical imaginaries framework, Jasanoff & Kim (2009) analyzed the difference in attitudes towards nuclear fission power in both the United States and South Korea. This paper found that South Koreans had a much more positive response towards nuclear fission as their government focused more on the country at large rather than individuals or smaller communities. On the other hand, the study found that Americans considered the faults of nuclear fission energy to eclipse the numerous benefits due to the focus on the individual over the collective in the U.S. Another paper, Goodfellow et al. (2011), investigated the effects of public perception on nuclear power's implementation. The paper deduced that overall, the fears surrounding nuclear fission's risks dominated its perception. Additionally, it found that those who support nuclear power tend to minimize the technology's risks while opponents tend to exaggerate them. Finally, Balogh (1991) explored nuclear fission energy's evolution from 1945 to 1975. The book concluded that during that time period nuclear power flourished due to scientists, industrialists, and politicians encouraging its implementation rather than the public. This changed around the 1980s, after the Three Mile Island incident (1979) and Chernobyl (1986), when the fears surrounding the technology began to grow ultimately resulting in the public pushing for diminishing nuclear fission implementation. As can be seen, current literature has covered the benefits and risks of nuclear fission power – and its perceived benefits and risk – as motivation to accept or reject its use, but analyses of how nuclear fusion power is characterized using similar metrics is sparse. This motivates the examination of how nuclear fusion's future might align with nuclear fission's troubled past, and if it does align, what can nuclear fusion do to better market itself?

Nuclear fusion does not have anywhere close to the amount of research that nuclear fission does. This is the case because nuclear fusion's implementation is a much more recent concept; therefore, aside from technical research being conducted on nuclear fusion, much of the additional research surrounding nuclear fusion discusses its potential permitting, policy, and safety rather than focusing on how social acceptance and public perception might affect its implementation. Articles dealing with safety, such as Latkowski & Vujic's (1998) work helping to increase the safety and minimize the environmental impact of fusion, Taylor & Cortes (2014) following the design and licensing of fusion plants, and Longhurst et al.'s (1996) early attempt to create a safety standard for fusion abound while nuclear fusion's acceptance by society has not been analyzed to great effect. Due to nuclear fusion's numerous benefits as discussed below, it is essential to ensure that the public perception of the risks of nuclear fusion do not become inflated resulting in impediments to its future development and implementation.

To analyze how nuclear fusion should approach marketing itself to avoid being connected to the problems of nuclear fission I used Pinch & Bijker's SCOT (Pinch & Bijker, 1984), Social Construction of Technology, framework with an emphasis on closure. SCOT argues that human action shapes technology, not the reverse. This results in the belief that a technology and its uses cannot be understood without knowing the technology's social context. To apply this to my research question, I used this framework to analyze what primary meaning is being inscribed into nuclear energy and how that has affected its ability to grow as an energy source. Additionally, I looked at how nuclear fusion can create a new primary meaning and reach a state of closure through the SCOT framework by shaping its public image.

Before discussing the concept of closure in the SCOT framework, the terms relevant social group, interpretive flexibility, and design flexibility must be defined. Relevant social groups in SCOT are any group of people who are affected by a technological development in a certain way. For example, some relevant social groups for nuclear energy could be residents near a nuclear power plant, environmentalists, politicians, and technicians for nuclear power plants. Interpretive flexibility describes how these relevant social groups each have their own meaning or interpretation of the technology. Design flexibility is similar to interpretive flexibility except it focuses on the multiple ways that a technology can be designed and constructed, each of which can have a different meaning to different social groups. Ultimately SCOT leads to the idea that different social groups will have different views of the technology requiring different designs of the technology to satisfy them. This is where closure comes in handy.

