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Deciding on the Future

Comparing the Environmental and Economic Advantages of Renewable Energy and Nuclear Power

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ME 311 (Thermodynamics)
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Concerns over public health and environmental hazards from fossil fuel-based power plants have been prevalent topics of discussion in recent years. A shift towards cleaner forms of power is a priority for citizens, politicians, and industry leaders alike. Many forms of renewable energy have been developed recently, and some are currently available for large scale use. Nuclear power has developed to the point where it is both safe and efficient. But a negative public opinion has continually pushed nuclear power away from the discussion as a possible energy source, while less efficient forms of renewable energy have been promoted due to their lower effect on the environment despite their higher financial burden. Both nuclear power and renewable energy have their own unique advantages and disadvantages, and neither one can be considered a definitively better choice. The ultimate decision comes from whether people believe economic efficiency or environmental preservation is a higher priority, both now and in the future. In this essay, nuclear power is compared to different forms of renewable energy based on cost, environmental impact, and efficiency while addressing the most commonly seen public concerns. The results from the research show that nuclear power is more economical, offsetting fewer negative effects of fossil fuel-based power plants, while renewable energy has a larger positive impact on the environment, requiring a larger financial investment.

1. Introduction

Technological advancements can bring about dramatic improvements to a society in many ways. The development of fossil fuel-based power plants brought widespread distribution of

electricity to homes and businesses. While these plants were hailed at their inception, many unforeseen consequences have come from burning such large amounts of fossil fuels for several years. Byproducts from fossil fuel combustion have caused health problems for people and animals and have contributed to major adverse changes in the global environment. Easily ac-



I am currently a senior studying mechanical engineering, and am originally from Spokane, WA. I worked with nuclear power for six years prior to beginning school at the University of Hawai'i, and plan to pursue a career in renewable energy after graduation. This article began as a paper on sustainability for Thermodynamics with Dr. Marcelo Kobayashi. My intention was to show that there are multiple factors to consider when making important decisions, and that it can be easy to focus only on the main aspect of an issue while overlooking secondary factors that can be just as critical to success.

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cessible electricity has become a necessity for people today, but fossil fuel-based power plants are outdated and need to be reduced or eliminated to minimize their impact on the environment. Different ways of converting energy into electricity are available, but most are still in the developmental phase and are not ready for use on a large scale. This essay argues that the best current alternatives to fossil fuel-based plants are renewable energy and nuclear power, and the decision about which one to use is dependent on whether the priority is on sources that are more environmentally friendly or economically advantageous.

Renewable sources of energy can greatly reduce emissions from power plants, providing clean energy and minimize the impact on the environment that is inherent with traditional fossil fuel-based power plants. However, output from renewable energy plants can vary greatly due to being dependent on the weather and climate of a region, which can be unpredictable at times and are not controllable. Nuclear power is not dependent on these same outside factors but still has a large effect when reducing emissions from power plant operations. Yet public opinion towards nuclear power tends to be negative, with much of the concern being the safety of the public. Operating a nuclear power plant incorrectly can lead to incidents that could possibly have serious effects on its nearby inhabitants and the surrounding environment. These incidents create an unfavorable view of nuclear power, whether their effect is as devastating as that of Chernobyl or as inconsequential as that of Three Mile Island. When implemented safely nuclear power can provide a large amount of efficient electricity to the public, yet it is not as effective at reducing emissions that can hurt the environment as renewable energy. While neither option is a perfect solution, both are preferable to fossil fuels due to their lower environmental impact and use of innovative technology. Because of this, transitioning away from fossil fuel-based plants and into either renewable energy or nuclear power must currently be given high prioritization.

