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Reviewing the Power Potential of the Planet

We cannot continue to burn fossil fuels as we have in the past. Aside from their finite availability, burning fossil fuels produces emissions that contribute to greenhouse gases and global warming.[1] According to an article from NASA's Earth Science Communications Team, continued emissions could have devastating consequences. They cite predictions of flooding, stronger hurricanes, rising sea levels, and even "megadroughts" ("The Effects of Climate Change"). On top of these concerning environmental impacts, the Intergovernmental Panel on Climate Change predicts global warming will cause significant monetary damage from environmental disasters that will increase with time (IPCC 65). We cannot continue to ignore the effects of our actions. We must stem our role in global warming—mainly the burning of fossil fuels—before the damage of climate change becomes irrevocable. Though we have no universal alternative to fossil fuels, we must consider the spectrum of options that are best suited for the region and find ways to effectively implement them. We should move from fossil fuels to reliable, clean sources, such as hydroelectric, geothermal, and nuclear power, supplemented by the less consistent wind and solar power. Each energy source has limitations, so we should focus on developing those that are best suited for any given power grid.

[1] Climate change is a very real effect, as testified by the vast majority of environmental scientists. NASA's Earth Science Communications Team states, "97 percent or more of actively publishing climate scientists agree [that global warming] trends over the past century are extremely likely due to human activities" ("Scientific Consensus: Earth's Climate is Warming").

While most people find renewable energy sources to be the most attractive options when considering substitutes for fossil fuels, these sources have their share of limitations[2]. Solar energy, for example, can be deceptively expensive and damaging to the environment. Ozzie Zehner, a writer with a master's degree in Science and Technology Studies from the University of Amsterdam, calculated that it would cost about $123 trillion to create the solar cells and batteries necessary to power the globe with a further annual maintenance cost of $694 billion. More importantly, this enterprise would produce a further 149 billion metric tons of carbon dioxide (9). That is equivalent to four years' worth of carbon emissions (Jackson et al. 1). Additionally, Zehner explains solar cell production emits some of the most potent greenhouse gases (18). One of these, nitrogen trifluoride, is 17,000 times more damaging than carbon dioxide (Docksai 10). These gases would have a serious impact on global warming. Beyond that, solar power is limited by location. Michael Fox, a professor of environmental science at Colorado State University, calculates that about fifty square miles of solar panels would generate about as much electricity as a typical nuclear power plant produces in a third of a square mile (82). Huge fields of solar panels can jeopardize fragile ecosystems.

There are also more prohibitive concerns with solar power, primarily location and inconsistency. Fox explains that those regions best suited for solar energy production do not have high energy demands. Transferring electricity from these areas to those that have a higher demand is inefficient. He states there can be losses of up to 20% of energy transmitted over a few thousand miles (82). Unless power companies invest significant funds into high-efficiency

[2]Politicians and mainstream media propagate the idea that energy sources such as solar and wind are "cure-all" energy sources. They are not; every energy source has flaws that must be considered. It is not practical to hail one or two energy sources as the one solution for every energy grid.

cables, solar energy must be produced locally to limit energy losses from this already unreliable source. He also explains the issue with intermittent energy sources in general: "[l]arge-scale electricity is not easily stored, so the supply has to match the demand at any given time" (90). When the sun is blocked by clouds or precipitation, or when the night falls, solar power cannot offer enough energy to meet demand.

These factors certainly limit solar power, but no energy source is without drawbacks. Greenhouse emissions from solar production would hurt the environment through climate change, but conversion to renewable energy would nearly eliminate our yearly emissions from power production. Solar power has a higher initial impact than other energy sources, but a single surge of emissions is better than continued production for years to come. From a financial standpoint, solar panels would not cost as much as fossil fuels after implementation. According to a study from the International Monetary Fund, fossil fuels cost taxpayers as much as $4.9 trillion per year, far more than the projected annual cost of solar power (Coady 18). However, these projections are hypothetical, as it would be impractical and wasteful to use only one power source to supply the globe. Considering the limitations of solar power, it is best implemented as a supplement to other power sources that can provide the majority of the power and lower their production when the solar cells are active. This smaller scale utilizes the most useful features of solar energy and avoids its drawbacks. Solar panels can still be effective in sunny areas, where transmission losses would be minimized, or be implemented on residential roofs to supplement power grids or heat water. We should work to implement a variety of new power sources to replace fossil fuels, not abandon everything we have already built for a single type of power plant.

