

Critical Analysis of the Use, Sustainability and Safety of Nuclear and Solar energy

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Introduction

With the current energy demand, searching for a sustainable and reliable energy source has become crucial. Considering this, many forms of energy production have arisen as a result. This list includes but is not limited to hydroelectricity, tidal power, wind, solar, nuclear fission and nuclear fusion. Each of these has its benefits and limitations. During this research, the project focus will be placed on critically analysing nuclear and solar energy use, application, sustainability and the safety of each. When nuclear power is mentioned, the Chernobyl and Fukushima incidents are always the first thing people think of, and if an explosion were to occur, the damage would be catastrophic. But when solar energy is mentioned, for example, solar panels, the materials and where they come from are not discussed, so they are not well known and may not be as sustainable as led to believe. This research will investigate each of the two energy sources and find out how sustainable each is and the safety implications associated with them. It will be a comparative dissertation looking into both sources of energy production; this is with the intention of analysing the better option for future power supply. The positives and negatives of using both solar energy and nuclear energy will also be evaluated in order to help reach a suitable conclusion.

Solar Energy

Solar energy is the process where sunlight is converted into electricity. This is done by using photovoltaic panels. Solar panels are used regularly on houses to help decrease the cost of electricity, especially in the current cost of living crisis, where the need for energy savings has increased dramatically. Casita (n.d.) stated that the "Average UK electricity prices per kWh averaged around 18.9 p/kWh in 2021, but will be closer to 51 p/kWh by the end of 2022". The statistics show how important it is for electricity usage to be decreased unless there is an improved solution to the process by which it is created. However, further analysis can establish whether the focus should be placed on developing and implementing solar energy or nuclear power sources. Also, not all UK homes have solar panels to help reduce electricity bills by up to 70%. Some houses, such as council houses, get the opportunity to have them added for free, while others have to pay for them, which can be expensive, and some places do not have room on the roof, or it might not be at an angle or direction that will work. Overall, "there are roughly 970,000 UK homes with solar panel installations. This means only 3.3% of the 29 million homes in the UK are generating electricity from solar panels" (Gill, 2022), which means only 3.3% get the extra help towards a reduced energy bill. Having more solar panels on houses helps with the current cost of living crisis, decreases kilowatt usage and is a step towards better energy bills.

Although solar panels positively affect the building it is on, there are always downsides. When attaching a panel to a rooftop, there is the potential risk of falling. This can cause serious injury and even death. Not just the person but the building can be damaged. If not installed correctly, structural damage may occur, leading to leaks and even the toppling of the structure. All safety precautions need to be taken to mitigate the risk. Within the house, the panels need to be wired. If installed inadequately, the risk of a house fire heightens and causes a severe threat to anyone nearby. Other than the risks incurred during the installation, having solar panels fitted to a house can cause problems when selling. Owners may also find it "difficult to obtain a mortgage on a house with solar panels, particularly if the panels are leased rather than fully owned" (PM Property Lawyers, 2020), which may make it a problem. There is also a mental health risk for people concerned about the panels and any damage caused. This can affect people's choices who are not interested in having solar panels. A fee may be charged when the house is sold, and it can also be challenging to find out who owns them.

