Journal of Physics Special Topics
An undergraduate physics journal

P5_1 Can the UK feasibly be powered solely by one nuclear power station?

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November 28, 2019

Abstract

The United Kingdom consumed 300 TWh of electricity in 2018 which came from a variety of sources. We calculated the mass of nuclear fuel one nuclear power station would need to power the UK for one year, for a typical nuclear reactor and a modern reactor. For a standard reactor this gave a total mass of 850 metric tonnes of uranium, this is equivalent to 34 standard nuclear power plants. Whereas it needed 650 tonnes of uranium for a modern reactor, equivalent to 25 standard reactors. It was found that one very large nuclear reactor is not a feasible answer to the energy needs of the country due to the high costs of maintaining the reactor and buying fuel.

Introduction

The United Kingdom consumed 300 TWh of electricity in 2018 [1] with the source of the electricity coming from many different places such as fossil fuels, renewable power and nuclear power stations. We investigated how much nuclear fuel would be required by one power station to satisfy all the UK power needs and whether this would be a feasible solution to the United Kingdom's electrical needs.

Theory

Nuclear power plants use the nuclear fission of heavy elements to generate heat that boils water and produces steam. This steam drives turbines connected to an electric generator to spin and produce electricity [2].

Uranium is commonly used as a nuclear fuel [3] and it was assumed that in this report all of the fuel was enriched uranium. A typical reactor is only 33% efficient [2] but more modern nuclear reactors can have a maximum efficiency of 45%. This means if a typical reactor produced 3000 MW of heat this would only convert to 1000 MW of electrical power whereas a modern reactor would produce 1350 MW. A reactor that could produce that amount of power would annually use 25 tonnes of enriched uranium [3].

Results

Taking the power output and fuel usage of a typical and modern nuclear reactor and scaling them up would give the amount of fuel required to power the United Kingdom for both a usual and best case scenario. The formula for energy power and time is given below in equation (1).

$$Energy = Power \times Time \tag{1}$$

The power needed by the United Kingdom for a given year is then energy divided by the total number of hours in one year, 8760, meaning 34 GW of electrical power is needed. As a typical reactor produces 1000 MW of power [2], this means the hypothesised single reactor would need to be the equivalent size of 34 standard reactors and would produce 100 GW of total power with 66 GW being wasted as heat. Therefore it would require approximately 850 metric tonnes of enriched uranium every year. A modern, more efficient reactor, would be the equivalent size of 25 standard reactors using 625 tonnes of uranium.

Discussion

The price of enriched uranium as of 2018 is on average $22 per lb of uranium [4], which converts to £39.60 per kilogram. This means that it would cost £33.7 million to buy one year's worth of uranium to power a typical plant and £24.8 million for a modern reactor. This is very expensive despite the fact this number is lower than it would be in previous years due to the price of uranium falling significantly [5]. This figure takes only the fuel into account but there are many other costs, such as disposing of spent fuel and control rods and building and maintaining the plant meaning that this would be a very expensive way to power the country.

The national grid experiences transmission and distribution losses equivalent to 334,058 GWh in 2018 [1] which would be greater if there was only one power station, due to the distances between where the electricity is generated and to where it is being supplied being far greater than the current distribution of power stations. It was assumed that a typical nuclear reactor could be made larger keeping the same design and this would not have any effect on the efficiency or function of the reactor. Both of these assumptions are flawed as there is no quantitative way of investigating how this would affect the production of power, but we believe that in reality it would make it less efficient and make it less feasible.

Another factor in lowering the cost would be that spent fuel can be reused, as not all of the fuel in a nuclear reactor is uranium, and spent fuel rods can be enriched. This means less new uranium would need to be purchased.

An average family house of four people uses 3,100 KWhs each year [4] with the price per KWh being anywhere from 12 to 16 pence. [4] This means assuming a household pays an average 14 pence per KWh it will spend £430 annually just on electricity. This would increase with only one nuclear power planet as customers would have to pay for the fuel and construction of the plant. However in the long term fossil fuels are becoming more expensive so nuclear power may be more cost efficient and cheaper for consumers.

Conclusion

Due to the increased costs associated with maintaining a very large both typical and modern single reactor, through buying the nuclear fuel and increased losses, the negatives of powering the UK this way far outweigh the positives. It is possible to power the United Kingdom with one reactor but the current system of several types of power sources and a distribution throughout the country has more benefits than one single reactor.

References

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