East Asian Journal of Multidisciplinary Research (EAJMR)
Vol.2, No.2, 2023: 627-642

The Usage of Micro Modular Nuclear Reactors on Military Headquarters as a Prospective Solution to Achieve Energy Security and Improve National Defense

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A R T I C L E I N F O

Keywords: Micro, Modular, Reactor, National Defense, Military Base

Received : 09, December
Revised : 12, January
Accepted: 23, February

A B S T R A C T

Recently, there has been a trend of developing Micro Modular Reactors in the Small Nuclear Reactor field that can produce up to 15 MW(e) of power. Micro Modular Reactor is the fourth-generation technology which is included in the sub-category of Small Modular Reactor or Small Modular Reactor. This reactor produces electricity and heat that is safe, clean and economical which is believed to be better than large-scale Nuclear Power Plants. Micro-reactors have several technological advantages in that they can be manufactured in a factory setting, transported and assembled more easily, and can be integrated with renewable micro-power grids. Through the literature study method, this research analyzes the prospect of using Micro Modular Reactor technology for military headquarters in order to support national defense. The results of the analysis of this study conclude that MMR technology is worth trying to be applied in Indonesia, especially for electricity generation in state institutions, but it is necessary to carry out a further feasibility analysis of the possibility of state losses as a form of the ideas put forward in this study.

DOI prefix: https://10.55927/eajmr.v2i2.3106
ISSN-E: 2828-1519
https://journal.formosapublisher.org/index.php/eajmr/index

INTRODUCTION

Domestic energy demand have continued to increase every day, where based on Indonesian Energy Outlook 2019 data, 92% of energy is supplied from fossil energy, 65% of oil consumption is met through imports. Within the scope of national defense, Indonesia's state defense institutions are still very dependent on fossil fuels, and for generation the average uses Diesel.

Based on data from the Directorate of Facilities and Services of the Ministry of Defense of the Republic of Indonesia (Ditfasjas Kemhan RI) in 2019, the total fuel consumption of the Ministry of Defense and the Indonesian National Armed Forces reached 520,681 Kiloliters, which is worth around 17 Trillion Rupiah per year (Kuntjoro, 2021).

Although in the principle of national defense, one of the priorities is the strength of the defense posture, but we still must not forget the concept of embodiment of national energy security as outlined in the concept of "4A + 1S" which consists of aspects of availability, accessibility, affordability.), acceptability (acceptability), and sustainability (sustainability).

The use of energy for defense will also have an impact on the contribution of national carbon emissions which, if not handled properly, will have a positive impact on climate and weather. Climate change can pose significant risks to the energy sector which directly affect fuel supply, energy production, physical resilience of energy infrastructure and energy demand.

The increased frequency or intensity of extreme weather events such as heat waves, forest fires, hurricanes, floods and cold waves can make power outages and demand management difficult. Therefore, it is necessary to utilize new and renewable energy resources (EBT) that can be managed for national defense.

Traditionally, technology based on fossil resources has been the most commonly used for power generation, but this technology has drawbacks, such as low electricity efficiency, the generation process (Lott, Pye, & Dodds, 2017), fluctuations in fossil fuel prices (Li, Feng, & Li, 2017), the greenhouse effect and CO2 emissions (Kibria, Akhundjanov, & Oladi, 2019). In recent years, a new development trend has emerged in the field of micro-reactors which can generate power up to 15 MW(e).

Micro reactors are included in the subcategory of Small Modular Reactor (SMR) or what is known as Small Modular Reactor, where this advanced technology is being developed mainly in Canada, China, the Russian Federation, the United States and several Member States in Europe.

Micro-reactors have several unique characteristics, whereby at a higher-tech type than some other SMRs, they can be made more complete in a factory setting, transported more easily to sites and connected to the end users of electricity and heat. It is possible for the reactor to be self-regulated, based on an inherent passive safety system and thereby achieve high levels of control and safety with minimal operator action.

Microreactors are also not limited to a particular type of moderator, cooler, or neutron, range in energy, and exhibit very different characteristics. For example, coolants can include helium, lead, air, water, molten metals, and heat pipes. Micro reactors are also often loaded for the life of the reactor. For deployment to become a reality, these minuscule power plants must also have proper safety and positive proliferation-resistant characteristics.

