Resources: Nuclear Energy Vs. Renewable Energy

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The world has about a decade to curtail greenhouse gas emissions in order to mitigate the dangerous effects of climate change. This requires a complete overhaul of the world's energy system away from fossil fuels and toward carbon neutral sources of energy. Nuclear energy and renewable energy both provide carbon neutral sources of energy which makes them viable candidates as the world's primary source of energy. However, both systems have their own environmental and sustainability concerns which need to be addressed so that humanity does not convert to another problematic source of energy that requires another need to overhaul the entire energy system in the future. Although neither system is perfect, a system of 100% renewable energy poses the best option moving forward in terms of sustainability in relation to its use and effect on Earth's resources. The concerns addressed include the availability of raw materials for construction and operation of each system, Waste, and land use. Solar energy, wind energy, and nuclear fission will be the primary focus.

Both nuclear energy and renewable energy face issues of resource availability in terms of their construction and operation. Nuclear fission relies on the resource uranium to operate, specifically uranium-235, when it comes to light water reactors (LWR) (Jackson, 2007, p. 162). According to Jackson (2007) the operation of 575 nuclear fission reactors would require 66,658 tons of uranium in total which means that known uranium reserves would run out in about fifty-three years when operating at 2007's rate of consumption (p. 163). According to Abbott (2016) there would be about 25 years left of power if the consumption levels of 2016 are scaled up to 3,000 reactors which is just enough reactors to replace coal plants (p. 10). It is important to note that there would have to be about 15,000 nuclear reactors to supply all the world's energy needs (Abbot, 2016, p. 10). This an issue of sustainability if the uranium supply cannot carry the nuclear industry to one-hundred years with 3,000 reactors never mind 15,000 reactors. There are solutions to this problem of sustainability that could potentially carry nuclear energy to the one-hundred-year mark. Technological advancements can always be made to more efficiently use uranium. Generating uranium-233 from Thorium can prolong the uranium supply (Jackson, 2007, p. 165). This is especially beneficial because according to Jackson (2007), “Thorium is about three times as common as uranium and economically exploitable reserves of 1,200,000 tonnes are known” (p. 166). Extracting uranium from seawater is another solution that is spouted; however, according to Abbott (2016), extracting uranium from seawater is “a fruitless suggestion as the uranium concentration is tiny, at 3.3 parts per billion. The energy it takes to lift a bucket of seawater by 50 metres is equal to the energy you’d get from its uranium. The energy return on investment simply doesn't add up” (p. 10). This means that extracting uranium from seawater is not a viable option because it requires excessive amounts of energy with little return. Furthermore, despite critics of renewable energy criticizing the use of rare metals in the construction of solar panels, batteries, etc., Nuclear energy also requires the use of rare metals such as hafnium, beryllium, zirconium, molybdenum, niobium, tantalum, etc. (Abbott, 2016, p. 11). This problem is made worse by the fact that these metals cannot be recycled when used in nuclear energy (Abbott, 2016, p. 11). This is inherently unsustainable.

The availability of resources for the construction of renewable energy devices is one of the primary concerns with implementing renewable energy systems at a large scale. Various renewable energy technologies require the use of rare metals such as neodymium, dysprosium, terbium, europium, and yttrium (McCombie & Jefferson, 2016, para. 9). Solar panels need gallium, indium, and tellurium which are very rare (McCombie & Jefferson, 2016, para. 12). It is estimated that in a 100% renewable energy scenario, the neodymium reserves would be exhausted by 2083 (Habib & Wenzel, 2014, para. 32). Dysprosium would be exhausted by about

2090 with recycling measures taking place (Habib & Wenzel, 2014, para. 32). This is problematic regarding the sustainability of renewable energy, and there are other metals that need to be studied and assessed, but it appears that renewable energy does not suffer worse sustainability issues regarding raw material use in construction and operation. In fact, renewable energy may have several advantages over nuclear energy in this category. For one, metals used in renewable energy can be recycled unlike the metals used in nuclear energy. The issue of resource availability can be solved when it comes to both nuclear energy and renewable energy with technological improvements and discoveries of new reserves. For example, a copper reserve that was estimated to contain 300,000 Gg of copper ended up containing 1,000,000 Gg of copper (Habib & Wenzel, 2014, para. 33). However, renewable energy is a much broader category than nuclear energy with a wider variety of technologies which gives rise to more potential to find new technological advancements that can utilize various different types of metals so that renewable energy does not have to rely on just a couple metals.

