Can Small Modular Reactors and Floating Nuclear Power Plants Become an Innovative Option for Sustainable Indo-Pacific?

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Abstract

The driving factor of the Indo-Pacific region's economic growth is energy. The region's energy sector is primarily traditional energy-based and import-dependent even though a few countries have nuclear in their energy mix. The current Russia-Ukraine conflict also impacts the region's sustainable and affordable energy goals in many dimensions. In the post-pandemic era, countries need to kickstart delayed economic growth and sustainable goals. That being said, it is difficult for countries to figure out how to maintain healthy cooperation in the region. Indo-Pacific countries are setting their own pace towards ambitious sustainable development goals. Therefore, countries could be classified as faster, slower, lagging behind, or advancing forward. To reduce the development gap, some countries are considering Small Modular Reactors (SMRs) and Floating Nuclear Power Plants (FNPP) as a solution. While others are concerned that nuclear expansion could be an added threat to the region's existing security challenges. Nuclear energy is a double-edged sword. It can provoke challenges as well as benefits. Therefore, nuclear energy could be an area of cooperation in terms of sustainable innovation.

Keywords: SMR, FNPP, advanced nuclear technologies, energy insecurity, climate change, Indo Pacific

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Introduction

The Indo-Pacific region is an active geopolitical region. The region covers several sub-regions–including East and Northeast Asia, Southeast Asia, South and Southwest Asia, and the Pacific–all with their own dynamics, governance mechanisms, power relationship patterns, and threats which can sometimes converge. Despite differences in conceptualisations of the geographic contours of the Indo-Pacific, countries in the region face common challenges–such as human trafficking, maritime insecurity, oceanic degradation, climate change, and energy insecurity, among others–that hampers sustainable development. This paper looks at energy insecurity as a regional problem focusing on how the emergence of advanced nuclear technologies is impacting the sustainability discourse.

Important Role of Energy

Economic development is considered the foundation for other important developments such as social, health, education, and science, and is crucial for a country to become a global leading power. Economic growth is typically measured by the increase in the quantity of goods and services produced in an economy. This growth leads to an increase in wages and allows society to raise its consumption levels of goods and services, leading to more production. The production process requires four essential factors: land, labour, capital, and entrepreneurship, with land including all natural resources such as water, oil, earth minerals, coal, gas, and forests. Energy, as one of the primary ingredients of economic growth, is crucial for countries, both developed and developing, to achieve continuous development and compete for the position of world leader.

Energy is crucial for modern life as it is required for daily activities and modern development. The energy consumption has risen since the mid-19th century when internal combustion engines and electric power lines were invented. This led to accelerated industrialisation which relied on conventional energy sources such as coal. Industrialisation first began in Great Britain followed by France, Germany, before spreading to other Western countries. The energy consumption of Western Europe in the mid-19th century rose from around 100 Mtoe to 340 Mtoe by the early 20th century. In Central and Eastern Europe, the consumption went up from about 80 Mtoe in 1850 to 208 Mtoe in 1900. America's energy consumption skyrocketed after World War II, leading to economic development through industrialisation and increased productivity.

Following the end of World War II, the Indo-Pacific region underwent extensive political reforms as part of the decolonisation process, including the establishment of independent political systems and governments. While some countries were successful in establishing stable governance systems that led to justice, stability, and economic development, others faced challenges in this regard. The political landscape of the region has been complex and challenging in many parts. Nonetheless, the demand for energy in the region's countries is growing at the same pace as the drive for economic growth, regardless of whether they are politically stable or unstable, developed or underdeveloped, geographically large or small, and democratic or non-democratic. Thus, the development in the Indo-Pacific region is as prominent as in other parts of the world.

The motivation behind maintaining or attaining economic development, infrastructure development, advanced technologies, health care, education, efficient social care, other important scientific/non-scientific inventions, and the intent to increase military capabilities are currently driving up the region's energy needs. The energy consumption has constantly been rising from 207.66 exajoules in 2011 to 272.45 exajoules in 2021 (1 Watt = 1 Joule/second). Energy consumption in the region is not likely to flatten in the near future. For a lot of developing countries in the region, ever-growing energy needs easily turn to energy insecurity because of insufficient supply in the face of massive demand.