2. Cost

While many different solutions have been proposed, economic feasibility is an inherent driving factor for each one. Environmental preservation is always a matter of concern when discussing energy solutions, but any proposed method is irrelevant if it cannot be economically implemented. Many factors must be considered when determining the overall cost of an energy source, including initial construction, connection to existing systems, labor required for operation and upkeep, and total energy output. Though fossil fuel-based plants are generally less expensive due to their widespread use and existing infrastructure, renewable energy and nuclear plants are still comparable on a per unit basis. Since many nuclear plants are more compatible with the existing infrastructure than renewable energy plants, and since overhauling energy system

infrastructure would require a very large monetary investment and take a very long time, nuclear power requires fewer initial resources and is more economically advantageous.

2.1 RENEWABLE ENERGY COSTS

Because many forms of renewable energy are available, many different types of plants can be utilized to take advantage of the available resources in different areas. This creates a wide range of costs between different types of renewable energy, as well as between plants that use the same renewable resources but implement different methods. The U.S. Energy Information Administration [1] has compiled cost data for plants entering service in 2022 using the 2016 dollar value and accounting for tax credits. Based on these figures, onshore wind facilities cost an average of \$52.20 per megawatt-hour (MWh) while offshore wind facilities cost an average of \$145.90/MWh, an average of \$99.05/MWh between the two. Solar photovoltaic plants cost an average of \$66.80/MWh while solar thermal plants cost an average of \$184.40/MWh, an average of \$125.60/MWh between the two. Hydroelectric plants had the lowest overall cost of all renewable sources at \$66.20/MWh. These costs are not appreciably higher than those of traditional power plants, but renewable energy sources are not generally compatible with the existing infrastructure currently in use. A widespread change in the types of energy sources used would require a large initial investment for modernizing or replacing existing energy facilities and infrastructure, which would only be worthwhile if there is a very strong long-term commitment to renewable energy.

2.2 NUCLEAR POWER COSTS

While nuclear power plants are never exactly identical, nuclear fission reactors are currently the only type of reactors that provide a useful energy output. Because of this the cost of a nuclear power plant is mostly based on its size, which is determined by the energy demand in the area it supports. According to the U.S. Energy Information Administration [1], advanced nuclear power plants have an average cost of \$99.10/MWh. This is about 50% higher than the average cost of hydroelectric plants, but is almost equivalent to the average cost of wind facilities and is about 21% lower than the average cost of solar plants. The main economic advantage of nuclear plants comes from the fact that they are able to use much of the same infrastructure as most fossil fuel-based plants currently in operation, greatly reducing the initial investment required. Because of this, nuclear plants have much lower short-term costs than renewable energy plants.

3. Environmental Impact

One of the driving factors behind the push for both nuclear power and renewable energy is the positive improvement they

both have on the environment when compared to traditional power plants. According to McClamb of the Ecology Global Network [2], fossil fuels provide nearly 88 percent of the world's energy and are the largest contributor to greenhouse gases that cause global warming. Both renewable energy and nuclear power reduce the total amount of carbon emissions and air pollution that come from plants that use fossil fuels, and both take advantage of resources that are more plentiful than fossil fuels. However, they each have their own unique repercussions that must be taken into consideration. While the overall negative effects of both renewable energy and nuclear power are less than that of plants using fossil fuels, they both present new challenges when faced with the problem of minimizing their impact on the environment. Since they partially rely on fossil fuel energy, nuclear plants will still contribute to carbon emissions and increased air pollution. Renewable energy plants have very few emissions and contribute very little to air pollution, and their effects on the environment are much less drastic and can be mitigated simply and easily. Because of this, renewable energy is much more effective at addressing environmental concerns.

3.1 RENEWABLE ENERGY IMPACT

Renewable energy plants take advantage of naturally occurring events, converting the energy expended by natural sources into usable power. This conversion of energy does not deplete any resources, but renewable energy plants still have their own negative effects on the environment aside from just the land and materials needed for construction. While renewable energy plants do not give off any emissions themselves, fossil fuel energy is generally used for material production, material transportation, plant construction, and operation of machinery. An initial contribution to air pollution is minimal when taken over a long period of time, and is easily offset by the reduction of emissions provided by using renewable sources for energy. The main concern for renewable energy plants is their impact on plants and wildlife after construction and during operation, and how that affects the local environment.

