Exploring the viability of nuclear energy as a carbon-neutral energy source

Committee: SPC2

Student Officer: Neal Ngoukam

Forum: Special Committee 2 (SPC2)

Issue: Exploring the viability of nuclear power as a carbon-neutral energy source

Name: Neal Ngoukam

Position: Chair

Introduction

One of the most innovative and infamous breakthroughs of the past half-century, arising from the destruction of Nagasaki and Hiroshima in 1945, has been the development of nuclear power as a key staple point of the energy mix. Yet, despite the immeasurable benefits it provides, nuclear accidents such as the 1986 Chernobyl and 2011 Fukushima disasters have cast a negative light on atomic power in the eyes of the public. The hysteria surrounding its dangers, particularly in a globe reeling from the potential nuclear holocaust stemming from the Cold War has influenced its gradual phase-out and decline across several wealthy states, such as Germany. In favour of colossal investment into renewable energy and reliance on growing Russian natural gas imports.

However, the Russian Federation's use of natural gas as a geopolitical weapon following the Russian Invasion of Ukraine and the subsequent closure of the Nord Stream 2 pipeline, and the sabotage of the Nord Stream 1 pipeline has exposed the deficiencies of the European energy sector, particularly in terms of energy security. The successive energy crisis, encompassing tremendous increases in energy, gas, and the general cost of living has had a disastrous impact on the European economy. Likewise, considering the international community's need to combat climate change and discover viable alternatives to fossil fuels, which are set to run out in the foreseeable future. Policymakers and the public alike have increasingly enquired into the viability of nuclear power as a carbon-neutral, eco-friendly, and sustainable energy source.

Nuclear power's ability to produce carbon-free, cheap, and reliable energy is an increasingly desired quality. Therefore, nuclear power is increasingly being considered an attractive alternative to non-renewable and toxic fossil fuels, whilst also producing more reliable energy than renewables such as wind and solar energy. Yet, one mustn't forget its drawbacks: cost, waste, risk, and societal perception. Nevertheless, nuclear power can have both positive and negative societal impacts.

Definition of Key Terms

Nuclear Power Plant

A power station holding one or multiple nuclear reactors, converting nuclear energy into electrical energy for domestic use.

Nuclear Reactor

A structure in which nuclear fusion takes place in a controlled environment.

Nuclear Fission

The process through which nuclear power plants produce energy. The production of energy from the controlled splitting of a uranium-235 nucleus into two or more smaller nuclei.

Nuclear Fusion

The process through which stars emit light, which requires extreme temperatures and pressure. The combination of two lighter nuclei into a singular heavier nucleus.

Capital Cost

The total cost incurred when bringing a project (in this case a nuclear power plant) to operational status.

Lifetime extensions

The extension to the pre-determined technical life and operation of a nuclear power plant.

Radiation

The emission of energy in the form of particles or waves from a radioactive source such as an unstable isotope’s nucleus.

Energy Security

The reliable availability of energy sources at an affordable price.

Petrostate

A state that is heavily dependent on the production and exportation of crude oil and/or natural gas.

Nuclear Proliferation

The spread of weapons of mass destruction to states that did not previously possess them.

