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The Environmental Impact Of Nuclear Power Plants With A Focus On Calvert Cliffs Nuclear Plant And How CO2 And CO2e Contribute To Climate Change

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Abstract: *Despite the vast power generating technology improvements humans have designed and implemented over the centuries, we must always keep in mind the impacts these technologies can potentially have on the natural environment. Although considered to be one of the best alternatives to fossil fuels, nuclear power plants should still be examined for their environmental impacts. Based on a case study of the Calvert Cliffs Nuclear Power Plant located in Calvert County, Maryland. This paper demonstrates the environmental impact of nuclear power plants and discusses the importance of Best Management Practices (BMP) of greenhouse gases.*
Keywords: *nuclear, environmental impact, fossil fuel, BMP*

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I. Introduction

A nuclear power plant is a type of power plant that is used to generate electricity using heat from nuclear reactions. These reactions occur within a reactor and the electricity generated by nuclear power plants is referred to as nuclear power. It is constructed near water that functions to remove the heat the reactor generates. There are about 449 nuclear reactors operating in 30 different countries around the world and there are about 60 new nuclear power reactors under construction in 15 countries. In the year 2014, nuclear power plants provided 11 percent of the world's electricity. In the United States of America, there are 61 nuclear power plants in operation with 99 nuclear reactors in 30 states. The state of Arizona has the largest nuclear plant located in Palo Verde and it generates about 3,937 megawatts of electricity. The cost estimates for the construction of a new nuclear power plant is about $9 billion and the cost will continue to increase (EIA, 2017).

Figure 1. Nuclear Power Plant (EIA, 2017)

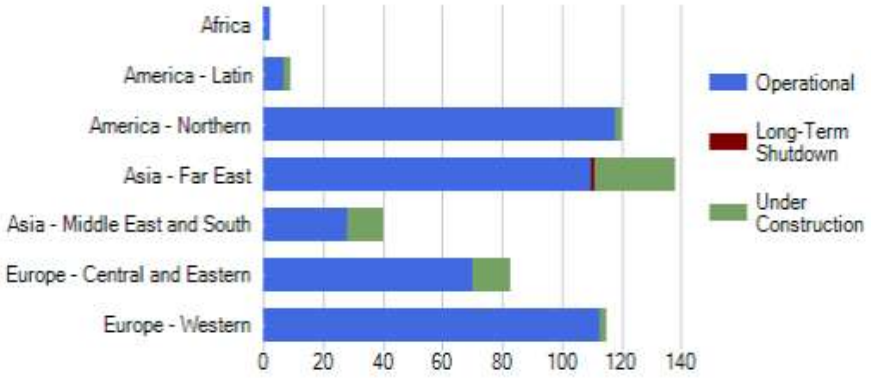

Figure 2. Regional Distribution of Nuclear Power Plant (PRIS, 2017)

How a nuclear power plant works

Nuclear power plants obtain the heat needed to produce steam through a physical process known as fission. In nuclear power plants, neutrons collide with uranium atoms, splitting them. This split releases neutrons from the uranium that in turn collide with other atoms, causing a chain reaction. This chain reaction is controlled with "control rods" that absorb neutrons. In the core of nuclear reactors, the fission of uranium atoms releases energy that heats water to about 520 degrees Fahrenheit. This hot water is then used to spin turbines that are connected to generators, producing electricity. Because nuclear power plants do not burn fuel, they do not produce as much greenhouse gas emissions as fossil fuels. (EIA, 2017).