Another positive of solar energy is battery backup. Even with houses with solar panels, previously if you have any extra power, it can be arranged to go to the national grid. However, if you own batteries for the panels, you get to store more energy, which is another way to reduce the bills and allows the user to use the stored energy outside of daylight hours and periods of unsuitable weather. Solar batteries “typically range between £1,200 and £6,000” (Vekony, 2022) which can be costly for most people, especially if you have had to pay for the panels. Although you would eventually make money back, in the long run, it is not always that easy to do. One downfall is that the panels last 20-30 years, and the batteries last 5-15, so more than one set will be bought, increasing the overall investment. There are three grants in the UK currently which help to fund solar energy plans. These are Energy Company Obligation 4 (ECO4), Smart Export Guarantee (SEG) and 0% VAT. According to Joshi (2022), ECO4 is partially or fully free solar panels; SEG is 1-7.5p per kWh, making it cheaper than the current rate, and lastly, 0% VAT can help save £1,300+ on the installation and the energy bill. As said above, not all people get them free via their housing society but choose to buy them, so this is a better way to help reduce their costs. Also, doing this means that even if they are not free, the overall price is reduced, meaning the consumer is able to make their money back quicker by saving on the overall energy bill. Saving on bills and investing is a balance game. One way to make back the money quickly is to sell any extra energy stored in the batteries back to the grid. It is possible to cut yourself off from the grid completely and become fully independent, but having a national grid as an option means being low on money or wanting to make the investment easier to deal with, as that is always an option. The batteries will be costly but can improve bills; they are sustainable and low maintenance, making life easier for the consumer.



Figure 1: Swansea Retrofitting Scheme (Heynes, 2022)

After looking at solar panels and batteries another solar solution has been made. In Swansea, a company called Sero have retrofitted homes to help with the current crisis. Retrofitting is adding something not originally there, such as panels and batteries. The project is an estate powered by solar panels connected with batteries installed inside the family's home. These solar panels fitted to the rooftops of these houses can be seen above in figure 1 (Heynes, 2022). The reason for doing this was that with the current crisis, people were panicking and eventually might not have been able to afford their bills. It also benefits people who cannot get solar panels on their homes. The “European Union, Pobl and western power” (Pigott, 2022) funded this project which cost around six million pounds. If the project is considered a success, there will be more incentive for this to be further applied around the UK.

As stated by Pigott (2022), “Retrofitted homes on the estate are expected to generate up to 60% of their own electricity, reducing bills, and cutting carbon emissions by as much as 350 tonnes per year”. With this in mind, if this does get introduced more in the UK the cost of living will dramatically drop and help the people who are in need. This solution makes households more sustainable and moves in the right direction. This is the sort of direction that needs to be taken to help everyone with the economic crisis.

Another application of solar panels is the creation of solar farms, which use the same concept as rooftop-mounted solar panels, but they are placed on large pieces of land. Many more solar panels are used on a solar farm that can take up acres of land. The panels are all connected in a circuit to gather mass amounts of solar energy. Solar farms allow a greater concentration of solar panels within the same area, enabling more energy to be harvested from the same area of land. According to Mulvaney (2019) an “obvious advantage of photovoltaics is that there is no direct air pollution or greenhouse gas emissions during operation”. This highlights that although during production and set up there could be effects on global warming, the use of them after has no effects on pollution. One of the benefits of a solar farm is that it is quiet. Rather than having a generator noise which can be loud and disruptive, solar farms can run all day with no noise at all. Elon Musk is known for his innovative inventions, such as his electric car company, Tesla. Musk has invested in a company called Solar City. Musk has claimed that “if the U.S. built a 10,000-square mile solar farm in the southwest desert, it could power the entire country” (Perry, 2020).

Doing this would require a one-square-mile battery pack (Perry, 2020), so more energy can be stored and used on days when the weather disrupts power. This would make a dramatic impact on energy savings for everyone, but the land and the wildlife are not taken into account. Musk’s theory has been fact-checked by the University College London (Smith, 2015) and Model Survival Blog (J, 2013). However, questions still need to be answered. The land that solar farms are built on is typically old crop fields, which means that it can affect local ecosystems. However, there are some theories that solar farms can help wildlife. As Nunez (2022) discussed, the studies performed by the Woodlands organisation show that panels can protect small mammals and birds by providing shelter from rain and predators. Although this is the case, it still takes up a considerable amount of land and will affect other animals. If animals and plants are still inhabiting the land, then action for the upkeep of the land will be regular. If flowers or any other plants start to overgrow and cover a panel, the energy being produced will be reduced and will not benefit the system.



