"In Hot Water: Solving Global Warming with Nuclear Energy"

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"Nuclear power is one hell of a way to boil water."

-Albert Einstein

Amid battling climate change, the world is transitioning from disastrous fossil fuels to new sources of power. While renewable energy sources like solar, wind, and hydroelectric power are long-lasting, they are still inefficient, unreliable, and expensive. Time is running out before irreversible damage from climate change is done to the Earth, but in their current state, renewable energies are not our savior. As Einstein understood, nuclear power needs to be the primary energy source of the United States because it is clean, efficient, and safe; it is a solution to our search for a sustainable energy source and will save the Earth from the effects of global warming and pollution, so Americans should push politicians to advocate for nuclear energy.

In most power plants, a turbine spins to generate electricity. Nuclear energy, like fossil fuels, uses its energy to heat water, creating steam to turn the turbine; however, nuclear power does not burn anything to create steam, meaning that no carbon emissions are being released into the atmosphere. Instead, nuclear power uses a process called fission. *The Oxford English Dictionary* defines nuclear fission as "the splitting, either spontaneously or under the impact of another particle, of a heavy nucleus into two (very rarely three or more) approximately equal parts, with resulting release of large amounts of energy." In nuclear power plants, uranium atoms are bombarded with neutrons, splitting them in two, releasing more neutrons and creating a chain reaction (Nuclear Energy Institute, n.d.). "Control rods," defined by *The Oxford English Dictionary* as rods that can be inserted into and withdrawn from a nuclear reactor to control the neutron flux, and therefore the rate of the reaction, absorb neutrons to maintain control of the chain reaction. Nuclear fission releases the energy of the uranium in the form of heat, which boils water at temperatures near 520 degrees Fahrenheit (Union of Concerned Scientists, 2014). The steam generated by boiling water spins a turbine connected to generators, producing electricity. Uranium is the heaviest and largest atom, with 92 protons; because of their size, the atomic forces holding the nucleus of a uranium atom together are relatively weak, making uranium efficient for nuclear fission (Union of Concerned Scientists, 2014).

According to the Union of Concerned Scientists the core of a nuclear reactor consists of a reactor vessel, housing the twelve foot long uranium, fuel rods, control rods, and water. This vessel is made of a zirconium alloy because of its resistance to corrosion and low neutron absorption. Pipes flow in and out of the vessel to release steam and pump water back onto the vessel. This whole contraption is surrounded by a thick, concrete containment structure. The United States uses two types of "light water" reactors. Most reactors are pressurized water reactors (PWR); the rest are boiling water reactors (BWR). In BWRs, the water directly in the vessel is boiled and sent through pipes to turn the turbine, generating electricity. This steam is condensed back into liquid water using cool water and is pumped back into the vessel. The cooling water is either sourced from a river or ocean or is circulated through cooling towers to have a continuous flow of cool water. The white smoke seen exiting the large cooling towers, often associated with nuclear power plants, is condensation, so no harmful gasses are being emitted into the atmosphere (Union of Concerned Scientists, 2014). In PWRs, the water within the core is held under pressure to prevent the water from boiling. The heat is transferred outside of the reactor core with a heat exchanger and boils water in a separate container, creating steam to produce electricity. This design is preferred because the water that is boiled is separate from the fission as to not irradiate it (Union of Concerned Scientists, 2014). Some foreign reactors use coolants other than water to condense the steam. Canadian reactors use "heavy water," water loaded with a stable isotope of hydrogen, deuterium, as their coolant; other reactors use gasses like helium as a coolant. Very few reactors use liquid metal or sodium (Union of Concerned Scientists, 2014).

Nuclear power is clean and has the potential to diminish the release of carbon emissions into the environment. This is clear from the current nuclear power effects on the environment. Prăvălie and Bandoc (2017) state that nuclear power is estimated to prevent 1.2-2.4 gigatons of carbon dioxide from being released into the atmosphere annually. Additionally, nuclear power was labeled a low-carbon technology by the Intergovernmental Panel on Climate Change in 2013. The emissions of nuclear power, over its entire life cycle, are comparable to that of renewable energy; it is estimated that the average quantity of carbon dioxide emission per unit of power generated is 15gCO_2/kW, which is comparable to that of wind power and is roughly 30/50/70 times lower than that of gas, oil, and coal respectively (Prăvălie and Bandoc, 2017). Currently, nuclear power accounts for 20% of the US power generation and accounts for almost all the low-carbon and pollutant-free dispatchable power (Roth and Jaramillo, 2017). This shows that nuclear power is clean, but to decarbonize and stop global warming, significant investments need to be made into nuclear power; the production of nuclear power would need to nearly triple current levels. This is achievable by investing more into creating nuclear power plants and replacing fossil fuel power plants.

