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A World of Nuclear Power

Since the early 1930's, scientists have been working with atoms to try and discover a way in which the energy of their bonds can power life around us. Atoms are made up of smaller particles, whose bonds can be broken and then used to power things in a grander scheme. Enrico Fermi, was the first scientist to discover that atoms could be split apart into smaller atoms of differing elements using neutrons (The History of Nuclear Energy 4). Nuclear energy has since grown into an integral part of our lives and many people across the globe do not even know it. Nuclear reactors power up to 1/5 of the energy demand in the United States (Nuclear Explained), and citizens of the US often are uninformed of this statistic. There has long been a social stigma to move away from nuclear power because of past meltdown incidents and its association with nuclear war, yet it is far safer than society generally thinks. Nuclear energy has the capacity to produce more energy with more efficiency than many other alternative energy solutions, and does not produce any carbon based emissions, or greenhouse gases, a rising concern among the public in many world nations. The world is in an energy crisis right now, and developed countries are trying to take action to combat things like climate change and limit greenhouse gas emissions across the board by moving away from the use of fossil fuels. Not only does nuclear power offer more efficient and reliable power production than any other method of energy production, an increase in nuclear plants will help clean the air and also provide countless jobs to

the workforce. With the rising prevalence of global warming in our world and a push for more green energy solutions in society, nuclear energy should be on the forefront of our minds because of its safety, reliable and efficient power output, and most importantly the environmental benefits it poses.

According to the book *The History of Nuclear Energy*, physicist Enrico Fermi was the first to experiment with atom splitting starting in 1934. He worked in Rome and began his experiments bombarding uranium atoms with lone neutrons to study the effect of the uranium splitting. He was surprised at his own results when he discovered that the byproducts of the reaction he had conducted did not conserve mass, and therefore the combined products were a lighter mass than the original uranium atoms (The History of Nuclear Energy 4). It was eventually concluded that the lost mass was energy that had been expelled in the form of heat energy. This reaction is what is known as a fission reaction, where atoms are split in a continuous cycle and the expelled heat can be measured and then used for energy. This heat can then be used to create steam from water, and power turbines for electricity. In 1941 Fermi and his associate Leo Szilard drafted their first ideas for a sustainable nuclear fission reaction, and on December 2, 1942, Fermi and a few other scientists tested their original model at the University of Chicago, known as Chicago Pile-1 (The History of Nuclear Energy 6). After a few hours, the fission reaction they were testing became self-sustainable and continued without human intervention, thus bringing humanity into the nuclear age (The History of Nuclear Energy 7). The Chicago Pile-1 design "…consisted of uranium placed in a stack of graphite to make a cube-like frame of fissionable material," (The History of Nuclear Energy 6).

This preliminary experiment is exactly how fission nuclear reactors work even today. Neutrons are used to split heavy elemental particles, whose fragments continue onward splitting

other atoms in the fuel source. Energy.gov explains the process simply when they say nuclear reactors "…contain and control nuclear chain reactions that produce heat through a physical process called fission. That heat is used to make steam that spins a turbine to create electricity," (Nuclear 101). This same article goes on to say that there are currently 450 commercial reactors in service across the globe, with 95 of them within the United States.

From the inception of nuclear power, the direction of its development diverged in two different ways, one path towards using the power as a weapon in the ending years of the Second World War, and the other direction aimed at providing power for citizens in a commercial aspect. In terms of the second goal it is quoted that, "A major goal of nuclear research in the mid-1950s was to show that nuclear energy could produce electricity for commercial use," (The History of Nuclear Energy 8). The United States expanded its nuclear power capabilities rapidly over the ensuing decades, and in 1991 nuclear power plants supplied upwards of 22% of all energy used within our borders (The History of Nuclear Energy 9). In 1991, it was recorded that "One hundred and eleven nuclear powerplants operate in the United States with a combined capacity of 99,673 megawatts," (The History of Nuclear Energy 20). The variation in US operating numbers stems from the opening and closing of nuclear plants across the states, and is also effected on when articles were written. The availability of nuclear powered electricity has expanded over time, and the safety standards of this energy source are continually expanding as well. As seen in The History of Nuclear Energy, The Energy Policy Act of 1992 was enacted to help "…maintain exacting safety and design Standard, to reduce economic risk, reduce regulatory risk, and to establish an effective high-level nuclear waste disposal program," (10).

