Nuclear power as a mitigation strategy to climate change

Report for the Environment and Communications Legislation Committee

Executive summary

This report is about how nuclear power can be used a mitigation strategy to climate change. The report will show the positives of nuclear power relating to climate change and rebuttals to the negatives of nuclear power. This report will also look at renewables and how they compare to nuclear power. Research for this report was mostly of non-scholarly articles as nuclear power is a current affair and most of the research came from documentaries, websites both government and non-government and prior knowledge was also used. The report is written for the Environment and Communications Legislation Committee.

The recommendations that this report makes are:

- Put in place education of nuclear power in the schooling system at a middle school level. With the push for renewables from the media and world organisations such as the UN with the 17 sustainable goals, this has pushed nuclear out of the question and needs to be taught to children as a mixture of solutions needs to be shown.

- The removal any legalpreventing the planning, construction and operations moratorium on the ban of nuclear power in Australia. With the closure of most coal fired power plants, Australia is losing its baseload capacity and the lifting of this ban will allow nuclear reactors to be used. This will also help Australia to meet the climate goals.

- The increase of research and development funds in new nuclear technologies from both the public and private sectors. With the development of Gen IV reactors by multiple companies and government organisations, more funding is needed to get these new reactors in service and commercially viable to help mitigate climate change.

- Run an Australia wide public relations campaign to improve the social support for nuclear power with both government and private sectors working together. With the anti-nuclear movement being mainly built on fear, the public relations program should decrease these fears by presenting the facts of nuclear power and stop the spread of misinformation.

- Ensure that the government does not overregulate nuclear power by implementing a regulator with time frames around approvals enshrined in law.

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1.0 Introduction

This report will discuss how nuclear must be used as a strategy to mitigate climate change, as well as look at the negatives associated with nuclear power and rebuttals to those negatives. The three main positives for nuclear is that, it is co2 free, better than renewables and that nuclear power saves lives. The three main negatives of nuclear are, the waste form nuclear power, meltdowns and the cost of nuclear power. These negatives will be replied to. Nuclear power is a method of energy generation that uses uranium as its fuel. This fuel goes through the fission process which creates heat, making steam and turning the turbine as shown in Fig 1. Fission is where Uranium 235 is split at an atomic level into two as shown in Fig 2. This creates 2 to 3 neutrons that hit other atoms and the process is repeated as shown in Fig 2.

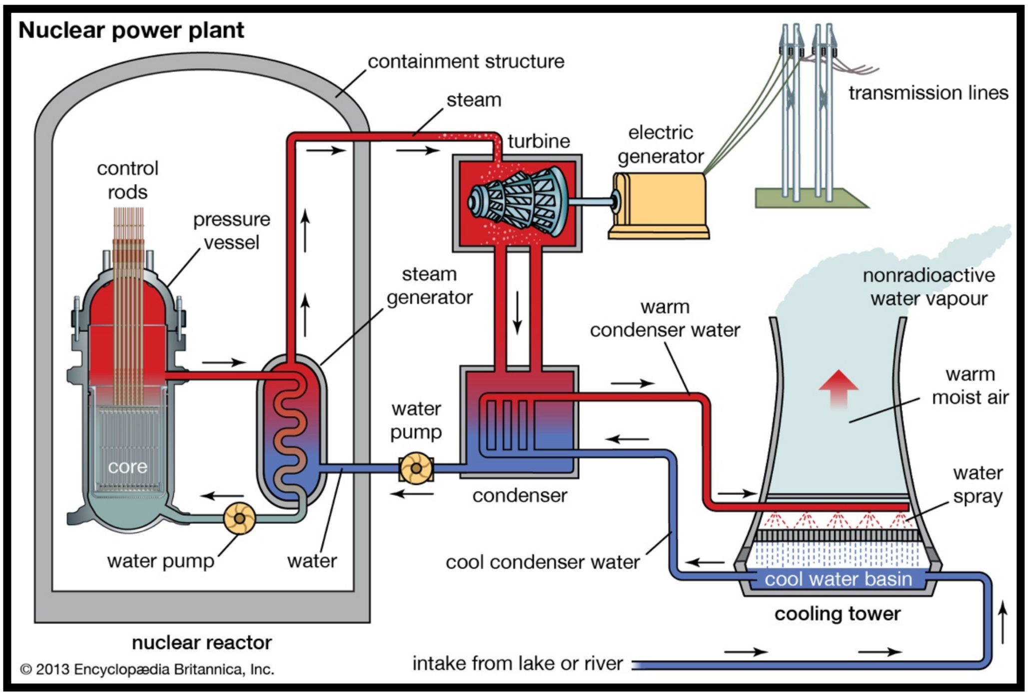

Fig 1: Nuclear power plant diagram (Martin, 2019)

Approx. 10% of produced electricity comes from nuclear power and makes up approx. 29% of clean energy output, globally (World Nuclear Association, 2020). Clean energy is defined as an energy during production emits zero co2 emissions. 30 counties operate 442 nuclear reactors around the world with the top 5 users being, the USA, France, China, Russia, and Japan as shown in Fig 3.

