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Nuclear Energy and Mitigation of Climate Change

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Nuclear Energy and Its Role in the Mitigation of Climate Change

Abstract

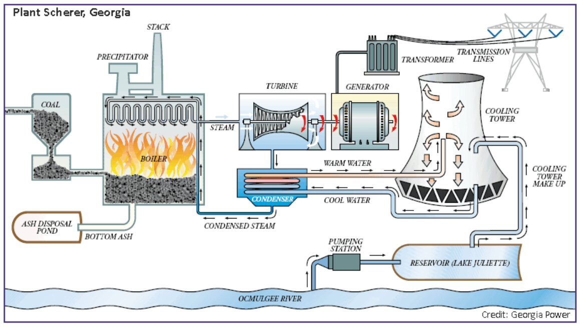
As we move into a future filled with unknowns we are consistently looking for answers to our problems. One of the biggest problems globally today is that of global climate change. In the recent past the concept of climate change has been highly debated, and widely unaccepted. As we move forward the idea is becoming more and more accepted among scientists worldwide, and more importantly the global populations are becoming less skeptic of its validity. Nations worldwide have started coming up with plans to mitigate and try to alleviate some possible damage from climate change. One of the mitigation strategies we as a global community have been looking into utilizing more is that of Nuclear Energy. This paper discusses some of the current energy production strategies we use, the concepts of nuclear energy production, and some of the implications of nuclear energy.

1 Today in the United States we currently use a large variety of energy sources. Mostly our energy sources are split up into mainly Coal Fire Plants, Natural Gas, and Nuclear Power Plants. The three of these sources combined make up nearly 86% of our energy in the U.S. Coal fire plants make up 37%, Natural gas contributes 30%, and Nuclear power plants make up only 18%. The other 14% of our energy is made up from hydropower dams (7%), petroleum (1%), other renewable sources like solar and wind (5%), and a couple of other gasses are used(<1%)(U.S. Energy Information Administration, n.d., p 1). For this document I will focus on the three largest contributors to both energy and climate change topics (Coal, Natural gas, and Nuclear). All three have upsides and down sides, but only nuclear power does not contribute to the increasing greenhouse gasses that are involved with the changing climate. The International Panel on Climate Change (IPCC) considers Nuclear power to be one mitigation idea to counter act the climate change we are witnessing. Coal and natural gas are contributing to the changing climate due to the processes that they undergo and the byproducts they make. Nuclear power's byproducts do not contribute to climate change the same way. This paper discusses these three sources of energy in detail.

1.1 Coal fire plants, right now, are the largest contributor to our energy supply. The coal fire plants make up nearly 37% of our power supply in the United States. The way a generic coal fire plant works is it pumps coal into a huge furnace. Then it burns the coal at an extremely high temperature to boil water. This highly heated water then creates a high pressure of steam that then spins turbines. These turbines are connected to large generators that move electrons and create the AC electricity we use to power our homes, charge our phones, and charge our electric cars. The steam is then run through a condenser then to a cooling tower. The steam is then cooled and returned to the system start its heating, spinning, cooling

Figure 1. This shows the basic working system of a coal fire plant. (U.S. Geological Survey, n.d., Retrieved Feb 2014)

cycle all over again.



The reason that coal fire is not included in the mitigation of climate change is because it is contributing to the changing climate. When you burn carbon, which coal is nearly all carbon-12, you need oxygen and you create CO_2. Carbon dioxide is a definite greenhouse gas and a large contributor to the changing climate. The chemical equation for the burning of coal is a very simple one, it is $C + O_2 = CO_2$. So simply put, for one 1 mole of Carbon combusted we yield 1 mole of CO_2. But coal is not simply pure Carbon. There are other elements and chemicals that rest in the carbons composition. For example Nitrogen pockets are nested inside of the carbon complex. The combustion from a single molecule of Carbon roughly released 4.08 eV (Shultis & Faw, 2008, p.78). With a little bit of math you can find out how much coal a 1000 MW coal fire plant would consume. After the math is done, you find that it would take 11E+06 kg or 11 Gg of coal. That is roughly 12000 US tons, equivalent to 850 lbs.