Not only is nuclear power on par with the low carbon emissions of renewable energy, but it is also far more efficient and reliable. Nuclear power has the highest capacity factor of any other form of power currently available. The Office of Nuclear Energy (2020) defines a power source's capacity factor as the ratio of the actual energy output over a given period to the maximum possible energy output over that given time. Nuclear power has a capacity factor of 93.5%, beating out all other energy sources: natural gas (56.8%), coal (47.5%), hydropower (39.1%), wind (34.8%), solar (24.5%) (Office of Nuclear Energy, 2020). This means nuclear powerplants produce at maximum power for 93.5% of the year, almost triple that of renewable energy. Nuclear power is more efficient because it requires less maintenance and refueling than natural gas or coal power plants. Renewable energy is limited by its availability of fuel; the sun is not always shining, and dirt, dust, and other debris builds-up on solar panels often. In wind energy, the wind is not always blowing, and, as evident by recent events in Texas, wind turbines can easily freeze up and break. Dams that produce hydroelectric power do not always release water. The Office of Nuclear Energy (2020) states that a 1 gigawatt (GW) nuclear powerplant cannot be replaced by one 1GW coal power plant; based on capacity factors, almost two coal or three to four renewable plants of 1GW each in size would be required to produce the same amount of energy.

Clean and efficient energy means nothing if it cannot be sustained. One of the main reasons the world is trying to turn away from using fossil fuels for energy is because it is a limited, non-renewable resource. Nuclear energy is not considered renewable, because fuel rods are depleted of energy and must be replaced. This means that there will be less fuel for continued use. According to the World Nuclear Association (2020), the world has about 6,147,800 tons of recoverable uranium. The world's nuclear reactors use about 67,500 tons of uranium per year, meaning there are roughly ninety years of Uranium fuel currently available (World Nuclear Association, 2020). While this may seem like such a short time, there are ways to increase the longevity of nuclear power. Primarily, uranium and plutonium can be recycled. Plutonium can be recycled easily as Mixed Oxide (MOX) fuel; additionally, reprocessed uranium can be recycled to generate enriched Advanced Gas-cooled Reactor (AGR) fuel to be used directly in nuclear power reactors (World Nuclear Association, 2020). Additionally, depleted uranium can be re-enriched as a future resource in fast neuron reactors or mixed with the MOX fuel from recycling plutonium; the efficiency of this process can be improved by utilizing enriching plants to produce natural uranium equivalent while recycling and re-enriching spent fuel save thousands of tons of fuel at current rates (World Nuclear Association, 2020).

The true sustainability of nuclear power lies in the future of nuclear power. Currently, uranium is the only fuel used in nuclear reactors; however, the World Nuclear Association (2020) states that thorium can be used in Canadian Deuterium Uranium (CANDU) reactors and reactors specifically designed for this purpose. Thorium can be used in a full reactor cycle if a fissile material such as uranium (U-235) or plutonium (Pu-239) is used to start the reaction. Thorium (Th-232) then captures a neuron to become fissile uranium (U-233) to continue the reaction. The World Nuclear Association (2020) adds, thorium is more sustainable than uranium, as it is roughly three times as abundant in the Earth’s crust. Slightly further in the future, the Nuclear Energy Institute (n.d.) states that next-gen reactors will be more efficient and flexible, operating with less waste, longer cycles, higher temperature, and lower pressures than current reactors; future reactors will also provide additional uses like water desalination, removing salt from water to create drinkable water, and hydrogen production. The advancements in nuclear reactors will help create sustainability in nuclear power, as well as provide clean water and hydrogen, which has several uses. The Nuclear Energy Institute (n.d.) also states advanced reactor designs will include Small Modular Reactors (SMRs) which produce less than 300 MW of electricity and use liquid metal, molten salt, or helium to transfer heat to a supply of water to generate steam; this will make SMRs less costly and allow them to be produced in factories to be shipped around the world. SMRs' purpose is to provide clean, carbon-free energy to developing countries and other remote areas, improving the lives of millions.

Some environmentalists condemn nuclear power for using radioactive fuel. They see it as a safety and environmental hazard. Paradoxically, Rhodes (2018) states, "nuclear power releases less radiation into the environment than any other major energy source." It is not commonly known that non-nuclear fuel sources release radiation; coal contains a rather high volume of radioactive elements like uranium and thorium. When coal is burned, its contents are concentrated into waste called fly ash; the massive amounts of coal that are burned create a large amount of fly ash and contributes a large amount of radiation emitted into the environment in the form of triuranium octoxide (U_3O_8). (Rhodes, 2018). Countries like South Africa and Hungary are researching ways to extract this uranium from fly ash to use for nuclear weapons. Therefore, not only does nuclear power produce less carbon than fossil fuels, but it also produces less radiation. This still leaves the comparison of nuclear energy to renewable energy. We are exposed to radiation all the time and in different forms. There is the non-ionizing radiation we get from all electronics and solar power, and there is ionizing radiation, which is the form of radiation received from nuclear power. However, we are exposed to ionizing radiation all the time as well. A good example of other ionizing radiation we are sometimes exposed to is X-ray machines. According to the World Nuclear Association (2020), most of the radiation we receive is background radiation from the Earth's crust. On average, 42% of the radiation we receive comes from Radon gas produced from the breakdown of radioactive materials in the crust; in fact, 85% of the radiation comes from nature: radon (42%), buildings and soil (18%), cosmic radiation (14%), food/drinking water (11%) (World Nuclear Association, 2020). Of the remaining 15% of radiation we are regularly exposed to, only 1% is due to the nuclear industry. The amount of additional radiation outputted into the environment from nuclear power is so minuscule relative to the world around us, that there is no need to worry about any adverse effects of nuclear power.

