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Analysis of Nuclear and Diesel-Electric Submarines' Efficiency and Emission in Supporting the Modernization of Defense Armaments (KRI Nanggala 402 and USS Nautilus SSN-571)

Rendy Ananta Prasetya[1], Syamsul Maarif[2], Jonni Mahroza[3], Luhut Simbolon[4]
[1,2,3,4]*Universitas Pertahanan Republik Indonesia*
rendy.ananta@gmail.com

Abstract

All Indonesian submarines operating today use diesel-electric submarines that rely on a diesel engine as propulsion when diving and an electric generator to charge the battery while on the surface. The presence of nuclear submarines is relied upon because of their long operating life and more powerful despite their large size and must be in diving conditions. The purpose of this study was to determine the efficiency of the use of nuclear submarines against diesel-electric. The method used is a literature study to collect relevant data related to nuclear and diesel-electric submarines which is then projected to calculate efficiency based on the resulting fuel emissions. The results show that KRI Nanggala 402 as a diesel-electric submarine requires 33.75 tons of oil with CO2 emissions of 106.64 tons, while the USS Nautilus SSN-571 as a nuclear propulsion submarine requires 0.182 kg of uranium that does not produce emissions. In terms of diplomacy, the increasing challenges in developing the modernization of nuclear-based defense weapons provide space for multilateral diplomacy for peaceful purposes.

Keywords
diesel-electric submarines; nuclear submarines; defense armament; emission

I. Introduction

Indonesia has a coastline of 95,181 km and is the second-longest coastline in the world, with an area of marine waters reaching 5.8 million square kilometers, which is 71% of the total area of Indonesia. This indicates the importance of securing and defending the territorial sea, which is carried out by the Marine Matra TNI in their duties and functions so that a defense system is needed to support them in carrying out these tasks.

In 2021, Indonesia's defense forces occupy the 16th position in the world with an index value of 0.2684 with the best score of 0.0000 based on data from Global Fire Power. The power of the marine dimension has assets of 282 units which are ranked 10th in the world, with 5 units of submarines occupying the 15th position out of 140 countries in the world. The sinking of Nanggala 402 became a deep sorrow for the Indonesian people so that the strength of the sea dimension with 4 submarine units consisting of Cakra 401, Nagapasa 403, Ardadedali 404, and Alugoro 405.

The four main defense systems have almost the same class type, namely Cakra 401 class type 209/1300, while the others are class type 209/1400. Currently, the four Indonesian submarines operate using diesel engines. When on the surface, the submarine is on the power generated by the diesel engine as propulsion when diving and electricity generation to charge the battery. Batteries can only last 2 days from the time of charging, so the submarine must

periodically surface using air to run its diesel engine. This is what worries submarines vulnerable to detection and attack.

The presence of nuclear submarines began to be ogled by the world because of their longer operating period and more powerful despite having a large size and must be in a state of diving. Uranium as reactor fuel can be replaced after 3 years of use. Although some countries with nuclear submarines still require the presence of diesel-electric submarines, except the USA. In addition, from an environmental point of view, the use of uranium also supports Indonesia's efforts to ratify the Paris Agreement an effort to reduce global emissions by keeping the global temperature rise below 2oC.

Studies on the modernization of the state defense equipment system continue to be carried out, including submarine orders as well as the knowledge transfer process carried out by South Korea to PT. PAL Indonesia in the manufacture of the Nagapasa 403 diesel-electric submarine, Ardadedali 404 and Alugoro 405 in 2015, which was launched in 2016 and was officially handed over to the Indonesian Navy on August 2, 2017. Therefore, the modernization of the defense equipment for nuclear-powered submarines needs to be carried out by Indonesia as well as diesel-electric submarines. Moreover, Indonesia with the concept of defense of the Green Water Navy which tends to create an atmosphere of peace, so that safeguards throughout Indonesia must continue to be carried out to maintain sovereignty and prevent the potential for war.

This is expected to be a continuation of Indonesia's grand defense strategy involving ends, means, and ways. Furthermore, Djajadiningrat in Aldhila (2021) suggests indicators in achieving sustainable development, namely "ecological sustainability, economic sustainability, socio-cultural sustainability, political sustainability, and defense and security sustainability". This is considered important, meaning that it is for the preparation of the defense in the trial court later (Octarina, 2021). Reduce/eliminate dependence on the use of foreign defense equipment products, standardization of defense equipment (Permana, 2022). Where the grand strategy maintains state sovereignty, means includes human resources, territorial areas, defense equipment, and energy availability, as well as ways that include strategies and tactics carried out by the mandala in field execution.