According to the Union of Concerned Scientists [4], wind turbines can pose a threat to birds and bats that can be hurt or killed if they fly into the moving blades. However, these incidents are not very common, and new technology and better siting of turbines has reduced these risks. Little information is available for offshore wind turbines since they have not yet been implemented to a large degree. Some believe it will hinder fish population due to increased ocean activity, but others propose it may increase their population due to creating artificial reefs. Land based turbines tend to have little effect on local environments, and more studies are necessary to gather a sufficient amount of information to determine the actual effects of offshore wind turbines.

Solar power does not pose a threat to wildlife the way

wind power does, but it can pose a risk to people who work at solar plants and those in nearby areas. The Union of Concerned Scientists [5] states that solar power requires the use of hazardous materials, mostly different types of acidic solutions, that are necessary for processing and maintaining photovoltaic cells. These chemicals can be detrimental to the health of workers if proper precautions are not taken when handling them, and could pose a risk to nearby civilians if they are not properly handled and disposed of. However, strict regulations encourage proper handling under threat of financial penalty, and many plants recycle these materials when possible. If regulations are followed and hazardous materials are handled properly, implementing solar power will have minimal environmental repercussions.

Hydroelectric power is another form that can have a detrimental effect on the nearby environment. The Union of Concerned Scientists [6] states that hydroelectric dams can have an indirect contribution to carbon emissions. When reservoirs are flooded after the construction of a dam, much of the vegetation and soil in the area will decompose and release carbon dioxide and methane. The reduced plant life also decreases the amount of oxygen that is converted from carbon dioxide. Small plants can emit between 0.01 and 0.03 pounds of carbon dioxide for each kilowatt-hour (kWh), while large plants can emit up to 0.06 pounds of carbon dioxide per kWh. Hydroelectric plants can also affect the local wildlife, both directly for aquatic wildlife and indirectly for others. Dams can disrupt fish populations, both by inhibiting migration and physically harming fish that come into contact with turbine blades. Dams can also reduce the amount of plants and microorganisms that fish eat, further lowering their population. This can affect animals that use fish as a source of food, indirectly lowering their population as well. Dams also change the way rivers and streams flow, and can dry out areas downstream. Areas upstream of the dam will have the opposite effect, as an abundance of stagnant water can promote overgrowth of some plants, crowding out other plants and possibly fish as well. These effects are usually controlled by manually removing invasive plants or using aerating turbines that help limit their growth.

3.2 NUCLEAR POWER IMPACT

While uranium used for nuclear power is not a renewable resource, the same amount of energy as fossil fuel-based power plants can be produced with a much smaller amount of fuel. In addition to this, new types of nuclear reactors are being developed that can use spent fuel from older reactors as their own fuel, greatly reducing the amount of waste. Despite these new technologies, there is still waste produced by nuclear plants that has little or no practical use and must be handled and disposed of properly to minimize its impact on the environment. According to the U.S. Energy Information Administration [3], nuclear plants produce waste in the form of uranium

mill tailings, used reactor fuel, and other forms which can all stay radioactive for up to thousands of years. The amount and severity of radioactivity varies between each type of waste and decreases over time through radioactive decay. The majority of waste generated by nuclear plants has a low level of radioactivity, mostly uranium mill tailings and different types of tools, clothing, and equipment that have small amounts of radioactive contamination. Due to the concerns over radioactive waste, strict regulations are put in place to ensure plants comply with procedures for disposal under risk of severe financial or operational penalties. As long as nuclear facilities stay compliant with these regulations, their radioactive impact on the environment is minimal.

