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SUSTAINABLE ISLAND (SAIL): AN INNOVATIVE WAY FOR REACHING A SIGNIFICANT RISE IN INDONESIA WATER, ENERGY, AND FOOD NEXUS INDEX

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ABSTRACT

Indonesia, being an archipelagic country, ranks third in terms of climate risk. Sustainable islands (SAIL) are novel ideas offered as an effective way of achieving Indonesia's sustainable development while also accelerating climate change mitigation and adaptation. The water, energy, and food (WEF) nexus approach will be used to expand SAIL's programs. In this nexus, water is the most essential governing factor for the ecosystem and society. Thus, the SAIL program is adopting rainwater harvesting (RWH), a sustainable technology that supplies water with low energy and cost. To irrigate the crops and generate electricity, the island RWH tank is created by impounding surface runoff over natural landscape depressions equipped with a hydrokinetic power system. An RWH system with a pico-hydropower system is installed on the roofs of all island buildings for both household water consumption and electricity generation. The immediate implementation of the SAIL concept promises to boost Indonesia's WEF nexus index.

Keywords: *Island; nexus; RWH; sustainability; WEF.*

1. INTRODUCTION

Indonesia is a marine archipelagic nation composed of 13,588 islands dispersed across three time zones. Due to its enormous biological and cultural diversity, as well as its tropical location, Indonesia is a unique country that is extremely prone to climate change. The entire archipelago faces a moderate to high level of natural hazard and climate risk, with no province subjected to a low level of natural hazard and climate risk [1-3].

Sustainable development is a strategy for overcoming the structural restrictions that may have contributed to climate change by living within the planet's 'income' rather than depleting its capital and by using renewable natural resources within the limits of their renewal [4]. The presence of a global development program that tries to save the environment and enhance human well-being is linked to the establishment of Sustainable Development Goals (SDGs). The SDGs are a global initiative supported by 193 world leaders, including Indonesia. Humans (people), the earth (planet), prosperity, peace, and cooperation (partnership) are the five pillars of SDGs, which aim to achieve three noble goals by 2030, e.g., eliminating poverty, attaining prosperity, and combating climate change [5].

Water, energy, and food are vital to every aspect of human life, including the ability to work, live, and conduct tasks. Food and energy cannot be produced without water, and neither can be processed or delivered in the absence of energy. As a consequence, the WEF Nexus approach is highly recommended as a framework for the implementation of the SDGs in a coherent, comprehensive, and integrated manner [6]. By emphasizing the significance of water to socio-economic development, the concept and objective of water security are significantly larger than those defined by SDGs goal 6 "Clean water and sanitation." In addition, SDG's goal 2 "Zero

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hunger" underlines the vital importance of sustainable agriculture techniques for increasing productivity and output. In addition, SDG's goal 7 "Affordable and clean energy" highlights the need to increase access to clean, modern, and renewable energy sources [7].

The WEF Nexus Index is a composite indicator that combines 21 worldwide accessible indicators. The current WEF Nexus Index result for Indonesia is 62.3, putting the country in 58th place among the nations evaluated. Indonesia had a score of 71.3, 62.1, and 53.6 for the water, energy, and food pillars, respectively [8]. This paper introduces sustainable islands (SAIL) as a novel strategy for increasing Indonesia's WEF nexus index significantly. Given the characteristics of Indonesia's archipelago, it is crucial to immediately initiate the process of establishing sustainable conditions on the islands.

Water is the most very important for living things [9] and became the most essential factor governing the WEF nexus. However, water resource management on an island is challenging because freshwater provisioning services are frequently limited, especially on small islands. In the meanwhile, demand is rising owing to population and tourism growth. As a result, it is exacerbated by water resource management and infrastructure being equally vulnerable to water- and climate-related disasters, with floods, droughts, and, eventually, tsunamis being the most common calamities [10]. Therefore, the SAIL concept highlighted the implementation of sustainable modified rainwater harvesting (RWH) technology. RWH systems with low energy and cost may be installed for agricultural and domestic usage. Thus, it is ideally suited for implementation on the island, which could boost the WEF nexus index.

2. IMPLEMENTATION OF NOVEL MODIFIED RWH TECHNOLOGY FOR THE SAIL PROGRAM

SAIL is a groundbreaking sustainability initiative designed and developed after participation in the Young Water Sustainability Leaders Bootcamp, specifically the WEF Nexus class. The SAIL is primarily designed to promote the sustainable use of an island's water resources. According to Gikas & Tchobanoglous [11], the previous concept of sustainable water resources has recently been shaken by the increase in per capita water use associated with development, recent population growth, and significant expansion of the tourism sector. Excessive development and uncontrolled construction on many islands have directly impacted the natural environment and ecological balance of the islands, resulting in environmental degradation and depletion of WEF resources, including the quality and quantity of surface and groundwater, exacerbated by the islands' vulnerability to natural and climatic catastrophes [11-12].