Wind turbines, at first glance, are less problematic than solar panels. The main issues arise from environmental and reliability concerns. Fox calculates that a wind farm needs about 540 square miles to match the power output of a nuclear plant (93). These farms can allow for ground ecosystems to remain, but environmentalists are concerned that wind turbines can knock unsuspecting birds from the air. However, according to a study in *Biodiversity and Conservation*, "[wind turbines] do not appear to be more detrimental to birds than other man-made structure[s]" (Lucas et al. 395). As for the other major environmental concern, there is little evidence that wind turbines will contribute to global warming. The materials used to make the turbines are also mined and thus have some carbon impact, but no power source is entirely carbon-free[3]. Mining materials and transportation for power plant production always has some effect on the environment. The emissions from mining materials for solar, wind, hydroelectric, geothermal, and nuclear power, however, are insignificant compared to the amount released from burning fossil fuels. While wind turbines have some environmental impact, it is insignificant in comparison to fossil fuels.[4]

The main issue of wind, however, is its inconsistency. As Zehner explains, the power companies have to fire up other plants to supplement the turbines every time the wind slows. Sometimes wind farms can consume energy, as idle turbines need power for steering (43). This makes wind power inefficient. Fox calculates that a wind farm with a rated power output of one gigawatt only produces about a quarter of that on average (45). All of these factors make it a

[3] Converting machinery and gas-powered vehicles to electrically power vehicles is another discussion entirely.

[4] As with solar, location is a limitation with wind power. Wind farms are loud and light up the sky with warnings for airplanes, so not many people want one in their backyard. As a result, energy companies have to face resistance when building farms near residential areas and generally opt to build them away from towns, in plains and off-shore.

nightmare to attempt to use wind alone to power an energy grid, however, power sources are most effective in concert. These turbines can still be a great supplement if implemented in non-residential areas where other clean energy sources can cover their lapses.

Hydropower is perhaps the most stable traditional renewable energy source. Water does not stop flowing and thus can produce steady power without regard to the weather or time of day. Unlike solar and wind, it can provide the baseload electricity for power grids without requiring economically and financially expensive battery systems or dirty supplemental power. Hydropower can theoretically account for a serious amount of the globe's power. In an article on the global potential of hydropower, several faculty members of the Civil Engineering and Geosciences Department of the Delft University of Technology estimated that the "gross theoretical hydropower potential" is equal to 33% of the annual global power demand (Hoes et al. 1).[5] That is a significant portion of the world's energy requirements. This study also calculates that we only utilize 3% of this potential capacity.[6] We could greatly reduce our reliance on fossil fuels for energy production through hydropower alone. Zehner argues, however, that expanding hydropower would "displace [thousands], disrupt fishing industries [and] place neighborhoods at greater risk of flooding" (134). These are valid concerns, but they are addressed in the Delft University study, where it is stated that the calculations consider the potential of hydropower without weighing the delicate factors of politics and local resistance to hydropower[7]. This means that this study's calculations are a little high, but hydropower can still provide a significant portion of our energy. The Delft University faculty estimated that the actual potential would be

[5] They do predict that this potential will grow, as areas that are currently not considered economically feasible might be developed in the future (8).
[6] As of 2017.
[7] The study also did not include dams which could severely damage the surrounding area (Hoes et al. 8).

reduced to 26.5% of the global demand (8). Hydropower can provide the steady energy required to support power grids, but like every other energy source, it cannot be a stand-alone replacement for fossil fuels.

Geothermal power plants remain obscure in many discussions of renewable energy sources despite their significant potential. According to an assessment from the U.S. Geological Survey, if we utilize Enhanced Geothermal System (EGS) plants, the mean estimated geothermal power potential of the United States is equal to half of its power demand (Williams et al. 3).[8] This estimate is from an older study, but it is still relevant today. The potential would not lower with time, but rise as advancements in geothermal technology are made, allowing for more efficient harnessing of the Earth's heat. This study excludes any potential sites in national parks, though it does include private property. Some property owners would surely be unwilling to allow geothermal development on their land, but even so, we can make an impact on our emissions by utilizing this energy source. Additionally, since these power plants do not burn fuel, they have virtually no impact on climate change.

Geothermal power has great potential, but it also has limitations. Zehner explains that EGS plants can produce radioactive waste and even cause earthquakes in some situations (137). He believes this makes EGS too dangerous, but these issues are not as significant as they seem. In an assessment of EGS, an MIT-led interdisciplinary panel concluded that:

> With more than 100 years of worldwide experience in geothermal operations […] future EGS power plant facilities can be designed and operated to have relatively small impacts on the local and regional environment. In fact, because EGS plants have a small footprint

[8] At the time of the study, there were virtually no geothermal plants using Enhanced Geothermal System technology, so it was very much theoretical. As of 2017, there were 18 significant implementations of EGS, according to Shyi-Min Lu (2902).

