How Important is Nuclear Power in Future?

Greenhouse gas (GHG) emissions have become a serious threat to humanity. With accumulation of these gases on the atmosphere, phenomenon like climate change and constant global warming have occurred. Many climate experts believe that such phenomenon is mainly come from human activities. Cook et al. (2016)[1] proved on their paper, which the consensus that humans are causing recent global warming, reached positive results with 97% of consensus. The human-induced greenhouse gases are clearly forcing the world to set changes, especially on the fossil fuel related industry. Nowadays, fossil fuel is very common resource that used in daily activity and industry. The energy sector precisely has burned countless fossil fuels and produced gigatons of GHGs. These contributions come from transportation, manufacturing, electricity generation, and building (WRI, 2021)[2]. In 2018, the global energy sector released around 33.75 Gt CO_2 which accounted around 90% of total CO_2 emissions (WRI, 2021)[3]. The coal-generated electricity is considered as one of the top contributors in global energy sector emission. Particularly in China, the demand for the coal-powered electricity is still huge.

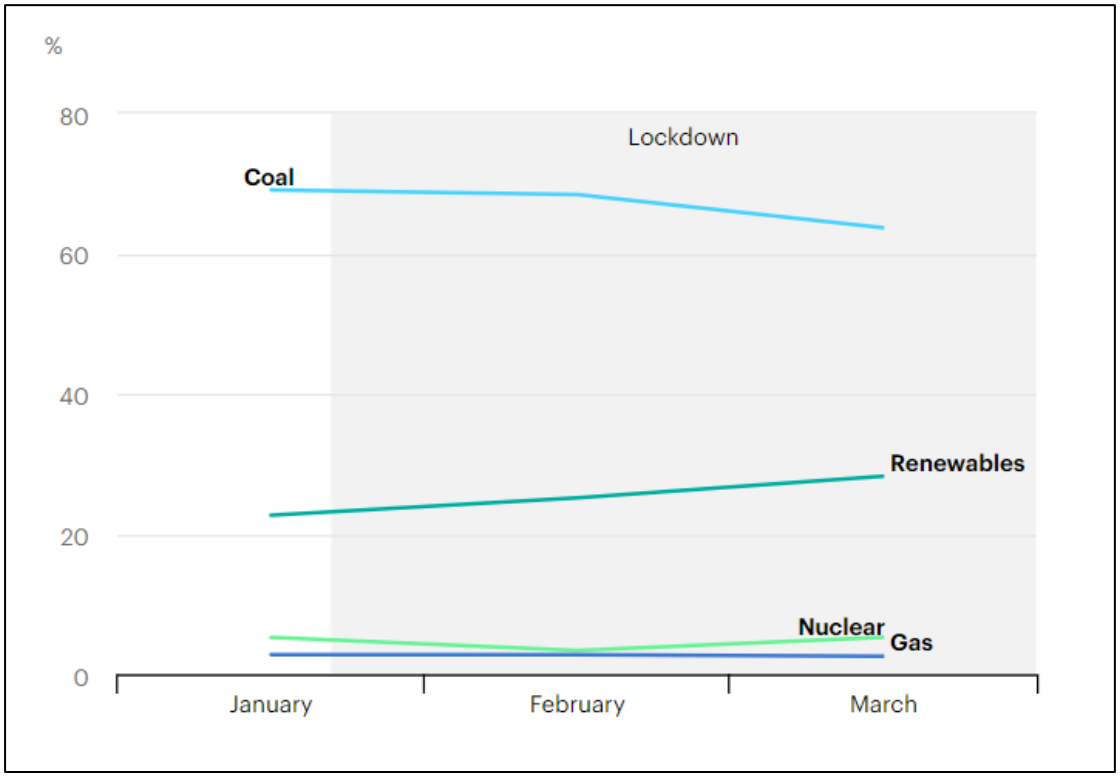

Figure 1. Different China Electricity Production Resources in Q1 of 2020. (Source: IEA, 2020)[4]

Despite the lockdown happened in the first quarter of 2020, the China's coal-powered electricity production still in favour. Yet, there is gradual increase in renewables at the end of first quarter 2020, with 28%. The nuclear power only reached 5% by March 2020. As the clean energy alternatives, this proportion is considerable small. Especially, China as the second world largest nuclear power generator with total of 344.7 TWh produced in 2020 (World Nuclear Association, 2021)[5]. Moreover, China pledges to reach carbon peak by 2030 and carbon neutrality by 2060 (China Government, 2021)[6]. This makes the investment not just in renewables energy but nuclear energy is a must as well.