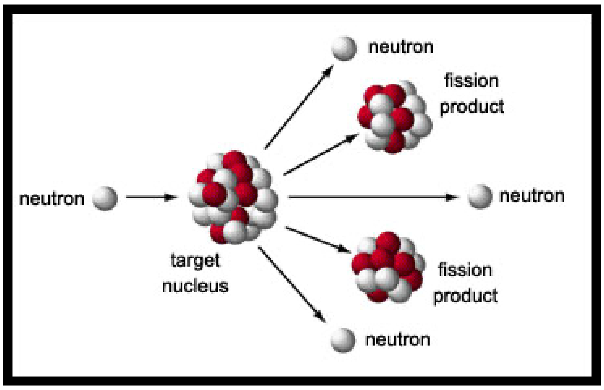

Fig 2: The process of fission (Atomic Archive , 2020)

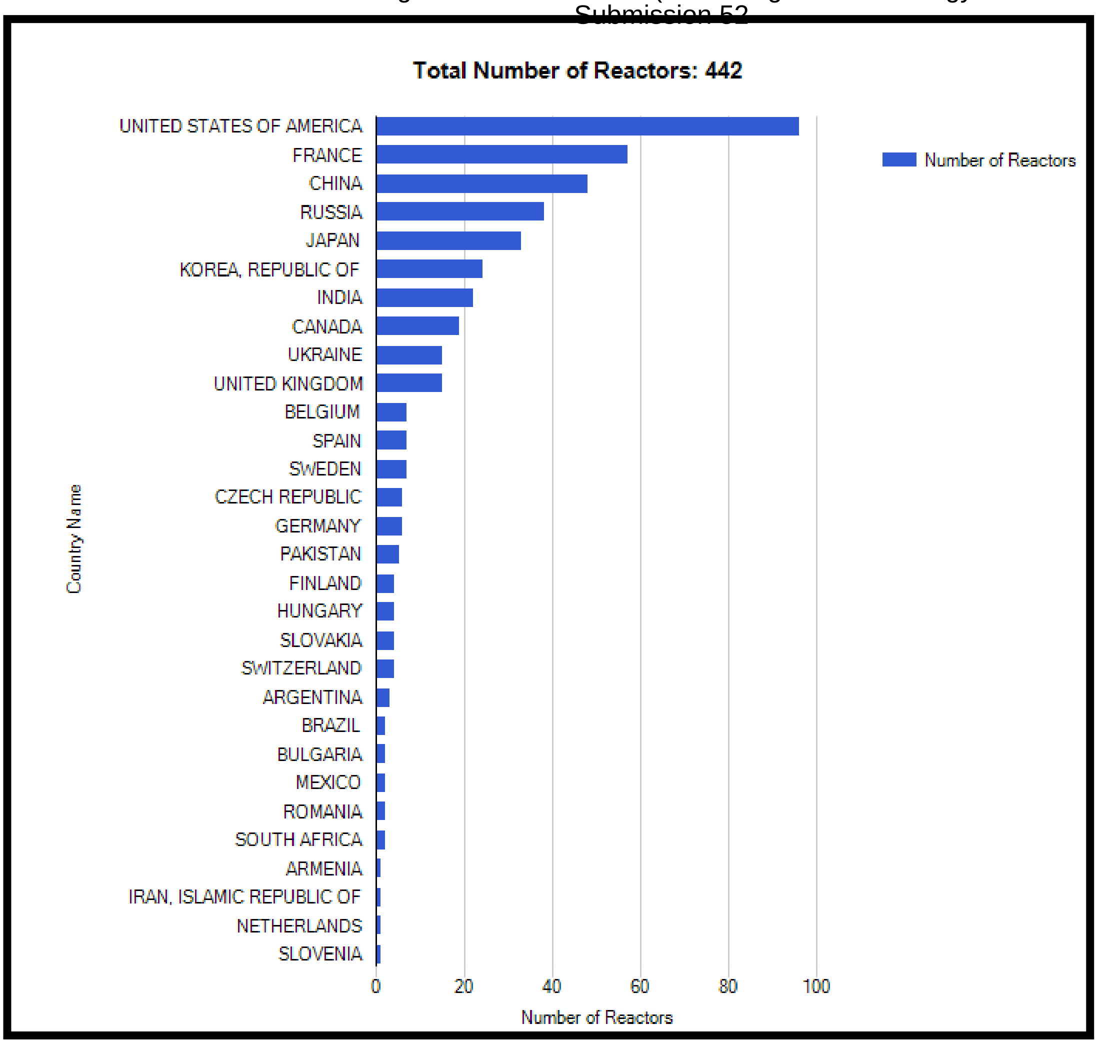

Fig 3: Reactor numbers within each country (International Atomic Energy Agency , 2020)