Closure in SCOT relates to the process of the interpretative and design flexibility combined into a singular idea. Pinch and Bijker outline two ways in which closure can occur. The first being rhetorical closure, where the relevant social groups ultimately believe the problems with the technology to be solved resulting in no need for design changes. This type of closure is what nuclear fusion hopes to achieve initially by exhibiting its benefits compared to nuclear fission thus showing the problem to already be solved. The second type of closure is achieved by redefining the problem. Closure is achieved in this method by shifting the focus of the technology to show that it solves another problem. By doing so, the current technology overrides previous concerns from social groups by showing that it solves a different problem. This type of closure is what current nuclear energy, fission, is attempting to pivot towards as the public opinion and lack of answers to questions such as what will happen with the nuclear waste will not allow nuclear fission to simply be seen as a finished or rhetorically solved energy technology. By analyzing the benefits of nuclear fusion energy compared to nuclear fission, ideas for how nuclear fusion can reach a state of rhetorical closure will be determined.

Methods

To review this evidence, I examined primarily secondary sources, with a focus on discourse analysis. Discourse analysis involves closely analyzing texts produced by agents to understand not just what the texts are saying, but who is saying it, to whom, and their motivations (Wall, 2015). The few primary sources focus around printed material such as news articles, and legal texts to analyze both the political and social responses to nuclear fission as it grew and developed. The secondary sources concentrate on academic journal articles analyzing nuclear energy and its public and political ramifications in addition to nuclear energy's response to shifting public opinion. The academic journals are also where the bulk of the research and data about nuclear fusion originate from. This is the case because despite the idea of nuclear fusion being present for many years it was not shown to be feasible until very recently. Discourse analysis (Wall, 2015) is employed to see how the nuclear industry is marketing itself and what effects that has had on public perception of the technology. Additionally, discourse analysis is used to draw connections between the tactics employed to boost or degrade nuclear energy's public perception and how to handle these tactics when nuclear fusion will inevitably run into the same techniques.

Analysis

Before any analysis, it is important to provide a foundational understanding of what nuclear fission and fusion are, how they work, their advantages and disadvantages, and where each currently resides as an energy source. The nuclear energy that is used today is called nuclear fission, which involves splitting isotopes – usually uranium-235 – into smaller atoms resulting in a tremendous release of energy in the form of heat. This heat is then converted into electricity through a turbine. While this sounds simple enough – split uranium atoms to generate heat to produce electricity – one of the main problems with nuclear fission emerges when considering the byproducts produced. When using uranium isotopes, nuclear fission generates highly radioactive waste that must be properly handled and disposed of. This is one of the main issues that is brought up when discussing nuclear fission's drawbacks.

Nuclear fusion, on the other hand, is the exact opposite process where smaller isotopes are forced together to construct larger isotope atoms. Instead of uranium isotopes being used, fusion employs hydrogen atoms, which when fused together form a heavier helium atom. Not only does this mean that fusion does not produce any long-lasting radioactive byproducts or waste like fission, but fusion also has been found to produce even more energy than fission on an atom-per-atom basis. Because of these factors, nuclear fusion is often deemed the holy grail of energy production, but many doubt if it can live up to these high expectations.

At their cores, fission and fusion are inversely related: fission is the splitting of atomic nuclei while fusion is the joining of atomic nuclei, both for the generation of energy. The differences go much further than how each method produces energy. To start, fission is much easier to initially produce energy from compared to fusion (TWI, n.d.). Although this means that fusion is inherently safer than fission because the fusion consists of a carefully balanced reaction where slight changes in conditions will cause the reaction to stop (EUROfusion, 2023). If a fusion reactor were to somehow become unstable it is very easy to interrupt unlike fission which requires constant cooling to make sure the reaction does not become too hot. Additionally, fusion is more powerful than fission, hypothesized to release several times the energy that fission can produce using the same amount of material (TWI, n.d.). Finally, the fusion process does not produce long standing harmful radioactive by-products that fission energy is characterized by (International Atomic Energy Agency, 2016). Overall, just based on the differences, fusion seems like the optimal choice due to the safety and production amount compared to fission.