> and can operate essentially emissions-free, the overall environmental impact of EGS power facilities is likely to be positive, reducing the growth of greenhouse gas emissions while providing a reliable and safe source of electricity. (Tester et al. 286)

While EGS power plants can cause earthquakes and produce radioactive waste, the MIT panel concluded that with the technology and data available in 2006, the risk of earthquakes and other environmental concerns of geothermal power plants can be minimized to the point where it is more reliable and less dangerous than other sources, such as fossil fuels. Since our technology is only improving, we can expect that these plants will become even less dangerous than this assessment predicts. With these estimates, geothermal is clearly an energy source we should pursue.

In many areas, renewable power sources can supplement each other to be sustainable unaided. In areas where this is not feasible, however, we need a steady power source to provide base power for our grids. Rather than using fossil fuels, which pump out greenhouse gasses in unimaginable quantities, we should look to the option that can provide clean base power: nuclear plants. Not only is nuclear energy almost emission-free, it is also incredibly efficient.[9] According to Fox, it has a 90% capacity factor, meaning that on average, a nuclear plant produces 90% of its rated power output (104). This is impressive in comparison to wind, for example, which has a 24% capacity factor. Since nuclear power is not dependent on wind or sunlight, it can provide energy without extensive battery systems. Unfortunately, the public has significant stigma associated with nuclear energy. If a plant has a design flaw, catastrophic accidents can occur, such as the meltdown at Chernobyl in April of 1986. Fox, however, explains that modern nuclear

[9] It was previously mentioned that no power source is carbon free. Keep in mind that nuclear produces insignificant emissions in comparison to fossil fuels.

power plants do not pose significant risk. The disaster at Chernobyl—the most significant and dangerous nuclear disaster—only occurred because of the reactor's flawed design (235)[10]. After Chernobyl, the only nuclear event considered to have "wider consequences" according to the International Nuclear Event Scale (INES) was the Fukushima nuclear accident of March 2011. This event was not caused by a foreseeable design flaw, but by an unfortunate combination of an earthquake and tsunami. According to a 2014 health risk assessment by the World Health Organization, "no discernible increase in health risks from the Fukushima event is expected outside Japan" (7). The Fukushima and Chernobyl nuclear disasters are the only two nuclear events in history considered "severe" by the INES, with an additional "major" event in 1957, and two events classified as having "wider consequences" in 1957 and 1979 (Högberg). These power plants can be dangerous, but our safety measures are improving and current reactors are held to higher standards. Provided that we continue requiring nuclear power plants to meet stringent safety regulations, there should be essentially no threat of another disaster. The other primary issue, nuclear waste, is not urgent. Radioactive waste can be safely recycled or stored while the radioactivity subsides over a few thousand years (Fox 205-6).[11] While nuclear power plants can be disastrous if poorly designed, modern plants are relatively safe and produce consistent energy without releasing greenhouse gases.

Climate change is a growing threat as our society continues to produce greenhouse gases at a record rates. We need to take action and drastically decrease our impact on climate change before we start to feel the consequences. Hydropower and geothermal power both have great

[10] There is no clear consensus regarding the death toll resulting from the Chernobyl event.
[11] The materials used as fuel in nuclear reactors is radioactive. Thus, we are taking radioactive materials from the earth and harnessing them, then leaving the resultant radioactive waste to safely decay.

potential to reduce emissions with few limitations, but they cannot be the only options we develop. Other renewable sources, such as wind and solar energy, can be great assets, but they cannot support electric grids without another source to provide steady base power. Nuclear power is one of the more versatile options that we can implement in areas where the more consistent renewable sources are unavailable. Unfortunately, disasters like Chernobyl and public misunderstanding of radioactivity build stigma towards nuclear energy. We must overcome these barriers and break down the public's preconceived ideas about nuclear power. The public considers renewable energy to be a perfect replacement for dirty energy, but every energy source has limitations and benefits. We cannot focus on switching to a single type of power plant, but rather we should work on a case-to-case basis, switching from fossil fuels to whichever combination is most optimal for a specific region. The consequences of years of essentially ignoring climate change are looming on the horizon, so we must properly implement clean power plants to replace the toxic energy sources of the past.

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