Renewable Energy requires a way to store energy since the sources of energy are intermittent (Dehgani-Sanij, Dusseault, Fraser, & Tharumalingam, 2019, para. 5). This is where energy storage systems come in. Many raw materials that go towards the implementation of renewable energy go towards the manufacturing of an energy storage system such as a battery. However, nuclear energy also requires the use of energy storage systems if uranium is to be used efficiently (Gnanapragasam, Rhyland, & Suppiah, 2013, para. 4). The fact that renewable energy needs energy storage systems is not a disadvantage compared to nuclear energy since both nuclear and renewable energy need to extract raw materials to manufacture these energy storage systems. Fortunately, different materials for each energy storage system means that the market can switch to a different storage system if resources become too scarce. Currently, there are five major groups of energy storage systems: mechanical systems such as compressed air energy storage (CAES); Chemical systems such as hydrogen storage; electrochemical systems which include the various types of batteries; electrical systems which include capacitors; and thermal systems (Dehgani-Sanij, Dusseault, Fraser, & Tharumalingam, 2019, para. 2) CAES show high potential for becoming a sustainable and practical medium for energy storage because CAES demonstrates “grid-scale potential, flexibility, [and] long life” (Dehgani-Sanij, Dusseault, Fraser, & Tharumalingam, 2019, para. 4). The long-life aspect is especially important because a longer life means there is less of a need to extract resources to construct new CAES systems. However, there are flaws in CAES systems such as their limitations in the type of site that CAES can be implemented on (Dehgani-Sanij, Dusseault, Fraser, & Tharumalingam, 2019, para. 4). Fortunately, there are many different types of batteries that can be implemented where CAES cannot be implemented such as zinc-carbon batteries, alkaline batteries, lithium-ion batteries, nickel-zinc, etc. (Dehgani-Sanij, Dusseault, Fraser, & Tharumalingam, 2019, para. 9-18). While there are some sustainability issues associated with renewable energy in regard to the extraction of materials to manufacture energy storage systems, it is important to note that these issues are also present in nuclear energy.

Nuclear energy shows an advantage over renewable energy, specifically wind energy, in regard to more common resources such as steel and concrete. Current LWRs with a 1000 MWe capacity need 45,000 t of steel and 100,000 meters cubed of concrete while Generation III plants like EPR and ABWR need about 56,250 t of steel and 170,000 meters cubed of concrete McCombie & Jefferson, 2016, para. 15). Renewable energy sources also require the use of concrete. Turbines for wind energy need 930,000 meters cubed of concrete for a 300 MW plant and 310,000 meters cubed of concrete for 1000 MW plant (McCombie & Jefferson, 2016, para.

14). This means that in terms of concrete use, wind power requires more than nuclear (McCombie & Jefferson, 2016, para. 14). However, concrete is an abundant source that can easily be recycled, so this issue is not a defining factor when it comes to determining the most sustainable energy source.

Land and space are other important yet limited resources that need to be considered when assessing the best possible energy system. Space is an important issue for nuclear energy especially when it comes to nuclear waste. The storage of nuclear waste is going to require a lot of space. This is especially problematic because nuclear waste takes thousands of years to decay which means that any space taken up by nuclear waste storage is essentially permanent. This decreases the amount viable space on Earth with each operation of a nuclear power plant. Nuclear waste is typically stored underground, so it would not interfere with land space required for other human activities; however, there are problems with this as well. Burying nuclear waste requires the disturbance of soils, something that should be avoided at all costs. Healthy soil is an essential resource that needs to be protected because of the environmental services healthy soils provide such as erosion control, filtration, and recharge of the ground water supply. Damage to healthy soils results in an overall decrease of resources because it requires resources to fix the damage caused by disturbing the soils that would not need to be used if the soils were maintained. Furthermore, the barrels used to contain nuclear waste requires the use of resources that would not necessarily be used to the same extent with renewable energy. There is also always the risk of leakage which can damage the environment around the site nuclear storage making the land and other resources of that area unusable and, therefore, lowering the overall amount of viable resources on Earth. Fortunately, there can be ways to mitigate this. Jackson (2007) suggests that removing uranium-238 can reduce the volume of waste (p. 164). In addition, Nuclear waste can be recycled to get more energy which helps reduce the amount of waste produced and also delays the depletion of uranium (Jackson, 2007, p.164). Other solutions include reprocessing which means to break the waste down into smaller units to deal with separately rather than store it (Jackson, 2007, p. 165). Nuclear waste does not stop at the waste generated after each use. The other waste generated by nuclear power comes from the end of a nuclear powerplant's lifespan. A nuclear powerplant has a life span of only forty years, and the decommissioning of a nuclear powerplant requires that nuclear vessels are buried (Abbot, 2016, p. 11). This has the same issues regarding the disturbance of soils that the nuclear waste generated after each use has.