Also, the energy demand and supply are often affected by other external factors such as global politics, competition between superpowers, and economic recessions. The impact of the Russia-Ukraine conflict on the world's energy market is a vivid example at the moment. Energy prices jumped after the invasion, reaching a 20% increase for five months straight. The IEA says high fuel costs account for 90% of the rise in average costs for electricity generation worldwide. The energy crisis has affected 70 million people who recently gained electricity access to no longer afford it. The risks of energy insecurity have become more prominent each time outside factors affect the energy market.

Energy Insecurity in Indo-Pacific Sub-Regions

The International Energy Agency defines energy security as:

> *"The uninterrupted availability of energy sources at an affordable price…long-term energy security has to deal with timely investments in energy to supply in line with economic development and environmental needs…and short-term energy security focuses on the ability of a given energy system to react promptly to sudden changes in the supply-demand balance".*

For a household, energy security can generally be defined as the ability to meet its energy needs regardless of disturbing factors.

Thus, energy insecurity can be understood as an interrupted availability of energy sources and an inability to provide households with their energy needs. In the Indo-Pacific, both developed and developing economies are experiencing energy insecurity in a similar way, albeit with some differences. Some countries' energy insecurity is rooted in the imports of energy, some in exports, some in demand, and some in supply. Though, the unavailability of energy sources, or 'energy insufficiency', is making countries have the same worries and concerns affecting their economic and social systems.

The Indo-Pacific region covers many different sub-regions including: 1. East and Northeast Asia, 2. Southeast Asia, 3. South and Southwest Asia, and 4. Pacific. Countries in the region may be geographically, politically and culturally different but share similar "concerns over energy security" amid current global challenges. In East and Northeast Asia, China, Japan, and South Korea (as well as North Korea) are major players. East and Northeast Asia region is the only sub-region in the Indo-Pacific where all major players possess nuclear technologies. Nevertheless, each country encounters their own energy issues.

China has been facing power shortages until recently and emergency power-rationing policies that were put in place in 2021 are still in effect. During the current post-pandemic economic recovery, the country's power consumption has increased significantly, but the power supply has been unable to keep up with the surge. The shortages in power supply are attributed to a number of factors, such as floods in China's primary coal-producing region, the rising demand of Chinese goods due to the relaxation of pandemic restrictions, conflicting energy policies, and market distortions including power rationing and price controls have also contributed to energy shortage. On the other hand, China is striving for keeping its commitment of achieving its own carbon neutrality target. In September 2020, President Xi declared that China would aim to have carbon emissions peak prior to 2030, followed by carbon neutrality by 2060. China's emission reduction targets are a crucial aspect of global efforts to mitigate global warming to 1.5 degree as China is the world's largest energy consumer and carbon emitter. China, in fact, is encountering a dilemma between energy sufficiency and carbon neutrality.

Japan and South Korea are encountering energy issues totally different, yet equally concerning, from those faced by China. Japan, one of the most developed countries in Asia, is relying on a vulnerable supply structure of energy. Due to lack of natural resources, Japan relies on imports for 94% of its primary energy supply. Japan is mainly dependent on oil, gas, and coal. Despite energy diversification and energy efficiency in Japan, oil still accounts for 40% of Japan's primary energy supply. Japan imports crude oil from the Middle East, coal from Australia and LNG from Asia, Australia, Russia, and the Middle East. Japan, at the same time, is facing difficulties improving renewables as infrastructures is being damaged by weather and natural disasters. South Korea is also facing similar issues as it relies heavily on fossil fuels. South Korea is ranked as the world fourth-largest importer of LNG in the world after Japan, EU, and China. Korea, like Japan, has no proven oil reserves, and the coal supply in the country is insufficient and of low-quality. In Korea, industries are the major consumers of final energy and Korea needs to find an alternative solution to maintain production. Regarding climate effects caused by carbon emission, Japan and Korea will have to establish effective future energy plans to reduce emissions in line with the Paris Agreement.