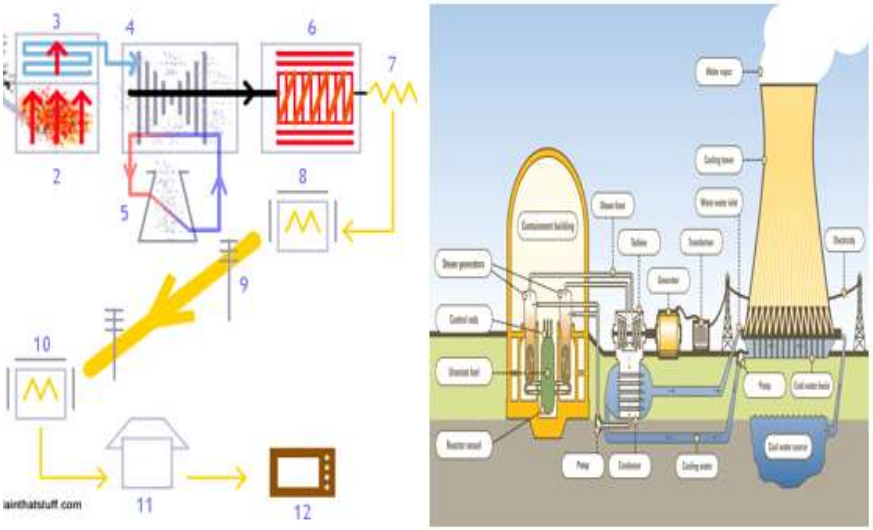

Figure 3. Nuclear Power Plant (EIA, 2017)

There are three main types of Fossil fuel namely coal, oil, and natural gas. Fossil fuels are important sources of energy because they are readily available, convenient, and effective (IER, 2017).

Coal was first wide used fossil fuel. Kilogram for kilogram, it also releases more energy than wood and made the industrial Revolution possible (IER, 2017).

Figure 4. Coal (Institute for Energy Research, 2017)

While the swampy forests were alive, the seas were teeming with algae and other microscopic sea creatures. As they died, their remains sank to the bottom of the oceans and mixed with the sediments on the sea floor. As the mixture of sediments and sea creatures built up over the course of millions of years, the sediments turned to rock and the remains of the creatures became oil (IER, 2017).

Figure 5. Oil (Institute for Energy Research, 2017)

Natural gas is a gaseous fossil fuel formed from the remains of marine microorganisms and found on top of oil reservoir. It is resourceful, plentiful, clean, and mainly consists of methane (CH_4) (IER, 2017).

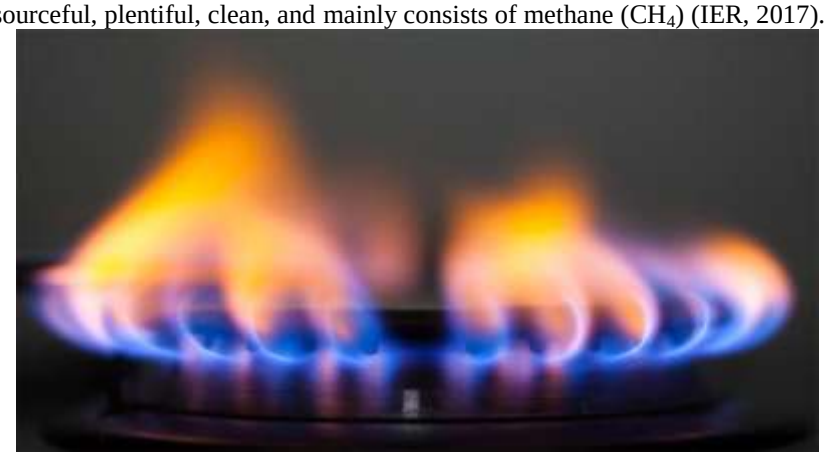

Figure 6. Natural gas (Institute for Energy Research, 2017)

When the fossil fuel are burnt they create pollution producing carbon dioxide, contributing to the greenhouse gases which result in climate changes. In addition, burning fossil fuels produce sulphur dioxide, a gas that contributes to the acid rain and nitrous oxides which causes smog.