The IPCC published a special report "Global Warming of 1.5°C" in 2018[7]. The report shows different pathways for human to limit the earth's temperature increase by 1.5 and 2 degrees at 2100. According to them, to fulfil these, the fossil fuel powered engines must be replaced by the clean & renewables immediately. Many countries have already taken further step in the renewable energy capacity and investment increase such as solar, wind and hydro power. Incentives by federal official and governments also applied to increase the renewables market. On the other hand, the nuclear power which serve as non-renewable clean energy is still lacking of attention. In couple years before 2021, more than half of the reactors permanently shut-down, not because of technical limitations, but because of political phase-out policies or the failure of markets to recognize nuclear power as future reliable source (Leon, 2021)[8]. UNECE (2021)[9] claims that the international climate objectives will not be met if nuclear power is excluded. Especially, in the post-pandemic, the global electricity demand expected to rebound sharply, there is also risk that greenhouse gas emissions will do so as well. As a low carbon source, the nuclear power actually has the edge over renewables.

Advantages of Nuclear Power

Nuclear power is clean but non-renewable energy source. Yet, it is considered as the most reliable clean energy. Since, nuclear power plants run 24 hours a day, 7 days a week. They are designed to operate for longer stretches and refuel every 1.5 – 2 years. According to Energy-Gov (2021)[10], in 2019, nuclear plants operated at full power more than 92% of the time, making it the most reliable energy source on the grid today. In United States, nuclear is the largest source of clean power. It generates nearly 800 billion KWh of electricity each year and produces nearly 55% of the nation's emissions-free electricity (NEI, 2020)[11]. This avoids more than 476 million metric tons of carbon each year, which is the equivalent of removing 100 million cars off of the road (Energy-Gov, 2021)[12]

Nuclear energy's land footprint is small. This means nuclear energy produces more electricity on less land than any other clean-air source. A typical 1,000-megawatt nuclear

facility in the United States needs a little more than 1 square mile to operate. Nuclear Energy Institute says wind farms require 360 times more land area to produce the same amount of electricity and solar photovoltaic plants require 75 times more space (Energy-Gov, 2021)[12].

Challenges of Nuclear Power

The risk during and after process involves nuclear power is high. For example, the radioactive materials which can be found at nuclear power plants, includes enriched uranium and radioactive waste (EPA, 2021)[13]. The radioactive release from the leak and system fail might occur as well, like the past incidents in Fukushima 2011 and Chernobyl 1986, in which both have known as the greatest nuclear disaster nowadays.

Due to this, many nuclear power plants are built and operated in isolation land for public safety reason. The waste mostly in solid form for better control and disposal. During the normal operation, nuclear power plants release very low amounts of radioactive materials into the air, which need to be monitored by the operators. Another form like liquid waste might also exist, but normally they will turn it into solid form by combining with other chemical substances.

The operators are also responsible to transport and dispose these wastes far underground permanently. Since it is hazardous, it needs to be handled carefully and safely. IAEA as the global organization that promote and support nuclear power, released the safety standard and regulations which required in nuclear power plant operation (IAEA)[14]. Further education and supports from such organization and officials are very crucial to develop global nuclear power industry.

As the result, the operation cost for the nuclear power is pretty high nowadays. NEI (2020)[15] found that the operational cost of nuclear power can double or even triple the capital expenditure. For instance, in 2019, the United States nuclear industry operation expenditure reached about $15 billion, yet the capital expenditure only totalled for about $5 billion. This imply that United States 2019 nuclear power operational cost triples the capital expenditure.

Another challenge is that uranium as main source of nuclear power is not renewable, which means at one point this source will run out. Since it is likely to be found in rocks and seawater, it is quietly common. But with global demand, more mining exploration still need to be made. However, according to Touran (2020)[27] that with current technologies likewise breeder reactors, it is expected that nuclear fuel will last us for 4 billion years. Breeder reactor will able the nuclear waste to be recycled which make nuclear power become renewable. Another alternative is by applying thorium as the substitute to uranium, which is still in experiment.

China Nuclear Power Capacity

At the end of 2020, there were 441 operable nuclear reactors globally, with a combined capacity of 392 GWe (Leon, 2021)[8]. On the same time, China itself owned 51 operable reactors which hold the capacity of 49.6 GWe, as well as generated 344.7 TWh electricity in total. This indicates around 13% of global operable nuclear reactors are in China (World Nuclear Association, 2021)[16]. Moreover, China ranked second as the most nuclear generation country, which United States had the most nuclear-powered electricity with 789.9 TWh by 2020 (World Nuclear Association, 2021)[5].

Since 2018, there is about 30% more of nuclear capacity installed in China, which totalled for 16.7% electricity production increased (World Nuclear Association, 2021)[17]. This implies that China's nuclear power industry is pretty solid globally. Despite that, the total of 344.7 TWh nuclear electricity production actually only nearly reached 5% of total China electricity production.

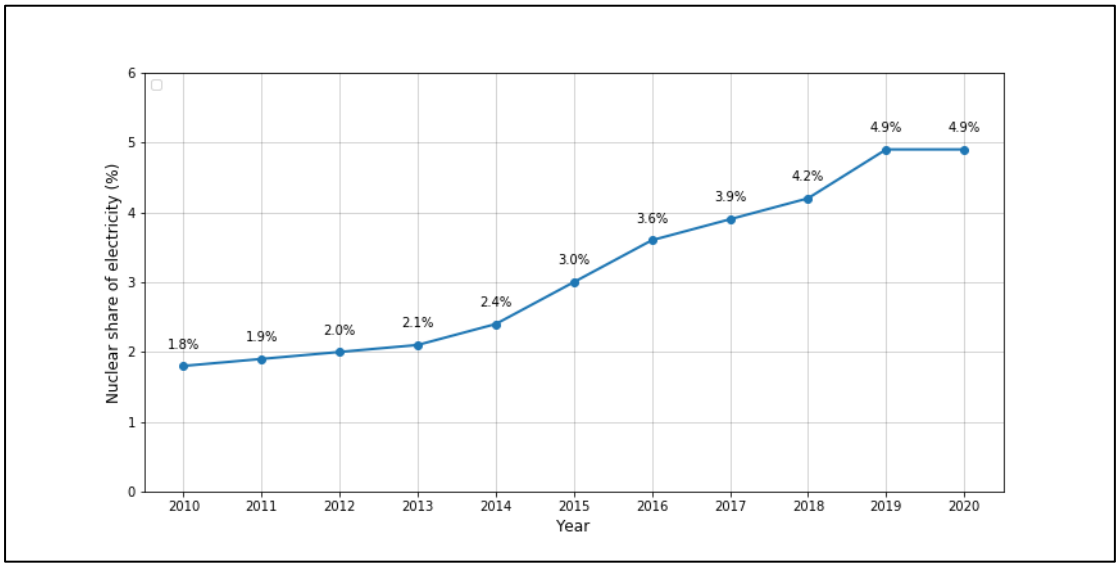

Figure 2. China electricity production shares using nuclear power from 2010 to 2020. (Source: IEA, 2020)[17]

In China, nuclear power is not popular as other clean energy source. In 2010, they only accounted of 1.8% shares of the whole nation electricity production. IEA (2020)[18] found, coal has become the primary resource which utilized almost 90% of total electricity production on 2010. Later in 2015, the UNFCCC[19] established a global agreement with specific emission reduction objectives, namely Paris Agreement. With total of 196 parties/countries, they pledge to limit global temperature rise to no more than 2°C, but preferably to 1.5°C by 2100. On the same time, they are required to cut the fossil fuel use and transition to cleaner energy. This includes China, where they pledge to reach carbon neutrality by 2060. As the result, there is significant growth in nuclear power electricity shares since 2015. According to the 13th Five-Year power planning, the installed capacity of nuclear power in China will reach 58 GW by 2020 (Xu, Kang and Yuan, 2018)[20]. However, by 2020, there is only 49.6 GW of total nuclear power capacity installed or 8.4 GW short from the expectation. This is due to sudden pandemic shock which halt the installation of more nuclear power capacity between 2019 and 2020.

Nevertheless, the rapid growth of nuclear power utilization since 2010 has shown that China has taken seriously the matter of expanding their nuclear industry. The country continues to dominate the market for new nuclear build. At the start of 2021, 16 of the 54 reactors under construction globally were in China (World Nuclear Association, 2021)[5]. Furthermore, on September 2021, there is finalize record of 18 nuclear reactors are actually still under construction, 37 nuclear reactors are planned, and 168 nuclear reactors are proposed. In total they might potentially provide approximately 257.3 GWe of electricity source (World Nuclear Association, 2021)[16].

Hainan Nuclear Utilization as a low carbon province

Hainan province for instance, which was pointed as the National Ecological Civilization Pilot Zone since 2019. Through this plan, they target the environmental quality and the resource utilization efficiency will be of world leading level by 2035 (Xinhuanet, 2019)[21]. To promote clean energy, Hainan has developed and invested in different kind of clean power energy. This includes the construction of Hainan (Changjiang) nuclear power plant. The plant is located in Changjiang High-tech Industrial Park. Currently, the construction project is on the second phase, which is being jointly developed by China National Nuclear Corporation (CNNC) and China Huaneng Group. The first phase was commenced in between 2015 and 2016, with two units of 650 MW or total of 1.3 GW worth nuclear power plant (NSenergy, 2021)[22]. The second phase was officially started on 31st March 2021, it is expected to build two units of 1.2 GW or total of 2.4 GW worth nuclear power plant (Seetao, 2021)[23]. The second phase project also known as China's first nuclear power project in the 14th Five-Year Plan period, which is huge for China's nuclear power industry. The construction period is expected for 60 months and hopefully can be put on the operation by the end of 2026. With estimation of 36.85-billion-yuan total investment, they estimate that the plant can deliver 18 billion kilowatt-hours of clean electricity to Hainan Province every year after completion (Seetao, 2021)[23].

In July 2021, the Hainan government issued the "Fourteenth Five-Year Development Plan for Hainan Province's High-tech Industry". The plan is to propose that by 2025, Hainan will achieve a huge leap-forward development in high-tech industry. This includes the optimization and

upgrading of clean energy, energy saving and environmental protection. Hainan (Changjiang) clean energy high-tech industry park is also highlighted in the proposal, which is very important for the Hainan as well as China's future nuclear energy (Minnews, 2021)[24].

How about the world perspective in Nuclear energy?

The United Nations Economic Commission for Europe (UNECE) which aim to promote pan-European economic integration, actually invest and embrace in the nuclear-powered electricity. They consist of 56 members States in Europe, North America and Asia, which also includes world number one nuclear power capacity, United States. In the latest report, UNECE (2021)[9] claimed that nuclear power will be an important factor to achieve the international climate objectives. They also showed if nuclear power has avoided about 74 Gt of CO_2 emissions over the past 50 years, nearly two years' worth of total global energy-related emissions.

Currently, the nuclear power is providing UNECE region about 20% of electricity generation, also 43% of low-carbon generation. 11 members/countries are in active part of the nuclear utilization, whereas 2 members/countries namely, Belgium and Germany announced to phase out nuclear power by 2025 and 2023 respectively. The remaining are still in power plant development and even proposing nuclear power programmes for the first time. They recorded since 2000, over 70 reactors have been shut down in the region due to political, economic or technical reasons (UNECE, 2021)[9].