General Overview

Economic Impacts

Nuclear power is a cost-competitive source of reliable energy once in operation. However, the construction of nuclear power plants are characterised by high upfront capital costs (typically ranging billions of US dollars), constant delays, long construction times and slow returns on investment. To summarize, one only reaps the benefits of the colossal investment into atomic energy one if not two decades after the commencement of a project. The World Nuclear Industry Status Report 2021 (WNISR) reported that in the past decade, the construction of 57 reactors was undertaken, yet by 2021, 15 were in operation, 39 remained under construction and 3 had been abandoned. Bureaucracy, COVID-19, financial negotiations, and licensing procedures are only a few examples of the many factors plaguing construction projects. Two projects, Mochovce-3 and -4 in Slovakia as well as, Bushehr-2 in Iran, have been in limbo for over 4 decades having had the construction work inaugurated in 1976. Henceforth, the suitability of nuclear energy to serve as a stopgap for the phase-out of fossil fuels in favour of renewable energy is under doubt, especially considering the limited time afforded by the impending climate crisis. The construction of new nuclear power plants can therefore not be regarded as a solution to climate or fossil fuel dependency. Nevertheless, the aforementioned viewpoint is one based only on huge conventional nuclear power plants. Not the smaller, innovative reactor designs currently being researched and developed by the nuclear industry. Hence the emergence of a less resource-intensive reactor design shortly may not be unprecedented and may disprove the notion held above. But this is mere conjecture, and the highly anticipated discoveries and designs may never see the light of day. Thus, one must not lend all hope to this possibility.

However, while the undertaking of building new nuclear power plants may be unfavourable due to time constraints and limited resources, countries with pre-existing nuclear infrastructure can always consider lifetime extensions, to increase or maintain nuclear energy's share of their energy mix. This policy has been actively undertaken in Europe, particularly in France, where reactors have an average design age limit of 40 years. Yet as previously described the French government has prioritized lifetime extensions to 50 years rather than building new reactors. This leaves a question unanswered regarding the future of nuclear energy, as there appear to be more reactor closures than start-ups. In the coming decade, the WSIR estimates that the total number of reactors globally will decrease by 123, likewise decreasing the total output of global nuclear energy by 95.5GW.

Regarding cost-competitiveness, reliability, and economic output once in operation nuclear energy is competitive among energy sources. The electricity market is defined by a daily change in demand characterized by fairly low demand in the morning and afternoon followed by a spike in the evening, which slowly dissipates by midnight. This cycle favours energy sources, which can change and adapt supply per the demand cycle. Nuclear energy is very effective in that aspect, as power plants can scale up and down electricity generation rather easily. This is a rare quality among carbon-neutral energy sources, which are often weather dependent.

Moreover, individual nuclear power plants have positive economic impacts on the state and local region in which they are located. Two case studies of this are the Ginna and Indian Point Power Plants both located in the state of New York in the United States. A US Nuclear Energy Institute (NEI) study reported that they had a combined local annual economic output of over $1.95 billion per year and contributed $2.95 billion per year to the national economy. The plants also provided hundreds of millions of dollars annually in tax revenue to the state of New York and supported over 10,000 jobs both directly and indirectly. To summarize the economic benefit of nuclear energy is undeniable and it unquestionably significantly contributes to both grid reliability and output. The environmental contribution of Indian Point was also significant, preventing the release of 8.5 million tonnes of carbon dioxide per year a quality of nuclear energy, which will be extended upon shortly.

Environmental Impacts

A common misconception is that nuclear energy is renewable. However, this is not the case. Nuclear power plants produce energy through the process of nuclear fission. This requires the isotope uranium-235 as fuel, which is a finite resource bound to run out within the coming century. Obtaining uranium requires extensive mining and drilling, which has several environmentally adverse effects, contaminating the environment with radioactive dust, radon gas, and water-borne toxins. Severely, damaging neighbouring ecosystems' biodiversity.

However, the process of nuclear fission itself is carbon-free, not releasing any carbon emissions or other toxic greenhouse gasses. In the United States alone, the NEI reports that more than 471 million metric tons of carbon dioxide emissions in 2020, were avoided thanks to nuclear energy. Corresponding to removing 100 million cars from the road and more than all other carbon-free energy sources combined. The environmental benefits this provides are immeasurable helping mitigate the negative effect of climate change on air quality and toxic air pollutants such as sulphur dioxide from contributing to acid rain, lung cancer, and smog. Henceforth, nuclear power provides an energy source that provides reliable energy without contributing to the greenhouse effect and global warming.