Figure 7. (Institute for Energy Research, 2017)

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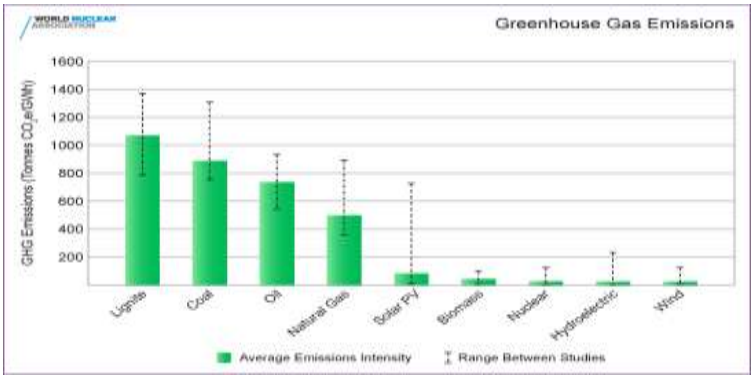

Figure 8. (World Nuclear Association, 2017)

Unlike fossil fuel power plants which produce methane and carbon dioxide which are the primary of greenhouse gases (GHG) nuclear power also produces gases in the form of water vapor which is not a GHG. The amount of greenhouse gases has been declined by nearly half because of the acceptance in the utilization of nuclear power. (Nuclear Energy Institute, 2017).

Nuclear power produces very cheap electricity. The cost of the uranium is very low. Although the capital cost of setting up nuclear power plants is moderately high, the operating and maintenance cost are quite low. The normal life of nuclear reactor is between 40-60 years, depending on how often it is used and how it is being used (Nuclear Energy Institute, 2017).

It also estimated that with current rate of consumption of uranium, there is enough uranium for another 70-80 years. A nuclear power plant when in the mode of producing energy can run without broken for even a year. They are very reliable unlike renewable energy source such as solar and wind energy which are dependent on whether conditions, nuclear power plant is not constrained by any climatic condition (Nuclear Energy Institute, 2017).

Nuclear energy is more compelling and more proficient than other energy sources, thus the number of nuclear energy innovations have made it a much more feasible choice than others compared to fossil fuels such as coal and natural gas power plants that discharge CO2 into the air. The amount of fuel required by nuclear power plants is comparatively less than what is required by other power plants as energy released by nuclear fission is approximately ten million times greater than the amount of energy released by fossil fuel atoms (Nuclear Energy Institute, 2017).

Even though nuclear energy is not renewable resource, uranium, the nuclear fuel that is used to produce nuclear energy is limited, although, by using breeder and fusion reactors, we can produce another fissionable element. One such element is called plutonium that is produced by the by-products of chain-reaction (Nuclear Energy Institute, 2017).

One of the major issues is environmental impact in relation to uranium since the process of mining and refining uranium hasn't been a pure process. In order to transport nuclear fuel from one place to another causes pollution damage. Also, once the fuel is used, it cannot be disposed in a landfill since it is radioactive and dangerous (Wise 2018).

A nuclear power plant creates 20 metric tons of nuclear fuel per year, which means that based on the current operating nuclear power plant approximately to 2,000 metric tons per year is being produced. The greater part of this waste transmits radiation, implying it can also cause damage to living things in and around the plants (Wise 2018).

The radioactive waste reduced life span and cause serious health effects on the lives of people as well as the environment. For instance, the Chernobyl accident that occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant in Ukraine was the worst disaster nuclear accident in the history. (Wise 2018).

Disposal of nuclear waste by blending it with glass and storing in solid structures is expensive and must be observed and watched to keep the materials from falling into the wrong hands and causing problems. In addition, it requires permission from several international authorities and it is normally opposed by the people who live in that region (Wise 2018).

Uranium is nonrenewable Just like other sources of fuel, and exists in few of the countries. It is expensive to mine, refine and transport. It produces considerable amount of waste during all these activities and can result in environmental contamination and serous health effects. Nuclear waste if not handled properly can be used to make weapons. If these weapons get into the wrong hands, that could be end of this world (Wise 2018).