Current Standings

Despite all the advantages fusion presents, little has been actually demonstrated about the energy source, rather a lot has been hypothesized. Fusion energy was first proposed in 1934 when physicist Ernest Rutherford validated the fusion of deuterium atoms into a helium atom. Since then, the process has been thoroughly studied, but until recently no experiment has generated more energy than has been put into the reaction. This all changed "on Tuesday [December 12th, 2022] [when] the first fusion reaction in a laboratory setting that actually produced more energy than it took to start the reaction" (Chang, 2022) occurred. Since then, nothing major or concrete has developed for nuclear fusion, but research has flourished.

Fission is an older and currently more feasible technology compared to fusion resulting in its problematic past. Currently, "the generation of electric energy using thermonuclear sources presents the best benefit–cost ratio in comparison with six other sources: coal, gas, biomass, hydropower, wind, and solar, especially when considering the average of seven parameters: greenhouse gases; electricity cost; distribution; land use; safety; solid waste and radiotoxic waste" (Marinho, 2021, p. 1).The United States' energy demand has been on a constant upward trend, but its nuclear electricity generation has been constant since 1990 (Energy Information Administration, n.d.). The reason for this stagnation is mainly due to fears of the potentially drastic consequences if something were to go wrong at a nuclear energy station regardless of the extensive benefits nuclear energy brings to the table. This left the public at one end of the spectrum or the other resulting in comments viewing the situation as: "We face the prospect either of destruction on a scale which dwarfs anything thus far reported or of a golden era of social change which would satisfy the most romantic utopian." (Gamson, 1989, p. 12).

Ultimately, the voices expressing opposition to nuclear fission seem to dominate the conversation. This can be seen today with the numerous nuclear power plants being shut down around the world due to push back from the public and fears of nuclear waste or fallout (Beyond Nuclear, 2022) There are certainly some groups who truly see the benefits of nuclear fission energy such as the Union of Concerned Scientists (UCS), who cautiously defend fission and admit nuclear power's disadvantages, but assert that "preserving the capacity of safely operated nuclear plants or ensuring that this capacity is replaced with zero carbon alternatives is an imperative that cannot be ignored" (World Nuclear News, 2018). Additionally, the American Nuclear Society supports nuclear power because out "Of all [the] low- or zero-carbon energy sources, nuclear energy is by far the most energy dense ... . Nuclear energy can generate the same amount of electricity as solar on a third of the land, as wind on a fifth of the land, and as hydroelectric on a twentieth of the land" (American Nuclear Society, 2020). While they may be correct and present convincing evidence, their opinions on nuclear fission have not been widespread enough to truly change the overall public perception of nuclear fission.

Those with an aversion towards nuclear energy tend to have two varieties of opposition as Taylor et al. (2012) found in a study: "Some critics condemn nuclear power for its environmental hazards; others find it inconsistent with democratic institutions" (p. 976). The Nuclear Information and Resource Service (NIRS), for example, opposes fission on the grounds that it is too expensive and "contribute[s] to further proliferation of nuclear weapons materials." (NIRS, n.d.). Greenpeace, the international environmental organization, also opposes fission – despite it being considered an environmentally friendly energy source – based on inevitable "design and operator errors, and the threat of terrorist attacks" (Leonard, 2015). Environmentalists are split on the merits of nuclear power, and the discussion surrounding its use will shape the U.S.'s energy future. The stagnating appeal in nuclear energy could be reinvigorated by nuclear fusion which may revolutionize the clean energy industry and restore nuclear energy's public perception by "potentially deliver[ing an] almost limitless supplies of energy" (Stallard, 2022).