II. Research Methods

This research uses a literature study to collect relevant data related to Nuclear Submarine. The reference obtained is processed using an analysis of the calculation of the efficiency of the need for fuel oil (BBM) from the main engine, namely by systematic calculations between the power produced by the submarine and the Horsepower (HP) unit so that the consumption of fuel oil is converted to uranium fuel. Thus, the estimated savings and emission reductions by submarine energy are obtained.

III. Results and Discussion

3.1 Results

According to Darma et al. (2010), the main engine is the main driving force that functions to convert mechanical power into the driving force for the ship's propeller so that the ship can move, where in operation the main engine is always in a continuous running condition. The main engine budget calculation method for fuel costs is as follows.

$$FCt = MCR\ (0.80 \times HP) \times SFOC \times 24 \times 0.001 \times 1.05 \text{ tons/day}$$

MCR = Maximum Continuous Rating
*nominal power of main/auxiliary motor calculated 0.80 to 0.95 x HP
SFOC = Specific Fuel Oil Consumption
SFC is calculated based on new engine conditions with a tolerance of 180 gr/HP/hour requirements
24 = 24 hours
10-6 = conversion of grams to tons
1.05 = factor that takes into account fuel requirements due to leakage due to engine aging

The first nuclear propulsion submarine was the Nautilus with a reactor power of 10 MW, and a speed of up to 20 knots (23 miles per hour). This submarine has been in service for 25 years and has crossed the ocean for 513,000 miles (Maruli & Puni, 2017). The following is a comparative study of KRI Nanggala 402 as a diesel-electric attack submarine with the USS Nautilus SSN-571 as a nuclear-powers attack submarine.

Table 1. Fuel Requirements for Diesel Engine Submarine and Nuclear Propulsion

Submarine Type	HP	MCR	SFOC				Fuel	Uranium
KRI Nanggala 402	9300	0.8	180	24	10^{-6}	1.05	33.75 tons	0.048 kg
USS Nautilus SSN 571	35325						128.19 tons	0.182 kg

The use of fuel is in line with the need for engine power, the higher the use of engine power, the fuel consumption will increase (Sa'id, 2011). The small volume of fuel needed in nuclear power plants has an impact on easier transportation problems and fewer land requirements for fuel storage.

In terms of the environment, the emissions produced by oil and uranium as nuclear fuel are very different. This is evidenced by the fact that the fuel oil used for power generation in Indonesia has an average carbon (C) content of around 87% (Finahari & Salimy, 2008). The combustion reaction that occurs is:

$$CBBM + O2 \rightarrow CO2$$

Based on the calculation of 1 ton of fuel, it is known that:
Total C in fuel = 87% = 0.87 tons.
The number of moles of C = 0.87/BM C = 0.87/12 = 0.072 moles, and
The moles of CO2 formed, moles of CBBM = 0.072 moles.
Amount of CO2 formed = 0.072x BM CO2 = 0.072 x 44 = 3.16 tons

Table 2. Diesel Engine Submarine Fuel Emissions and Nuclear Propulsion

Submarine Type	Fuel	Emissions
KRI Nanggala 402	Fuel : 33.75 tons	106.64 ton CO_2
USS Nautilus SSN 571	Uranium : 0.182 kg	-

3.2 Discussion

Regarding emissions produced by nuclear reactors, UNDP has not provided data on emission factors because nuclear power plants in Indonesia are still not operating. By considering the heat generation process that does not use the combustion of carbon compounds, it is assumed that nuclear power plants in Indonesia have no emission factor or zero kg/kWh (Firmansyah & Suparman, 2013).

Efforts to reduce global emissions are an implication of the Paris Agreement, which keeps global temperature rise below 2oC by limiting fossil energy that has high emissions globally and increasing the energy mix. This requires responsive action through the formulation of policies and regulations at the sectoral level. The Indonesian government needs to adopt an integrated program to be able to achieve the GHG emission reduction target according to the Paris Agreement target (Arinaldo et al., 2019).

