The Key to a Sustainable Future: Why Nuclear Power Matters

Exordium

On November 22, 2022, the National Aeronautics and Space Administration released an article that states that “Humans have caused major climate changes to happen already, and we have set in motion more changes still.” In addition, they predicted that there is a time between “what we do and when we feel it,” but the time we have is “less than a decade.” (NASA, 2022) In 2016, 194 parties across the world joined the United Nations “Paris Agreement”. This agreement would ensure that nations abided by the goal to “substantially reduce global greenhouse gas emissions to limit the global temperature increase in this century to 2 degrees Celsius while pursuing efforts to limit the increase even further to 1.5 degrees.” (United Nations, 2016) Scientists used this margin as a threshold which the Intergovernmental Panel on Climate Change (IPCC) said must have, “no or limited overshoot.” (IPCC, 2022) According to the United Nations Secretary-General, in accordance with the IPCC's 2022 climate report, “We are on a pathway to global warming of more than double the 1.5-degree (Celsius, or 2.7-degrees Fahrenheit) limit.” (United Nations, 2022). But where does the root of these greenhouse gasses come from? The U.S Energy Information Administration (EIA) collected preliminary data through the Monthly Energy Review for carbon dioxide (C02) emissions by each energy sector

in the United States. The data found that the coal sector releases 59% of emissions, and natural gasses release 40% of emissions. These two sectors account for more than 99% of all C02 emissions. To reduce greenhouse gasses and reverse the effects of climate change, we must begin

to implement substitutes for traditional means of generating electricity (coal & natural gasses). Renewable energies are not capable of producing enough energy to offset the reduction of these greenhouses' gasses. However, through my research, I have determined that nuclear power may be able to. Nuclear power is beneficial for the environment, is spatially friendly, creates reliable energy, and strict regulations ensure its safety in populated areas. Therefore, nuclear Power is the best source of energy for the future, and we should persuade government officials around the world to promote and fund the implementation of power plants as well as research into developing new generation reactors to reverse the effects of climate change. **Narration**

Nuclear power is defined as "electricity generated by power plants that derive their heat from fission in a nuclear reactor" (Martin). Throughout the late 1930s and early 1940s, the creation of nuclear power derived from the discovery of harnessing nuclear fission. This was first discovered by scientists Otto Hahn and Fritz Strassmann in 1939 when they found that nuclear fission "not only released a lot of energy but that it also released additional neutrons which could cause fission in other uranium nuclei and possibly a self-sustaining chain reaction"(WNA). The process of fission, defined by the writers of the Massachusetts Institute of Technologies Nuclear Reactor Laboratory's article, "The Fission Process", states that in the nucleus of each atom of Uranium-235, there are 92 protons and 143 neutrons. As the Uranium-235 collides with neutrons, it splits into two lighter nuclei and releases two to three neutrons, which continues the chain reaction. Using this concept, scientists were able to generate electricity using a nuclear

reactor on September 3, 1948. According to the Office of Nuclear Energy, the purpose of a nuclear reactor is to "house" the chain reaction. Reactors use fuel rods, a material made up of uranium. Some 200 uranium rods bundle together forming a "fuel assembly"; Water submerges

the fuel rods acting as a “moderator for the neutrons”, which can be manipulated with control rods, reducing the reaction rate (Office of Nuclear Energy, 2022). By 1958, the United States opened its first commercial power plant, the Shippingport Atomic Power Station. However, the public fear of nuclear power grew after the incidents in Three Mile Island in 1979 and Chornobyl in 1986. On March 28, 1979, an operating plant in Harrisburg, Pennsylvania malfunctioned due to both mechanical and human errors. The incident occurred when a valve in the major cooling system failed to close. This caused the reactor to overheat, leading the control rods to partially melt. Though there were no immediate injuries or deaths, small amounts of radioactive gas seeped into the atmosphere and this meltdown is considered the worst nuclear power incident in the United States, and one of the worst in the world (HISTORY, 2018). Seven years later, on April 26, 1986, a surge of energy during a system test destroyed the Unit of the Chornobyl nuclear power station. The incident resulted in a fire that release copious amounts of radioactive material into the atmosphere. In addition, officials were forced to close off 18 miles of area and evacuate over 300 thousand people over the next coming years (U.S.NRC, 2022). While the United Nations predicts that only 50 deaths can be attributed to the effects of this incident, data points to indirect deaths spanning well over 100 thousand from both children exposed in a nearby radius, to clean-up workers (Nesterenko, 2009). However, throughout the early 21st century, public opinion began to sway back in favor of nuclear power as 62% of people favored the use of nuclear energy as one of the ways to provide electricity for the U.S. (Statista). However, public opinion once again changed after the Fukushima nuclear incident in 2011. On