Public Perception of Fission and Fusion

For nuclear energy to succeed it is essential to understand how the public opinion on nuclear power is established and swayed and what kind of influence it has on policy. These perceptions on nuclear energy, particularly on fusion moving forward, will shape America's energy future. It is therefore imperative to understand where these public perceptions originate. Nuclear fission's public perception mainly revolves around the perceived risks associated with the technology. In the 1960's when commercial nuclear power was first starting out there was "little negative press comment about nuclear reactors" (Palfreman, 2006, p. 3). This is mainly due to not having had a nuclear energy disaster yet that the public could clearly associate with the technology. By the 1970s though the narrative had shifted, "driven by popular culture, by antinuclear advocacy and by two highly publicized nuclear accidents" (Palfreman, 2006, p. 3). In particular, the Three Mile Island incident (TMI), one of the two "highly publicized nuclear accidents" mentioned above, "effectively halted the expansion of nuclear power in the U.S., with no new plants constructed for 30 years after the partial meltdown at TMI" (Reinhart, 2019). The hesitancy surrounding nuclear energy and its safety only grew as each one of the "three major nuclear accidents in the history of civil nuclear power generation, which are Three Mile Island (United States 1979), Chernobyl (Ukraine 1986), and Fukushima (Japan 2011), has hit the pause button of nuclear energy development for years, and also increased the public's opposition to nuclear power" (Wang, 2021, p 2). Previous nuclear disasters have clearly had a monumental influence on nuclear fission's public perception, but cinema and anti-nuclear advocacy has also swayed many of the public. Films, such as *The China Syndrome*, use nuclear energy for the plot resulting in sensationalized depictions of the technology resulting in some viewers believing the real technology to be just like the movie's depiction. The incorrect connections continue as many correlate nuclear fission to the world's deadliest weapon, the atomic bomb, adding to the already poor perception of nuclear power.

Out of all these perceived risk factors, only a few present valid fears. Sadly, the perceived fears greatly overreact to the risk of nuclear fission. Out of the over 18,500 cumulative reactor-years from commercial nuclear power plants since 1951 there have only been three high risk accidents (mentioned above) (World Nuclear Association, 2022). Thomas (2015) summarizes this nicely by stating that "public fears far outweigh the risks from civilian nuclear technology, which has seen only a handful of serious accidents in the intervening decades." While it may seem like nuclear energy has a high number of accidents for the amount of energy it produces, it is actually quite small. The ratio of deaths per terawatt-hour of energy produced for numerous energy sources: Brown Coal – 32.72; Coal – 24.62; Oil – 18.43; Biomass – 4.63; Natural Gas – 2.82; Nuclear – 0.07; Wind – 0.04; Hydropower – 0.02; Solar – 0.02 (Ritchie, 2020). These results show that "contrary to popular belief, nuclear power has saved lives by displacing fossil fuels" (Ritchie, 2020). The perceived risk from the immense devastation a nuclear catastrophe could cause skews the public away from the reality these numbers show. The discrepancy between the reality of nuclear fission versus the perception of risk is what has caused nuclear fission to stagnate, and what leads to doubts about nuclear fusion's potential.

How can nuclear fusion better handle this already harsh perception of nuclear energy and reach a state of rhetorical closure? To start, nuclear fusion, unlike fission, has a much harder time being associated with nuclear weapons. A more fitting connection is the sun, which is constantly undergoing nuclear fusion as hydrogen atoms fuse to form helium. This means that instead of being associated with the most devastating weapon humanity has ever created, nuclear fusion may become associated with the star that all life on earth depends on. This is an important distinction to draw as this is the first step to showing the relevant social groups that nuclear fusion is a beneficial technology and energy source.