Calvert Cliffs Power Plant

In today's constantly changing technological world, there are many concerns regarding the use of fossil fuels in order to generate energy. The impacts on the environment include issues such as air and water pollution as well as land degradation. The Calvert Cliffs Nuclear Power Plant is located Lusby, Maryland in Calvert County, Maryland. This is a very powerful nuclear plant as it generates 1756 MW of electricity serving over 1 million customers each year (Exelon 2009). The plant has two Pressurized Water Reactors (PWR) with the first one put into commission in 1975 and the second reactor in 1977. A PWR is a unique system that uses condensed water and heat in order to turn a turbine in order to generate electricity. According to nrc.gov, the core inside the reactor vessel creates heat and the pressurized water in the primary coolant loop carries the heat to the generator. Thus, once inside the steam generator, the heat from the primary coolant loop vaporizes the water in the secondary loop and steam is produced. Once this steam is produced, it is directed to the main turbine causing the turbine to rotate which then produces electricity (nrc.gov 1995). A diagram of a PWR is shown in Figure 9. Other types of reactors are Boiling Water Reactor (BWR), Pressurized Heavy Water Reactor (PHWR) and Gas-Cooled Reactor.

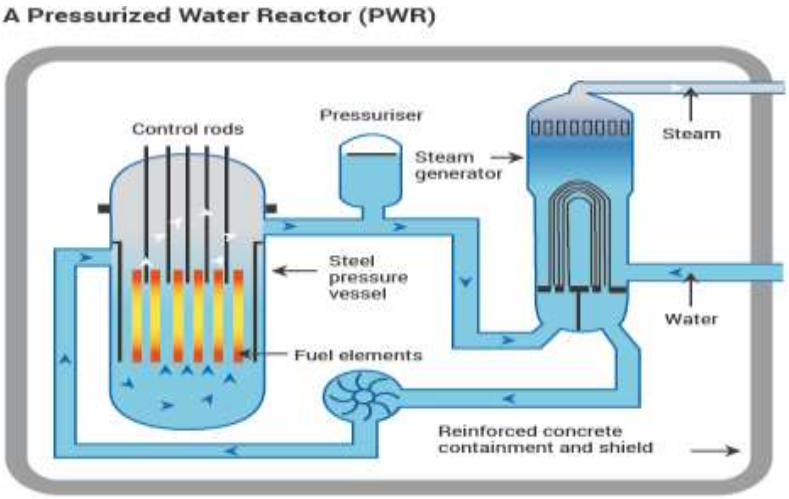

Figure 9. Pressurized Water Reactor (world-nuclear.org)

Although a nuclear power plant produces electricity for millions of people, there are many environmental impacts of a power plant that need to be noted. Generally speaking, nuclear power plants impact the surrounding environment through its massive water consumption, radioactivity and greenhouse gas air pollution.

The Calvert Cliffs Nuclear Power Plant sits on the shore of the Chesapeake Bay in Maryland. This, in turn means that the water needed to operate the plant comes from the Chesapeake Bay. As stated above and demonstrated in the diagram, water is a necessity to operate a PWR. In order to operate such a large capacity nuclear plant such as Calvert Cliffs, a massive amount of water is required to generate electricity from the two units. To give a rough estimate, Wise International states that, "The Nuclear Information and Resource Service notes that a typical once-through coolant system draws into each reactor unit more than one billion gallons…daily" (Wise International 2013). Taking into account this water estimation of consumption is for only one unit, Calvert Cliffs that contains two units, and is planning to add a third in the future, consumes roughly 2 billion gallons of water per day. This water is used to cool the system and then the heated water is then dumped back into the bay. With this massive water consumption, the environmental is sure to be effected. The withdraw and then return of the water "kills trillions of fish and other aquatic organisms, particularly small, fragile eggs and altering the aquatic food chain and ecosystems" (GraceLinks 2013). Within the bay are millions and millions of species of fish and underwater organisms along with the millions of microorganisms that live within the micro ecosystems in the water. Since the water is returned into the Chesapeake Bay at higher temperatures, this delta in water temperature "sets up a thermal gradient that can throw the system off balance, and destroy the species that survive there" (Greenpeace). In other words, many species survive in only certain water temperatures and by displacing higher temperature water into the bay, the equilibrium of that surrounding area is thrown out of balance making the area of water inhabitable.