4. Nuclear Power Safety Concerns

When it comes to the concerns about nuclear power, many have their origins in the imaginations of comic book authors and science fiction film directors. According to a Gallup poll from March 2016 [7], 54% of U.S. residents oppose nuclear energy, the first time since the survey began in 1994 that the majority of people in the country do not support the use of nuclear power. While long term health risks caused by proximity to operating nuclear plants can be a concern, sudden extreme biological changes in people, plants, and animals have never been officially confirmed. However, there are still legitimate concerns when it comes to the safety of operating a nuclear reactor. Serious consequences due to malfunctioning, incorrectly operated, or damaged nuclear reactors are a possibility, though this can be true with any type of power plant. The main concerns are the potential immediate effects of a major nuclear accident on the surrounding inhabitants, as well as the long term effects of safely operating plants. Much research has been done in this area, and all results have shown that safely operating nuclear reactors do not produce any major health risks.

4.1 IMMEDIATE EFFECTS

In the case of a nuclear accident, the immediate effects on the people and surrounding environment depend largely on the severity of the accident. The largest nuclear accident in the United States occurred at Three Mile Island power plant in Pennsylvania. From the World Nuclear Association [8], one of the reactors at Three Mile Island was initially operating at just under its maximum capacity when a malfunction caused the temperature of the primary coolant to rise and led to an automatic shutdown of the reactor. A relief valve failed to close and was not indicated by its instrumentation, and operators misdiagnosed the problem and failed to take appropriate actions. These factors led to the draining of primary coolant and a rise in core temperature, causing severe damage to the core. After a few days a small amount of radioactive gas was released to the

environment, but it was below the background level of radiation for the area and did not cause any death, illness, injury, or adverse health effects to any plant workers or nearby residents. The damaged reactor was removed and Three Mile Island continued operation. The largest nuclear accident in the U.S. produced no negative immediate effects, showed that nuclear plants can maintain their integrity as designed during an accident, and provided useful information for designing improved nuclear plants that can better withstand accidents.

4.2 LONG TERM EFFECTS

While unanticipated accidents are the main concern when it comes to radioactive exposure from nuclear reactors, many are still concerned with the long term effects that come from being near an operating nuclear reactor for an extended period of time. Assuming that all exposure is from normal plant operation and there is no contribution from any kind of accident, these concerns appear to be unfounded. According to the U.S. Nuclear Regulatory Commission [9], a person living outside an operating nuclear power plant can expect to receive 0.1 millirem (mrem) in one year. For comparison, a round trip flight from Washington D.C. to Los Angeles produces 5 mrem, a chest X-ray produces 8 mrem, a full set of dental X-rays produces 40 mrem, and the total amount of radiation from background sources in one year is 360 mrem. In addition, the U.S. Nuclear Regulatory Commission [10] states that there is no data showing a link between cancer and doses of radiation below 10,000 mrem. They also state that a whole body dose between 350,000 and 500,000 mrem is necessary to be fatal to about half of the population. Based on these figures, close proximity to a normally operating nuclear power plant will not have any negative consequences on the long term health of individuals.

5. Conclusion

While it can be seen that either nuclear power or renewable energy would be a much cleaner form of energy than fossil fuels, it is not clear if either option is strictly the better choice. Nuclear power is economical and requires very little fuel to provide large amounts of energy, but it is still dependent on power supplied by fossil fuels and does not have much public support. Renewable energy is not as economical as nuclear power, but it reduces dependence on fossil fuels and is better at mitigating the harm they cause. It also has a large amount of support from the public, regardless of the higher cost and less efficient output. While in theory using many sources of power could combine the advantages of the different forms of energy, in practice it appears they are too different to coexist successfully. Developing the infrastructure necessary for using both types of power simultaneously would be much more expensive

than using one form or the other. Ultimately the decision is dependent on whether the priority is environmental impact or economic feasibility, both now and in the future. If efficiency and cost are the priority, then nuclear power is the correct choice. But if reducing carbon emissions and dependence on fossil fuels is more important, renewable energy has the advantage. Regardless of the higher cost and increased investment, dependence on fossil fuels must be greatly reduced to diminish their impact on the environment and push the U.S. towards modernization.

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