It is important to address that renewable energy also has some waste issues. Solar panels and wind turbines will break down at some point and will have to be replaced. Energy storage systems will also have to be replaced. This means that disposal of batteries and other aspects of renewable energy technology will have to be addressed. The disposal of batteries and renewable energy technology are another issue of space since these things need somewhere to go at the end of their life. Fortunately, batteries can be recycled, minimizing their impact on the environment by keep them out of landfills and filling up space (Dehgani-Sanij, Dusseault, Fraser, & Tharumalingam, 2019, para. 38). The issue of batteries is once again not exclusive to renewable energy, so the issue of battery disposal adds to the already present issues of nuclear waste. However, the solar panels themselves are exclusively related to renewable energy waste. Solar panels need to be replaced about every 20 to 30 years (Gönen & Kaplanoğlu, 2019, p. 414). 65% of the solar panels can be recycled reducing overall waste but still generate some waste that will need to be stored (Gönen & Kaplanoğlu, 2019, p. 417). Unfortunately, the amount of waste generated from solar panels alone can be immense. By 2045, it is estimated that there will be about 1.2 million metric tons of waste from solar energy alone in Mexico; however, about 920,000 metric tons of that waste is able to be recycled (Domínguez & Geyer, 2017, para. 52). That means about 76.67% of solar panel material can be recycled reducing the amount of waste left in storage. Solar energy has a problem with waste, but the issue does not appear to be worse than the issue with nuclear waste.

Land is a very important and limited resource. It is important to choose an energy system that not only has the physical capabilities to be fully implemented on the land available on Earth, but also uses that land as little as possible. Land use is directly tied to the depletion of healthy soil which is another important resource that needs to be preserved because of the important ecological services soil provides. It is imperative to choose an energy system that preserves healthy soils as much as possible. Land use is an issue that affects both nuclear and renewable energy, but renewable energy shows significant advantages over nuclear energy in this area. Land availability is a problem when it comes to implementing nuclear energy. In order to power the world on nuclear power, there needs to be 15,000 nuclear powerplants (Abbot, 2016, p. 10). There are very limited areas for nuclear powerplants that are close to a source of water and are far from populous areas (Abbot, 2016, p 10). Land use is also a concern when it comes to renewable energy because there is an issue of sprawl since wind turbines and solar panels typically spread themselves out over larger areas of land than nuclear power. The National Renewable Energy Laboratory estimated that the United States would need about 0.4% of land to power the country entirely on ground mounted PV solar panels (Outka, 2010, p. 1074). However, there are very simple ways to mitigate these issues with sprawl. Solar panels can be placed on rooftops. This does not require any extra use of land. An Agrivoltaic system maximizes land use by allowing crops and solar panels to exist on the same land (Amaducci, Yin, Colauzzi, 2018, para. 2). The design of the Agrivoltaic systems can be utilized on non-farmland to minimize land use when it comes to implementing solar farms on a large scale. Agrivoltaic system where the solar panels are raised high above the ground on thin mounts will not disturb the soil beneath as much because the mounts only cover a small area of soil. This leaves large areas of uncovered soil which reduces soil impaction and optimizes the soil's ability to absorb water. This reduces runoff and replenishes the groundwater supply. Nuclear power does not have the ability to coexist on farmland or urban areas. Furthermore, solar power has the potential to be installed on brownfields which are not currently being utilized for anything, so the solar panels can minimize their installation on undisturbed soils and healthy ecosystems (Outka, 2010, p. 1075).The NREL found 737 brownfield sites and other limbo sites within the United States that could be used for renewable energy (Outka, 2010, p. 1075). These brownfield sites are often within or close to cities which makes them unsuitable for a nuclear power plants but fine for renewable energy. Furthermore, solar power carries the potential of possibly restoring brownfields because solar panels allow for minimal ground cover. Solar power also does not need to be near a source of water and can exist in populous areas which increases potential sites (Outka, 2010, p. 1081). Wind farms also sprawl out over larger areas in comparison to nuclear power plants; however, there is also a potential benefit to sprawling out the wind turbines and leaving grassy land between each turbine because that allows percolation of rainwater throughout the wind farm rather than having one large impervious surface like that of a nuclear power plant. Land used for wind turbines can also be used for agricultural purposes (Diesendorf, 2016, para. 9). Just like with the Agrivoltaic system, this prevents sprawl; therefore, this also prevents deforestation which has negative impacts on the soil. The amount of land used could also be reduced by utilizing offshore wind farms. Offshore wind farms make for a more ideal location for wind farms anyway because wind speeds tend to be higher on the ocean than on land resulting in more power (Karakosta, Marinakis, Pappas, & Psarras, 2013, para. 15). Placing turbines in areas where they work efficiently reduces the need to create more wind turbines, therefore, saving raw materials and space.

