Environmental Influences of Nuclear Power

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Abstract

To mitigate the effects of climate change, alternative forms of energy, which release little or no greenhouse gases while also having minimal impact on other aspects of the environment, must replace fossil fuel-based energy sources. Nuclear energy is one such potential energy source for the future because it emits small amounts of greenhouse gases, but the mining process, facilities, and waste disposal all have other negative impacts on the environment. Nuclear reactor meltdowns and the impacts of the leaked radiation on the surrounding wildlife and habitat must also be considered. It is important to conduct a thorough literature review on the environmental influences of nuclear power to inform policy-making decisions in the future as to whether or not it could or should be included in green energy plans as an alternative to fossil fuels.

Introduction

While the Earth's climate has changed in the past due to variations in its orbit, known as the Milankovitch cycles, and variations in atmospheric Carbon Dioxide (CO_2) levels, modern-day CO_2 concentrations are unparalleled within the glacial record (Pillans et. al, 1998). This is anthropogenic climate change, caused by continued input of greenhouse gases into the atmosphere through the burning of fossil fuels. To slow the rate of greenhouse gas emissions and mitigate the impact of anthropogenic climate change, renewable energies that emit low amounts of greenhouse gases should replace the use of coal, oil, and natural gas (Gagnon et. al, 2002). While not renewable, nuclear power does not release greenhouse gasses directly into the atmosphere (Vujic et al., 2012), and does not release greenhouse gases during energy production, making it a viable alternative energy source. There are, however, other sources of greenhouse gases associated with nuclear power, as well as environmental considerations beyond greenhouse gas emissions. To better understand nuclear power's place in the growing field of green energy, a full assessment of its influences on the environment should be conducted.

Literature Review

Nuclear Power Production

Nuclear energy is produced by the fission of uranium atoms in a nuclear reactor. The energy from this process is released in the form of heat, which boils water that surrounds the outside of the reaction chamber (Nuclear Energy Institute, 2017). In Boiling Water Reactors, the steam from the water turns turbines which produce electric energy (Seeliger, 1985). In Pressurized Water Reactors, the water is under so much pressure as to make it incapable of boiling (Nuclear Energy Institute, 2017), and is instead pumped through a pipe which passes through what is called the steam generator -- a large tank of water. Through the pipe, the superheated water from the reactor boils the water in the steam generator, producing steam which again rotates a turbine to generate electric energy (Nuclear Energy Institute, 2017).

In 2004, nuclear energy accounted for 17% of the world's energy production, equivalent to a reduction in carbon emissions of 0.5 gigatons (half a billion tons) of carbon per year (Ewing, 2004). Nuclear energy contributes about 15,000 tons of CO_2/TWh (Carbon dioxide per terawatt hours) that is similar to other renewable energy sources such as photovoltaic (13,000 tons CO_2/TWh), solar panels, or hydrodynamic with reservoir (15,000 tons CO_2/TWh), dams (Gagnon, Belanger, and Uchiyama, 2002). One kilogram of uranium also produces 50,000 kilowatt-hours, compared to the same amount of coal producing 3 kilowatt-hours, and oil producing 4 kilowatt hours (Rashad and Hammad, 2000).

Mining and Enrichment

^{238}U and ^{235}U (Uranium -238 and -235, respectively) are both mined as fuel for nuclear power (Nuclear Energy Institute, 2017). The uranium is mined from the surface or underground, and the ore is ground into a fine mixture. This slurry is then leached with sulfuric acid to extract pure uranium oxide, which is later converted to uranium hexafluoride, separating the ^{238}U from the ^{235}U. ^{235}U, unlike ^{238}U, must first undergo energy-intensive enrichment processes if it is to be used in nuclear energy generation (Fthenakis and Kim, 2007).

Nuclear Facilities

Nuclear facilities and the processes of energy production have a significant influence on the environment surrounding the plant. Nuclear power plants disrupt the surrounding ecosystem and decrease habitat from threatened and endangered species, as well as migratory species, by taking away otherwise-undisturbed land located away from cities and other manmade structures (Keeney and Robilliard, 1977). Nuclear facilities also have a largely negative impact on aquatic and marine ecosystems where they are located due to the intake and output of water from their cooling towers (Hung et al., 1997). The high temperatures of cooling water discharge can result in coral bleaching events, and can also cause severe spinal deformities in some fish species (Hung et al., 1997). In Connecticut, the majority of larval and juvenile fish experienced mortality due to mechanical or thermal stress from the nuclear effluent at the plant. About 80% of the studied fish died due to mechanical damage, and 20% due to thermal stress from temperatures being above 28°C (Marcy Jr., 1973).

Waste Products

There are two main nuclear fuel cycles: open and closed (Ewing, 2006). The open cycle treats all nuclear waste as spent fuel without reclaiming usable ^{235}U or ^{239}Pu (Plutonium-239) for energy production. The closed cycle reclaims usable fuel from spent fuel instead of indiscriminately storing it all (Ewing 2004). All nuclear waste is intended to be stored long-term in underground depositories in the Yucca Mountain nuclear waste repository, but the majority of existing nuclear waste is currently being stored on-site where it was produced, which poses major health and environmental hazards if the containments vessels leak or degrade (Energy and Commerce, and Interior and Insular Affairs, 1987; Ahearne, 1997). The Yucca Mountain nuclear waste repository, while built, is not currently in use due to public opposition and lack of governmental funding, and its future is unclear, as the Department of Energy is reviewing alternative locations for a nuclear waste depository (Slovic, Layman, and Flynn, 1991).

Meltdowns

A nuclear meltdown is the result of overheating and melting in the reactor of a nuclear power plant. In the past, meltdowns have been caused by failings in the reactor cooling systems, allowing the superheated nuclear material to melt through the reactor (Biello, 2008). To date, there have been approximately 100 nuclear accidents, with two of the most notable being the Chernobyl accident and the Fukushima-Daiichi accident (Nuclear Energy Institute, 2017).

The Chernobyl meltdown occurred in 1986 near Pripyat, Ukraine, and there have many observed impacts on the wildlife in the region as a result of the leaked radiation. Ten years after the incident, rodent populations in the exclusion zone have not experienced a reduction in abundance and diversity, but many individuals have enlarged spleens (Baker et. al, 1996). Barn swallows (*Hirunda rustica*) breeding within the exclusion zone were found to have a higher incidence of partial albinism typically associated with a loss of fitness. There was also evidence found supporting increased germline mutation rates, meaning that mutation events were two- to tenfold higher in the Chernobyl populations compared to control populations (Ellegren et. al, 1997).

The Fukushima-Daiichi accident of 2011 in Okuma, Fukushima Prefecture, Japan was caused by a tsunami disabling the cooling of three reactors. This meltdown leaked large amounts of radiation into the surrounding environment. Plant, soil, and water samples showed high amounts of the radioactive materials ^{131}I, ^{132}I, ^{134}Cs (^{133}Cs), ^{137}Cs, ^{110m}Ag (^{109}Ag), ^{132}Te, ^{140}Ba, ^{140}La, ^{91}Sr, ^{91}Y, ^{95}Zr, and ^{95}Nb around the nuclear plant after the meltdown (Shozugawa et al., 2012). Large amounts of radiation were also leaked into the ocean as the seawater from the tsunami receded, and background levels of many radioactive contaminants are high. However, initial calculations suggest that there should be little to no impact on marine biota (Buesseler et al., 2011).

Methods

To conduct a review of the existing literature on the environmental impacts of nuclear power, I will I start by searching various databases, like ScienceDirect and Web of Science, and journals, like Environmental Pollution and Nature, to collect relevant papers, of which there will be multiple folders representing different topics. There will be one folder for general aspects of nuclear power operations and emissions, and one folder for each of the following: the comparative environmental impacts of mining and refining; nuclear power facilities; waste disposal; and nuclear accidents/meltdowns. I will then begin writing each section individually, starting with the section on general nuclear power information and finishing with the introduction and conclusion. Throughout the project I will continue gathering and reading papers to ensure that it is comprehensive and up-to-date. Once the paper is complete, I will spend the month leading up to the presentation focusing on designing my poster and practicing my speech. All steps for this project are visualized in Table 1, and the projected budget in Table 2.

Table 1: Projected timeline for the researching and writing of the paper, starting January 2018.

	January	February	March	April	May	June
Gather papers	X	X	X	X		
Write “Nuclear Power”		X	X	X	X	

Write "Mining & Enrichment"		X	X	X	X	
Write "Nuclear Facilities"		X	X	X	X	
Write "Waste Products"		X	X	X	X	
Write "Meltdowns"		X	X	X	X	
Write "Introduction"			X	X	X	
Write "Conclusion"			X	X	X	
Prepare poster and speech					X	X
Presentation						X

Table 2: Budget

	Cost	Total
Equipment	N/A	
Supplies	N/A	
Databases/Journals (i.e. ScienceDirect and Web of Science/Environmental Pollution and Nature)	$100	$100

Significance of Study

Climate change is the term used to describe changes in the world's climate, including a general increase in global temperature, due to increases in the concentration of greenhouse gases in the atmosphere. Long-term effects are expected to have major environmental impacts on biotic and abiotic factors, including melting polar ice caps, alterations in weather patterns, altered phenology, and changes in habitat (Meehl et al. 2003; Parmesan and Yohe, 2003). To alter the course of climate change, society must begin using alternative forms of energy and phase out use of fossil fuels, as they are a large source of greenhouse gases, to reduce our carbon footprint and to increase climate change mitigation. Looking toward more sustainable energy, it is pertinent to look at all possibilities, including nuclear power. The aim of this review is to evaluate the environmental impacts of nuclear power production in hopes of contributing new information useful in future management and safety policies involving the continuation of the use of nuclear power as a potential widespread energy source.

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