Micro reactors are typically targeted to serve future electricity niches and district heat markets in remote locations (arctic or island communities), mining, industrial and fishing operations, to provide back-up power (also for data centers), to service oil platforms or for use in sea cruise. This market was served by diesel power plants for decades.

Compared to SMRs which meet energy demands by adding additional capacity with moderate financial commitments by utilities, micro reactors are more focused in this particular market and will typically compete in markets currently served by diesel generators.

Some experts see micro-reactors as an entry point for SMR implementation, especially since the initial business case may be more profitable for them as there are currently no other off-grid solutions and diesel generators are expensive to operate and polluting.

THEORETICAL REVIEW

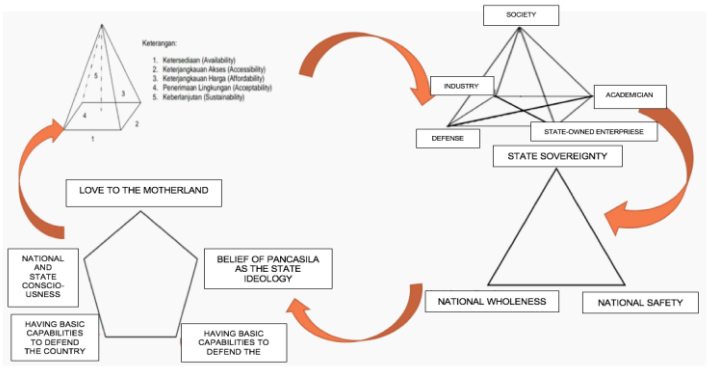

Figure 1. Concept of Energy Supporting Defense and Defense Supporting Energy (Octavian, 2021)

Energy is a crucial resource that ensures the dependability of defense equipment (movement, maintenance, and maintenance), and it also plays a significant role in a nation's ability to achieve energy security in both peacetime and armed conflict. Energy can be utilized to support military's advantage. One resource that helps the defense system by supporting it is energy. Energy can be used in military operations as a power source and a deadly weapon, like a nuclear bomb. A larger portion of the focus energy devoted to defense and security efforts is needed to accomplish military strategy objectives and missions.

The Energy Trilemma is a framework that is used in non-military settings to guide energy decisions. By maintaining energy prices at reasonable levels, ensuring sustainable access to energy, and adhering to environmental regulations and goals, this framework seeks to ensure economic competitiveness and social welfare. Because it is a part of the infrastructure that supports defense, energy has a crucial role to play in defending military operations, bases, and headquarters.

For instance, in border regions, the use of PLTS and PLTD (Hybrid) to meet the TNI Radar Unit's needs for electricity at the border, in this case the case study of the Tanjung Sofi Radar Unit Planning, Indonesian Air Force Base Morotai. Defense logistics are also aided by energy, particularly when it comes to transporting defense machinery by land, sea, and air. As a result, it plays a crucial role in military operations. Sufficient energy reserves, which depend on logistical capabilities (sustainability), are needed to support military operations over the long term.

Another actual example of energy supporting defense through the use of energy for defense equipment needs is plans to use PLTS and PLTD (Hybrid) to meet the electricity needs of radar units at the border (Tanjung Sofi Radar Unit, Morotai Lanud) and Installation of PLTS by The Republic of Indonesia Defense University at the third Infantry Brigade Command Headquarters, third Marine Corps Katapop, Sorong Regency in August 2019 (Kuntjoro, 2021).

This paper puts forward the idea of using the MMR® for military headquarters to pursue energy security, with the concept of energy supporting defense and defense supporting energy in order to support Indonesian national defense.

METHODOLOGY

This research uses qualitative methods by conducting literature studies or on journals, research, and articles and other published documents related to SMR and MMR technology.

RESULTS

Micro Modular Reactor

The MMR® (Micro Modular Reactor) power system is a fourth-generation nuclear power system that provides users with safe, clean and economical electricity anytime, anywhere. MMR is a subcategory of SMR, and the MMR technology that the authors discuss in this study refers to Ultra Safe Nuclear Corporation's MMR® technology which is licensed in Canada and the United States and is the first commercially available "fission cell". An order form has been created for the first users.

The demonstration block is scheduled for commissioning of the first nuclear power plant in 2024. In 2019, a site application was submitted by Global First Power for one SMR, using UNSC's Micro Modular Reactor (MMR®) technology, at the Chalk River Laboratory site in Renfrew County, Ontario (Canadian Nuclear Safety Commission, 2021).