Nuclear reactors implement layered defense systems, physical protection systems, and security systems (Lumbanraja SM et al., 2016). Government Regulation of the Republic of Indonesia No. 43 of 2006 concerning Nuclear Reactor Licensing it is stated that seifgard is any action at ensuring that the purpose of using nuclear materials is for peaceful purposes only. Nuclear fueled ships are more economical if the ship operates for a long period because nuclear fuel will still be used even if the ship stops completely. Meanwhile, oil-fueled ships will not be used if the ship is not operating (Maruli & Puni, 2017).

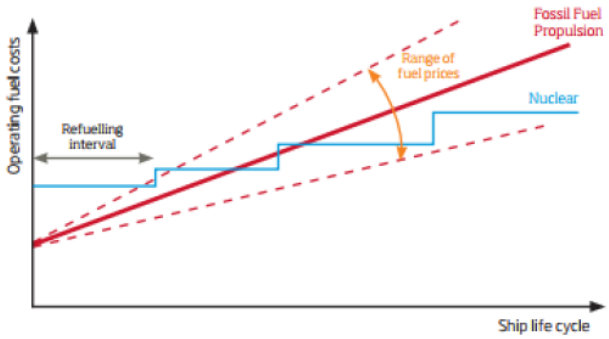

Figure 1. *Analysis of the cost of nuclear fuel and oil [Maruli]*

In terms of diplomacy, with the increasing challenges in dealing with the proliferation of nuclear weapons coupled with the advancement of science and technology, Seifgard's actions have been successfully expanded and strengthened which are then integrated into the existing system. This new seifgard approach is outlined in the integrated safeguards document. Seifgard International Atomic Energy Agency (IAEA) inspection is one of the measures to verify nuclear material declared by the operator so that the operator does not misuse the nuclear material for the manufacture of nuclear weapons (Endang Susilowati, 2009).

The advantage of nuclear submarines is that they have a longer operating life and are more powerful despite their large size and must be in a submerged condition, uranium as fuel from the reactor can be replaced after 3 years of use. Unlike diesel submarines, which must come to the surface to suck the air needed by diesel engines.

The only limiting factor for its operating period is the need for crew supply. Diesel-electric submarines are submarines with the oldest submarine propulsion system still in use today. The diesel-electric propulsion system is so reliable that even nuclear submarine-owning countries still feel the need to have this type of submarine. Of the five countries that own nuclear submarines, only the United States does not use this diesel-electric submarine. Under certain circumstances, this type of submarine is more deadly than a nuclear submarine.

Table 3. Advantages and Disadvantages of Diesel Engines and Nuclear Reactors as Submarine Propulsion

Diesel	Nuclear
• Using the diesel engine while on the surface and	• The nuclear reactor as a source of propulsion • Heats water and converts it to high pressure which

using the battery while driving • No need to appear on the surface can use a snorkel for air supply • When diving and operating on battery power, submarines are very quiet, making them more difficult to detect • More agile to maneuver with a sharp enough degree angle, because the ship's body is smaller	drives a steam turbine, rotating a steam turbine to turn the ship's propellers and turn a generator to produce electricity • Nuclear reactor fuel can be used continuously, 20-30 years • Oxygen and clean water are produced from seawater processing • Oxygen is produced by electrolysis, separating oxygen and hydrogen from water molecules • Freshwater is obtained through the seawater process by reverse osmosis • Able to operate for 6 months • The large body of the ship can accommodate various types of weaponry
• Limited dive duration, the battery only lasts 2 days • Periodically must rise to the surface to start the diesel engine to charge the battery, making it more vulnerable to enemy detection and attack	• Nuclear submarines, reactor coolant pumps, and steam turbine engines produce a very loud sound, making it easier to detect through the passive sonar of other ships. Sonar ship noise measurement will measure the noise level of the submarine. • Insufficient supply of food and logistics for crew members for ship diving during nuclear for 6 months • The ship's body tends to be larger, so it is less agile to maneuver

The author recommends doing the same with ordering submarines from abroad. In addition to modernizing defense equipment, it is also an effort to improve the quality of human resources. Currently, Indonesia's second order for South Korea which consists of 3 submarines is a continuation of the first order, in which the knowledge transfer process was carried out by sending experts from PT. PAL Indonesia in the manufacture of the Nagapasa 403 diesel-electric submarine, Ardadedali 404 and Alugoro 405 in 2015, which was launched in 2016 and officially handed over to the Indonesian Navy in August 2, 2017. Furthermore, the second-order has the following details.

