[REMOVED]

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Nuclear energy, Glowing Green Goo? Or the best energy source for the modern age?

Nuclear power has gotten a lot of bad press over the years ever since its invention. The most memorable being The Simpsons, depicting nuclear materials as a glowing green goo. While entertaining, is very much not the case and has planted lots of undue public distrust in the field of nuclear science. In fact, nuclear energy is the best clean energy source providing the most safety, greatest potential developments, and increased efficiency over other energy sources.

Nuclear Energy is widely regarded as one of the safest energy sources contributing to its status of the best energy source. Throughout the history of the field every major accident has been preventable and was either the result of gross negligence or extraordinary circumstances such as natural disasters. One of such cases was the incident at the Fukushima Daiichi nuclear plant in 2011 where a tsunami struck the building. This would not have been an issue because the building was designed to withstand waves of up to 18.1ft (NRC). However, the tsunami that struck the plant was estimated to be from 46 to 49ft high. The specific height is not known because the tide gauge installed on the building failed with the maximum measured height being 24.6ft (NRC). During the design phase, the 18.1ft number was decided because it was estimated based on the data from historical tsunamis from the area (NRC). “In 2006, TEPCO performed a study on the development of probabilistic tsunami hazard analysis, which used the Fukushima coast as an example. The study estimated the probability of the Fukushima coast experiencing a tsunami greater than 19.7 ft (6 m) to be less than 1.0 E-2 in the next 50 years” (NRC). The 49ft

tsunami was completely unprecedented and impossible to predict. Alongside the basic reactor protections such as cooling pumps and control rods most reactors have passive safety systems. These systems do not require power or operator input to function and most of the time cannot be bypassed. One example is the Molten Salt Reactor Experiment at the Oak Ridge National Laboratory. The key design principle of the Molten Salt Reactor is that it has an actively cooled "drain plug" that the fuel sits on. When the fuel gets too hot in the event of a cooling loss the plug melts and the fuel spills into a separate chamber where it does not have access to the reaction boosting substance. Stopping the reaction and averting the potential catastrophe without any human intervention. There is another more common type of safety measure called "Active safety measures". These include things such as control rods and coolant. Active safety measures are usually more effective than passive safety measures while powered. However, if power is lost the system is essentially useless hence the "active" title.

One of the best things about nuclear is that it's still relatively new as far as science fields go so there is plenty of room for new innovations. Whether the innovations are in safety or the production itself, the sky is the limit for nuclear sciences. One such current innovation is fast neutron reactors. Fast neutron reactors are a type of reactor that was designed in the 1950's but not commonly used commercially having only 20 land-based reactors contributing around 400 "reactor years" of power combined globally (IAEA). Fast neutron reactors have a huge advantage being an extremely high usage of the available energy in uranium with minimal waste as opposed to the traditional thermal nuclear reactors (IAEA). Another hugely innovative reactor type is the "Pebble bed reactor." First theorized in the 1940's the pebble bed reactor relies on pebbles of fuel incased in graphite that are held in a chamber filled with a circulating nonflammable gas such as helium to remove heat from the reactor. The main safety feature of the

pebble bed reactor is that the fuel starts to lose efficiency at higher temperatures reducing the reactor to a safe power level. This alongside the reactor being designed around these temperatures means that it is impossible for the reactor to expel any hazardous waste as a result of any or all supporting machinery such as coolant systems. This design was tested with the German AVR and later tested in China with the HTR-10 and put into a full-scale design in 2021 with the HTR-PM and hopes of the reactor design replacing China's coal-based power plants (Rogers). The biggest nuclear innovation which is widely regarded as the "holy grail" of nuclear science is fusion. Nuclear fusion would create practically wasteless power generation with decreased levels of radioactivity with an abundance of fuel. As of 2023 only one instance of fusion ignition has occurred and only for a brief period on December 5, 2022, at the National Ignition Facility. Fusion energy still has a long way to go but if it becomes feasible it would become the cleanest and most efficient energy source by far. With nuclear fusion being somewhat related to the more common nuclear fission, any developments in fusion while not advancing fusion could be used to drastically improve the current nuclear technologies we have. While fusion is quite far beyond the horizon, fission energy is here to stay. With cleaner and cleaner techniques being developed the future of fission is bright.

Speaking of cleaner energy, climate is a hot topic when it comes to electricity. Nuclear power is one of the cleanest forms of energy currently due to the sheer efficiency of the fuel itself, and lack of atmospheric contamination. According to the United States Department of Energy nuclear power is at full capacity 92.5 percent of the time as with the next best being geothermal at 74.3 (DOE). In this context the higher percentage of full energy is better because that means there are less obstructions and "off time" for nuclear power. When a nuclear plant is running it is running at full power meaning that all available energy is being produced. The other

7.5 percent of the time includes things such as planned maintenance and refueling which takes place around every 1.5 to 2 years (DOE). The uranium fuel pellets that are used in nuclear powerplants are also highly efficient on their own. On average one pellet produces as much energy as one ton of coal (NEI) making nuclear energy highly efficient while reducing waste. Nuclear energy also does not contaminate the atmosphere at all. The only byproduct of nuclear energy that is released into the air during normal operations is steam which is completely harmless. Alongside nuclear wind and solar energy also produce no emissions, however nuclear has one major advantage being that it generates an incredible amount of power much more reliably than wind and solar (NEI).

Despite the overwhelming positives about nuclear energy there are still some detractors. The biggest opponent being the portrayal in the news throughout the years. Nuclear has always had opposition stretching back to the 1940's however it really picked up in the 1970 with the Three Mile Island disaster and the Chernobyl disaster in 1979 and 1986 respectively (Koerner). Many pieces of media claim that nuclear energy is "slow" and does not create enough energy to justify the long wait times. Nonprofits like Greenpeace claim that "Uranium extraction, transport and processing is obviously not free of greenhouse gas emissions either. All in all, nuclear power stations score comparable with wind and solar energy" (Leman). In terms of total greenhouse gas emissions nuclear energy may be compared to renewables. However, in terms of total power generation, a single nuclear reactor produces about 3.125 million solar panels worth, or 431 utility scale wind turbines (NE). Nuclear energy is incredibly power dense and is arguably the most efficient power source in terms of energy produced for space and emissions. Also, nuclear is generating energy almost 100% of the time as opposed to solar where you need to have a clear and sunny day.

Nuclear energy is the best energy source due to its many safety systems, room for innovation, efficiency, and little climate impact. These are all contributing factors to nuclears potential dominance in energy generation replacing fossil fuels and potentially even some of the less effective renewable sources if allowed to innovate and expand.

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