Figure 2: Morriston Hospitals Solar Farm (ITV,2022)

Morriston hospital in Swansea is the first hospital in the UK to be ran using its own solar farm. Their farm is located at Brynwhillach Farm which is 3km away as seen above in figure 2 (ITV, 2022). The hospital is able to obtain the energy as the panels and the hospital are joined by cables for the energy to travel. As stated by Palmer (2022) due to the current energy crisis they hoped the hospital would save £480,000 but the actual figure is currently closer to £1 Million. This shows that the solar panels are making an input in saving on energy bills and are a vital piece to keep the hospital running. Hospitals run all day, every day, so a lot of energy is needed to keep them running. Solar farms are a great way for this to continue, and as stated before, solar batteries can be used to keep any extra energy. With this in mind, the health board are paying back their loan needed for the farm with any money that they will and have already saved by having the farm. The use of solar farms also decreases the hospitals dependency on the national grid allowing for the energy from the solar farm to be used instead if there is an interruption in power coming from the national grid.

Furthermore, materials need to be taken into consideration. Solar energy is the highly promoted clean green energy source, but materials and their impact of them are never mentioned. When looking at solar panels, materials such as silicon solar cells, aluminium, glass sheets, wire, boron and gallium are used. These panels cause a threat because of their materials and how they are produced. During the process, hazardous materials and chemicals are used. This happens when making the panel and cleaning and purifying the final product. As mentioned by Zagame (2022), when it comes to environmental impact, gathering silicon and glass are both non-issues, as these are abundant and non-toxic, but when it comes to all the metals that are used, mining is the method of extraction. When mining, it will create greenhouse emissions and can pollute the air, water and soil.

Three types of solar panels are produced, Polycrystalline, Monocrystalline and thin film panels. The polycrystalline process uses electricity when making panels, adding to the emissions produced. The monocrystalline process uses the highest amount of energy, and lastly, the thin film process uses toxic materials which affect not only humans but the environment. The production method is complex. Coals are used to melt down the silicon during the process. Silicon is not just found and put into the panel "silicon is mixed with copper and hydrochloric acid to produce trichlorosilane gas, which is then reduced with hydrogen to make silane gas. The silane gas is heated into molten silicon, which leads to silicon crystals that can be reformed and used for PV cells" (Boyd, 2015). The positive to the manufacturing process is the disposal; they can get rid of the waste safely and without harming the environment. Lithium used in the batteries is extracted from the "Lithium triangle" (Anon., 2022). The triangle includes Chile, Argentina and Bolivia. The batteries that are used for solar panels are able to

be recycled, whereas the solar panels themselves are rarely recycled. There are places, but currently there is not enough demand for recycling centres to be made, which would help with disposal. Large areas of land are required to construct recycling centres and to hold solar farms, which affects wildlife. Therefore, from start to finish, solar energy is disturbing nature. The overall manufacturing process emits greenhouse gases, creates waste and can be dangerous if not handled properly.

Having solar energy as an increasing source has the potential to create more jobs. People are needed to install panels on homes and farms. If anything was to go wrong, an engineer would be sent out to rectify the issue. As it produces very little pollution, it is a cleaner energy source, so allows for less air pollution, resulting in cleaner air in cities, making them healthier places to live. Solar energy does not rely on fossil fuels and uranium, which will eventually run out. Although, as mentioned before, there is no real recycling for panels, it is still a working design.