1. 6 modules, of which 4 modules are from South Korea and 2 modules are from Indonesia. Assembly is carried out in South Korea.
2. 6 modules, of which 2 are by South Korea and 4 are by Indonesia. Assembly is carried out in South Korea.
3. 6 modules, all of which are carried out by PT. Indonesian PAL. Assembly is carried out in Indonesia.

According to the author, the steps taken for the manufacture of nuclear submarines are also similar. Considering that nuclear is a radioactive material that needs supervision from the IAEA, it is necessary to re-examine this new seifgard approach as outlined in the integrated safeguards document. Able to ensure that Indonesia's territorial area requires carrying capacity following nuclear characteristics, namely durable, low emission, especially not to misuse nuclear materials for the manufacture of nuclear weapons.

IV. Conclusion

The conclusion show that KRI Nanggala 402 as a diesel-electric submarine requires 33.75 tons of oil with CO2 emissions of 106.64 tons, while the USS Nautilus SSN-571 as a nuclear propulsion submarine requires 0.182 kg of uranium that does not produce emissions. In terms of diplomacy, the increasing challenges in developing the modernization of nuclear-based defense weapons provide space for multilateral diplomacy for peaceful purposes.

References

Aldhila, A., et.al. (2021). Management of Slum Settlements based on Sustainable Development in the Deli Watershed of Medan City. Budapest International Research and Critics Institute-Journal (BIRCI-Journal) Vol 4 (2): 2791-2799.

Arinaldo, D., Mursanti, E., & Tumiwa, F. Implications of the Paris Agreement on the Future of Coal Steam Power Plants (PLTU) in Indonesia. Accelerating Low-Carbon Energy Transition. 2019; 96(3), 445.

Country Military Strength, Available at Globalfirepower.com/country-military-strength-detail.php?country_id=indonesia, accessed at February 2022.

Darma, NM, Supomo, H., & Nugroho, S. Analysis of the Condition of the Ship's Main Engine Using the Application of the Fuzzy Inference System Method. Proceedings of the XI National Technology Management Seminar. 2010; 1–12.

Endang Susilowati. Seifgard International Atomic Energy Agency inspection. Nuclear Reactor Management Bulletin. 2009; 6(1), 1–11.

Finahari, IN, & Salimy, DH The Contribution of Nuclear Power Plants in Reducing CO2 Emissions in the Study on Optimization of the Sumatran Power Generation System Development. Journal of Nuclear Energy Development. 2008; 10(2), 97–103.

Firmansyah, R., & Suparman. Calculation of Co2 Emission Factors for Coal Power Plants and Nuclear Power Plants. 2013; 1–8.

Government Regulation of the Republic of Indonesia No. 43 of 2006 concerning Nuclear Reactor Licensing. 2006; 1.

Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia. Press Release Number: SP204/SJ.04/VIII/2019.

Maruli, S., & Puni, A. Nuclear Propulsion Ship in Indonesia. Proceedings of the National Seminar on Research & Community Service. 2017); 1–6.

Militaryfactory.com/ships/detail.php?ship_id=kri-nanggala-402-diesel-electric-attack-submarine-indonesia

Octarina, N.F., and Faridah, U. (2021). The Role of Legal Advisors in Criminal Case Settlement Process. Budapest International Research and Critics Institute-Journal (BIRCI-Journal) Vol 4 (4): 9342-9352.

Permana, I., Afrihan, M.D., and Perwira, I.C. (2022). Indonesian National Army: A Human Capital Strategy to Modernized National Army Power. Budapest International Research and Critics Institute-Journal (BIRCI-Journal) Vol 5 (1): 11-21.

Sa'id, SD. Analysis of the Efficiency of Fuel Use for the Purse Seiner Ship's Main Engine at the Pekalongan Archipelago Landing Port. Echo Technology. 2011; 16(2), 99. https://doi.org/10.14710/gt.v16i2.22135.

Setyawan, BA. Get to know the Nuclear Technology Ships. Bina Widya. 2016; 25, 1–10.

USS Nautilus SSN571 Details, Available at Militaryfactory.com/ships/detail.php?ship_id=USS-Nautilus-SSN571, accessed at February 2022.