To the remaining public, concern still lies with the risk of accidents. There have been three major nuclear reactor accidents in the history of nuclear power: Three Mile Island, Pennsylvania; Chernobyl, Ukraine; and Fukushima, Japan. According to Rhodes (2018), the partial meltdown at Three Mile Island released minimal radiation; the two million people surrounding the reactor were exposed to an average dose of radiation less than the exposure from a chest X-ray. The full meltdown of the Chernobyl reactor was, by far, the worst nuclear accident in history. Twenty-seven disaster relief members died of radiation poisoning. However, according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2008) who studied, at regular intervals, the effects of the Chernobyl meltdown, the incident had no long-term health effects other than thyroid cancer in residents near the reactor that were "children or adolescents at the time of the accident, who drank milk contaminated with iodine-131, and who were not evacuated." Of some 6,500 cases of thyroid cancer in the Chernobyl region, only 15 deaths were attributed to cancer by the UNSCEAR (2008). Rhodes (2018) compares these nuclear accidents to that of any other industrial accident, claiming "the worst possible accident at a nuclear plant is less destructive than other major industrial accidents;" A pesticide plant in India leaked forty tons of methyl isocyanate, killing 3,800 people immediately. Rhodes (2018) adds that, during a typhoon, a hydroelectric dam in China failed, drowning 26,000 people. Although there are other methods of assessing the dangers of a particular energy source, based on human fatalities, nuclear power is safer than other forms of power production. Since then, nuclear plants have increased in safety and pose little risk of nuclear accidents with major complications.

Linked to the public's concern of nuclear accidents is the concern of nuclear waste. As stated previously and supported by Rhodes (2018), most nuclear waste, about 90%, is recyclable. The remaining nuclear waste is currently being stored in impenetrable concrete-and-steel dry casks on the nuclear plant's site until the radiation decays enough to be disposed of regularly. Finland has dug out a permanent repository some 400 miles below an island in the Baltic Sea to permanently store its waste; this is a viable option because the granite bedrock prevents any radiation from escaping into the environment (Rhodes, 2018). With a safe way to store any remaining nuclear waste, nuclear power remains safe and clean to use.

With global warming threatening the future of our Earth, The United States needs to shift from using fossil fuel power plants to nuclear power plants because of its superior efficiency, sustainability, and low-carbon emissions. The power to make this change is in the hands of the American People by pushing for nuclear power in the public and private sectors. Politicians should be pushed to advocate for nuclear energy over other forms of power generation. Nuclear power doesn't radiate pollution, it radiates hope for the future.

References

Nuclear Energy Institute. (n.d.). *How a Nuclear Reactor Works.* https://www.nei.org/fundamentals/how-a-nuclear-reactor-works

Office of Nuclear Energy. (2020, April 22). *Nuclear Power is the Most Reliable Energy Source and It's Not Even Close.* https://www.energy.gov/ne/articles/nuclear-power-most-reliable-energy-source-and-its-not-even-close

Office of Nuclear Energy. (2020, May 1). *What is Generation Capacity?.* https://www.energy.gov/ne/articles/what-generation-capacity

Prăvălie, R., & Bandoc, G. (2018). Nuclear energy: Between global electricity demand, worldwide decarbonization imperativeness, and planetary environmental implications. *Journal of Environmental Management, 209*(2018), 81-92. https://doi.org/10.1016/j.jenvman.2017.12.043

Rhodes, R. (2018, July 19). *Why Nuclear Power Must Be Part of the Energy Solution.* Yale Environment 360. https://e360.yale.edu/features/why-nuclear-power-must-be-part-of-the-energy-solution-environmentalists-climate

Roth, M. B., & Jaramillo, P. (2017). Going nuclear for climate mitigation: An analysis of the cost effectiveness of preserving existing U.S. nuclear power plants as a carbon avoidance strategy. *Energy*, *131*(2017), 67-77. https://doi.org/10.1016/j.energy.2017.05.011

Union of Concerned Scientists. (2014, January 29). *How Nuclear Power Works.* https://www.ucsusa.org/resources/how-nuclear-power-works

World Nuclear Association. (2020, April). *Nuclear Radiation and Health Effects. https://www.world-nuclear.org/information-library/safety-and-security/radiation-and-health/nuclear-radiation-and-health-effects.aspx#:~:text=Radiation%20particularly%20associated%20with%20nuclear,an%20electron%20from%20an%20atom.*

World Nuclear Association. (2020, December). *Supply of Uranium.* https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx