Nuclear Energy: Application and Limitation

Introduction

The following scientific report will discuss how nuclear power is used, its impacts and developments within the clean energy field, and will focus on the Applications and Limitations. Nuclear power is the primary focus of his SHE task, with key concepts revolving around this energy source such as its uses, properties, impacts and developments.

Scientific Background information/history:

Nuclear power is derived from using reactions to release nuclear energy to generate heat, which is commonly used by heating water, rising as steam to push turbines, producing electricity. Uranium-235 atoms undergo fission in the reaction process in the reactor vessel. (figure 1)

Nuclear technology started its production in the 1940’s, during the second world war. The technology was mainly focused on the production of bombs, research was then directed towards clean energy production in the 1950’s. (WorldNulcearAssociation, 2019)

Civil nuclear power plants now operate in 30 counties worldwide. Many counties, such as Denmark and Italy, get almost 10 percent of their energy from imported nuclear power. (WorldNulcearAssociation, 2019)

Physics concepts behind a power plant

The nucleus of a uranium-235 atom has protons and neutrons, these are very tightly packed together, with immense force. Uranium has 92 protons.

Neutrons are fired at the nucleus at speeds specific for a split to occur, a process called fission. Because uranium atoms are so large, the atomic force that binds it together is relatively weaker than other atoms, making uranium good for fission.

3 neutrons are released during fission, causing a chain reaction. (figure 2) It is extremely important to control these reactions with 'control rods' that absorb neutrons.

In the core of nuclear reactors, the fission of uranium atoms releases controlled energy that heats water to about 271 degrees Celsius (PATRICK J. KIGER, 2019). The rising of boiling water is then used to push blades on turbines which are connected to a generator.

Application and Limitation

Application of nuclear fission

In 2016, the world's electricity consumption amounted to approximately 21.8 trillion kilowatt hours (T.Wang, 2019), displayed in figure 3. The most cost-effective solution to this energy

crisis is to burn coal, natural gas or oil, which results in carbon dioxide emissions, which are harmful to the environment by tapping heat and evoking climate change. Nuclear is a good environmental and efficient candidate for energy production, as 6 grams of nuclear fuel yields the amount of energy equivalent to that generated by a ton of coal, 120 gallons of oil or 17,000 cubic feet of natural gas. (Debashree Sen, 2019) Being more cost effective and producing marginally less emissions. The application of nuclear physics (more specifically nuclear fission) in the energy industry is a good solution to the growing demand for energy, while addressing many environmental concerns.

Discoveries

A major concern within nuclear energy production is in safely monitoring the reaction. As you can see from figure 4, the process of beta decay releases an antineutrino. Antineutrinos are subatomic particle with infinitesimal mass and no charge, the typical nuclear reactor produces approximately 6 x 1020 antineutrinos per second (Griffiths, David, 1987)

The potential use of above ground antineutrino detectors for monitoring existing pressurized water reactors was confirmed through extensive simulations done by researchers at the Georgia Institute of Technology. (Georgia Institute of Technology, 2019)

Antineutrino detectors offer a solution for continuous, real-time verification of what is going on within a nuclear reactor without actually having to be in the reactor core,' said Anna Erickson, associate professor in Georgia Tech's George W. Woodruff School of Mechanical Engineering. (John Toon, 2019)

Sustainability

Uranium is relatively sustainable, according to the NEA, there is a roughly a 230-year supply of uranium, based on our consumption rate today (Steve Fetter, 2009). However, nuclear power does have the possibility to become renewable, if the source of uranium was extracted from seawater, which would make available 4.5 billion metric tons of uranium—a 60,000-year supply at present rates (Steve Fetter, 2009). This is highly expensive process, and is not economically viable now.

Future predictions

In June 2019 the OECD’s International Energy Agency (IEA) published a report, Nuclear Power in a Clean Energy System. This report concludes the possibility of economical failure in investing in existing and new nuclear power plants, using collected data over a large time frame. From the data gathered, it would seem the transition to cleaner energy is more challenging and costly than it looks from the surface.

Economic, social and ethical implications in Australia

Economic

There are several implications when nuclear power plants are economically viewed. Generally, plants are expensive to build and maintain, yet relatively cheap to run. Coal plants are

considered to be the more economically attractive option in counties such as Australia, China and the USA (this is because coal is reliable, affordable, abundant and safe). This will not most probably not change until a price is put on carbon emission.

Social

Today, there is a very split opinion in Australia on whether the prospect of clean energy outweighs the potential danger and long-term issues in creating it. A nation-wide survey was conducted in 2010 to investigate the Australian public's attitudes to nuclear power in relation to climate change and in comparison, to other energy alternatives. The survey showed a large portion of respondents (58%) were not willing to accept nuclear power if it would help tackle climate change. (Deanne K.Bird, 2014) This was due to nuclear energys history

Nuclear energy is as safe or safer than any other form of energy available. No member of the public has ever been injured or killed in the entire 50-year history of commercial nuclear power in the U.S. (Center for Nuclear Science and Technology Information of the American Nuclear Society, 2018)

Nuclear energy has proven itself to be safe and effective, but public debate is stuck with the notion of another potential catastrophe, even though these catastrophes happened under very dangerous conditions (Chernobyl), and not with the technology itself.

Environmental

The only waste produced by nuclear reactor is spent fuel, which is radioactive and stored underground. The properties of this waste are they undergo beta radioactive decay for approximately 1000-10000 years (WorldNuclearAssociation, 2017), and are dangerous to humans in concentrated amounts. This may cause the public to believe that nuclear reactors are dangerous, but storing waste safely underground is a much better alternative to releasing carbon dioxide directly into the air that the population breaths, and warms the planet.

Beneficial and unexpected consequences

It was discovered that the nuclear disaster of Chernobyl was caused by the jamming of several control rods, due to intense pressure and the loss of structural integrity. This extreme heat and an inability to control the rate of the fission reaction caused a meltdown. This is the consequence of untrained/overworked personnel and a cheap and unsafe soviet-era reactor. Reactors today cost more to ensure safety, and have much better trained personal.

Summary of beneficial uses of nuclear power:

- Zero carbon emissions
- Somewhat economical after construction
- Very efficient power production
- Technology is mostly developed

Summary of the limits to nuclear power

- Dangerous radioactive waste is left over from spent fuel rods, resulting in soil and air contamination if not stored correctly.
- Operational risks
- Uranium mining risks
- Nuclear weapon proliferation
- Adverse public opinion caused by public debate
- large costs of initial construction and maintenance

Conclusion

In conclusion, nuclear fission is the process of splitting uranium nuclei using neutrons, to produce energy, which boils water, rises as steam runs generators. The application of nuclear fission in the renewable clean energy industry provides us with solutions to the energy and climate change crisis, as well as cheaper and more efficient fuel. With the current environmental situation, nuclear energy needs to stay relevant though informative and persuasive public debate in Australia, to redirect the false sense of danger and encourage the government to act. We must also look past the short-term economic issues, to more long-term gains. It will be difficult for nuclear power to overcome its economic and social barriers, but untimely worth it for cleaner, safer and more efficient power.