2.0 Positives of Nuclear Power.

2.1 Nuclear power is co2 free.

Since nuclear power uses uranium as its fuel, this make nuclear power co2 free. 1 ton of uranium equal 17 0500 tons of coal (Kurzgesagt, 2015). Nuclear power is the only baseload power source that is co2 free. With a capacity of 92%, this means that a nuclear reactor is producing energy 92% of the year (U.S. Energy Information Administration , 2020). With coal being the main culprit for climate change, it makes sense to replace baseload power for baseload power. Due to nuclear power, 64 gigatons of co2 have not being pumped into the atmosphere from 1971 to 2009 (Kharecha & Hansen, 2013). This makes nuclear power optimal for climate change mitigation as it is clean and can produce clean, reliable and most importantly cheap power. For example, in France, 75% of its energy comes from nuclear, the highest percentage in the world (World Nuclear Association , 2020). With this energy configuration, France ranks 20th in the world for co2 emissions (The Work Bank, 2014).

2.2 Nuclear power is better than renewables.

Nuclear power can be built anywhere it is derisible as it is a baseload power by having a capacity factor of 92% (U.S. Energy Information Administration , 2020). This makes nuclear climate independent. Renewables on the other hand need to go where the sun shines and the wind blows. Due to the capacity factor of renewables ranging from 10% to 30% (Shellenberger, 2019), renewables need a vast area. This area needed for renewables is cleared and deforested. For example, in Europe the push for renewables there is clearing protected forests to make way for renewables (Neslen, 2018). Nuclear power can use land that has already being cleared and/or repurpose land. Renewables can also require 17 times more materials than nuclear to produce the same amount of energy as seen in Fig 4.

2.3 Nuclear power saves lives

Nuclear power has the lowest energy production to death ratio. Less than 5000 have died, both direct and indirect (this a projection made by the UN and it's difficult to measure indirect deaths from nuclear power). 7 million die from air pollution a year (World Health Organisation , n.d.). The main cause of air pollution is from coal fired power plants that have no control over waste. In fact, nuclear power has saved approx. 1.8 million lives between 1971 and 2009 (Kharecha & Hansen, 2013). Compare this to renewables where, in England for example, 14 people died from wind turbine accidents in 2011 (Shellenberger, 2019). In the same year nuclear killed 0, even with the meltdown at Fukushima, Japan.