1.2 The way we turn natural gas into electricity is roughly the same concept as a coal fire plant. We first make a large boiler to super heat water. We then use the steam to turn a large turbine that is connected to a generator. This generator being spun by the turbine then creates the AC electricity we use. The natural gas we burn is much cleaner than that of the combustion of coal due to is higher purity. Natural gas is made of a mixture of hydrocarbons and a few other compounds. The largest component of the natural gas burned is Methane. Methane's composition is one Carbon and four Hydrogen atoms bonded to the Carbon, this is denoted as CH_4. The chemical equation for the combustion of methane is $CH_4 + 2O_2 = CO_2 + 2H_20$. Hydrocarbons follow the same basic principal as the Methane combustion equation; 1. Take a hydrocarbon 2. Introduce oxygen 3. Add heat to initiate the reaction 4.yield carbon dioxide and water.

1.3 A nuclear power plant has a system similar to that of coal or natural gas to create Alternating Current energy for human use. There is a creation of heat, the heat then imparts its energy to water to create steam to spin a generator. Thus creating the AC energy we use every day. The main difference between nuclear energy and chemical energy is that how we harness the energy to heat the water. The physics and chemistry behind how we go about creating that energy release is much more complex than adding heat to initiate a chemical reaction. Some parts of nuclear physics are still being theorized about. As of now we still are unsure the exact way the nucleus of an atom is composed. There are two models for the composition of the nucleus. These are highly complex and interesting theories, and there are many papers and research on them. All you need to understand for this paper is that there is a "binding energy" that holds the nucleus together. What we do understand is how we can use this binding energy to our advantage. We can have a release of energy from the nuclear reaction by splitting an atom, fission, or smashing two atoms together to create a totally new atom, fusion.

1.3.1 The nuclear reaction we use in the production of energy in the world now is the process of nuclear fission. This is the splitting of an isotope of an atom with a high mass number. The most common isotope used in the fission reactors today is Uranium-235. It is very hard to create a pure sample so there are many levels of enrichments and many ways to make that enrichment higher. One fission event of Uranium-235 releases roughly 210 Mev per fission (Shultis & Faw, 2008, p.78). Remember back to the energy released from coal, this number was 4.08 eV. If the same question is asked about how much material it would take to run a 1000MW reactor for one day, but this time we will use Uranium being the material and not coal. The reactor would consume roughly 3.8 kg per day, which is 8.4 lbs per day. In contrast it took roughly 850 lbs of coal to run said reactor per day. The energy released from a fission event is nearly 50 million times that of the coal reaction.

1.3.1.1 The basic idea behind nuclear fission reactors is to hit atoms of fissile materials with neutrons to create fission events. But that is the most basic way to say it. The term fissile means a nuclide that can be fissioned by neutrons of any energy, but mainly thermal neutrons. Thermal neutrons mean a neutron with energy of .025 eV, the number may be meaningless to you, just know it means lower energy neutrons. The most common of these fissile materials are Uranium-235, Uranium-233, Plutonium-239, and Plutonium-241. The one we use the most for fission reactors is Uranium-235. Now to elaborate on the basic idea behind nuclear fission, the nuclear reaction looks like $92235U+01n\rightarrow 92236U\ast\rightarrow 56142Ba+3694Kr$. The first part of the reaction is showing that a neutron is being shot into to the nucleus of the Uranium to create a compound nucleus, Uranium-236, and then the compound nucleus splits apart into Barium-142 and Krypton-94. This reaction takes split seconds. The Ba and the Kr are referred to as the fission products. This is not the only way that the Uranium-235 reaction can result in, nuclear fission yields a variety of nuclides. The reaction is repeated millions and millions times in the reactor vessel. In the reactor, the fuel, enriched Uranium, is placed in the reactor core. The Uranium is then hit with neutrons to create fission events. The millions of reactions each create the rough 210 MeV per fission. This energy rapidly heats the water till it has a phase change. The super-heated steam then spins the generator that creates the AC energy. There are more ways to utilize the energy imparted by the fission events, but this is the basic idea. The advanced boiling water reactor (BWR) is one of the nuclear power plant designs that utilize this type of concept of turning fission event energy to AC energy. **Figure 2** is a