Nuclear Energy

Nuclear energy works from the release of the core of an atom, which is made up of protons and neutrons. There are two types of nuclear power, fusion and fission. Fusion happens when nuclei fuse together, and fission is when the nuclei of an atom split into several parts. The process of fission uses uranium fuel to produce electricity. This is the process used in nuclear power reactors. Nuclear power does not produce air pollution or carbon dioxide, it “has a minimal carbon footprint of around 15–50 grams of CO₂ per kilowatt hour (gCO₂/KWh)” (Serin, 2022) which has the smallest footprint compared to gas and coal power. Although the energy produced has a small footprint, the plant and the waste produced are issues that need to be addressed. The power plant and machines inside are made of metal and concrete. The processes used, such as mining and refining uranium ore to make the fuel. Uranium which is used in nuclear energy, is found in rocks and seawater. According to World Nuclear Association (2022), 6,147,800 tonnes of uranium was sourced around the world in 2019. The world only has a limited supply of uranium, and reactors could run more than 200 years at current rates of consumption. As a result of this, if the world was to only rely on nuclear energy, the depletion of uranium would be so great that it would guarantee the stopping of the use of nuclear energy, which currently provides 10% of the world’s electricity.

According to The Open University (2015), nuclear energy can reduce the UK’s greenhouse gas emissions by 80% by 2050. Nuclear power is a safe means of generating electricity as the risks are low and declining. Nuclear energy produces more electricity on less land than solar. According to the Office of Nuclear Energy (2021), “a nuclear facility needs a little more than 1 square mile to operate. Wind farms require 360 times more land area” lowering the impact on the environment and wildlife when building. Also, when nuclear plants are built, flooding is taken into consideration. The building is engineered onto a platform to decrease the chances of anything happening. If something was to occur, then backup generators are there to help. If any panels were damaged, an engineer would need to be called out, which adds to the costs of owning them.

Other than nuclear fission, there is nuclear fusion. In Nottinghamshire, UK, the government have decided to build its first UK prototype plant to be built by 2040. The overall idea is called STEP, Spherical Tokamak for Energy Production. Fusion “is the process by which two light atomic nuclei combine while releasing large amounts of energy” (GOV.UK, 2022). This is in hopes that sustainable and low-carbon energy is made. Although difficult to achieve, nuclear fusion has a high energy density, causes less pollution and is considered more sustainable than nuclear fission. Radioactive waste is still produced using this method, so still does hold a disadvantage.

Another environmental impact to take into account is radioactive waste. The uranium tailings remain radioactive for thousands of years. To reduce radiation levels in disposal sites and workers, the short half-life waste is often stored temporarily. It can affect not only the workers but also land, water and freshwater. Although temporary solutions are safe, there must be permanent disposal of all radioactive waste. In Finland, they have buried the waste underground which does help to dispose of the waste, but if anything was to go wrong in the future, as this has never been done before, then it risks the spread of pollution. The underground storage is not cost-efficient which still sparks more ideas and talks about slowly fading away from nuclear power.

One negative aspect of the use of nuclear power stations is the potential for them to be targeted by terrorists that intend to cause significant harm and destruction to the area surrounding the power plant and disrupt power being distributed across the country. In recent years, there has been an increase in the number of terrorist attacks that are occurring. Since the attacks on the world trade centre in 2001, there has been a major concern about aircraft being hijacked and used for the purpose of a targeted attack on places of significance. Should a nuclear power station be a target of such a terrorist attack, the power plant needs to withstand the damage inflicted to ensure that the nuclear process remains under control. This is due to the potential to cause devastation to the local environment, should the nuclear process be uncontrolled and radioactive materials released into the surrounding area. However, as discussed by the World Nuclear Association (2022), there have been a number of studies conducted to mitigate the risks of a terrorist attack having such a devastating effect. These studies have found that the structures are able to withstand direct impacts from large passenger aircraft.

One study concluded that should a terrorist attack happen using an aircraft as a projectile into a nuclear power plant, the aircraft would disintegrate upon impact and that “about 96% of the aircraft’s kinetic energy went into its destruction and some penetration of the concrete – while the remaining 4% was dissipated in accelerating the 700-tonne slab” (World Nuclear Association, 2022). Further discussed by the World Nuclear Association (2022), to penetrate through the reinforced concrete used within nuclear power stations would require “multiple hits by high-speed artillery shells or specially-designed “bunker busting” ordnance”. As a result of these experiments, it can be concluded that although there is still a risk of a terrorist attack on nuclear power plants, the likelihood of there being a catastrophic incident is unlikely to occur due to the structures in place.