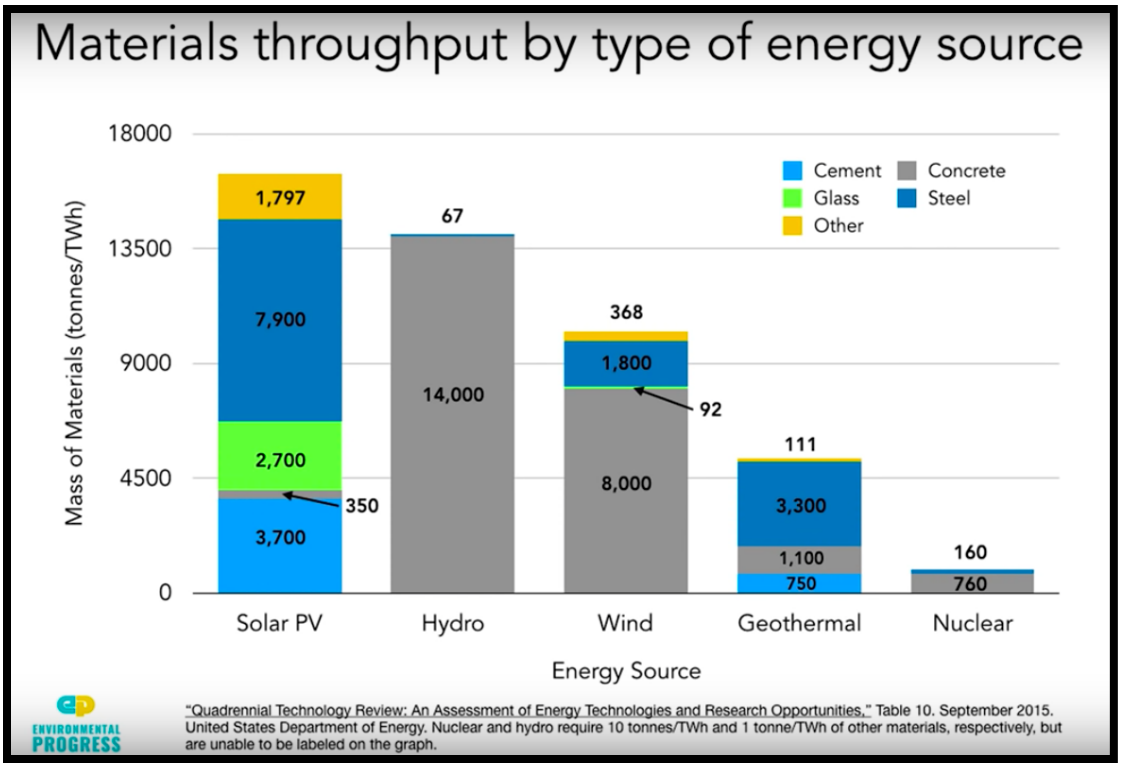

Fig 4: The materials required for each energy source (Shellenberger, 2019).

3.0 Negatives of Nuclear Power

3.1 Nuclear Waste

Nuclear waste is radioactive as only 5% used of the total uranium is used in the reactor. The 5% is U235 which is enriched uranium and optimal for fission. This means there is 95% waste. The total amount of nuclear waste in the world is 370 000 tons (World Nuclear Association, 2020). Nuclear waste is split into 2 levels of radiation. One is low-level waste and the other is high-level waste. 97% of the world's nuclear waste is classified as low-level waste. This low-level waste decays over tens of years. Nuclear waste loses it radioactivity over time, ranging from 1000 years to 10 000 years (World Nuclear Association, 2020). The other 3% is considered high-level waste and this waste needs to be stored long term for thousands of years.

3.2 Meltdowns

Meltdowns is when the reactor core overheats and evaporates the coolant and the reactor explodes due to the pressure and heat caused by the uncontrolled fission reaction. This also leads to the melting of the fuel rods. The 2 main examples of a meltdown are, Chernobyl in 1986 in the former USSR and lastly, most recent, Fukushima 2011 in Japan. On April 26th, 1986, a safety test was conducted, on reactor No.4 at Chernobyl, which the reactor has done before. Also, the reactor had a flaw in the design, which is where the reactor becomes unstable at low power. Even with Soviet guidelines stating that the test be done at 700MW to 1000MW (Bartlett, 2004), this is ignored by the Chief Engineer, who is not in the control room regularly. There was an argument over said levels. The test was done at 200MW. To do this all the control rods were removed. This led to an uncontrolled fission reaction and the reactor exploded.
At Fukushima, a tsunami on March 11th, 2011 caused by a 9.0 earthquake, flooded the underground back up power for the coolant pumps. This allowed the reactor to continue the fission process. Fission in these circumstances

gives off hydrogen as a by-product. This build-up of pressure led to 3 explosions in separate reactors one day after the tsunami (O'Brien, 2016).

3.3 Nuclear power costs

Nuclear power costs approx. $10 billion dollars along with a 10-year construction time. This, however, is assuming that there is no budget blowout and extended construction time. In the building of nuclear reactors, budget blow outs and extended construction time are a common occurrence. For example, in France the leader of nuclear technology, has the Flamanville nuclear plant. A new reactor was to be built by 2012 and cost 3.1 billion Euros. However, the project has now a cost of 12.4 billion Euros and construction to finish in 2022 (Keohane, 2019). Another way to measure cost is the levelized cost of energy. This takes in all aspects of producing energy, including operational costs. Nuclear power is the 3rd most expensive power source at $74.88 per MW/h (U.S. Energy Information Administration, 2020) with renewables cheaper than nuclear.

4.0 Rebuttals to the negatives of nuclear power

Rebuttals to the negatives of nuclear power will be replied with technology in the form of Gen IV reactors, led by small modular reactors (SMRs). SMRs is a type of nuclear reactor that is smaller than the average 1GW, usually ranging from 40MW to 300MW (Ellis, 2019) (1000mw = 1GW). Fig 4 shows an SMR diagram.