March 11, 2011, a magnitude 9.0 earthquake occurred in the city of Sendai. This earthquake was picked up by the plant and automatically shut down the reactors, enabling the emergency

generators. Unfortunately, the earthquake caused a tsunami that crashed into the plant knocking out these generators. These generators overheated and exploded, allowing radioactive material to leak into the atmosphere (BBC, 2021). As of 2022, 437 reactors are operational today, but despite strict regulations and intensive safety measures designed for plants, the nuclear power debate will influence if there are more power plants or not.

Partition

Nuclear Power is the best source of energy currently available to protect the future from the effects of climate. In addition, we should persuade government officials around the world to promote and fund the implementation of power plants as well as research into developing new generation reactors that produce energy efficiently and more cost-effectively. First off, nuclear power plants are the cleanest source of energy, which is crucial for reducing greenhouse gasses. Furthermore, nuclear power plants are very spatially friendly and can be built on most of the land in the world. On top of that, nuclear power plants produce a lot of energy in a manner that is extremely reliable and efficient.

Confirmation

Reason #1

Nuclear power plants produce clean energy, in terms of carbon dioxide emissions and waste management, which is crucial in reducing the effects of climate change. According to the World Nuclear Association (WNA), the process of nuclear fission that occurs within the nuclear reactor produces zero carbon emissions (WNA, 2022). Although the process of mining and refining uranium ore causes 29 tons of CO2 per gigawatt hour (GWh) of energy to be released,

40% of these emissions are released due to the burning of fossil fuels to generate electricity

(WNA, 2022). In addition, other clean energies such as solar, wind, and hydroelectric power also produce about 10-40 g CO_2 per kWh of electricity (Time for Change, 2015). This means that no alternative energy is completely clean. The National Energy Institution reported that the use of nuclear power plants has avoided the release of 60.28 million short tons of sulfur dioxide, 24.95 million short tons of nitrous oxides, and 16.72 billion short tons of carbon dioxide into the atmosphere since 1995 (NEI, 2022). Moreover, the U.S Energy Information Administration (EIA), an agency that collects, analyzes, and disseminates energy information, reported that nuclear energy makes up 18.9% of the total annual electricity generation in the United States, and 10.1% of the energy generated worldwide (EIA, 2022). Despite how small the nuclear sector takes up; it creates a very clear and positive impact on the environment.

Contrary to common conception, nuclear power produces very limited waste, which most of the time is recyclable, and can be safely stored when still toxic. According to the Office of Nuclear Energy, the United States produces about 2000 metric tons of waste a year (Office of Nuclear Energy, 2022). “Waste”, in this case, refers to the amount of fuel discharged from the nuclear reactor. To put this number into perspective, data collected by the EIA found that all waste produced by the U.S. nuclear sector since 1960 could fit onto a football field with a depth of under ten yards (Office of Nuclear Energy, 2022). This is attributed to the fact nuclear waste is very dense and can be reprocessed and recycled. In addition, the energy produced by a single uranium pellet with a height of one inch is equivalent to 17,000 cubic feet of natural gas, 120 gallons of oil, and 1 ton of coal (EIA, 2022). This means that nuclear power produces less waste with the same amount of energy production. Furthermore, most waste is not only safe to store but most can be reprocessed and recycled for reuse. According to the WNA, are three types of