Moreover, nuclear energy’s land footprint is considerably smaller than other energy sources, such as wind and solar farms. Producing more energy on less land. The average nuclear facility producing 1MW of electricity requires 640 acres of land, whereas a wind farm hoping to produce the same amount of energy would require 360 times more area approximately 230,000 acres of land. The reduction of visual pollution from nuclear energy is therefore unprecedented.

However, nuclear energy’s environmental record is not perfect. Nuclear fission produces highly radioactive waste, which is the remnants of the uranium used as fuel. The waste is stored to avoid exposure to radiation and leakage, and to ensure the waste safely decays for safe future disposal. Storage sites are highly varied from dry casks at reactor sites to geological tombs more than 400m underground such as in Finland. However, most waste approximately 90% by volume is low-level nuclear waste, which can be safely disposed of by incineration or through land-based disposal. States, such as France have recently discovered innovative methods to recycle and reuse nuclear waste back into standard fuel. Alongside, nuclear waste’s extreme density means that nuclear waste only takes up a small area of land. All of the nuclear waste ever produced by the United States over the past 6 decades could fit in a 9-metre-deep football field.

Due to past disasters, such as Chernobyl and Fukushima the effect of nuclear accidents on the environment has been widely studied in the past decade. And unexpectedly while the initial high radiation levels are damaging and toxic to humans, after 30 years nature is thriving in the Chernobyl Exclusion Zone (at least before the Russian Invasion of Ukraine). Largely due to the absence of humans, the land has become a haven for several endangered species such as the Eurasian lynx, European bison, Prezwalski horses, and 60 other rare species, constituting a boom in the biodiversity of the local ecosystem. The exclusion zone now represents the third-largest nature reserve in mainland Europe. Whilst this does not incentivise or excuse nuclear accidents, it rather showcases that the environment and nature can recover and thrive rather quickly following accidents and that in fact, they are not as damaging to the environment as previously thought.

Social Impacts

Thanks to the highly publicized nuclear accidents of Chernobyl and Fukushima public sentiment has largely been in opposition to nuclear power, as hysteria surrounding its safety and the risk of accidents spread, significantly contributing to the decline experienced by the nuclear industry in the past decade and reversal of nuclear energy policy in several states. However, much of this fear and hysteria is unfounded nuclear energy is very much safe. The causes of the previous accidents have been eliminated due to constant innovation in the industry. In the entire 60-year history of civil nuclear energy usage, there have only been three accidents at nuclear power plants, the two aforementioned events, and the more obscure 1979 Three Mile Island accident.

Said accident was caused by a cooling malfunction in reactor #2 causing a part of the core to melt and the reactor to be later destroyed. However, radiation was contained, no adverse health or environmental effects were discovered in the local area and thanks to the disaster the Institute of Nuclear Power Operations (INPO) and National Academy for Nuclear training were created. Both organizations have helped improve safety and minimise risk by improving the training of staff and introducing tight restrictions for American power plants to follow.

On the other hand, the radiation emitted from the destruction of block 4 of the Chernobyl power plant wasn't able to be contained, causing serious health concerns for the local population from the City of Pripyat, which has battled with radiation sickness and cancers since the disaster. Yet such a disaster can no longer take place, the Soviet RBMK-1000 reactors present in the facility had serious design flaws and the staff of the plant was not highly trained. All remaining RBMK reactors have either been retrofitted or shut down, hence an explosion such as the one that took place at Chernobyl can no longer take place.

The Fukushima accident was caused by a 15-metre tsunami which disabled the power supply and cooling of the power plant, resulting in the melting of the cores of three reactors. 100,000 people living around the plant were evacuated due to high levels of radiation and the surrounding aquatic environment was severely contaminated, thankfully only one person died due to radiation from the plant. In fact, in the present day, the surrounding area is safe and populated. However, this disaster was mainly due to the incompetence of the company operating the plant Tepco. They ignored countless warnings ranging from the US Nuclear Regulatory Commission and various Japanese government committees that a high-magnitude tsunami would overwhelm the plant's tsunami defences. Hence, if proper procedural conduct was followed the disaster would have been avoided, clearly indicating that there is not a systemic risk with nuclear energy if adequate safety measures are maintained.

Political Impacts

Nuclear energy is a crucial component of the energy mix and is obtained through building and operating nuclear power plants in one's territory. Uranium-235 is the only component of the process which is imported from external sources. Excluding that, once constructed and operational nuclear energy is consistently and reliably available to a state regardless of external factors, relating to geopolitics. Hence, atomic energy provides Europe in particular with an alternative to Russian natural gas and reliance on gas-producing countries, significantly improving Europe's energy security. Ensuring the reduction of Russian soft power and influence in the European Union and likewise the growing influence of authoritarian petrostates such as Qatar and Azerbaijan.

Alternatively, the construction of nuclear power plants and reactors has been used as a façade to mask the development of nuclear weapons in violation of the treaty on the non-proliferation of nuclear weapons. Such fears have stuck Iran's burgeoning nuclear industry in a perpetual quagmire under constant international rebuke and US sanctions. The Israeli Air Force even bombed and destroyed a Syrian Nuclear Reactor in construction due to such fears. Henceforth, the international community has always been vigilant of the construction of nuclear reactors in a pariah state and its capacity to result in nuclear proliferation. North Korea's acquisition of such weapons thanks to a Soviet-designed nuclear reactor in the state serves as a warning to the international community on the destabilizing effect this can have on international affairs.

Timeline of Key Events

Date	Event

December 1938	German physicists Lise Meitner and Otto Frisch discover nuclear fission
2nd December 1942	Creation of the first nuclear reactor in Chicago
6th and 9th August 1945	Atomic bombings of Hiroshima and Nagasaki
20th December 1951	Electricity generated for the first time by a nuclear reactor
27th June 1954	Obninsk Nuclear Power Plant, USSR, became the first nuclear power station to generate electricity for a power grid
27th August 1956	Calder Hall Nuclear Power Station, UK, became the first commercial nuclear power station to connect to the national power grid
29th July 1957	Creation of the International Atomic Energy Agency
28th March 1979	Three Mile Island accident
26th April 1986	Chernobyl disaster
11th March 2011	Fukushima nuclear accident
5th December 2022	Breakthrough reached in nuclear fusion experiment, reaching breakthrough for the first time

Major Parties Involved

France

France is one of if not the most nuclear-dependent country, deriving approximately 70% of its total electricity from nuclear energy from 56 reactors, due to a long-standing policy originating in the 1980s prioritizing energy security. In February 2022 France announced plans to construct six new reactors and possibly a further eight. France is also the world's largest net exporter of electricity generating €3 billion annually in income. The French have also been frontrunners in innovations in nuclear technology, developing new methods to recycle and reuse nuclear fuel, roughly 17% of France's electricity derives from recycled nuclear fuel.

Germany

Following the 2011 Fukushima Nuclear accident, Germany reversed its nuclear energy policy introducing a phase-out plan for 2022, by which all nuclear power plants are to be shut down.

Instead, Germany imported greater amounts of Russian natural gas through the Nord Stream 1 and 2 pipelines. However, the Russian invasion of Ukraine has brought an end to that policy and has delayed the nuclear phase-out by a year. Instead, Germany has fallen back upon coal to replace the deficit in production left by gas and nuclear.

Japan

Following the 2011 Fukushima Nuclear accident, all of Japan's 54 nuclear reactors were closed indefinitely, due to public outcry and mistrust originating from the disaster. In 2022 Japan announced plans for nuclear power to generate a third of total electrical power by 2030 planning on investing in newer reactors and reactivating 33 reactors at a later date. Regardless, 24 reactors are scheduled or are in the process of decommissioning.

United States of America

The United State's 92 commercial reactors account for 22% of the nation's total electricity generation. The American government has cemented nuclear power's place in the energy mix for the transition to more renewable energy sources, but in the wake of the 2011 Fukushima disaster plans for an expansion to nuclear energy were cancelled.

Finland

Finland operates five reactors, the most recent one entering the commission phase in February 2022. Nuclear energy accounts for 34% of the nation's electricity generation. Finland will also open a state-of-the-art geological nuclear waste storage unit more than 400m underground in 2023.

Iran

Iran has been operating a nuclear program since the 1950s, yet because it ratified the Non-Proliferation Treaty, ensuring its program is only for peaceful use it's been subject to international inspection from the International Atomic Energy Agency. Reports from a dissident group revealed that nuclear activities were being conducted in the state, resulting in a United Nations Security Council resolution demanding the suspension of said activities. Following the collapse of the 2015 Iran nuclear deal, which ensured the conversion and limitation of nuclear facilities in the state, thanks to President Trump's withdrawal in 2018. Sanctions ranging from energy services to financial services were placed on Iran by the United States.

International Atomic Energy Agency

An international organization, autonomous yet within the United Nations system which seeks to promote the peaceful use of nuclear energy and inhibit its military usage, particularly through supervision and inspections.

Possible Solutions

The recent breakthrough in the field of nuclear fission has rejuvenated interest and imagination into the possibility of fusion, as a near-limitless source of clean, safe and carbon-free energy, a marked on nuclear fusion, as it would produce four times as much as a nuclear fission reaction of the same mass. However, we are far from that point in the present day, yet another breakthrough in the field could make nuclear fission reactors on earth a reality.

Although storage isn't a pressing issue, the establishment of a common international storage centre, accessible to all states with nuclear energy capacity could be an interesting notion. Yet the suitability of the location of the unit would have to be heavily evaluated, considering public opinion, potential environmental damage, accessibility, and willingness of the host nation to keep it as a politically neutral space.

While commonplace in France recycling nuclear waste is not a common practice in all countries. Ensuring it may be an effective undertaking to increase the efficiency and decrease the environmental footprint of nuclear energy.

Public animosity and mistrust towards nuclear energy has been a major obstacle facing the industry. Hence, any method of educating the public, such as an advertising campaign or positive social media presence may help shift public opinion.

Nuclear proliferation is a danger stemming from the expansion of nuclear energy to potentially hostile international actors. Hence, the international community would need to create an effective mechanism to ensure that safety standards, procedures and training are met in all nuclear power plants. The successful implementation of such a mechanism and framework would need to have a successful deterrent to deter member states from breaching ratified measures.

Bibliography

A.Meneleyc, Daniel. "Why Nuclear Energy Is Sustainable and Has to Be Part of the Energy Mix." *Sustainable Materials and Technologies*, Elsevier, 20 Nov. 2014, https://www.sciencedirect.com/science/article/pii/S2214993714000050.

"Climate." *Nuclear Energy Institute*, https://www.nei.org/advantages/climate.

"How Can Nuclear Combat Climate Change?" *Nuclear Energy and Climate Change - World Nuclear Association*, https://world-nuclear.org/nuclear-essentials/how-can-nuclear-combat-climate-change.aspx.

Iea. "Nuclear Power in a Clean Energy System – Analysis." *IEA*, https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

International Atomic Energy Agency. https://www.iaea.org/sites/default/files/21/10/nuclear-energy-for-a-net-zero-world.pdf.

"Is Nuclear Power a Green Energy." *Orano.group*, https://www.orano.group/en/unpacking-nuclear/is-nuclear-power-a-green-energy.

"Nuclear Energy for 24/7 Carbon-Free Energy: What's Better for a Net-Zero Future? by Flexidao." *By FlexiDAO*, https://www.flexidao.com/post/nuclear-energy-24-7-carbon-free-energy.