Nuclear energy has progressed so far in the decades since its inception. There have been over 17,000 reactor years since the dawn of nuclear reactors, with a rector year being defined as

one reactor running for one year, and the number can be combined with all running reactors each year (Safety of Nuclear Power Reactors). All of these reactors running for so long have still yielded only three major failures in the world. These three reactor failures, or meltdowns, were at Three Mile Island in 1979, Chernobyl in 1986, and Fukushima in 2011 (Safety of Nuclear Power Reactors). These three incidents, combined with the fear of nuclear war and disaster that built up during the Cold War, have created such a negative stigma in society against nuclear energy that has largely halted progress and advancements in the field. Despite popular thought, when the facts of these meltdowns are examined it is shown that only one was an uncontained incident. When examining the first meltdown incident on Three Mile Island, the World Nuclear Association tells us that there were no fatalities stemming from the incident, and the radiation that was lost into the atmosphere from the event was very nominal and well below the threshold of radiation levels that can cause an adverse effect in either the environment or the people living nearby. The meltdown was due to faulty equipment, a lack of training for this type of event, and also a lack of systems to indicate reactor status. The meltdown happened because of a malfunction with the cooling pumps, and although system status updates told the crew that certain valves may have been working properly, there was no visual way to tell for sure, which inevitably led to leakage of coolant water and eventually damage to the reactor core. Despite the incident it was contained and threat levels mitigated.

When the Ukrainian Chernobyl incident is examined, we see the only incident of detrimental effects on both humans and the environment directly tied to a nuclear reactor meltdown (World Nuclear Association). Chernobyl is by far the most referenced nuclear power disaster, as many documentaries, movies, and even references in video games have been made after the event. Chernobyl was such a disaster when the nuclear meltdown occurred because

there was a lack of safety procedures for the operating team, and also there was no containment structure for the reactor (Safety of Nuclear Power Reactors). The World Nuclear Association attributes the incident to "…violation of operating procedures and the absence of a safety culture…" (Safety of Nuclear Power Reactors). Since there was no containment structure, when the meltdown and subsequent explosion occurred, radioactive nucleotides and dust were spread far and wide across much of Europe and Russia (Safety of Nuclear Power Reactors). The same site, reports that 56 crewmembers died either during or after the explosion, upwards of 300 first responders had radiation sickness, and 130,000 people received a high dose of radiation in the surrounding area and countries. These 130,000 people continue to be monitored for radiation complexities, such as increased cancer rates, which is being seen today in people who were under 18 at the time and are developing more thyroid cancer than any other cancer type. The meltdown was caused by a mistake in testing, where the crew was trying to see how the reactor would function when there was power loss and low coolant water levels, in case of attack or complications from the Cold War. This incident was by far the most detrimental in terms of nuclear energy drawbacks because of the lack of containment and adverse effects it has left of both people and the environment, which remains uninhabitable today.

The last main nuclear reactor meltdown occurred in Fukushima, Japan, in 2011. This nuclear reactor incident occurred from a loss of power, similar to the reactor in Chernobyl, but this time because of power loss due to an earthquake and corresponding tsunami (Safety of Nuclear Power Reactors). Although there was a meltdown, there was no adverse health effects or environmental problems to follow the reactor meltdowns, which were eventually stabilized (World Nuclear Association). Monitoring of citizens and the environment continues to happen, and although there may be dispute among sources, the World Nuclear Association states that the

radiation levels were contained to the point where no human deaths or environmental effects can be attributed to the meltdown. The world and its governments have learned a lot from these incidents, and there is multiple guidelines and safety rules that have been produced since to help nuclear reactor crews perform a safer job and teach them about safety of containment as well.

Stemming from these incidents we find ourselves looking at the impact nuclear energy has on the environment. One main concern that many people have with nuclear reactors is that the radioactive waste that is produced from the fission reactions will poison the land and the water and that there is no place to properly dispose of it. This simply is not true, as there are rules and regulations put in place so that any radioactive waste will not harm the environment or people when it is disposed of. As a general rule, disposal of this waste is done in three ways, "(1) concentrate and contain (concentrate and isolate the wastes in an appropriate environment); (2) dilute and disperse (dilute to regulatory- acceptable levels and then discharge to the environment); and; (3) delay to decay (allow the radioactive constituents to decay to an acceptable background level)," (Baisden and Choppin). These rules allow for proper waste management and ensure that there is no radioactive or toxic material being dumped into nature where it can prove harmful to the habitats it may be in or the people that may come in contact with it. It is a common misconception that the used fuel rods and toxic waste are just left out to decay, but this is clearly not the case. In fact, nuclear reactors are so efficient, that if you took all nuclear waste that has ever been produced, it would sit on the area equivalent to one football field about 20 feet high (Shellenberger) which does not sound like quite so much when you consider there have been 17,000 reactor years since the dawn of nuclear power.