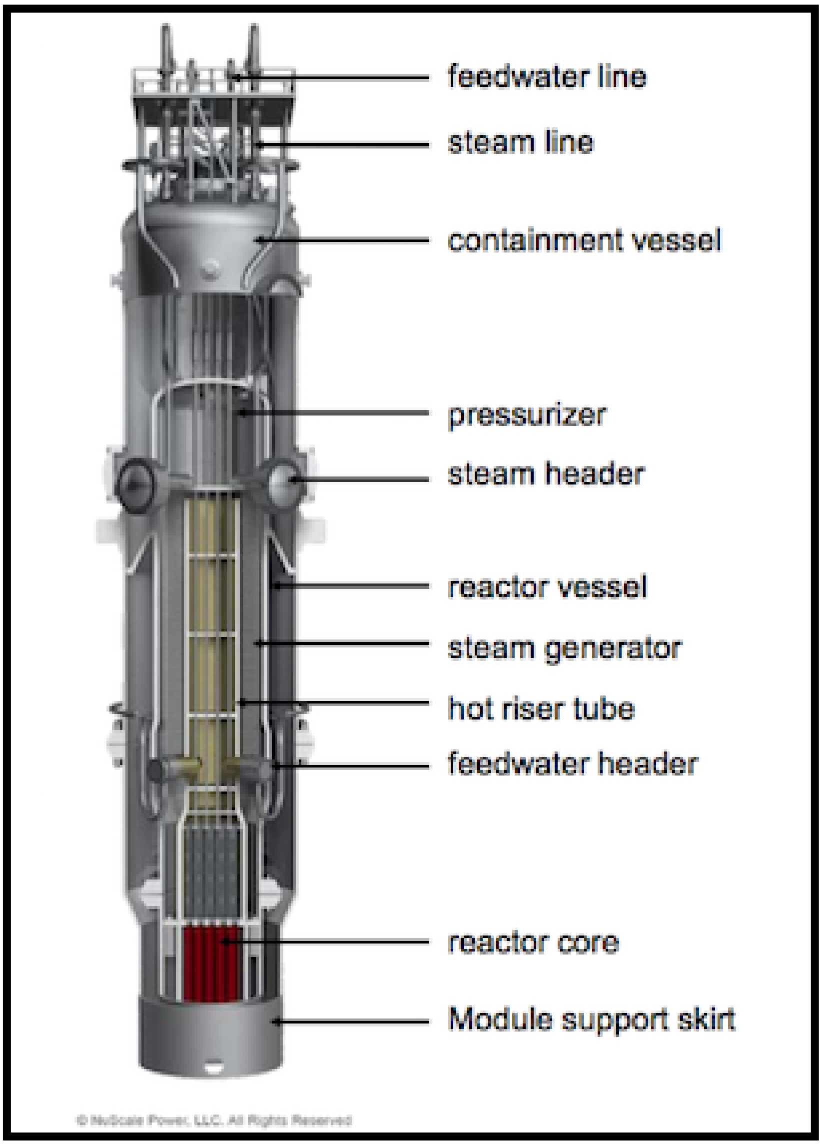

Fig 5: A diagram of a SMR. (Fares, 2016)

4.1 Rebuttal to waste

The nuclear industry is the only energy source that takes cost and full responsibility of its own waste. Renewables meanwhile have no set plan. There is so little nuclear waste, that it is possible to put all the US nuclear waste onto a football field, only 9 meters high (Office of Nuclear Energy, 2020). There are 3 main ways to deal with nuclear waste. These are: produce less of it, bury it and lastly, recycle it. Currently, only approx. 5% of the fuel is used. A company called Transamotic is developing a liquid fuel that can use the fuel in a higher efficiency, hence less waste (Long, 2017). The second way to deal with waste is bury it. This is how most of the waste is dealt with or is stored on sight in concrete cartes. Finland, however, has come up with a long-term solution where, the waste will be buried deep underground to house the nuclear waste for 100 000 years (Productions, 2017). Lastly, nuclear waste can be recycled. The Argonne National Laboratory has come up with a process to recycle the fuel. Only 5% of the fuel is used, so 95% is left. The first step is to separate the waste from the unused fuel. To do this pyropcessing is used. This is where elevated temperature is used to bring about a physical change or chemical change. Next, the fuel is put into rods as little pellets stacked and put into a fast spectrum reactor as seen in Fig 6.