Taking into consideration the requirements mentioned previously to penetrate through the reinforced concrete structure, this creates a greater risk for nuclear power stations that are within a warzone. Any nuclear power plants located within a warzone become more of a target as the invading forces would be seeking to cause damage to the infrastructure and disrupt the energy supply of the country that they are invading. As discussed by the BBC (2022), this is currently evident in the attack on Zaporizhzhia, a Ukrainian nuclear power plant by Russian forces. Further discussed by the BBC (2022), this attack had the potential to have 6 times the devastating effect as that of Chernobyl and cause destruction across Europe.



Figure 3: Chernobyl Disaster (Wilkes, 2021)

In the history of nuclear power, there have been two big incidents. This has caused a negative perception of the energy source. One of which was on April 25th and 26th 1986 in Ukraine where Chernobyl a nuclear power station exploded which can be seen above in figure 3 (Wilkes, 2021). This was caused by two explosions which then turned into one big one causing the lid to fly off. This is the only one in history to happen and cause extreme fatalities. When this occurred “two workers died due to the explosions, as well as 28 emergency personnel and plant workers from acute radiation syndrome (ARS; commonly known as ‘radiation sickness’). There were also about 5000 thyroid cancer cases, many of which could have been avoided by preventing the consumption of contaminated foodstuffs, such as milk” (World Nuclear Association, n.d.) which shows the extreme rate of fatalities caused. Thirty thousand people were evacuated from the area. As stated by Britannica (n.d.) “Between 50 and 185 million curies of radionuclides escaped into the atmosphere—several times more radioactivity than that created by the atomic bombs dropped on Hiroshima and Nagasaki, Japan” which highlights the extreme rate of radiation released due to the accident.



Figure 4: Fukushima Accident (Britannica, 2022)

In Okuma, Fukushima, Japan 2011, the second worst nuclear accident occurred. An image showing the Fukushima accident can be seen above in figure 4 (Britannica, 2022). An earthquake and tsunami took place, which caused the power to be disabled and melt all three cores, leading to the release of

radiation. Due to the catastrophe “Explosions resulting from the build-up of pressurized hydrogen gas occurred in the outer containment buildings enclosing reactors 1 and 3 on March 12 and March 14, respectively” (Britannica, 2022) which caused exposed nuclear material in the cores. On March 15 was the third explosion, which caused a fire and again released high levels of radiation. Due to the accident, residents nearby were told to evacuate and leave, 47,000 in total left. The plant has cooling systems in case of accidents, the tsunami was that intense it damaged the backup generators causing them to fail. Many attempts were taken to cool down the reactor, helicopters and hoses were used. To make matters worse, the ocean and local foods and water were contaminated making it unsuitable for people to consume creating a food shortage. It took until December of 2011 for the Japanese Prime Minister to “declare the facility stable, after the cold shutdown of the reactors was completed” (Britannica, 2022) and took until 2013 for the evacuation orders to be lifted in some areas. Overall it took six years for all evacuation areas to be lifted and for things to go back to normal. Due to the accident, overall, according to World Nuclear Association (n.d.), 19,729 people died, and 2,559 are still missing. Although there have been no radiation deaths or cases, long-term psychosocial health effects and stigmatisation have occurred.

Analysis and Discussion

Solar energy has many different applications, being used in a variety of ways to produce energy, whether it be on a small single-home scale or supplying energy to the national grid. However, the manufacturing of solar panels creates an environmental challenge, depending on the type of solar panels being produced. The manufacturing of polycrystalline solar panels uses electricity, with the monocrystalline process using the highest amount of energy. Alternatively, the thin film manufacturing process uses toxic materials harmful to humans and the surrounding environment. Recycling solar panels on a mass scale cannot be done at present as there is insufficient infrastructure. This is due to a lack of demand for the infrastructure to be put in place. This makes the use and application of solar panels less sustainable. Taking this into consideration, the use of solar panels is significantly more sustainable than other means of producing energy. When taking into consideration the safety of solar panels, it can be established that with proper installation and safety measures taken during the installation, the use of solar panels can be a very safe form of energy production.