Where the environment is concerned, nuclear power also has one of the greatest benefits for our planetary climate crisis when compared to alternative power solutions, which is that it

does not expel any carbon dioxide or other greenhouse gas as waste. There is a large push in society today to ween off of fossil fuel usage because of the danger they pose to the environment. Reducing carbon emissions is the talking point of not only climate change activists, but also the talking points of politicians, scientists, and normal citizens alike. Energy sources for society like coal plants and fracking specifically cause lots of greenhouse gas production. Nuclear power plants are different in the sense that the only gaseous product given off during their reaction is steam, or vaporized water. "It is now widely recognized that unless drastic actions are taken to reduce global warming, the world could be heading not only towards reduced growth but also more importantly towards environmental disaster," (Menyah and Wolde-Rufael). Not only will the continued production of greenhouse gases accelerate the rate at which the Earth warms, GDP of many countries is projected to decrease because of the warming climate, with the United States reportedly on track to have GDP decrease by about 25% (Menyah and Wolde-Rufael). A great way to begin our reduction of carbon dioxide production starts at lessening the use of fossil fuels, and using the most efficient alternative energy source, which would be nuclear power. One way in which developed countries are trying to fight climate change is through the passage and adherence to the Kyoto protocol. As referenced by Menyah and Wolde-Rufael, "The Kyoto Protocol places an obligation on all signatories to ensure that GHG emissions in 2012 are not greater than the total of such emissions in 1990. The possible avenues for reduction in GHG emissions include the use renewable and nuclear sources of energy." According to statistical testing with a modified Granger causality test, done by Kojo Menyah and Yemane Wolde-Rufael, it was found that there was a direct causation between increased nuclear and renewable energy production, and the lessening of CO2 rates in our atmosphere, without negative effects to economic growth potential. Therefore, these results give hint that not only can nuclear power, by

far the most efficient alternative energy source, reduce carbon emissions with increased prevalence, but also it will not negatively impact our economy if we begin to switch over from fossil fuel usage.

Nuclear energy has the potential to be a great ally in combatting the climate crisis, yet it is currently being reduced in percentage of power output in the world because of a fear of what can go wrong when using nuclear energy. According to Michael Shellenberger's TED Talk, solar and wind power only provide energy between 10 and 20 percent of the time. According to Ipsos market researching company, a December 2015 survey was done across the world about public opinions on nuclear energy, and it was found that nuclear energy was one of the least popular forms of energy, even showing lower response results than oil for energy production (Shellenberger). When Shellenberger attended an energy conference in China, he found out that not only is nuclear energy declining in favor, but he also found out that funding and research into the development of new and improved nuclear reactors is not being provided at the extent that it is promised. A researcher working on a Thorium reactor stated that they do not have even 1/3 of the budget that they were promised, and they also have not been receiving data on nuclear reacting testing from the US Department of Energy which they were promised (Shellenberger). Over the last 10 years, energy produced from nuclear reactors has declined about 7 percent across the world, and solar and wind power has barely made up half of that loss because of its inefficiency (Shellenberger). The power grid and the electricity that our societies demand to continue running and progressing and advancing socially, is too great for solar and wind power to be a dependable way in which power is created. After the Fukushima disaster in Japan, they deactivated all nuclear reactors in the country (Suzuki et al.). This move led to the power supply

being replaced with fossil fuel programs, which has in turn even increased the price of power in the country (Suzuki et al).

Nuclear energy has become increasingly safe for use, and a study by British journal "Lancet" reported that despite the accidents that have been seen across the world, whether it be the three major incidents or smaller issues at power plants, nuclear energy is still the most reliable and safe way to produce power in society (Shellenberger). Not only is nuclear energy the safest form of electricity and energy production, but it is by far the most efficient as well. According to Mike Mueller, Senior Digital Content Strategist at the Office of Energy Efficiency & Renewable Energy, nuclear power plants by far have the highest capacity factor of any energy source at 93.5%. This means that over 93% of the time, a nuclear power plant is producing maximum possible energy output. Natural gas comes next at only 56.8%, coal at 47.5%, hydropower at 39.1%, wind power at 34.8%, and solar power producing maximum energy output at a mere 24.5% of the time it is in operation (Mueller). Nuclear power plants can run for a longer period of time without refueling in comparison to other energy sources, and also is designed to need less maintenance (Mueller). Based on the statistics of power output and how efficient each energy source is, to attain the same power output of one nuclear power reactor, you would need at least 2 coal power plants or up to 4 renewable power plants with a large storage housing for power, which is currently unavailable, to replace the energy made and able to be used by a nuclear plant (Mueller).