nuclear waste: Low-level, Intermediate-level, and High-level waste. Of all waste produced, 90% is attributed to Low-level waste, and 7% is attributed to Intermediate-level waste, which accounts for 5% of all radioactivity, meaning that most waste produced by a nuclear power plant is not highly dangerous (WNA, 2021). High-level waste is very minuscule in comparison. From a 1000-megawatt nuclear power plant, only about 2000 metric tons, or about 3 cubic meters of high-level waste is produced a year. When compared to a 1000-megawatt coal-powered plant, about 300,000 tons of ash and 6 million tons of carbon dioxide are released a year (WNA, 2021). In addition, the WNA stated that "approximately 97%" of spent fuel "could be used as fuel" in different types of nuclear reactors. High-level waste which cannot be recycled is safely stored in water pools or dry storage casks. While the United States recognizes that these are not permanent solutions, this system in the last decade due to how little waste is produced (EIA, 2022). While many countries do not participate in the recycling of spent fuel, it proves how nuclear power limits the amount of waste in the environment.

Nuclear power is also safe for plant workers and civilians that live in proximity to a plant. Since 1960, a total of fifty nuclear power plant employees have died as a direct result of nuclear power operations (EP, 2019). In contrast, from 2005 to 2016, coal power plants were the cause of an estimated 329, 417 premature deaths. There is also no evidence to support that people who live at close distances to power plants may be exposed to large amounts of radiation. Living near a nuclear power plant exposes you to approximately 1 mrem of radiation (University of Michigan, 2021). To compare, radon in the average United States household (with no proximity to a nuclear power plant) exposes 228 mrem of radiation. To emphasize this safety, the United States enacted the Price-Anderson Act. Lawmakers must propose strategies to fund and implement nuclear power plants to reduce the harmful effects of climate change. Nuclear power,

though not perfect, does help reduce the number of greenhouses emitted into the atmosphere. In addition, it creates very little waste, which is good for the health of the environment, and it produces energy in a very small

Reason #2

Nuclear power is also very geospatially friendly and can be built and operated in most areas of the world. Due to how geographically different regions are across the world, an energy source must be able to perform efficiently in any climate, environment, or weather. The most common reactor in the United States is the Pressurized-Water Reactor. With this reactor, nuclear fission heats water in the core, which is pumped to a separate water source, creating steam. This steam spins a turbine and an electric generator to produce electricity (U.S NRC, 2015). This reactor allows coastal regions with bodies of water to operate and regulate nuclear power plants safely and efficiently. In addition, dry regions also may use pressurized-water reactors despite the lack of natural bodies of water. The Palo Verde power plant, located in Arizona primarily relies on "municipal wastewater" versus a natural body of water (WIRED, 2022). Today, nuclear power plants are operational in 32 countries across the world, in nearly every type of climate with additional plants in Turkey and Egypt currently being constructed. These power plants come from every continent but Australia and Antarctica (WNA, 2021). Because it spans a vast number of regions, nuclear power is very clearly operational in different types of climates. In contrast, many other types of energy cannot be used in different geospatial regions as they are too dependent on weather. For example, solar power is a very prominent source of renewable energy. However, "not all locations get the same amount of annual sunlight", so the effectiveness of solar power heavily differs based on the distance a region is from the equator (Sawrey, 2022).

inefficient than regions in equatorial regions. Geothermal energy is another example of an energy source that is geospatially constrained. Geothermal reservoirs must be “above 100C” for most large geothermal plants. In addition, these reservoirs are only located in very “specific locations” which are usually around tectonic plates (EnergySage, 2021). This requires a large sum of money to finance “research” as well as the “identification process” of finding a suitable location (Bhatta, 2021). Wind power also is constrained by weather factors. The most preferable sites to house wind farms are in very specific locations. Wind patterns vary greatly across different regions, and even during different seasons within those regions (Lott 2015). Wind energy is “intermittent”, meaning it is disrupted by the “inconsistencies of wind” (Just Energy, 2022). These factors make wind energy too inconsistent between regions.

Nuclear power plants are also very land efficient and contribute a small spatial impact on the surrounding environment. According to the NEI, a 1000-megawatt nuclear plant needs only about one square mile of land (NEI, 2015). When compared to wind farms, data from the NEI reports that nuclear power produces the same amount of power in 0.27% of space (Office of Nuclear Energy, 2021). Moreover, solar photovoltaics, the most prominent type of solar facility, require over 75 times the amount of land area to produce the same output as nuclear plants (NEI, 2015). Although renewable energy such as solar, wind, and geothermal also reduce carbon emissions caused by greenhouse gasses, the climate and weather make the efficiency of these energy sources unpredictable. This is a problem, especially in regions which don’t get a lot of sun or wind. To have a reliable energy source for the future, it must be accessible for most if not all countries in the world.