The benefits of fusion – being a safe clean energy source with an abundant fuel supply which produces a high output of energy – mean nothing if the public does not inherently trust or support the energy source, as seen with nuclear fission. As explained above, not much research has been done to analyze nuclear fusion's public perception, but research has been done on the potential design of nuclear fusion power plants with a focus on safety and minimizing environmental impact, as these are believed to be some of "the strong motivations for pursuing the development of fusion energy … low environmental impact and very good safety performance" (Taylor & Cortes, 2014, p. 1) that will hopefully help push fusion towards being embraced and reaching closure. The paper *Prospects for attractive fusion power systems* (Najmabadi, 1999) discusses this idea by categorizing the requirements for commercial success of fusion power: gaining public acceptance; operational reliability and availability; and economics. The paper discusses the importance of public acceptance and how to garner support with:

> Gaining public acceptance through safety and environmental attractiveness is essential. It can be achieved by ensuring that the consequences of the most severe accidents are minimal, e.g. there should be no need for a public evacuation following severe accidents. Further, the waste produced by the power plant should be disposable with a reasonable cost and time period, e.g. plants should generate no higher than low-level radioactive waste. (p. 3)

To properly ensure safety that would satisfy the public, fusion could follow in nuclear fission's footsteps and require strict authorization for their construction, commissioning and operation. A nuclear regulator would require, as for any nuclear fission facility, that the design conforms to regulations and high safety standards, and that it is demonstrated that all necessary safety provisions are incorporated in the design (Taylor, 2015).

While fusion can market itself as a cleaner, safer, and more environmentally friendly version of fission energy to reach a state of rhetorical closure, it could also find closure by redefining the problem. By redefining the problem, closure is achieved by shifting the focus of the technology to show that it solves another problem. By doing so, the current technology overrides previous concerns from social groups by showing that it solves a different problem. Fusion can attempt this form of closure through its potential implementation in old fission power plants. Instead of marketing itself as a new unique energy source, it could instead pivot towards simply being a better "updated" version of fission energy. As "many of the country's existing nuclear power stations are potentially approaching the end of their service lives and the [fission] industry faces pressure from organized opposition to the use of nuclear power as well as competition from cheaper energy alternatives such as natural gas” (Reinhart, 2019), fusion has the ability to revitalize these old power stations by keeping costs down, upgrading the technology used, and remaining a reliable environmentally friendly technology.

While fusion can be marketed as a wonder technology to help its public perception and implementation to reach a state of closure, that does not mean that it is not without downside. To start, fusion is a safer alternative to fission and safety measures can be put in place to prevent accidents, but that does not mean that safety is guaranteed automatically. Accidents can still happen with any possible future fusion reactor, and the risks presented are still similar to those of nuclear fission reactors, such as the release of radioactive materials (Wang, 2021). Another problem fusion might face is the cost associated with its implementation. Similar to fission, nuclear energy is a highly complex process that requires a lot of energy to develop and maintain. This results in a significant upfront investment to construct and operate. The benefit though is that once the station is done fusion and fission can operate for many years producing a massive amount of energy over the station's lifetime compared to a solar or wind farm. Overall, these downsides should not drastically outweigh the benefits posed by nuclear fusion leading to the downsides not pulling public perception towards opposition.

Conclusion

Nuclear fusion technology is a potentially pivotal power source of the future that if accepted by the public and implemented will revolutionize the energy industry. Unlike wind and solar – two widely accepted green energy sources – fusion has the ability to supply power that can meet the demand our civilization has and will continue to have. However, the social perception of nuclear fusion cannot be ignored, due to previous incidents and perceptions involving nuclear fission. Public perception has the ability to push fusion forward towards implementation or pull society away from this promising energy alternative. While there has not been much previous research into how fusion will be perceived by the public, the effects of the public on nuclear have been noted: "The public's trust, acceptance, and involvement in nuclear regulatory decisions, therefore, are critical to a successful nuclear power program" (Smith, 2015). Therefore, diffusing public opposition and increasing active support of nuclear power is critical for the development of nuclear fusion. The established public distrust of nuclear power has and does negatively affect the development of the industry based on more popular opinion and media instead of scientific fact. Once lost it can be quite challenging to rebuild public trust and support making the next steps for fusion energy crucial in its development.