Nuclear energy was on the forefront of development and progress in many countries around the world for decades. It has the potential to reduce fossil fuel consumption and usage all around the globe. These nuclear reactors are very efficient, produce little radioactive waste, and most importantly only give off steam into the atmosphere rather than harmful greenhouse gases

that contribute to the increased rate of global warming that we find ourselves struggling to rectify. However, nuclear power plants have the potential to do much more good than solely limiting carbon dioxide releases into the air.

Tiny atoms provide so much for our lives that we mainly never hear about. According to the Nuclear Energy Institute, nuclear reactors provide a form of national security on top of just a power source. Nuclear reactors allow the US to maintain a position of power globally, because of our influence and knowledge of the topic, it provides a resilient electrical grid back in the states that rarely ever must be shut down or stopped, and also powers many ships within our navy (What is Nuclear Energy?). On top of these things, nuclear power helps maintain our military strength in the world because of the weapons and technology we have created using it. NEI also states that nuclear reactors produce carbon-free electricity 24 hours a day, 7 days a week, which is now irreplaceable in terms of renewable energy and clean energy production (What is Nuclear Energy?). On top of these things, nuclear energy and the knowledge of it, ensures that the United States remains at the forefront of technology production as we progress farther and farther with it, and nuclear energy offers reliability that many other energy options do not by running for 18-24 months at a time without stopping (What is Nuclear Energy?).

Another significant aspect of nuclear power usage is the jobs it inevitably creates for the workforce. Especially in a time of slight recession and job loss due to this year's coronavirus pandemic, the creation of more jobs is a necessity whether it be operators of the reactor, safety staff, management, or even those who industrialize and make parts for the reactors (What is Nuclear Energy?). And finally, nuclear energy protects our air, boosts international development of lower income countries by helping them attain sustainable energy goals, and even relates to

electric cars and the powering of such vehicles, as nuclear energy interconnects with all other types of clean energy (What is Nuclear Energy?).

In a world where climate crisis is a term heard almost daily, and there is a large push to eliminate the use of fossil fuels, we as a world must turn our attention to a new energy source, one which is cleaner and more reliable than any other option of energy production. Nuclear energy is by far the most efficient source of energy production, outcompeting even current fossil fuels which much of the world still uses. It is almost 4 times as efficient as a renewable energy source like solar or wind power, and has been tested and tried for decades. The reason there is such little proliferation of nuclear power in the world today is mainly due to social stigmas. People are afraid of its association with nuclear weapons, remember the 3 major disasters associated with nuclear reactor meltdowns, and also question what to do with the radioactive waste. However, these concerns have been addressed by scientists, political leaders, and engineers since the dawn of nuclear power. As times have gone on, we have learned more about how to control a reactor and the fission within, and have developed safety standard with margins so great that a meltdown and devastating effect is highly improbable. In Michael Shellenberger's words, "…the World Health Organization finds the same thing: the vast majority of harm is caused by people panicking, and they're panicking because they're afraid. In other words, the harm that's caused isn't actually caused by the machines or the radiation. It's caused by our fears, (Shellenberger). The nuclear disasters that have happened at Three Mile Island, Chernobyl, and Fukushima could have been prevented with better monitoring equipment, and better training for staff. Both of these things have been developed over time. Although there are other minor problems in smaller reactor sites, out of 17,000 reactor years there has only been these 3 major events that scare the public away from nuclear power, and 2/3 of these events were

contained to the point where no harm was done to the surrounding ecosystem or population of humans. Nuclear reactors have developed an incredible amount since their inception in the 1940s. They are safer, more reliable, and extremely more efficient than competing energy alternatives. They boost the economy and security of the United States, keep us at the forefront of innovation and world development, and also helps our environment. With the current disposal methods of nuclear waste, and the horizon ahead of space travel and possibly exporting waste into the vacuum of space, our worries diminish by the day. We must trust the scientists and professionals, and move to this clean energy source as a means of protecting our environment, weening away from fossil fuels, and hopefully curbing climate change.

Bibliography

Baisden, Patricia A., and Choppin Gregory R. "Nuclear waste management and the nuclear fuel cycle." Radiochemistry and Nuclear Chemistry (2007): 1-63.

This article discusses how nuclear and radioactive waste is currently handled and disposed of in society. There are rules and regulations as to how to dispose of this waste, and this article can help me address the nature aspect of my research.