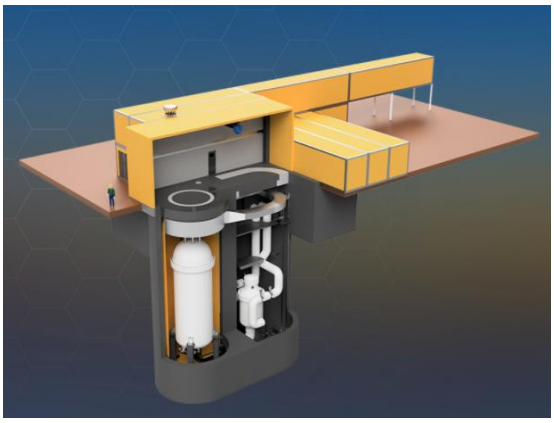

Figure 1. MMR® Installation

Based on claims from USNC, some of the advantages of MMR including:

1) Can be parked anywhere
   MMR® can be parked anywhere needed. The MMR® Energy System uses no water and requires no power grid or infrastructure support. MMR® is compatible with the harshest climates from arctic to desert to tropical.
2) No refuelling
   MMR® operation is simple with minimal maintenance requirements, no fuel storage, handling or processing on site. The MMR® reactor is only fueled once for the life of the reactor. For a fuel cartridge rated at 20 years full strength. If it is desired to operate the Energy System for more than 20 years, cartridge replacement is possible.
3) Total Non-Proliferation
   MMR® uses FCM® fuel which cannot be reprocessed using currently available reprocessing schemes. The MMR® fuel cartridge is factory sealed and the fuel is not accessible.
4) Independency
   The MMR® Energy System can operate as a stand-alone off-grid power plant to produce fully transportable, resilient power, or can be connected to an existing grid.
5) Total Environmental Protection
   There is no risk of spillage with environmental impact during an accident. Nuclear fission products are permanently locked in the FCM® fuel state during and after electricity production.

Heat conversion technology into electricity

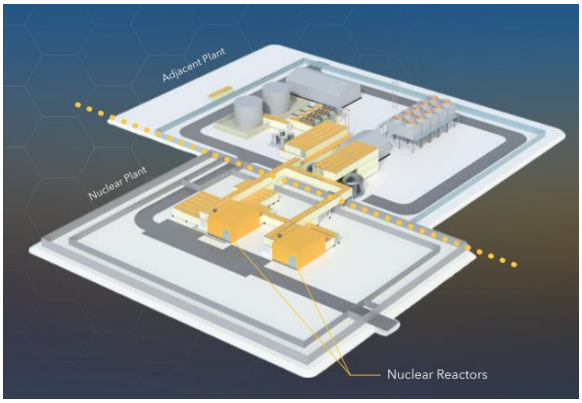

Figure 2. Layout design of MMR® and side-by-side generator for heat conversion

MMR® has the technology of converting heat into electricity through the following tools and processes:

a. Generator Separation
   The MMR® Energy System consists of two plants, a Nuclear Plant and an Adjacent Power Plant. The Nuclear Power Plant contains several MMR® units and all the equipment needed to transport heat to the Adjacent Power Plant. Adjacent plants contain equipment that converts heat into electricity or processes heat according to needs.
b. Helium
   Helium gas is the main coolant of the MMR. This gas passes through the nuclear core where it is then heated through a controlled process of nuclear fission. This helium gas then carries heat out of the nuclear core to the primary heat exchanger, a vessel with lower pressure to the side of the reactor.
c. Molten Salt Thermal Storage
   The heat from the reactor is stored in a tank of molten salt, resembling a concentrated solar power plant. When demand increases, the hot molten salt is used to generate steam and drive electric turbines. MMR® Energy Systems will typically store up to 10 hours of thermal output of the power plant and can be equipped with a hydrogen burner. The use of molten salt thermal storage allows significant flexibility in power supply and process heat. While the MMR® unit operates at constant power, electricity and heat are delivered on demand from the power plant.
d. High Temperature Heat
   MMR® high temperature heat has many uses beyond electricity generation. District heating, desalination and process heat are all possible with MMR®. Any industrial process that uses heat can be fully or partially decarbonized using MMR®. Steam temperatures of 600 °C are easy to deliver, and temperatures up to 950 °C are possible in future MMR® variants.

MMR® fuel

MMR reactor fuel contains low-enriched uranium. The fuel is produced with Triple Coated Isotropic (TRISO) fuel particles, whose main purpose is to retain fission products. The basics of ceramic-coated particle fuel were developed in the 1960s. The TRISO fuel is then applied to the gas-cooled reactor.

In the 1980s, the TRISO fuel was adapted for higher temperature operation in High Temperature Gas-cooled Reactors (HTGRs). TRISO technology has demonstrated irradiation performance. This historically reliable and proven TRISO fuel is suitable for use in MMR reactors. TRISO particles are highly resistant to proliferation and provide environmental protection during and after operation.

The TRISO particles bond together to form fuel pellets. TRISO particles provide containment of radioactive material during operation and accident conditions. TRISO particles can be bonded together in graphite or silicon carbide to form fuel pellets. Exhibit 3-6 illustrates the MMR fuel concept. MMR fuel will be manufactured in a separate fuel fabrication facility, separate from the Project and not located on the Project site (Global First Power, 2021)

Fuel Based Safety

MMR® produced by USNC uses Fully Ceramic Microencapsulated (FCM®) fuel. This fuel provides a new approach to built-in reactor safety by providing the safest fuel possible. The industry standard TRISO fuel, which contains the radioactive byproducts of fission in a layered ceramic layer, is encased in a fully solid silicon carbide matrix. This combination results in a very robust and stable fuel with outstanding high temperature stability. fuel packaging starts with Uranium Fuel Kernels less than 1 mm in size.

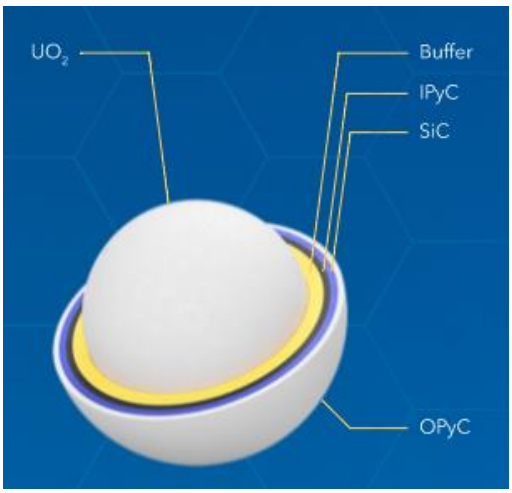

Figure 3. TRISO MMR® Particle Fuel
(Ultra Safe Nuclear Corporation, 2021)

As can be seen in Figure 3., the TRISO Kernel particle fuel is coated with a special coating that is designed like a small pressure vessel. The coating contains fission products inside and ensures mechanical and chemical stability during irradiation and temperature changes. These are called TRISO Particles.

Developed in the 1960s for gas cooled reactors, TRISO has enjoyed continued international development providing an excellent starting point for USNC.

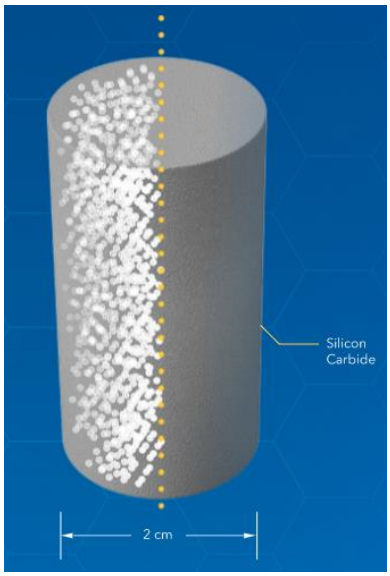

Figure 4.
TRISO Particles encapsulated by USNC's FCM® Fuel
(Ultra Safe Nuclear Corporation, 2021)

USNC's FCM® Fuel is encapsulating TRISO Particles in a dense matrix of Silicon Carbide, which we call Fully Ceramic Micro-Encapsulation Fuel, or FCM® Fuel.

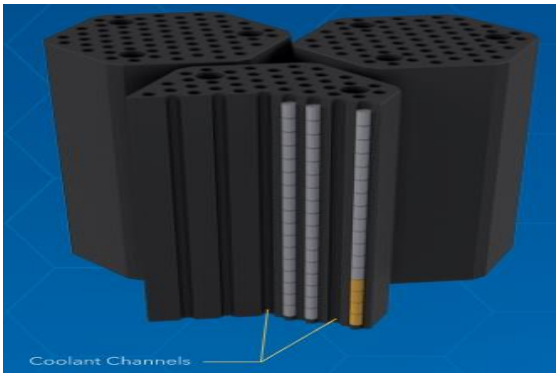

Figure 5. FCM® Graphite Block
(Ultra Safe Nuclear Corporation, 2021)

FCM® Fuel Pellets are stacked and placed into a Graphite Block. Graphite is a moderator that slows down the neutrons and increases the likelihood that the neutrons will cause fission reactions in the fuel. Cooling channels are built into the Graphite Block.

Cold helium flows through cooling channels and picks up heat. The Reactor Core consists of several hundred Graphite Blocks with several tons of fuel. Various openings and channels are used for control rods and coolant flow. Intrinsic Safety Benefits The core is housed in a Micro Modular Reactor (MMR®) housing.

FCM® fuel unlocks a number of system benefits including isolation of fission products which enhances worker and plant safety, improves proliferation resistance, and minimizes emergency planning zones.

DISCUSSION

The usage of MMR® for Military Headquarters

The Advantages of MMR®

The high supply of Uranium in Indonesia which can be used to manufacture MMR® fuel is an advantage for the application of MMR® in Indonesia. In addition, the MMR® Facility uses standard modules, where these modules must be assembled, tested, and commissioned at the factory. So that it will minimize government costs for the construction of Nuclear Power Plant sites.

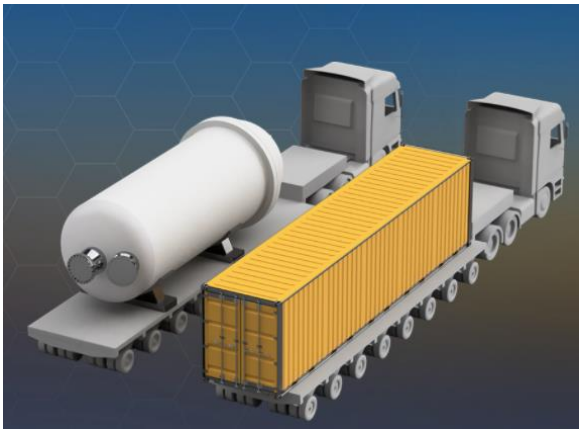

Figure 6. MMR® Transport
(Ultra Safe Nuclear Corporation, 2021)

The modules will be sized for standard International Standards Organization shipping containers, allowing for easy transport by ship, rail or truck. So that this module can also be sent to military bases/and/or bases, including in border areas and remote areas.

The MMR module is relatively fast to build, where after being transported to the site it can be assembled. MMR® plant construction is fast, simple and scalable. Several MMR® reactors can be linked together to provide as much power as needed. Modules can also be combined in different ways for

different locations and needs including integration with renewable microgrids that utilize renewable energy in the local environment.

Security

In the event of an accident, the MMR® reactor is unable to melt, as all heat dissipates passively to the environment with no moving parts or fluids, regardless of the scenario. The plant does not need an active system to remove heat. In addition, the plant does not require any outside services, including electric power, to operate safely.

The MMR® is also an underground (buried) reactor that provides excellent protection against acts of terrorism. But in the case of a reactor vessel leak, the primary helium coolant will come out with very little heat energy and next to zero fission products.

FCM® fuel provides full radionuclide containment for every millimeter-sized bit of encapsulated fuel. This is micro containment, that will protect itself. After being turned on, the reactor becomes self-protective because of its radiation. The fort and reactor buildings were designed in such a way that the reactors were inaccessible without special equipment.

MMR® raises safety standards to include events currently classified as out-of-design accidents for other reactor technologies. MMR® has unparalleled tolerance for outside-of-normal conditions, whether natural hazards such as floods and earthquakes or human actions such as operator error or willful sabotage. What is a high risk and sometimes catastrophic accident for traditional reactors and other advanced reactors is little trouble for MMR®, even when the scenarios occur simultaneously.

Deterrence Effect

Thomas Schelling explains the concept that military strategy can no longer be used as a criterion for military victory. He argues that current military strategy is more like coercion or threat and deterrence techniques. Schelling stated that the ability to destroy other countries was used as a motive for other countries to avoid it and influence their actions. To incite violence or to deter other countries, we must adapt to anticipate and avoid violence. Thus, the use of force as a bargaining power to cause damage is the basis of the theory of deterrence and that deterrence is most effective when not used (Schelling, 1966).

Even though Indonesia has ratified the Treaty On The Southeast Asia Nuclear Weapon Free Zone through Act Number 9 of 1997 Concerning Ratification of the Treaty On The Southeast Asia Nuclear Weapon Free Zone, in this case the author argue that in the context of the use of nuclear technology for nuclear power plants for the benefit of national defense, this treaty does not constitute a problem or violate it.

Because the utilization of nuclear technology through the use of small and micro modular reactors is not to be used as a weapon but to support the availability of energy supply which also supports national energy security. Although the idea is that, through the possession and use of nuclear power plant technology, it will provide a deterrence effect for enemies where if we can

use nuclear power to generate electricity, it means that this technology is also possible to be used for defense weapons.

But once again, because we have ratified the treaty on a nuclear weapon-free area in Southeast Asia, we must put aside the concept of nuclear weapons for weapons and focus on our energy security, unless we revoke the ratification.

In the United States, a 2008 Defense Intelligence Agency report warned that the United States will be completely dependent on foreign governments for commercial nuclear power in the future unless the American military acts as a prime mover to revive this critical energy technology with small distributed power reactors.

Some of the most prominent small reactor concepts rely on technology refined in laboratories and Federally funded research programs, including the Hyperion Power Module (Los Alamos National Laboratory), NuScale (DOE-sponsored research at Oregon State University), IRIS (started as DOE - sponsored projects), Small and Transportable Reactor (Lawrence Livermore National Laboratory), and Small, Enclosed, Transportable, and Autonomous Reactor (developed by teams including Argonne, Lawrence Livermore, and Los Alamos National Laboratories).

However, there are a number of competing designs under development from more than twelve. If the United States Department of Defense does not act early to support the small US reactor industry, it is likely that the industry will be dominated by foreign companies (Andres & Breetz, 2011).

Environmental Impact

In terms of safety and impact on the environment, the MMR® implements total environmental protection. Environmental Protection The MMR Total Energy System uses no water. There is no risk of spillage with environmental impact during an accident.

Nuclear fission products are permanently locked in the fuel form of FCM during and after electricity production. Based on the Press Release of the Indonesian National Research and Innovation Agency (BRIN) No: 189/SP/HM/BKPUK/XI/2021, the Government of Indonesia is serious about realizing its net zero emission (NZE) commitment in 2060 or sooner and is also planning the construction of a Power Plant (National Research and Innovation Agency, 2021)

The first nuclear power plant (PLTN) starting with a commercial operation date (COD) in 2045. Head of the National Innovation Research Agency (BRIN), Dr. Laksana Tri Handoko said that in the general scenario of the energy transition in Indonesia, currently 75% of the emissions generated come from the use of fossil energy. (National Nuclear Energy Agency, 2018)

Meanwhile Djarot S. Wisnubroto, Research Professor and Main Expert Researcher at the National Agency for Research on Nuclear Power Research Organization, revealed that for more than two decades, the topic of nuclear energy was not on the agenda of the climate change conference coordinated by the United Nations. But at the COP26 Summit which took place in Glasgow, nuclear energy is starting to become a concern.

Professor Djarot said that with almost carbon-free characteristics, and being able to produce large amounts of power continuously, nuclear power plants are one of the solutions to overcome global warming. The challenges related to the scourge of the Chernobyl and Fukushima events are still lingering, but going forward as the climate crisis intensifies and the need for the transition from fossil fuels to become urgent, it is believed that many countries will begin to change (National Research and Innovation Agency, 2021)

Waste Management and Disposal Plan

In terms of the waste management and disposal plan, MMRWaste will be separated at the source as non-radioactive waste and radioactive waste or potentially radioactive waste.

Waste will be temporarily stored at the project site in designated areas and transported to authorized processing facilities in a timely manner, depending on the category and type of waste. Radioactive waste will be monitored and further categorized based on the type of waste and processing options for the different types of waste.

After fuel loading during reactor commissioning, material and personnel exiting the controlled zone will be monitored and contaminated items will be processed accordingly. All radioactive waste generated during normal operation and routine scheduled maintenance will be transferred within the controlled zone to a designated waste area, where it will be categorized and packaged for removal from the project site to a licensed waste disposal facility or will be stored onsite until decommissioning (Ultra Safe Nuclear Corporation, 2021).

The waste management strategy that has been projected and systematically worked out by USNC will make it easier for the Indonesian military to execute waste management because the guidelines made by USNC are already available, so it only needs to be adapted to the situation and conditions in Indonesia if MMR® is used for future generation. electricity in Indonesia.

Current and Future Issues

In Indonesia itself in 2018 it was stated that the High Temperature Gas Cooled Reactor (HTGR) technology would be applied to the Experimental Power Reactor which BATAN planned to build in the Puspiptek Area, Serpong, South Tangerang at that time.

HTGR is a power reactor technology which is the fourth generation which emphasizes a high level of safety. RDE with a capacity of 10MWt or equivalent to 3MWe was initiated at the end of 2014. In 2018, the RDE development was in the middle of completing the preparation of Detail Engineering Design (DED), where in 2017 the Basic Engineering Design (BED) was completed. In Indonesia, HTGR R&D is considered quite active, including in fostering international cooperation (National Nuclear Energy Agency, 2018)

Professor Deendarlianto stated that the Center for the Study of Energy Technology at Gadjah Mada University, Yogyakarta, had conducted research that nuclear energy could meet massive energy needs and was suitable for

increasing Indonesia's industrialization capabilities in the future. Thus, to meet massive and sustainable energy needs, there is no other option to replace the use of conventional energy resources except for the use of nuclear energy (Nua, 2021).

On another occasion, the Director General of Mineral and Coal at the Ministry of Energy and Mineral Resources, Ridwan Djamaluddin, said that nuclear is a quite attractive option for power plants in Indonesia. According to him, nuclear or radioactive energy is a substitute for coal-based energy or fossil-based energy which is currently being campaigned to be reduced (Mudassir, 2021).

SMR usage requirements in Indonesia

In the usage of SMR in Indonesia, several things that become requirements include:

1) License Terms
   The factory must be licensed by the regulatory national authority before it is established and implemented in Indonesia. SMR must be licensed in the country of origin or in the absence of such license, the SMR vendor may apply for a license to the nuclear Energy Regulatory Agency (BAPETEN).
2) Economic Requirements
   Economic goals can simply be stated as: the leveled cost of electricity from nuclear plants should be competitive or below the cost of electricity generation in the national system (7 cents USD/kWh). Whereas for placement in remote areas or in smaller areas in developed areas the economic criteria for the expected alternative SMR are the greatest social benefits, and; less than the cost of upgrading the infrastructure and means of transport to eliminate qualifying "isolation".
3) Special Requirements
   Special requirements including workforce development, specific training courses and job training, national infrastructure and participation, maximum local content (involvement of national industry, transfer of technology, licensing support, technical support, long-term partnership (R&D cooperation), and funding scheme in order to minimize national burden. (Wisnubroto, 2019)

In addition, public perceptions and economic factors (the cost of nuclear power plants) are the main issues that are a challenge in Indonesia.

CONCLUSIONS AND RECOMMENDATIONS

From several advantages and benefits that are provided by the MMR®, the authors found that the MMR® technology is a potential option to generate electricity on military headquarters, as an independent generator that will support the military institution to obtain energy security in order to increase Indonesian national defense. The MMR® offers solutions related to safety, security and waste management which have always been the problem regarding the use of nuclear for power plants in Indonesia. Joint development, localization, industry participation, international cooperation, and Research and Development (R&D) are needed to develop SMR technology, especially MMR in Indonesia.

Recommendation

Trial of the usage of MMR® needs to be conducted, before applied in Indonesia, especially for the benefit of generating electricity in national defense institutions. Although in this study the authors focus on the advantages of USNC's MMR® technology, in the future it is necessary to conduct research related to selecting the right SMR and MMR reference models to be used for Indonesia, especially to support energy supply in national defense institutions. It is necessary to carry out a feasibility analysis of the prospects for using SMR and MMR for national defense—use at military bases and bases—as a further form of the idea that is put forward in this research.

FURTHER STUDY

In the future, in-depth studies and research by the government and related parties are needed regarding the feasibility of using MMR technology in Indonesia for both defense and electricity generation in general.

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