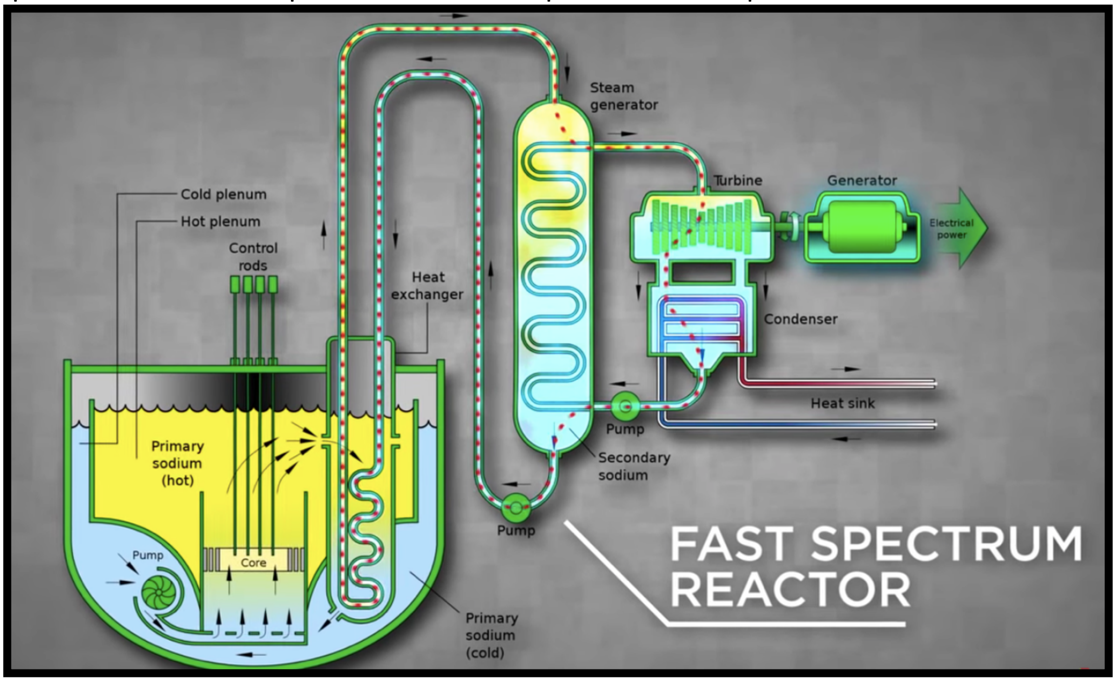

Fig 6: Diagram of a fast spectrum reactor (Argonne, 2012)

4.2 Rebuttal to meltdowns

The common theme with Chernobyl and Fukushima was the flawed design of the plant. SMRs, like NuScales SMR is designed to be meltdown proof. The way it does this is using electromagnetic forces that are switched off when there a power failure. This allows the control rods to fall into the core and stop fission from occurring. These reactors will be online in 2026 (Ellis, 2019). Another way to stop a meltdown is by using convention and gravity. The AP 1000 does exactly that. When there could be a potential meltdown, the reservoir of water can be dumped into the core cooling the core and buying time to restore power (O'Brien 2017). Magnesium mixed with potassium, is another way to prevent a meltdown. With water having a boiling point of 100°c, while magnesium mixed with potassium has a boiling point of 1600°c (O'Brien 2017). This was tested at the Argonne National Laboratory on April 16th 1986 with all the coolant pumps turned off similar to Fukushima. The temperature started to rise quickly but it slowly came down, preventing a meltdown as seen in Fig7.

Fig 7: Visual representation of the temperature during the test (Stone, 2013).

4.3 Rebuttal to cost

As previously mentioned, the levelized cost of energy for nuclear is the third most expensive. However, this is not reflected by the cost of energy for consumers. This is shown in Fig 8 where there is a strong collection between high renewable percentage and high-power prices.