Nuclear Power Plants such as Calvert Cliffs maintain a process of mining and refining uranium. In the nuclear reactor, rather than the burning of coal or gas, the fissioning of uranium atoms is how the high temperature heat is created. This is the heat that is used to make the steam and produce the electricity from the turbine (World-Nuclear). The issue with the mining of uranium is its effects on the health of humans. The most at risk are those who mine the uranium who are exposed to the particles as well as a by-product of uranium

called radon which is a radioactive gas (IPPNW 2010). When inhaled, uranium, may cause lung cancer and with the mix of radon gas, Schneeberger Disease. The toxicity of uranium "attacks the inner organs, such as the kidneys…causes birth defects in fetuses and infants, and the risk of leukemia is increased" (IPPNW 2010). Nuclear power plants such as Calvert Cliffs create large quantities of highly radioactive materials. Human beings are exposed to low-level radioactivity constantly from naturally occurring radioactive isotopes and cosmic rays from outer space. However, in large doses, radiation has many harmful effects. Therefore, it is necessary for Nuclear Power plants to in-build many safety mechanisms to keep the population safe. (Nuclear Power Education, 2017). The exposure to nuclear-reactor fallout does not cause acute illness because it can elevate long-term cancer risks. (New England Journal Medicine, 2011). The production of energy and electricity does not only impact the long-term climate through the release of greenhouse gases but also directly impacts human health due to the particulate and heavy-metal air pollution from fossil plants or harmful doses of radioactivity in the event of severe nuclear accidents. (Markandya and Wilkinson, 2007).

Another environmental impact of the Calvert Cliffs Nuclear Power Plant is its emission of greenhouse gases (GHG). Greenhouse gases are "gases that trap heat in the atmosphere" and include Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O) (Epa.gov). The GHG we will focus on with the Calvert Cliff Nuclear Power Plant is CO_2. According to Benjamin K. Sovacool, author of **Valuing the greenhouse gas emission from nuclear power: A critical survey,** "the mean value of emissions over the course of the lifetime of a nuclear reactor is 66 gCO_2e/kWh, due to reliance on existing fossil-fuel infrastructure for plant construction, decommissioning, and fuel processing along with the energy intensity of uranium mining and enrichment" (Sovacool 2008). Although nuclear is safer choice compared to other fossil fuels such as coal and natural gas in regards to its release of CO_2, there still exists an emission. This emission contributes to global climate change which will be discussed further in the paper.

Best Management Practices for Greenhouse Gas Emissions

When fossil fuel is burned, it puts carbon into the atmosphere. The main cause of climate change is the burning of fuels, which emits carbon dioxide into the atmosphere.

According to Sally et al, 2015 carbon dioxide is a gas that occurs naturally and is also produced by the burning of fossil fuels. More fossil fuels are being consumed by way of either, cars and other vehicles, or by deforestation (Sally, et al, 2015). Human activities currently release over 30 billion tons of CO_2 into the atmosphere every year, which is 135 times as much CO_2 as volcanic eruptions released each year in the past, (EPA report). In 1970, the United States Environmental Protection Agency (EPA) amended the Clean Air Act and set limits for vehicle emissions in response to data that showed vehicles were responsible for roughly 80 percent of the carbon dioxide in the atmosphere. The Clean Air Act was further amended in 1990 to address new environmental concerns (Sally et al, 2015).

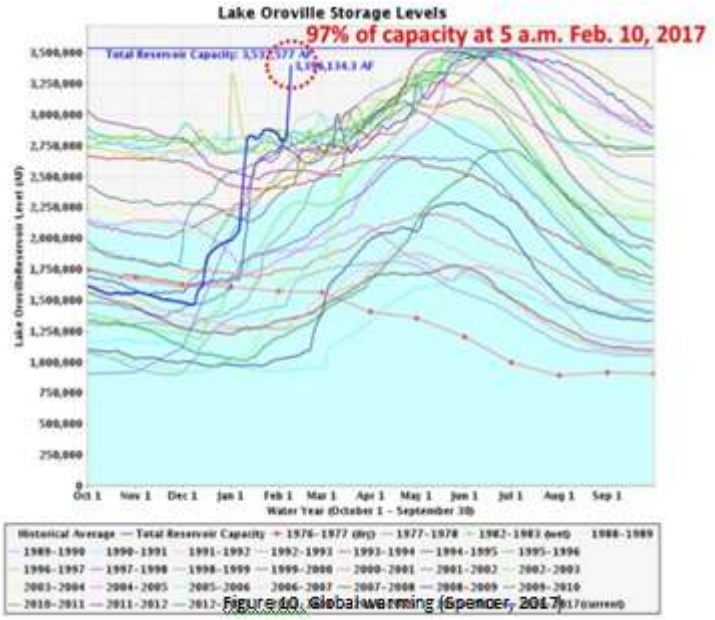

Figure 10. Global warming (Spencer, 2017)

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In our society, CO_2 accounted for about 82% of all U.S. greenhouse gas emissions from human activities. According to EPA, "Carbon dioxide is the primary greenhouse gas emitted through human activities

Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle. Also, Human activities are altering the carbon cycle, both by adding more CO2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO2 from the atmosphere. While CO2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution" and Scientist has been able to come to an agreement that
Human activities are highly the cause of an increased Co_2 in the atmosphere.
Increasing fossil fuels in the atmosphere increases the emission of gases which result in an increase in global temperature and high increase in the global temperature results to an increase sea level. Some other effects of this emission are high rate of diseases, drastic change in our agricultural production and harsh weather events such as storms. The figure showing a reservoir that was nearly full in some previous years but is suggesting a continuing flooding issue in the coming month due to climate change (Aramesh Shahbazi and Behnam Rezaei Nasb, 2016).
Examples of how Climate Change could drastically affect us are
Powerful storms, larger floods, extreme storm surges, extreme hot days, stronger winds, high intense tropical cyclones
In an assessment done by the Scientific and Technical Group (STWG), the critical aim of this assessment was to compare future climate impacts in which fusel fuel gas emission continues to grow throughout the 21st century. Two scenarios were observed. The higher scenario considered an independent world with an increasing developing population while the lower scenario considered a decreasing population growth. (Hawkey, 2008)

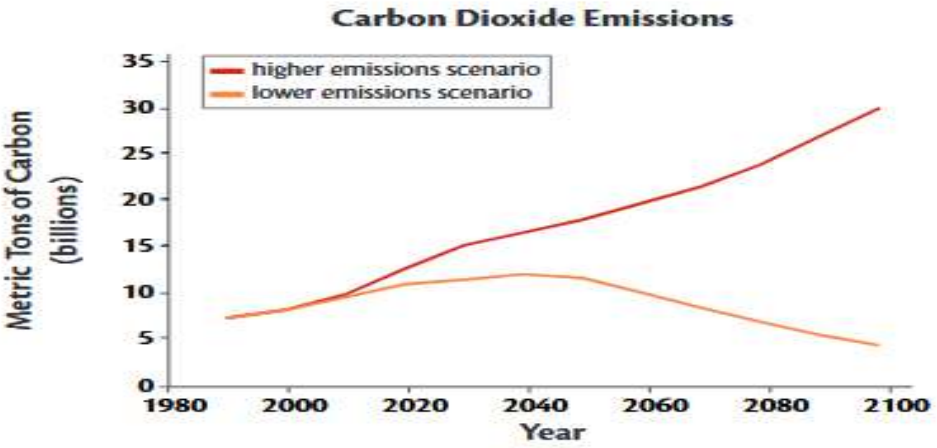

Figure 11. (Carbon dioxide annual emissions for the low and high emissions (Hawkey, 2008)