As with all forms of energy production, there are some limitations. With energy production limited to the surface area available, it has a few limitations. Solar energy is only capable of supplying energy during the daytime, whereas a nuclear power plant is capable of producing energy throughout the entirety of its lifetime. In order to maximise energy production on a large scale, a large area of land that receives a lot of sunlight dedicated to harvesting solar energy is required to install solar panels. However, this limitation can be counteracted by fitting solar panels to the roofs of homes throughout the country and having them linked to the national grid so that the energy harvested throughout the day can be used by the country and then having alternate power sources supply the energy throughout the night.

Using nuclear power stations to supply energy to the national grid helps to significantly decrease greenhouse gas emissions. It has a higher energy yield than that of solar energy and wind energy per area of land used. However, in comparison to solar energy, nuclear energy requires a large and very specific location for the power plant, which means that the population would not be able to purchase their own for the use of producing energy for their own homes.

There are major safety concerns regarding nuclear power stations that arise from previous and current events due to the potential to cause devastation to the local environment. However, these safety concerns have been mitigated with thorough design analysis and testing to ensure no radioactive

material is released into the local area. The structural design of the nuclear power plant is able to withstand terrorist attacks that use aircraft as a projectile and would require specialist military equipment in order to cause sufficient damage to the structure. However, these safety concerns are still valid as there is still the possibility of a nuclear powerplant suffering a nuclear meltdown, as shown by Chernobyl and Fukushima. Nuclear power plants also become a high-value target when located within a warzone which can have devastating effects. In order to increase the safety of the use of nuclear energy, further steps need to be taken, potentially including redesigning the powerplant and including more redundancy systems to ensure that the risk of a nuclear meltdown under all circumstances is mitigated even further.

The use of nuclear power as it stands at present isn't sustainable in the long term due to the materials being used within the manufacture of the power plant. The radioactive isotopes that are used for generating power are inherently unsustainable due to the current consumption rate and will only provide approximately 200 more years of energy. At the end of the usable life of the radioactive isotopes used within powerplants, the material is still very radioactive and requires specialist disposal. In order to increase sustainability, other ways of harnessing nuclear energy with a higher energy yield need to be further researched and developed. Nuclear fusion achieves this and does not produce as much harmful radioactive waste.

Conclusion

In conclusion, both of these forms of energy are significantly more sustainable than fossil fuels and produce significantly fewer greenhouse gas emissions. However, the use of solar panels is significantly more favourable in terms of safety as there are fewer risks and hazards associated with the manufacturing, use and disposal of the panels compared to the use of nuclear fission power plants. In contrast, using nuclear power plants has a significantly higher energy density allowing for more usable energy to be produced within the same land area. Continuous research and development is thoroughly recommended and should be done for both energy sources as there is still much potential for improvement. With solar energy, higher energy-density batteries would be greatly beneficial. They would allow for more energy to be stored within a smaller area, allowing more space for more solar panels or more batteries, increasing the overall energy available. Research and development should be done focusing on nuclear fusion to increase the safety, energy production and sustainability of nuclear power. Making the switch to nuclear fusion instead of fission allows for more energy production and less radioactive waste per mass of material used.

One source of energy should not be used exclusively instead of another, but in collaboration with each other in order to ensure sufficient energy is available to the population whilst increasing the sustainability of each. Focus being placed on one source of energy would require so many natural resources to be used and would deplete these resources faster than they can replenish. Continued research and development of other energy sources should also be done in order to ensure the longevity of each energy source and to mitigate the consumption of natural resources.

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