Southeast Asia, home to more than 622 million people, has the world's third-largest labour force behind China and India. Despite the pandemic and other instabilities in the region, ASEAN remains an attractive destination for investments. The region's growing economy together with its ever-increasing population is driving up the region's energy requirements. Another major issue is that 20% of its population (134 million people) do not have access to electricity. The lack of accessible electricity in the least developed countries–such as Myanmar, Laos, and Cambodia, and the isolated location of certain islands in the Philippines and Indonesia–account for much of the region's electricity issue. The region is mainly relying on coal for its energy. It is estimated that coal will rise in the region's energy mix and would account for up to 50% of power generation by 2035. Coal, for ASEAN, is a reliable and affordable energy source even though it is very polluting. Large utilities companies are not interested in developing renewables as they prefer sizable returns. Thus, ASEAN, like the countries in East and Northeast Asia, needs a solution to deal with its electricity and carbon issues.

Pacific Island countries, when it comes to energy security, are facing specific challenges. Pacific Island countries depend on imported fuels for electricity and transportation. Like some other regions mentioned above, the remoteness and size of island countries are resulting in little access to electricity, and high energy prices. Pacific Island countries are currently developing renewable energy projects to increase access to reliable and clean energy with assistance from the United Nations Industrial Development Organization. Although, the absence of effective policies that facilitate the progress and use of renewable energy technologies is hindering the development of renewables. On the other hand, Pacific island nations are under the threat of global warming and serious climate change. A large numbers of islands are at an elevation slightly higher than the sea level. At the current pace of sea level rising due to global warming, island countries will face flooding, coastal erosion, and storms in the near future. To cope with the issue, island countries as well as the regional community need to work together and find a cooperative solution. Australia and New Zealand are no exception. Both countries depend heavily on fossil fuels, particularly coal. Moreover, they are struggling to deliver consistent and affordable energy at a satisfactory level,and therefore the countries also should seek innovative solutions.

South Asia is another interesting story. Bangladesh is facing energy insufficiency and the country is dependent on coal and imported natural gas. The country is one of the world's poorest and most densely populated countries. It has limited energy reserves–only small amounts of oil, coal and countable natural gas reserves–and about 93% of power generating thermal plants are gas-based. In addition to the energy scarcity, the country is also considered one of the most impacted countries by climate change. Natural disasters and environmental challenges have put the livelihood of people in Bangladesh, who mainly rely on agriculture, at risk.

In Iran and Pakistan, people have had power shortages due to the insufficient fuel at power plants. Critics have said that energy insufficiencies in these countries are due to mismanagement of administrative bodies and a lack of enabling energy policies. Like countries in other sub-regions, the countries in South Asia are dependent on fossil fuels, especially oil and gas. Regarding renewables, both countries have the potential to develop solar energy but renewables are still underdeveloped due to little interest by investors and the need for fiscal support.

Home to 1.3 billion people, India stands as one of the biggest markets and consumer bases globally. India is the third largest energy consumer after the United States and China. India's domestic natural gas production has fallen since 2013, and the country currently has to rely on imported gas due to the increasing demand for power. India's oil demand is also rising and it has to increase imports as domestic production is stagnant. Coal production in India remains key to the power sector as over 70% of power generation is coal-based. India is the world's third largest producer of hard coal and demand is estimated to rise up to 772 million tonnes by 2040. In India, inequalities are also a major issue when it comes to energy access. A census indicates that 77 million households still use kerosene and 44% of households lack access to electricity. Despite India's attempts to implement various programs and initiatives to tackle energy poverty, there were logistical problems and inadequate implementation issues. India has recognized the risk of energy insecurity and potential shortages in the near future and is taking steps to address it by investing in the development of renewables and nuclear. India has been working on indigenous nuclear technologies including reactors and submarines. An added benefit would arise if India ever thinks of investing in the development of SMR technologies along with other renewable projects.