Reason #3

Finally, nuclear power is also able to produce massive amounts of energy very reliably and efficiently. This provides countries across the world with substantial amounts of energy. Globally, there are actively 427 nuclear power plants in operation, based on data gathered by the International Atomic Energy Agency. The plants, combined, retained a net capacity (the maximum output of energy a plant can produce) of 382,796 megawatts electric (MWE), which will further be explained later. Nuclear power in the United States produced about 97.78 quadrillion British thermal units (28.65 trillion kilowatts-hour) of energy (EIA, 2022). This energy is used to create electricity that powers things like air conditioning, water heating, appliances, and lighting in millions of homes across the United States (Directenergy, 2022). Additionally, thirteen different countries produced at least 25% of their using nuclear power, such as France, which consumes over 70% of its electricity from nuclear power (WNA, 2022). Nuclear power plants are also the most reliable plants in terms of producing consistent energy. This is because nuclear power has the highest capacity factor, the measure of how efficiently and reliably a plant produces energy. According to the United States Office of Nuclear Energy, the agency in charge of gathering and analyzing research about nuclear power, nuclear power plants are producing at a capacity factor of 92%. This means that nuclear power is efficiently producing energy for 92% of the year. This is nearly two times more than natural gas and coal units, and nearly three times more reliable than solar and wind plants (Office of Nuclear Energy, 2021). Furthermore, the average global load factor availability of pressurized-water reactors over the last 40 years operated at about 75%, meaning that the pressurized-water reactors had only used about 75% of their maximum output (IMechE, 2009). However, as of 2009, nuclear energy companies began to operate pressurized-water reactors much more efficiently, producing at a

load factor of 83%. This means that a reactor that's purpose was to be a cheaper, more

environmentally friendly option produces an output that is still greater than the next energy source (geothermal ~ 74.3%) (EIA, 2022).

Nuclear power plants were also designed to run over long periods with little to no maintenance. The reason we see such a high-capacity factor is that nuclear power plants require very little maintenance. Plants can run without refueling for about one and a half to two years (Office of Nuclear Energy, 2021). Nuclear power plants are also able to run all day every day to provide consistent electricity. A nuclear power plant was designed to safely operate for about 40 years before it needs major repairs (Seacoast Anti-Pollution League). In comparison, photovoltaic cells in solar farms last for about 20 years until it needs a replacement (National Geographic). Solar farms usually only last around 30 and up to 40 years with proper maintenance (Kami, 2022). It is also unknown how long wind turbines last. Lisa Linowes, a director for the WindAction Group, stated that "We don't know with certainty the life spans of current turbines." However, it is estimated that these turbines may last up to 20 to 25 years until major repairs are needed (Phillips, 2022).

Additionally, Nuclear power today primarily runs on a fuel called low-enriched uranium (LEU). At current rates of production, LEU would be able to power reactors for around 200 years (Fetter, 2009). However, to match total energy output across all sectors, LEU would only last 70 years, neglecting factors like changes in energy usage (Baez, 2010). In this respect, it is hard to see how this can be a long-term solution. However, the solution to this issue is with thorium reactors. Thorium reactors are a form of nuclear energy fueled by the uranium-233 isotope that comes from the element, Thorium (Gaille, 2018). Furthermore, using thorium in

nuclear power is beneficial because it takes away “Uranium Enrichment”, the most "dangerous and risky" process in nuclear power (Gaille, 2018); she also states that thorium is very abundant

and cheaper to extract. By implementing thorium reactors, the need for coal and natural gas powered plants may decrease, which would reduce carbon emissions, but would also be a sustainable and reliable source of fuel for many years.

The assumption made is that governments want to solely focus on energy production when regarding choices made on what energy source to implement. This is logical because consistent and reliable energy production is necessary to power everything that requires electricity. Although coal and natural gas power is produced at a very low cost, this data shows that nuclear power, in addition to being very environmentally friendly, can also provide a lot of power very consistently over a substantial period.