Nuclear fusion has two routes ahead of it to initially gather public support for itself. These routes are ways of reaching a state of closure and potentially becoming the next popular energy source that could revolutionize the energy industry. To summarize, these are by reaching a state of rhetorical closure – by promoting the innumerable benefits that the technology poses over both its predecessor and other green energy sources and then following through on the claims – or by redefining the problem – by leaning into its connection to nuclear fission and replacing old power stations with better, more updated technology. If fusion can confidently pursue these courses, it would be hard to find a way for the public to not accept the technology.

While this paper proposes ideas for how fusion can become a better accepted energy source, effort and action must be taken sooner rather than later to actually push fusion along these paths or else it may find itself right back alongside fission; therefore, the next steps are to turn this design and framework into a reality.

References

American Nuclear Society. (2020, April 17). *Nuclear's Role in the Clean Energy Economy*. American Nuclear Society. https://www.ans.org/nuclear/energy/clean/

Balogh, B. (1991). *Chain Reaction Expert Debate and Public Participation in American Commercial Nuclear Power, 1945-1975*. Cambridge University Press.

Beyond Nuclear. (2022, January 18). *Reactors are closing*. Beyond Nuclear. Retrieved from https://beyondnuclear.org/reactors-are-closing/

Chang, K. (2022, December 13). Scientists Achieve Nuclear Fusion Breakthrough With Blast of 192 Lasers. *The New York Times*. https://www.nytimes.com/2022/12/13/science/nuclear-fusion-energy-breakthrough.html.

Energy Information Administration. (n.d.). *U.S. Energy Facts Explained*. U.S. Energy Information Administration. Retrieved from https://www.eia.gov/energyexplained/us-energy-facts/

EUROfusion. (2023, February 22). *Fusion vs Fission*. EUROfusion. Retrieved from https://euro-fusion.org/fusion/fusion-vs-fission/

Gamson, W. A., & Modigliani, A. (1989). Media Discourse and Public Opinion on Nuclear Power: A Constructionist Approach. *American Journal of Sociology*, *95*(1), 1–37. http://www.jstor.org/stable/2780405

Goodfellow, M. J., Williams, H. R., & Azapagic, A. (2011). Nuclear renaissance, public perception and design criteria: An exploratory review. *Energy Policy*, *39*(10), 6199–6210. https://doi.org/10.1016/j.enpol.2011.06.068

International Atomic Energy Agency. (2016, October 12). *Fusion - Frequently Asked Questions*. IAEA. Retrieved from https://www.iaea.org/topics/energy/fusion/faqs

Jasanoff, S., & Kim, S.-H. (2009). Containing the atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva*, *47*(2), 119–146. https://doi.org/10.1007/s11024-009-9124-4

Kurzgesagt. (2021, April 13). *Do We Need Nuclear Energy To Stop Climate Change?* [Video]. Youtube. https://www.youtube.com/watch?v=EhAemz1v7dQ.

Latkowski, J. F., & Vujic, J. L. (1998). Inertial Fusion Energy: A clearer view of the environmental and safety aspects. *Fusion Technology*, *33*(3), 298–340. https://doi.org/10.13182/fst98-a35

Leonard, A. (2015, August 12). *Nuclear power is a losing proposition*. Greenpeace USA. https://www.greenpeace.org/usa/nuclear-power-is-a-losing-proposition/

Longhurst, G. R., Petti, D. A., Dinneen, G. A., Herring, J. S., DeLooper, J., Levine, J. D., & Gouge, M. J. (1996). Development of Fusion Safety Standards. *Fusion Technology*, *29*(4), 627–631. https://doi.org/10.13182/fst96-a30703

Marinho, C. A., Santos, A. A., Neto, J. V., & Quelhas, O. L. G. (2021). Filming the atom: Systematically exploring images of nuclear energy and their messages in popular movies. *Energy Research & Social Science, 79.* https://doi.org/10.1016/j.erss.2021.102158

Najmabadi, F. (1999). Prospects for Attractive Fusion Power Systems. *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, *357*(1752), 625–638. https://doi.org/10.1098/rsta.1999.0344