The risk, economic and political reasons have ceased the nuclear industry to grow, especially Europe region. However, UNECE (2021)[9] believe that nuclear power is the simple solution to decarbonise energy intensive industries. Since the market still not significant, many people still questionable about this prospect. But UNECE still have confidence in nuclear power to help achieve future zero emission and carbon neutrality.

How is the future, does it look promising?

As two giants in nuclear industry, China and United States will lead the world future nuclear power.

With 19.7% of total shares on electricity in U.S., nuclear power has become important clean energy asset for the states. The nuclear energy sector is also directly responsible for approximately 100,000 well-paying jobs, and considers as the highest paying industry in the electric power generation sector (Desai, 2020)[25]. Moreover, with the pledges from the states, cities, and major electricity consumers and producers to completely decarbonize their electricity supply. United States definitely will include their nuclear plan to reach future low carbon targets.

Similarly, China' nuclear power generation in **Figure 2** experience significant growth in last 5 years. With more than 100 power plants are being proposed and planned, China's nuclear industry seems promising. Some new nuclear power technology and innovation have been proposed as well. Recently, China prepares to test thorium-fuelled nuclear reactor. Instead of Uranium, they replace it with thorium as the main fuel source. According to Mallapaty (2021)[26], if China's experimental thorium reactor is a success, it could lead to commercialization and help the nation meet its climate goals. Since it has the potential to produce nuclear energy that is relatively safe and cheap, while also generating a much smaller amount of very long-lived radioactive waste than conventional reactors.

Furthermore, thorium is much more plentiful than uranium, which will be sustainable to have in 50 or 100 years' time. Thus, it is suitable for the commercial use, and if this succeed, there will be a breakthrough in China's nuclear power industry.

Many other countries such as Canada, Czech Republic, Finland, France, Hungary, Poland, Romania, Slovakia, Slovenia, Russian Federation, Ukraine and United Kingdom have explicitly stated that nuclear power will play an important role in reducing their national emissions in the future (UNECE, 2021)[9]. This show how strong is nuclear industry in Europe as well. However, not all Europe countries are aligned with the nuclear power plan, some countries like Belgium and Germany actually objected future nuclear power development because of political and economic reason.

Opinion and Insight

Overall, despite nuclear power is pretty reliable clean energy, but it is not simple to operate. Especially, when managing the waste disposal. Beside it requires federal official consent, it also yield in high operational cost. Since the complex method, the operational cost might surpass its capital cost, which have become common challenge for nuclear power to get into the commercial market.

With future innovation and technologies, it is expected the operational cost can potentially be reduced. Replacing main fuel source with other cheaper and clean source for nuclear plant might also be another alternative. In order to compete and take over the coal and gas source, cost reduction on nuclear power and renewable is a must. Moreover, incentive given by government and federal official might also encourage the enterprises and commercials to lift up the industry market.

Projection and pathways for world nuclear power was made by IPCC 1.5°C in 2018 report[7], they forecast nuclear generation would grow on average 2.5 times from today's level by 2050. In addition, mid-term illustrative scenario was made as well, in which along with current condition, the demand for nuclear generation increase six-times by 2050 with the technology providing 25% of global electricity.

China and U.S. have started the nuclear power race, some already in active operation, yet some still in early transition. Particularly China, after the latest 14th Five Year Plan issued in March 2021, they pledge to further promote nuclear power source as clean energy alternative to achieve 2060 carbon neutrality. With more than 100 nuclear reactors in waiting list, China's nuclear industry can be important factor to tackle global fossil fuel and climate change issue. The transition also needs to be made along with other clean energy such as wind, solar, hydro power. If we would like to achieve the future climate goals, at least 80% of world electricity production need to be clean and at least 25% of it comes from the nuclear power. By the note that the world is not rely on fossil fuel as primary source anymore.

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