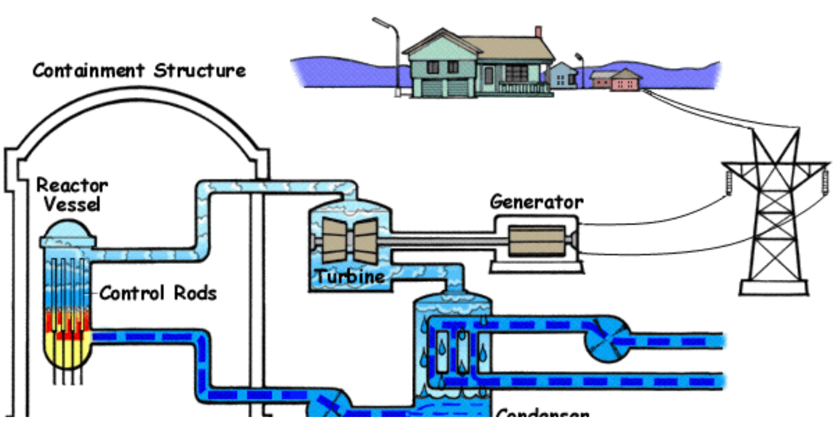


Figure 2. This figure shows the basic over view how a Boiling Water

simplistic diagram of how a BWR nuclear power plant system works.

1.3.1.2 As I discussed in the previous section, there are many different end results from a fission event. These end products are defined as fission products, and they can largely vary in many ways like mass number, radioactivity, and physical states. In **Figure 3** you can see how these fission yields vary. Figure 3 is what is called a fission yield curve. These curves vary for each different nuclide that has gone under fission. For example the curve that Plutonium-239 would differ from that of the curve in figure 2. In short it is all a probability of what two nuclides will be created from a nuclear fission event. This is where the infamous nuclides people fear so much come from, nuclear fission events. These nuclides are mainly Iodine-131, Cesium-137, and Strontium-90, they are at least the nuclides you hear the most about when a nuclear event occurs.

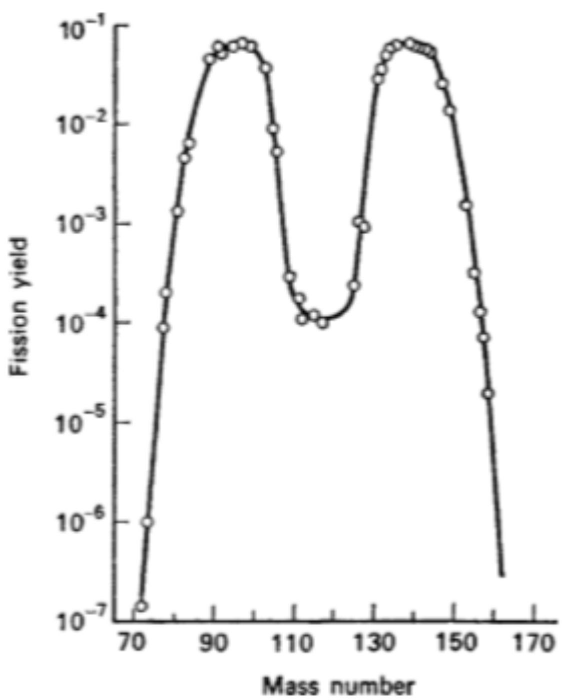


Figure 3. This figure shows a graph of the fission yields from Uranium-235. (Cember & Johnson, 2009, p. 643)

The fission yield graph in figure 3 has fission yield on the y-axis and mass number on the x-axis. The graph shows that there is a high yield of nuclides with a mass number of 90 ± 10 and 140 ± 10. These are the nuclides that have a higher probability of production in a fission event. This is not to say that the other nuclides are made in a nuclear reactor, it is they are just less probable of being made. Remember that there are millions and billions of fission events happening in a nuclear reactor.

1.3.2 Instead of trying to split a nuclide and have a fission event, we have thought of crashing two nuclides together to create larger nuclide. This is called fusion. The idea is that we can super heat and collide two small atoms, hydrogen isotopes, and smash them together and create a larger atom. This change in a fusion event releases an even larger amount of energy than in a fission event. There is a running joke in the nuclear industry that fusion technology is roughly 20 years out. Now the part that's funny is that people have been saying fusion is 20 years out since the 70's. What I am trying to get at here is that physically it is very hard to make fusion event happen. It is even harder to harness the energy created in a fission event. To top it off, it is even more difficult to create a reactor to house millions of fusion events and hold its integrity. The theory and physics are there, and it looks great on paper. When it comes down to it though, it is just plain difficult to create. Hold your arms strait out, look from one had to the other and notice the length between your fingertips. Now imagine the hottest temperatures in the universe at the tip of your right fingers and the coldest temperature in the universe at your left.

This one of the biggest hurdles to overcome when designing and creating a functioning fusion reactor that will be able to run, and supply constant power. On the inside of the reactor there are temperatures upward of 400000 Kelvin, and on the outside of the reactor you need temperatures near zero Kelvin.