Sustainable Development and Energy

The Sustainable Development Goals (SDGs) were adopted in 2015 by the United Nations as a global appeal to safeguard the planet and secure peace and prosperity by 2030. There are seventeen SDGs and it is considered that the action in one area will impact outcomes in others and that development must balance social, economic, and environmental sustainability. The seventeen SDGs include - 1. No Poverty, 2. Zero Hunger, 3. Good Health and Well-being, 4. Quality Education, 5. Gender Equality, 6. Clean Water and Sanitation, 7. Affordable and Clean Energy, 8. Decent Work and Economic Growth, 9. Industry, Innovation and Infrastructure, 10. Reduced Inequality, 11. Sustainable Cities and Communities, 12. Responsible Consumption and Production, 13. Climate Action, 14. Life Below Water, 15. Life on Land, 16. Peace and Justice Strong Institutions, 17. Partnerships to achieve the Goal.

In a world without energy, people would not be able to work efficiently, live comfortably, or access information instantly. Cooking and chores would take a long time and consequently, girls and women would get over-burdened. Industries would not be running and innovations would never take place. Insufficient access to electricity results in inadequate healthcare and delays in establishing sustainable cities. A lack of energy access will lead to poor living standards and increase the number of people living below the poverty line. Unregulated use of energy and excessive production of fossil fuels contribute to climate change, amplifying its impacts on both terrestrial and aquatic ecosystems. Ultimately, energy insecurity undermines peace. It is obvious that all seventeen goals are interrelated and influenced by energy insecurity.

The seventeenth goal of sustainable development, Partnership, is crucial towards achieving sustainability, and every country will have to pool their technology, creativity, human and financial resources. For the countries in the Indo-Pacific region, operative cooperation and partnership should be in place more than ever to deal with energy insecurity because most of the countries share the same concerns of energy poverty and climate change.

SMR and FNPP: Advanced Nuclear Technologies

An innovative solution that the paper would be recommending and discussing to cope with the above-mentioned challenges is the Small Modular Reactor (SMR) and Floating Nuclear Power Plant (FNPP) technologies. SMR and FNPP are advanced nuclear technologies being developed, promoted, and marketed currently by the United States, China, and Russia. China and Russia, countries that already have operational SMR/FNPP deployed.

SMRs are advanced nuclear reactors that have 50 MW to 300 MW power capacity per unit which is about one-third of the generating capacity of traditional nuclear power plants. Small modular reactors are physically as small as a fraction of the size of a conventional nuclear plant and are designed for factory-made mass production purposes. Floating Nuclear Power Plants are nuclear plants with one or more nuclear reactors on a platform at sea. SMRs on a ship or a mobile platform at sea can be called an FNPP. Both SMRs and FNPP possess mobility, SMRs on land and FNPP in the water.

As nuclear energy is classified as clean energy, SMRs and FNPPs can become a reliable solution for the fragile Indo-Pacific region without having any accumulated impacts on the environment and climate like other fossil fuels-based solutions. Moreover, nuclear energy is more stable than other renewables that have challenges of intermittency due to weather conditions. Another advantage of SMRs and FNPPs is that they can generate more power within a limited space unlike some renewable projects such as solar plants. For energy-poor or latecomer countries in the Indo-Pacific, SMR and FNPP technologies will help boost their development.

Small modular reactor technologies are not totally new. The development of those technologies can be traced back to the 1950s when the United States and the Soviet Union both invented small reactors for military purposes. Today, the technologies are under research and development for efficient civilian use in power generation. There are various SMR/FNPP technologies currently being developed. Depending on the size, design, features and cooling types, these technologies are diverse and significant. Examples of SMR/FNPP technologies include - 1. Integral pressurised water reactors, 2. High temperature gas-cooled reactors, 3. Molten salt reactors, 4. Liquid metal cooled reactors, 5. Solid state or heat pipe reactors, 6. Sodium-cooled fast-neutron reactors, and 7. Lead-cooled fast-neutron reactors. IAEA's Advanced Reactor Information System (ARIS) lists over seventy types of conceptual, developed and deployed SMRs.

Dr. Jor-Shan Choi listed SMR technologies being developed or deployed in the Indo-Pacific as follows. (Russia is included in the list as it is having nuclear cooperation with a few countries in the Indo-Pacific.)

Country	Type	Status
China	**High Temperature Reactor**	**Connected to the grid, one reactor operational out of two.**
	Floating Nuclear Power Plant	Under construction
	Integral Pressurized Water Reactor	Under construction
	Molten Salt Reactor	Prototype testing
	Pressurized Water Reactor	Research and Development
	Molten Salt Reactor	Research and Development
Japan	Boiling Water Reactor	Research and Development
	High Temperature Reactor	Research and Development
Russia	Integral Pressurized Water Reactor	Installed
	Floating Nuclear Power Plant	**Operational**
South Korea	Pressurized Water Reactor	Research and Development (Jointly with Saudi Arabia)
	Floating Nuclear Power Plant	Research and Development
United States	Integral Pressurized Water Reactor	Design reviewed. First commercial plant is expected in 2027.
	High Temperature Reactor	Construction is expected to begin in 2025.
	Molten Salt Reactor	Research and Development (Jointly with Indonesia)
India	Small thorium-based high temperature gas-cooled reactors (STGRs) of 20-40	Research and Development

	MW sizes	
Pakistan	N.A	Pakistan seems to be interested in SMR technology. However, no further information can be confirmed.

Interestingly, countries in the South East Asia and South Asia, despite the lack of technology and capacity, reveal an interest in traditional as well as advanced nuclear technology, and are enthusiastically cooperating with nuclear technology developer countries.

Country	Partnership/Cooperation	Status
Vietnam	United States	IAEA considers Vietnam ready to develop nuclear energy for power generation.
Philippines	United States, South Korea, Russia	Congress amending legislative and regulatory frameworks on nuclear safety, security, and safeguards.
Thailand	United States, China	Developing a policy and regulatory regime since 2007.
Indonesia	South Korea, France, China, Russia	IAEA considers Indonesia ready to develop nuclear energy for power generation. Regionally, Malaysia and Indonesia are cooperating through a memorandum of understanding.
Malaysia	United States	Implemented the provisions of the IAEA Code of Conduct on the Safety and Security of Radioactive Sources, as well as the Supplementary Guidance on the Import and Export of Radioactive Sources. Organizing domestic training programs on radiological security, developing a disposal facility using the borehole technology.
Cambodia	Russia, China	Having asked the International Atomic Energy Agency (IAEA) for assistance in drafting laws on nuclear safety and radiation, environmental protection and controlling radioactive waste.
Myanmar	ROSATOM Russia	Establishing of Nuclear Research Center, organizing trainings with IAEA experts*
Singapore	N.A Singapore is still considering nuclear for its energy transition.	More than 300 Singaporean experts and fellows are trained through IAEA support in radiation medicine and health, radiation safety, nuclear security, isotope hydrology and nuclear technology applied to industry in the areas of materials testing and characterization. Experts are sharing knowledge and expertise with neighbouring countries.
Laos	Russia	Signed an MOU for cooperation in 2016. No further information available on the development.

Sri Lanka	Russia	Submitted a self-evaluation report to the International Atomic Energy Agency (IAEA) in 2022
Bangladesh	Russia	Completed the installation of the reactor pressure vessel at Bangladesh's first atomic power plant.

*Interviewed a Burmese government staff by the author

The receiver countries (of nuclear technology) mentioned above are newcomers to the nuclear world due to energy security and/or energy transition. Countries are keen to engage in cooperation for the development of both traditional nuclear power plants as well as advanced nuclear technologies. The major limitation for impactful cooperation is the readiness of regulations and safety measures to implement nuclear reactors and power plants.

For SMR developer countries, according to the list above, it is obvious that the technologies are mostly in the research and development stage. For the United States, two out of three are at the licensing stage and expecting to begin the construction of commercial plants soon. For all other countries interested in SMRs, there are delays in approving the adoption of SMR technologies or implementing regulations. The reasons behind the delays, as well as the challenges that small modular reactors and floating nuclear power plants impose, will be discussed in the following section.