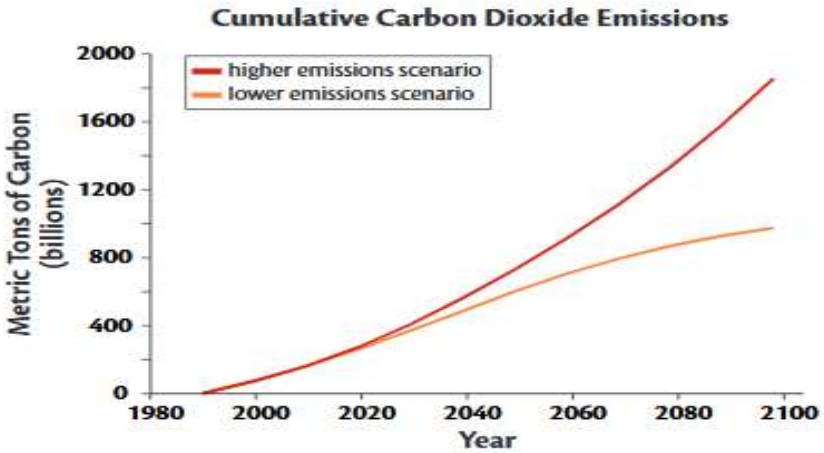

Figure 12. Total carbon dioxide emissions from 1990 to 2100 (Hawkey, 2008)

It was noticed that because carbon dioxide is contained in the atmosphere for a long time, the full effect of this regression manifests in the late century.

Smog hangs over a Baltimore highway clogged with traffic.

Figure 13.

There is a need to develop regulations and best management practices to reduce CO_2 emission. Some of the methods currently recommended are:

1. Carbon sequestration method

Sequestration and capture of carbon dioxide produced by fossil fuel is an important method to reduce global warming. Apparently, it has been considered a pathway to a continuous Energy production, which means carbon capture is characterized as a solution where industry craved their path towards prospective clean energies. Carbon sequestration and capture is defined as the removal of carbon dioxide from the production plant. This method serves as a major tool for reducing CO_2 in our environment from large pollution sources like power plants that use fossil fuel and transporting it to places where they cannot harm the environment (Farahiyah Abdul Rahmana et al, 2017). It is the process by which the waste carbon dioxide is stored mostly underground. It is done to prevent massive quantities of carbon dioxide from being released into the atmosphere. The capturing and storage of carbon dioxide is a difficult, complicated, and expensive process. This process requires sophisticated technology to be performed. According to Center for Climate and Energy Solution, the cost of transportation and storing of CO_2 is about "$15 per metric ton of CO2" (Carbon Capture and Storage).

2. Regulation Rules governing Gas emission

Different regulations have been put to place to reduce gas emissions in our society today: some of the regulations are

3. Command and Control

This is the most commonly use form of pollution control in the U.S. This regulation limits the amounts of pollutants that major companies may emit. (Climate change policy, 2010)

4. Cap and Trade

In this method, the cap and trade system would cap the overall quantity of greenhouse emitted and distribute emission allowance to emitters. Every year, the cap is tightened to mitigate emissions until a purpose is achieved. (Climate change policy, 2010)

5. Carbon Tax

A carbon tax imposes a dollar tax per ton of CO_2. The tax would probably be imposed only on large sources to facilitate administration, but could be imposed in many conceivable ways. (Climate change policy, 2010)

II. Conclusion

Nuclear Power Plants are environmentally friendly source of source electricity. Their contribution to global climate change and impact on the environment are a result from carbon dioxide equivalents (CO_2e) from production of water vapor and radiation from the uranium is small compared to that from fossil fuel power plant. From this case study of the Calvert Cliffs Power Plant located in Calvert County, Maryland, the environmental impact this plant poses is its massive water consumption producing water vapor and increase in the temperature

of waste water released to the Chesapeake Bay which kills trillions of fish species in the process. Radiation emission from fission of uranium impact human health and its existing fossil-fuel infrastructure contributing to global climate change such as natural events like more powerful storms, large floods and extreme hot days. In an attempt to minimize the environmental impact of nuclear power plant and greenhouse gases, policies need to be put in place through Best Management Practices for sustainability.

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