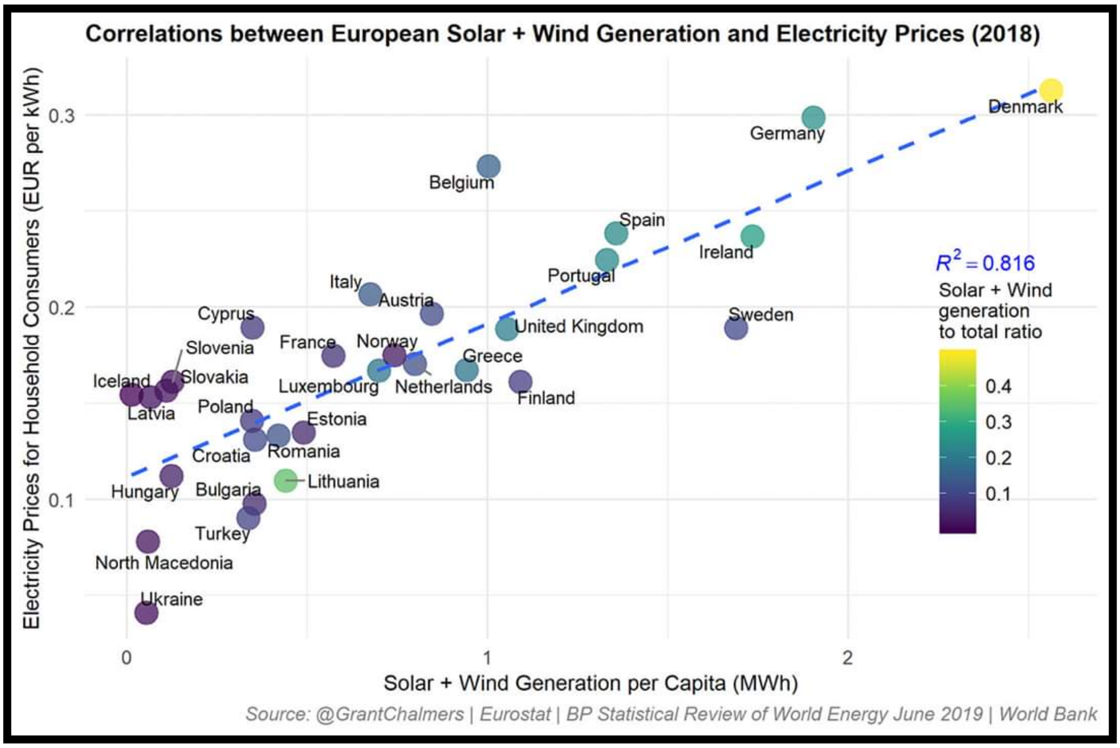

Fig 8: Correlations between European Solar + Wind Generation and Electricity Prices in 2018 (BP Statistical Review of World Energy, 2019).

With the emergence of SMRs, this will drive down the cost of nuclear power. SMRs can be mass produced on an assembly line reducing costs and construction time of the plant. Roll Royce has stated that the company can build SMRs by 2030 as seen in Fig 9. The cost of 1GW is $6.1 Billion, 4 billion below the average cost of a conventional plant.

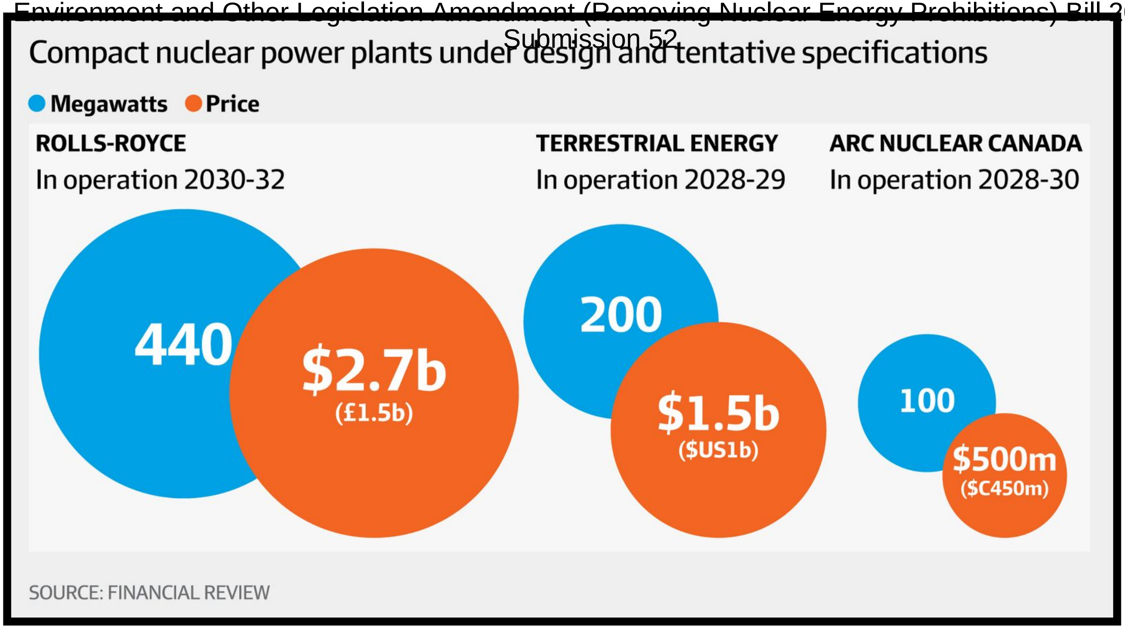

Fig 9: The cost for various SMRs from different companies (Patrick, 2019).