Refutation

Green America is an organization that informs its readers about sustainable living and eco-friendly options. They believe that nuclear power should seize production and not be used to reduce the climate change issue because the risk of running a plant is too dangerous, nuclear waste is generated from plants and is toxic to the environment, and the plants increase the chances of cancer. The author claims that nuclear accidents are caused to stop production. For example, the author refers to “The accident in Three Mile Island in 1979, the Chernobyl accident that occurred on 26 April 1986” as well as “the Chernobyl Nuclear Power Plant in Ukraine” which “was the worst nuclear accident in history.” Not only are there few details provided about these incidents, including the causes of each explosion, but it is also a hasty generalization. Though there were three incidents of nuclear meltdowns, the claim to stop the operations of

plants is irrational because increased safety measures prevent any future risk of a meltdown of this caliber. For context, according to Britannica, tsunami waves caused by March 11, 2011, earthquake caused the reactor cooling systems to malfunction, leading to a meltdown.

Government officials then evacuated “over 47,000 residents” living within a 20 km radius of the plant (Munro, 2018). The nuclear power plant was built on top of a fault line that is prone to earthquakes, in addition, the plant could have been safely shut down by putting the control rods back. Regarding Chornobyl, according to the Nuclear Regulatory Commission, “The Chernobyl reactors, called RBMKs, were high-powered reactors that used graphite to help maintain the chain reaction and cooled the reactor cores with water.” This type of reactor is no longer in use and an event like this could not possibly happen on any current reactor, especially not a generation IV reactor (an improved reactor that is in development).

Additionally, the states that “There are no long-term storage solutions for radioactive waste.” Because of this, there is potential harm to the environment. Again, there is no data to provide information on how much nuclear waste is produced, how much of it is toxic, or how much storage there is. The author uses an appeal to ignorance to describe that nuclear power generates extreme amounts of highly radioactive waste, which is a falsehood that appeals to the common understanding. Nuclear power produces the least waste out of all energy sectors (U.S Department of Energy, 2021). As stated earlier in the argument, Uranium fuel is "extremely energy dense" and one pellet of uranium waste is the energy equivalent of 17,000 cubic feet of natural gas, 120 gallons of oil, and 1 ton of coal (Department of Energy, 2021). Furthermore, safe modes of storage, such as dry casks and water pools can hold enough non-recyclable waste, are in use, and can last many decades, taking up very little space (EIA, 2022).

The final argument the source used was that nuclear power increases the risks of cancer. For example, it is stated that "significant risk of cancer associated with fallout from nuclear disasters, studies also show an increased risk for those who reside near a nuclear power plant, especially for childhood cancers such as leukemia." The source again fails to back up its claim

with empirical data connecting this claim. In addition, the author uses a slippery slope to conclude that nuclear power causes cancer. However, the grounds they use state that it was "fallout from nuclear disasters" while not nuclear power plants themselves, which is very misleading for the reader. Nuclear meltdowns release abundant amounts of radiation into the environment which does increase the likelihood of cancer, but stable, properly functioning plants do not. As stated earlier, nuclear power plants have almost no impact on radiation exposure to nearby people. According to data collected by the Energy Protection Agency in 2018, living near a nuclear power plant causes 1 millirem (a measure of radiation) of exposure to a person. In perspective, 228 mrem are produced from radon in the average US home, 29 mrem are produced from natural radioactivity in the body, and 10 mrem are produced by 1 chest x-ray procedure (University of Michigan, 2021).

Peroration

Nuclear energy is by no means perfect, but to reduce the effects of climate change, now is the time to act and currently, nuclear power is by far the best option. This is because it has a massive impact on carbon dioxide reduction, has a very limited impact on the surrounding environment, and creates sustainable and reliable energy that can be used to power a massive amount of electricity. Misconceptions and dismay revolving around nuclear power have been quite harmful and must be changed to begin implementing this solution seamlessly. While

legislation has been passed to help reduction of carbon dioxide emissions into the atmosphere, more must be done to sustain our future in the long run, especially beyond the federal government. Other governments must also begin to implement nuclear power plants, especially in countries with high-carbon output. Action must be taken to quickly implement the best solution to the climate crisis, and that is nuclear.

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