Cost Benefit Analysis of SMR Technologies

SMR/FNPP technologies are generally considered promising, innovative, and reliable while discussing the future of global energy requirements. They are clean, high capacity, durable and suitable for any geographic location. In addition, advanced nuclear technologies can be the solution to climate issues, inequalities, and energy poverty in a lot of Indo-Pacific countries.

There are numerous technical advantages. SMRs are compact and can pack a lot of energy with very little footprint, unlike other renewables projects and traditional nuclear power plants. For comparison, to generate 1,000 MWe of electricity, an SMR plant would need less than 1% of the land that a solar, wind or hydropower project would need to generate the same amount of power. The modular design allows for individual parts to be factory-made, then assembled, and later transported to operating sites, making it cost and time effective. For investor companies, the modular design allows them to begin production of a single module and later expand later, as per demand.

SMR designs include passive safety features that can shut off and cool down the reactor during abnormal conditions. In case of accidents, SMR power plants will not need computerised or human intervention to control the temperature of the core. Thus, it can be said that SMRs are safer than conventional nuclear power plants. Another advantage of SMRs is that they require refuelling less frequently. Traditional nuclear plants need refuelling every one or two years while SMRs need to be refuelled every three to seven years. In some designs, SMRs are made to function for up to 30 years without refuelling. There are also some other designs allowing SMRs to reuse and recycle spent fuel.

For developing countries, SMRs will be a sustainable option for providing better and more reliable energy while reducing carbon emission and adverse climate impacts. SMRs are suitable for remote areas where infrastructure remains under-developed, sites with limited water and acreage, and small economies with low energy needs and smaller grids. Moreover, SMR technology is appropriate for unique industrial applications as it can offer the possibility to process desalination with the heat it produces while generating electricity. So, SMRs, when fully developed, will have two applications, that generates electricity and heat at the same time.

Most importantly, SMRs have a distinct advantage of preventing proliferation due to facility protection systems being applied in new SMR designs. Most SMRs are designed to be built below grade for safety and security enhancement, addressing vulnerabilities arising from natural disasters and sabotage scenarios. To minimise risks in handling nuclear materials, small modular reactors are tailored to be fabricated and fuelled in a factory, and then sealed and transported to the site for power generation, and returned to the factory upon life cycle completion.

Nevertheless, authorising bodies in many developer-countries are delaying approvals and taking a lot of time to issue licenses due to debates over the credibility of advanced nuclear technologies. The advantages of SMR technologies seem very reassuring but the disadvantages are also prominent.

It is argued that SMRs are not affordable, and are deemed expensive due to their inability to achieve economies of scale. In order to do so, manufacturing facilities need to produce thousands of SMRs along with plans and projects for thousands more. This necessitate a substantial demand in the market, with hundreds of consecutive orders to facilitate large-scale production. SMRs are still in the developing stage and not yet proven. It is quite a financial risk to mass-manufacture unproven SMRs without ensured demand from the market. Without economy of scale and mass production, mass-deployment of SMRs remains impossible.

Even though SMRs are technologically safe and have strategic non-proliferation capacity, the supply chain and wastes still require significant defence measures to prevent terrorists, and others, from abusing radioactive materials. Supplementary costs (security, transportation, etc.) will be applicable when SMRs are deployed in remote areas. All in all, there is no centralised nuclear waste repository and thus the concept of returning used reactors to the processing sites for decommissioning seems unrealistic. Furthermore, unexpected failures or design errors in built-in modular reactors and their displaceability can also impose security threats. There are questions raised over the guarantee of the quality of factory-made small modular reactors and consequences in case of errors in manufacturing.

It is also argued that SMRs cannot contribute to the provision of affordable energy due to its costs in larger projects. The price par SMR may beat the overnight capital cost of a traditional nuclear power plant but the total capital costs for a fleet of SMRs will not help lower the energy price per kilowatt for purchasers. Basically, nuclear reactors, whether big or small, have high fixed capital costs and low variable costs for fuel and maintenance and thus they are unsuitable for fluctuating demands. In large nuclear reactors, the high fixed capital costs are spread out over large number of kilowatt hours which can make each KWh cheaper. Although, in SMRs, as they are made to provide small or variable demand, the price of energy per KWh as well as the operational costs will be raised due to the operation at partial load.