Conclusion

This report has outlined the 3 main positives of nuclear power, the 3 main negatives of nuclear power, also the rebuttals to those negatives. The 3 main positives are, nuclear is co2 free, it is better than renewables and nuclear power saves lives. The 3 main negatives of nuclear power are, the waste, meltdowns the cost. The rebuttal to those negatives were led by technology and more specifically, SMRs. Nuclear power is one of many mitigation strategies to climate change and should be utilized for clean, cheap, reliable power.

Reference List

Argonne, N. L. (Director). (2012). *Argonne explains nuclear recycling in 4 minutes* [Motion Picture].

Atomic Archive . (2020, n.a. n.a.). *Nuclear Fission: Basics*. Retrieved from Atomic Archive : http://www.atomicarchive.com/Fission/Fission1.shtml

Bartlett, R. (Director). (2004). *Zero Hour: Disaster at Chernobyl Discovery Channel (2004)* [Motion Picture].

BP Statistical Review of World Energy (2019, June n.a.)

Ellis, L. (Director). (2019). *Mini-Nuclear Reactors Are Coming, and They Could Reinvent the Energy Industry* [Motion Picture].

Fares, R. (2016, May 19). *3 Ways Small Modular Reactors Overcome Existing Barriers to Nuclear*. Retrieved from Scientific American : https://blogs.scientificamerican.com/plugged-in/3-ways-small-modular-reactors-overcome-existing-barriers-to-nuclear/

International Atomic Energy Agency . (2020, n.a. n.a.). *Operational & Long-Term Shutdown Reactors*. Retrieved from International Atomic Energy Agency : https://pris.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx

Keohane, D. (2019, October 9). *EDF adds further €1.5bn to Flamanville nuclear plant costs*. Retrieved from Financial Times: https://www.ft.com/content/fc6a8610-ea5e-11e9-a240-3b065ef5fc55

Kharecha, P., & Hansen, J. (2013, April n.d.). *Coal and Gas are Far More Harmful than Nuclear Power*. Retrieved from National Aeronautics and Space Administration: giss.nasa.gov/research/briefs/kharecha_02/

Kurzgesagt (Director). (2015). *3 Reasons Why Nuclear Energy Is Awesome! 3/3* [Motion Picture].

Long, Z. (Director). (2017). *The fight to rethink (and reinvent) nuclear power* [Motion Picture].

Martin, W. (2019, June 14). *Nuclear power*. Retrieved from Encyclopaedia Britannica: https://www.britannica.com/technology/nuclear-power

Neslen, A. (2018, Febraury 15). *This article is more than 3 years old Protected forests in Europe felled to meet EU renewable targets – report*. Retrieved from The Guardian: https://www.theguardian.com/environment/2016/nov/24/protected-forests-in-europe-felled-to-meet-eu-renewable-targets-report

O'Brien, M. (Director). (2016). *Fukushima Uncensored* [Motion Picture].

O'Brien, M. (Director). (2017). *The Nuclear Option* [Motion Picture].

Office of Nuclear Energy. (2020, March 30). *5 Fast Facts about Spent Nuclear Fuel*. Retrieved from Energy.gov: https://www.energy.gov/ne/articles/5-fast-facts-about-spent-nuclear-fuel

Patrick, A. (2019, August 28). *The Rolls-Royce option for Australian nuclear power*. Retrieved from Financial Review : https://www.afr.com/companies/energy/the-rolls-royce-option-for-australian-nuclear-power-20190822-p52jpn

Productions, W. (Director). (2017). *The Nuclear Waste Problem* [Motion Picture].

Shellenberger, M. (Director). (2019). *Why renewables can't save the planet | Michael Shellenberger | TEDxDanubia* [Motion Picture].

Stone, R. (Director). (2013). *Pandora's Promise* [Motion Picture].

The Work Bank. (2014 , n.d. n.d.). *CO2 emissions (kt)*. Retrieved from The World Bank : https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?cid=GPD_31&most_recent_value_desc=true

U.S. Energy Information Administration . (2020). *Electric Power Monthly.* Washington, DC : U.S. Energy Information Administration .

U.S. Energy Information Administration. (2020). *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020.* n.a.: U.S. Energy Information Administration.

World Health Organisation . (n.d., n.d. n.d.). *Air pollution*. Retrieved from World Health Organisation : http://www9.who.int/airpollution/en/

World Nuclear Association . (2020, March n.d.). *Nuclear Power in France*. Retrieved from World Nuclear Association : https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx

World Nuclear Association . (2020, February n.d.). *Radioactive Waste - Myths and Realities*. Retrieved from World Nuclear Association : https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-and-realities.aspx

World Nuclear Association. (2020, March n.a.). *Nuclear Power in the World Today*. Retrieved from World Nuclear Association: https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx