PNB Research Institute

PNBRI Views 03/23 | 26 April 2023

ABSTRACT

Over the coming years, it is expected that there will be a substantial increase in energy demand due to the expansion of the world's population and economy, coupled with rapid urbanisation. The technology of nuclear power is an important option for the world to meet future energy needs without emitting carbon dioxide and other atmospheric pollutants. However, the use of nuclear as a source of electricity is still a topic of debate among the world's countries as it involves safety risks, environmental impacts, location suitability, disposal methods and maintenance cost.

This informative piece by the author highlights the basics of nuclear energy and clarifies its use in the generation of electricity and associated risks. It also discusses the development of nuclear technology and its applications, together with issues with commercialisation including costs and the negative perception against the use of nuclear power. Going forward, nuclear technology holds a major potential to accelerate the global goal towards a carbon-negative world.

NUCLEAR ENERGY: POTENTIAL BOOM OR DOOM?

by **Adibah Amira Nazarudin**

This article is the first of an upcoming series by PNB Research Institute, that aims to feature key clean energy technologies for our common understanding – towards our firmwide goal of transitioning towards Net Zero and becoming a knowledge-based Institution.

Introduction: To appreciate is to understand

When the idea of writing about nuclear was first raised within the team, it faced scepticism by the team head. She can hardly be blamed – even though her only ever reference point was the highly-rated HBO series "Chernobyl", the sheer bad press that has always been surrounding nuclear takes a mental shift to overcome, even though nuclear energy had been powering 2% of America's and 5% of China's populations on average.

The opportunities for nuclear energy to be the main solution for climate change are rather vast, ranging from its more well-known applications in providing green electricity, to its lesser-known usage in climate assessment such as using radioisotopes for environmental tracing. The ability to trace and provide accurate measurements of any elements through any systems on earth, such as greenhouse gases (GHG) levels in the sea, glacier, or any earth deposits across time,[1] provides a huge advantage for better risk planning as the global trend shifts from net zero to decarbonisation. On the green energy front, nuclear energy is highly regarded as the most efficient, zero CO2-emitting energy source.

However, its most overlooked advantage by far has got to be the opportunity to reprocess nuclear waste for wider use. For example, it can be used to extend the life of available uranium to be further used to generate electricity[2].

Several European countries, Russia, China, and Japan already even have policies to reprocess used nuclear fuel. However, despite all the real prospects of nuclear technology, it remains as a “non-option” for Malaysia, based on virtually no policy discussions that are close to implementation on it until today. To further understand this, this short write-up intends to demystify the use of nuclear in electricity generation and its risks. Nuclear technology developments and its uses will also be discussed, alongside commercialisation challenges such as costs and the stigma against the use of nuclear.

What is nuclear energy, really?

This portion of the article is heavily sourced from World Nuclear Association

Nuclear energy is simply the innate energy in the nucleus (the core of an atom) that holds the nucleus together. To create electricity, that innate energy must be released from its atom through the process called nuclear fission, or the splitting of an atom through firing a particle (a neutron) at the atom. The fissioning (splitting) of atoms produces massive energy in the form of heat which is then used to generate steam and drive turbines to generate electricity. The typical, most used nuclear fuel, or the atoms to be split, is Uranium, which is now more commonly mined through a method called in-situ leaching. The mined uranium solution then is separated, filtered, and dried to form uranium oxide concentrate called yellowcake, and is further enriched to increase the uranium-235 isotope from 0.7% (typical level found in natural uranium) to 3% - 5% level so it can be used in most nuclear reactors. Enriched uranium is then converted into uranium dioxide powder in a fuel fabrication plant, and pressed into fuel pellets, inserted into fuel rods, and further grouped together to form a fuel assembly. Each fuel assembly contains 90 to over 200 fuel rods, depending on the type of reactor, and assembled to stay in the reactors for several years. Alternative nuclear fuels, such as plutonium and thorium can also be used.

Nuclear energy is deemed as the most sustainable green electricity option for three reasons: it has massive generating capacity, emits absolutely no greenhouse gases, and produces minimal waste.

Firstly, nuclear has massive generation capacity. For context of what “massive” hear means, the European Nuclear Society (ENS) estimates that 1kilograms of coal can produce c.8kWh, 1kilograms of mineral oil produces c.12kWh, and 1kilograms of Uranium-235 produces c.24,000,000kWh, which is enough to power one-fifth of Malaysian establishments in a day[3].

Secondly, it emits zero carbon. In contrast to the massive energy it produces, the CO2 emission created by nuclear energy in one life cycle is only 12 grams per kWh generated [4] and around 15 to 50 grams of CO2 per kilowatt hour (gCO2/KWh). In comparison, the average footprint of a gas-powered generator is 30 times more at around 450 gCO2/KWh and for coal it is around 70 times more at around 1,050 gCO2/KWh[5]. Note that said emission value comes from the planning, mining, construction, and operating stages, and not from the nuclear fission reaction itself. Additionally, due to the dense fuel size – each pellet is roughly an inch in size – the amount of nuclear waste (used fuel) produced is much lower.

Thirdly, notwithstanding these indicators of efficiency, nuclear fuel waste is also actually “recyclable”. Waste nuclear material can be reprocessed for further use in reactors that can be fuelled by processed uranium by way of extracting elements that can still generate electricity.

However, despite the many advantages of nuclear-generated electricity, it still carries significant risks. The fission process does create a huge amount of radiation, which includes essentially energy emissions or even hazardous particles that are shot out by the unstable atoms to stabilise itself through the decaying process. As Uranium-238 (a common nuclear fuel) is a radioactive material, the nuclear fission reaction will cause the radioactive nucleus to radiate alpha particles. Managing this highly radioactive material is essentially what drives up the capital cost of building a reactor, compared to other green-sourced energy plant. Because nuclear plants require high protection for humans and the environment from radioactive materials, more remote handling operations, and a fool-proof nuclear waste treatment.

The basic treatment of nuclear waste includes the transportation of high-level fuel waste (which is highly radioactive) from the reactor to wet storage facilities to cool the material down, followed by the storing of the materials in a dry storage facility after a period of initial cooling, to undergo recycling or direct disposal in an underground repository. Nuclear fuel is immobilised underground through a process called *vitrification*.

Nuclear technology is beyond electricity production

The use of radiation in medicine is already a very familiar concept. In fact, most of us may have been exposed to it through X-ray examinations. Radioisotopes, a by-product of nuclear fission reactions, has the unique ability to trace any elements. Its usage has advanced the detection of cancer-related diseases and it is further used to kill the cells through exposure to radiation or radiotherapy.

Another use of *radiotracers* (radioactive tracers) is to detect and analyse pollutants moving through groundwater. Radioisotopes can be used to date the source while stable isotopes can be used to assess the level of vulnerability and safety of the water. Further development and application of this isotope techniques can help to map natural groundwater and better plan its sustainable use.

Apart from the ability to do tracing, radioisotopes continue to produce energy throughout its decaying process. Radioisotopes power systems (RPS) have been used to power satellites for deep-space exploration where the lack of sufficient sunlight and natural heat limit the use of solar panels.

Another non-power application of nuclear technology is in food irradiation, which essentially a process that kills bacteria that causes food poisoning thus lengthening the shelf life of food, without turning the food radioactive. Irradiation can also be used in agriculture for environmentally friendly pesticide control by rearing, sterilising, and releasing large populations of male insects to reduce their offspring dramatically through a technique called sterile insect technique (SIT).

Locally, another use of nuclear technology has been developed – spearheaded by Nuclear Agency Malaysia. The technology, known as gamma ray mutagens, have been used widely in agriculture to produce new mutant crop varieties that are disease-resistant such as paddy, grass, banana trees, and groundnuts. A total of 53 mutant varieties have been developed including rice (19), banana (1), groundnuts (2), orchids (6), chrysanthemums (7), hibiscus (3), roselles (3), and other ornamental and landscaping plants (12)[6].

Negative perception and high cost remain as major implementation challenges

The two major challenges for nuclear energy implementation are the negative public stigma and high costs associated with commercialisation.

Firstly, the stigma around nuclear energy continues to plague the Malaysian public mindset. There had been numerous perception studies done between 2009 and 2017 to gauge public acceptance on Malaysia having its own nuclear power plant (NPP). The year 2011 was a key inflection year. Before the 2011 Fukushima incident, the studies showed 74% - 85% support on NPP. However, after the incident, support dropped to at most 47%[7], indicating that public perception is highly influenced by exposure to information. In short, it can be concluded that news from the 2011 Fukushima incident – which were featured on multiple news outlets and is continually used as propaganda mantra – affected the Malaysian public's perception, compared to information disseminated on nuclear energy, radiation and its safety handling, the advanced technological development in nuclear, and scientifically verified use cases.

In contrast, a perception study on NPP in Indonesia conducted from 2010 to 2016, interestingly showed that national support exceeds 70%. The number did drop in 2011 immediately following the Fukushima incident but the perception recovered in the following years[8].

This contrasting result between both countries can be attributed to the level of importance people placed on energy-related issues. In Malaysia, energy is not deemed as the top five important issues[9], while in Indonesia, electricity stability is ranked as a top concern. Another observation is the different level of optimism towards government programs. The Indonesian public generally trusts and support any governmental program considering past successes and positive spill overs to infrastructure development and employment, while Malaysian public generally trusts information coming from established organisations, professors, NGOs, or independent regulatory body more than the government. Therefore, it is crucial to intensify the promotion of positive, objective, and correct information about NPP or any nuclear-related programs for Malaysian which involves all related parties, especially technical experts, and established organisations.

Secondly, cost remains a key challenge. In the same perception study in Malaysia, when asked about the three priorities for the government's energy policy, low prices for consumers tops the list – despite already having enjoyed subsidised electricity. Admittedly, nuclear energy is still expensive due to its capital costs. Globally, nuclear energy has yet to meet the USD0.10/kWh rate threshold (equivalent to RM0.44/kWh namely TNB commercial tariff) for it to be commercially viable. As of 2021, Lazard's Levelised Cost of Energy (LCOE) is estimated at USD0.130/kWh to USD0.204/kWh for new nuclear plants, assuming a 7.7% commercial cost of capital over 40-year lifetime[10].

However, this need not be the case. One reason is that most reactors can operate for longer periods than that. An average nuclear plant may operate for 60 years without interruptions, and in 2019, two units (units 3 & 4) at the Turkey Point nuclear facility in Florida were the first reactors to be licensed for operation for 80 years.

A second reason is the possibility of lifetime extension via fuel reprocessing and lower discount rate, which could effectively bring down the LCOE from nuclear sources further. In fact, Lazard's LCOE for an operating NPP is at a competitive rate around USD0.024/kWh to USD0.033/kWh (equivalent to RM0.11/kWh – RM0.13/kWh which is in line with TNB's residential tariff).

This also shows that most of the cost is attributable to upfront capital expenses while most of the savings are in spreading the costs across a longer functioning plant lifetime and in the salvaging value of the nuclear fuel. Therefore, one way that could help incentivise Malaysia's nuclear market to produce electricity at competitive LCOE is to explore subsidies of the upfront capital cost.

Conclusion – Pushing nuclear forward

Our position is that nuclear technology holds a major potential to accelerate the global goal towards a carbon negative world. Continuous development in reactor technology and handling of nuclear waste has helped mitigate the safety risk in operating a nuclear power plant. On top of its ability to generate zero-carbon electricity, nuclear technology has a wider use, for example in dating and understanding element changes on earth and help with food security through water source tracing and producing disease-resistant crop. Nevertheless, more work around myth-busting and effective communications needs to happen to improve the stigma around nuclear technology use, especially locally in Malaysia. Political will may be needed to translate information into driving public education to improve knowledge and awareness of the potential of nuclear energy, as well as boosting interests of commercial players through subsidies to build nuclear reactor plants. These efforts can put Malaysia in a competitive advantage in green energy space, and more importantly able to address the local green energy supply shortage towards decarbonisation.

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