Paster, Pablo. "Ask Pablo: Is Nuclear Power Really 'Carbon Neutral?"." *Treehugger*, Treehugger, 11 Oct. 2018, https://www.treehugger.com/ask-pablo-is-nuclear-power-really-carbon-neutral-4857729.

Pearce, Joshua M. "Limitations of Nuclear Power as a Sustainable Energy Source." *MDPI*, Molecular Diversity Preservation International, 7 June 2012, https://www.mdpi.com/2071-1050/4/6/1173.

Weber, Joscha. "Fact Check: Is Nuclear Energy Good for the Climate? – DW – 11/29/2021." *Dw.com*, Deutsche Welle, 29 Nov. 2021, https://www.dw.com/en/fact-check-is-nuclear-energy-good-for-the-climate/a-59853315.

"What Is the Role of Nuclear in the Energy Mix and in Reducing Greenhouse Gas Emissions?" *Grantham Research Institute on Climate Change and the Environment*, 9 Dec. 2022, https://www.lse.ac.uk/granthaminstitute/explainers/role-nuclear-power-energy-mix-reducing-greenhouse-gas-emissions/.

"Economics of Nuclear Power." *Nuclear Power Economics | Nuclear Energy Costs - World Nuclear Association*, https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx.

World Nuclear Industry Status Report. https://www.worldnuclearreport.org/IMG/pdf/wnisr2021-lr.pdf.

Dewar, Dale, et al. "Uranium Mining and Health." *Canadian Family Physician Medecin De Famille Canadien*, U.S. National Library of Medicine, May 2013, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3653646/#:~:text=Uranium%20mining%20has%20widespread%20effects,nuclear%20power%20and%20nuclear%20weapons.

"3 Reasons Why Nuclear Is Clean and Sustainable." *Energy.gov*, https://www.energy.gov/ne/articles/3-reasons-why-nuclear-clean-and-sustainable.

"Nuclear Waste." *Nuclear Energy Institute*, 22 Nov. 2019, https://www.nei.org/fundamentals/nuclear-waste.

Www.iaea.org. https://www.iaea.org/sites/default/files/iaea-ccnp2022-body-web.pdf.

Moore, Thomas. "Inside the World's First Nuclear Waste Tomb in Finland." *Sky News*, Sky, 19 Oct. 2022, https://news.sky.com/story/inside-the-worlds-first-nuclear-waste-tomb-in-finland-12723295#:~:text=World%27s%20first%20nuclear%20necropolis%20in,tunnels%20carved%20into%20the%20bedrock.

"Is Nuclear Energy Renewable or Sustainable? Pros & Cons." ***Is Nuclear Energy Renewable Or Sustainable? Pros & Cons | Perch Energy*****, https://www.perchenergy.com/blog/energy/is-nuclear-energy-renewable-sustainable.**

"How Chernobyl Has Become an Unexpected Haven for Wildlife." *UNEP*, https://www.unep.org/news-and-stories/story/how-chernobyl-has-become-unexpected-haven-wildlife.

"Fukushima Daishi Accident." *Fukushima Daiichi Accident - World Nuclear Association*, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.aspx.

"Three Mile Island Accident." *Three Mile Island | TMI 2 |Three Mile Island Accident. - World Nuclear Association*, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx.

"Safety of Nuclear Reactors." *Safety of Nuclear Reactors - World Nuclear Association*, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx#:~:text=The%20risk%20of%20accidents%20in,radioactive%20releases%20can%20be%20avoided.

IAEA Publications, https://www-pub.iaea.org/MTCD/publications/.

***YouTube*, YouTube, 10 May 2019, https://www.youtube.com/watch?v=zZUMoEfTr7w. Accessed 25 Dec. 2022.**

***YouTube*, YouTube, 6 June 2020, https://www.youtube.com/watch?v=UC_BCz0pzMw&t=29s. Accessed 25 Dec. 2022.**