Menyah, Kojo, and Yemane Wolde-Rufael. "CO2 Emissions, Nuclear Energy, Renewable Energy and Economic Growth in the US." Energy Policy, Elsevier, 2 Feb. 2010, www.sciencedirect.com/science/article/pii/S0301421510000303?casa_token=VmvZoNulbCcAAAAA:4ysvNO9E-Ca3O7dsWfs4hlfNFmGBSp8FOUHEkofCd_jT4-0dsOiu7a7kmeeFlZCP9b6CNQ-AAA.

This article discusses the trends of carbon dioxide emissions in comparison to the rising prevalence of nuclear and renewable energy from 1960-2007. It was found that there was a direct causation between more nuclear and renewable energy production and the lessening of CO2 rates in our atmosphere.

Mueller, Mike. "Nuclear Power Is the Most Reliable Energy Source and It's Not Even Close." Energy.gov, www.energy.gov/ne/articles/nuclear-power-most-reliable-energy-source-and-its-not-even-close.

Mike Mueller talks about the efficiency of nuclear energy in today's society as compared to other forms of energy, almost doubling the efficiency of natural gas and coal sources, and providing 3.5 times more power than wind and solar power plants. He also shows how nuclear

energy has been supplying a fifth of America's power and details why these power plants may be more dependable.

"NUCLEAR 101: How Does a Nuclear Reactor Work?" Energy.gov, www.energy.gov/ne/articles/nuclear-101-how-does-nuclear-reactor-work.

This article is a basic publication on the energy.gov wensite that explains how a nuclear eactor works. It gives insight to the reader about how fission reactions take place, and shows how we go from an atom to electricity in the power grid.

"Safety of Nuclear Power Reactors." Safety of Nuclear Reactors - World Nuclear Association, www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx.

This article from the World Nuclear Association gives perspective as to how safe a nuclear energy plant truly is. Since its inception there have been 17,000 reactor years, one reactor running for one year. Between all of these reactors running simultaneously for so long, there have only been 3 singular incidents that deter people from moving forward with more nuclear energy in the world.

Shellenberger, Michael. "How Fear of Nuclear Power Is Hurting the Environment." TED, www.ted.com/talks/michael_shellenberger_how_fear_of_nuclear_power_is_hurting_the_environment#t-797755.

This TED talk has to do with the negative connotations that society all over the world has about nuclear energy. Society is withholding the resources needed to expand the prevalence of this energy source based on fear that should not be so warranted in today's society. New

developments in safety and efficiency cannot even be made because researchers that are promised money by the UN are never even given what they are promised.

Suzuki, Tatsujiro. et al. "Aiming at a Low Carbon Society in Japan by 2050 : Impact of the Fukushima Nuclear Accident and CO 2 Reduction Target." Economics of Energy & Environmental Policy, vol. 5, no. 1, 2016, p. 89. EBSCOhost, search.ebscohost.com /login.aspx?direct=true&db=edsjsr&AN=edsjsr.26189400&site=eds-live&scope=site.

This article discusses the effects that have been seen in Japan following the nuclear disaster in 2011 at Fukushima. From 2013 to 2015 there was not a single nuclear reactor running anymore because of governmental, and public fear, causing fossil fuels to take their place and energy prices to rise.

"U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." U.S. Nuclear Industry - U.S. Energy Information Administration (EIA), www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php.

This article discusses the prevalence of nuclear power plants in America. It talks about how many reactors there are in the United States, despite what the public may think, and how much these reactors contrinute to our every day lives.

"What Is Nuclear Energy?" Nuclear Energy Institute, 22 Nov. 2019, www.nei.org/fundamentals/what-is-nuclear-energy

While not directly forming with one of my disciplines, this article discusses the benefits of nuclear energy that extend beyond carbon free energy. As per the article, "Nuclear powers space exploration, sterilizes medical equipment, provides potable water through desalination, supplies

radioisotopes for cancer treatment and much more." This article shows many benefits that come along to society with this clean energy, and I can use it in my discussion of how to possibly alter the views of people in said society.

The History of Nuclear Energy. U.S. Dept. of Energy, Office of Nuclear Energy, Science and Technology, 1985.

This is a pamphlet/ book produced by the US Department of Energy which describes the history of nuclear power and how it became integrated into the world we know today. The pamphlet discusses how nuclear energy was developed and by whom, gives insight into the workings of a nuclear fission reaction, and then tells how nuclear energy has been integrated into and used in society in the decades since.