The space utilized by renewable resources has the benefit of easily being reused and restored. Meanwhile, Nuclear energy sites cannot be as easily restored, therefore, reducing the amount of viable land every time a nuclear powerplant is decommissioned (Diesendorf, 2016, para. 9). The impact of potential nuclear accidents is an important factor that needs to be analyzed. Nuclear power plants are becoming safer as more precautions are taking place, but this does not erase the fact that there is still risk for nuclear accidents. This risk is not present with renewable energy systems like solar and wind. Nuclear accidents can lead to a “long-term loss of land use” if an accident were to occur (Jefferson & McCombie, 2016, para. 18). This reflects a consistent problem concerning the sustainability of nuclear energy whether its in relation to accidents, decommissioning, or waste storage and that is the fact that whatever space is needed for nuclear energy is going to have to remain for nuclear energy because that space needs time to recover. Once again, this issue is not present in renewable energy. It is more beneficial to need more land but have that land be both multipurpose and easily recoverable than to need less land but have that land be single use and depleted. This issue makes nuclear energy inherently unsustainable.

In general, the issues of land-use are more easily solvable for renewable energy than they are for nuclear. The broad category of renewable energy means that there are multiple options and, therefore, multiple ways to make technological advancements like that of an Agrivoltaic systems to help solve problems of land use. Renewable energy systems are also more flexible in terms of land use due to each unit being relatively small in size compared to a nuclear powerplant. This makes accommodations to the environment easier with renewable energy technology easier than with nuclear energy technology. In addition, the more efficient technological advancements make renewable energy the less land is needed to accommodate society's energy needs. Furthermore, there seem to be very little solutions to solving the issues of land use with nuclear power like there are with renewable energy.

Nuclear energy and renewable energy both demonstrate to have issues in terms of resource use and availability which affects their overall sustainability. However, renewable energy demonstrates to have several advantages over nuclear energy because renewable energy demonstrates to have more of an ability to coexist with the environment and have a high potential for technological advancements. Furthermore, although the problems with nuclear energy and the environment have the potential to be solved in the future, the problems that widescale nuclear power implementation will cause now such as nuclear waste storage, accidents, and decommissioning will only incur problems that need to be dealt with in the future that would not be dealt with if renewable energy was implemented in the first place. The issues with renewable energy are not more significant than the issues with nuclear power, and the issues that do come with renewable energy can be easily solved with technological advancements and smart implementation. The issues with renewable energy are worth incurring if it means avoiding the issues with nuclear power. It is important that society switches to renewable energy instead of implementing new nuclear power plants in order to create a society with a clean and sustainable energy source that would not require another extensive overhaul of the energy system in the future.

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