NIRS (n.d.). *Nuclear Information and Resource Service*. Nukes and Climate Change. https://www.nirs.org/climate/

Palfreman, J. (2006). A Tale Of Two Fears: Exploring Media Depictions Of Nuclear Power And Global Warming. *Review of Policy Research*, *23*(1), 23–43. https://doi.org/https://doi.org/10.1111/j.1541-1338.2006.00184.x

Pinch, T. J., & Bijker, W. E. (1984). The social construction of facts and artefacts: Or how the sociology of science and the Sociology of Technology might benefit each other. *Social Studies of Science*, *14*(3), 399–441. https://doi.org/10.1177/030631284014003004

Reinhart, R. (2019, March 27). *40 Years After Three Mile Island, Americans Split on Nuclear Power*. Gallup.Com. https://news.gallup.com/poll/248048/years-three-mile-islandamericans-split-nuclear-power.aspx

Rhodes, R. (2018, July 19). *Why Nuclear Power Must Be Part of the Energy Solution*. Yale E360. https://e360.yale.edu/features/why-nuclear-power-must-be-part-of-the-energy-solution-environmentalists-climate

Ritchie, H. (2020, February 10). *What Are The Safest And Cleanest Sources Of Energy?* Our World in Data. https://ourworldindata.org/safest-sources-of-energy

Stallard, E. (2022, December 14). Nuclear fusion breakthrough – what is it and how does it work? *BBC*. Retrieved from https://www.bbc.com/news/science-environment-63957085.

Smith, T. (2015). Nuclear Licensing In The United States: Enhancing Public Confidence In The Regulatory Process. *Journal of Risk Research, 18*(8), 1099–1112.

Taylor, N., & Cortes, P. (2014). Lessons Learnt from ITER Safety & Licensing for DEMO and Future Nuclear Fusion Facilities. *Fusion Engineering and Design*, *89*(9-10), 1995–2000. https://doi.org/10.1016/j.fusengdes.2013.12.030

Taylor, N. (2015). Safety and Licensing of Nuclear Facilities for Fusion. *2015 IEEE 26TH SYMPOSIUM ON FUSION ENGINEERING (SOFE).* IEEE. 978-1-4799-8264-6

Taylor, T. R. B., Ford, D. N., & Reinschmidt, K. F. (2012). Impact Of Public Policy And Societal Risk Perception On U. S. Civilian Nuclear Power Plant Construction. *Journal of Construction Engineering and Management*, *138*(8), 972–981.

Thomas, G. (2015, August 6). Distrust Of Nuclear Power Is A Post-Hiroshima Hang-Up We Can Fix. *New Scientist*. https://www.newscientist.com/article/dn28009-distrust-of-nuclearpower-is-a-post-hiroshima-hang-up-we-can-fix/

TWI. (n.d). *Nuclear Fusion vs Fission: What's the Difference?* TWI. Retrieved from https://www.twi-global.com/technical-knowledge/faqs/nuclear-fusion-vs-fission

Wall, J. D., Stahl, B. C., & Salam, A. F. (2015) Critical discourse analysis as a review methodology: An empirical example., *Communications of the Association for Information Systems, 37*(11). https://doi.org/10.17705/1CAIS.03711

Wang, Z., Chen, Z., Chen, C., Ge, D., Perrault, D., Zucchetti, M., & Subbotin, M. (2021). Quantitative safety goals for fusion power plants: Rationales and suggestions. *International Journal of Energy Research*, *45*(6), 9694–9703. https://doi.org/10.1002/er.6399

World Nuclear Association. (2022, March). *Safety of Nuclear Power Reactors*. World Nuclear Association. https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx

World Nuclear News. (2018, November 9). *Union of Concerned Scientists calls for policy to preserve nuclear*. World Nuclear News. Retrieved from https://world-nuclear-news.org/Articles/UCS-calls-for-policy-to-preserve-nuclear