1.3.3 Internationally the regulation commission for nuclear energy is the International Atomic Energy Agency, IAEA. This agency sets recommendations for the nuclear industry around the world. In the United States we follow the regulations set in place by multiple agencies, the largest and most prominent agencies are the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA) is the other agency we follow. The NRC sets all the regulations and gives out all the special certifications for nuclear power plants, radiation laborites, medical radiation facilities, and all facilities that deal with nuclear materials. The EPA helps enforce regulations for emissions from nuclear facilities in the US and waste disposal.

1.3.4 There are a few ways to deal with the nuclear waste created by the operations of a nuclear power plant. One way is to send the waste to a repository. An example of this is a place like the Yucca Mountain repository. This is a repository that the U.S. has constructing for our nuclear waste. Sweden is in the process of making a deep geological repository site now. The other way is to a refinement process. In this process the spent fuel rods are taken and the good fuel is separated and reused. The problem now is this process is not really efficient and is expensive. So what countries are doing are using repositories and waiting till the refinement process is better. In the U.S right now we do not have a operational repository, and we do not export our waste. We are keeping our waste on the nuclear facility's sites. This is causing some real big arguments between the U.S. government and the private companies that have nuclear power plants.

2. Today our energy needs are being met, to an extent. In the past there have been rolling black outs due to a need for power, and even states, like Oregon and Washington, have started projects to place hundreds of wind power turbines to help with the growing need for power in our country. We are also coming to an age where carbon emissions are at an all-time high. Also the growing concentrations of CO_2 in our atmosphere are becoming a growing concern for our future. Since this realization we have started looking into more renewable and cleaner ways of obtaining energy. We have invested money and time into the development of photovoltaic power cells, wind turbines, and other sources of clean energy. Still none come close to the efficiency and power output of a nuclear power reactor. The IAEA estimates that the emissions from a nuclear power reactor (light water reactor) are estimated to be at 15.9 g of CO_2 per KWh of generated electricity (International Atomic Energy Agency, n.d., p. 11). The use of nuclear power plants have helped greatly avoided the amount of greenhouse gases (GHG) that potentially could have been released by the burning of coal and natural gas. In 2010 it was estimated that nuclear power globally helped avoid 2.2 Gt of carbon emissions, hydropower reduced 2.9 Gt, and other renewables besides hydropower was .9Gt (International Atomic Energy Agency, n.d., p. 15). This is a sure sign that there is a need to move our efforts toward nuclear power and renewables to mitigate the climates change due to increased amounts of GHG's in the Earth's atmosphere.

3. The world's population has a perception of nuclear power that is commonly a negative perception. There has been a stigma placed upon the nuclear field. This is the result of many factors. One of these factors is the nuclear accidents that have happened in the past. The biggest accident was the Chernobyl accident in the Ukraine on the 26th of April 1986. Another accident is the Fukushima Daiichi reactor failure on the 11th of March 2011. This is the most prevalent because of how recent it was. The last that has helped with the stigma on nuclear power is the Three Mile Island (TMI) accident. There have been so many years of fear of nuclear power that have not been addressed, and this is just leading to more of a fear from nuclear power, radiation, and all that is affiliated with it. If we are going to move into a reduced carbon emission world we are going to have to break this stigma and fear. We need to start, I believe, with education. We need to educate the people about nuclear related topics. Something most people do not know is that we don't see adverse effects of radiation till a low dose accumulation of 100 mSv. In the U.S. the NRC has set regulation limits on the dose that a nuclear facility can give to the public at 0.02mSv per hour or 1mSv on whole body per year (Nuclear Regulatory Commission, n.d., 10.CFR.20 Subpart D**)**. To put this into perspective for you, to see adverse effects from a normally functioning nuclear facility as John Q. Public you would have to be standing at the fence for 100 years. It is time for people to understand what is really going on when it comes to nuclear energy and end the stigmas and fear.

Conclusions

In conclusion nuclear energy is an extremely viable mitigation option for climate change. Its small release of GHG's into the atmosphere and its high energy output with small solid waste makes nuclear energy the power source that could power us into a brighter future. The major implication with using nuclear energy as a mitigation strategy is the fear and stigma that have been created around the nuclear fields. People are afraid of radiation, and if we want to use nuclear power as a mitigation agent we are going to need to change the perception of the public. We need to inform and educate the people on nuclear energy and what it really does and really is. Until a change of heart, nuclear power might be put on the bench in the fight against climate change. Nuclear energy can be the future; we just have to want it to be.

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