The Benefits of Cooperation

SMR/FNPP technologies are still at the research and development stage, under debate, and not yet fully proven. Undeniably, SMRs have the potential to become a solution to the world's energy insufficiency and climate change. Thus, cooperation on advanced nuclear technologies is in the best interests of Indo-Pacific countries. There are currently about 70 different SMR/FNPP technologies and they still have several imperfections. Developer-countries of these technologies are competing, and no specific SMR technology is yet considered as the most appropriate. As long as countries cannot achieve an agreement to work on the development of a particular SMR technology, neither economy-of-scale or mass deployment is possible.

Regarding legal framework and regulations, a number of countries are not ready to adopt advanced nuclear technologies. Most non-nuclear-power countries are unfamiliar with setting up necessary policies, rules and regulations for advanced nuclear technologies. Even for countries with nuclear power, additional regulations and mandates are required. Also, the International Energy Agency still needs to work on the study of advanced nuclear technologies to make sure the regulatory framework they establish for SMRs covers every feasible complexity. In such a case, sharing knowledge, information and expertise among countries will help smoothen the regulatory process.

Can SMRs and FNPPs become an Innovative Option to build a Sustainable Indo-Pacific?

Given the information about SMRs and FNPPs and the debate over them, it can be assumed that advanced nuclear technologies can be an innovative option to build future sustainability in the region if there is effective cooperation among the interested parties.

There is a speedy escalation of country-specific energy needs and demands in the Indo-Pacific region. Some countries need to diversify energy sources while others need to replace old power plants with efficient, new-generation power plants to provide reliable energy. On the other hand, carbon emission reduction commitments are a pressure point for countries in the region. There is no shortcut to reduce carbon emission except to increase the portion of clean energy in the mix. SMRs and FNPPs can help nations cope with these issues to a certain extent. This provides other renewable energy projects with longer timelines to develop and become profitable.

Inequalities due to energy poverty can also be addressed through advanced nuclear technologies. Households with better electricity access will allow women and girls to spend less time completing chores and more time for education. The electricity will also grant access to advanced information technology for individuals to enhance access of information. Innovations and production will witness an uptick once there is sufficient power. Scientific advancement and technologies will continue to evolve, leading to the generation of more sophisticated inventions.

In the Indo-Pacific, a few countries are halfway to the development of advanced nuclear technologies while the majority are just beginning to consider the technologies as an option. When it comes to cooperation among countries at different economic or technological development stages, there will definitely be developer-countries and receiver-countries. The question arises: “What kind of benefits will the developer-countries achieve in cooperating with less developed/developing receiver-countries?” The technology-developer countries will receive access to a wider market in technology-receiving countries. Thinking practically, every country cannot manufacture small modular reactors within a short cooperation time, except for developer-countries. Developer countries can not only help and share their knowhow, but also assist in setting up regulatory guidelines and platforms for further trade agreements of SMRs.

No country can afford to neglect the, short or long term, effects of climate change. Even if a country manages to meet carbon neutrality standards, it cannot avoid the impacts of climate change which eventually is the result of other carbon emitting countries. Countries in the Indo-Pacific region should consider the domino effects of climate change and choose to assist each other via cooperation, especially in the development of an innovative solution for sustainability.

Conclusion

In brief, countries in the Indo-Pacific, facing energy insecurity in their own unique way, should consider advanced nuclear technologies as an alternative to diversify energy sources. Regarding the urgency to address energy insufficiency issues and global warming, the region truly needs to cooperate in developing SMR/FNPP technologies. The only important thing is that the countries will have to agree upon what specific SMR technology/technologies to develop so that the region could avoid the delay in establishing successful SMR deployment. Peter Kropotkin, Russian philosopher, historian and scientist, once said, “Competition is the law of the Jungle, but Cooperation is the law of Civilization”. SMRs and FNPPs, as advanced nuclear technologies that will leave their mark on our historical timeline, serve as a testament to the elevated level of civilization we have achieved where cooperation triumphs over the law of the jungle and paves the way for progress.

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