The concept of SAIL drew attention to the use of rainwater harvesting (RWH) technologies, an ancient practice that allows for the long-term storage of a significant amount of water of adequate quality at a reasonable cost. It is widely regarded as a viable solution for previously unknown ecological systems. In many countries, it is recognized as a reliable and environmentally friendly method of water management [13-14]. According to Jiang [15] and Hasanah et al. [16], an RWH system is a device that can help mitigate the effects of hazards such as runoff during periods of heavy rainfall and provide other benefits.

It is possible to install RWH systems with low energy requirements and low operating costs for agricultural and domestic use. The island will be equipped with various RWH technologies that have been modified and will be deployed at different locations on the island. Based on Hasanah et al. [16], the roofs of all buildings on the island can be used as domestic catchment areas, while the island's open fields can be used as agricultural catchment areas. The innovative SAIL program will modify the RWH technology to maximize the application of this technology to increase the WFE nexus index.

2.1. Modified Agriculture RWH System Design

Hasanah et al. [16] highlighted the RWH designed by Meter et al. [17] for agricultural area (Figure 2). The construction of earthen banks or bunds over natural depressions in the terrain forms the RWH tank. Runoff from the tank's catchment area completely submerges the tank bed during

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rainfalls. An irrigation canal supplies water to agricultural land downstream of the tank bund through irrigation canals that have sluices that can be closed to regulate the flow of water from the tank to the irrigation canals. A cascade of tanks is common, with overflow from upstream tanks flowing into pipes connected to downstream tanks or nearby rivers. The hydrological network formed by tank cascades, which can range from a few tanks to more than a hundred, connects not only individual tanks but also small farm ponds, wells, and rivers throughout the terrain.

The recommended change to increase the WEF nexus index in this agricultural RWH technology proposed at SAIL is the addition of a turbine in the feeder channel. Hydrokinetic energy in a water channel could be used to generate electricity with this device. Hydrokinetic power generation has virtually no problems with interruptions. As long as water flows through the channel, the rotors will continue to spin and generate energy. A specially designed turbine should be placed at the bottom of the channel. The turbine is equipped with an underwater generator that supplies power to the system using a permanent magnet generator AC. Based on Niebuhr et al. [18], to achieve the maximum power output from the hydrokinetic system, a flow velocity of 3.1 m/s is required. If the velocity is lower due to the flat terrain, narrowing the channel to increase power could be a solution. A turbine can be installed between a set of guide plates to narrow the channel section.

2.2. Modified Domestic RWH System Design

Hasanah et al. [16] highlighted the RWH designed by PB et al. [19] for domestic use (Figure 1). The ideal roof rainwater harvesting and conservation system consists of a Roof for the surface where rain falls; Gutters and Downspouts for the conveyance system from catchment surface to storage; Leaf screens and Roof Washers Systems that remove contamination and debris; Cistern or Storage Tanks where collected rainwater is stored; Conveyance as the delivery system for treated Rain Water, either by gravity or pump; and Water Treatment that consists of Filters and equipment as well as additives to settle, filter and disinfect the water.

The recommended change to increase the WEF nexus index in this domestic RWH technology proposed at SAIL is the addition of a pico-scale hydroelectric (pico-hydro) power system. This idea is based on the fact that rainwater falling on roofs has potential energy. Energy can be generated if this water is forced to fall at high velocity onto a turbine. Pico-hydro is a simple method of power generation that can be used in remote locations where electricity is not available. Based on Budiarso et al. [20], pico-hydro systems generate power of less than or equal to 5 kW, which could provide a remote community with enough energy to run light bulbs, radios and televisions, and other appliances. This system does not always need a high-rise building. Fernando et al. [21] found out that it can also generate electricity with a building with a roof height of 2.5 meters. Pelton turbines are suggested in SAIL because it suitable for low flow applications. The attachment of the turbine blades is connected to the drive shaft (rotor). The output is then connected to the charging circuits for energy storage, but direct output from the generator is also possible to be used without storage [22].

3. EXPECTED RESULT FROM THE IMPLEMENTATION OF SAIL INNOVATIVE PROGRAM

3.1. Current WEF Sector

Island resources are often discussed in the context of environmental impact, water, food and energy availability, climate change, and overall sustainability. However, these discussions have not adequately addressed the challenges of the WEF nexus. It is therefore important to prioritize creating and developing an all-encompassing nexus framework. A brief analysis using the WEF nexus approach is presented to illustrate the potential of SAIL using modified RWH technology on islands to increase the WEF nexus index, can be seen in Figure 1.

Water is a vital resource that ensures the continuation of life. According to Syahriani et al. [23] and Prihantono et al. [24], one source of clean water on the island is bore wells, which are used by islanders for daily bathing and washing. However, because borehole water occasionally contains

tastes and odors, it does not meet the criteria for clean water. Due to seawater intrusion, salt pollution has often contaminated groundwater as well. Some islands also have access to piped water. While the need for clean water is met in terms of the quality of tap water, the need for quantity is not always met due to price and distance constraints.

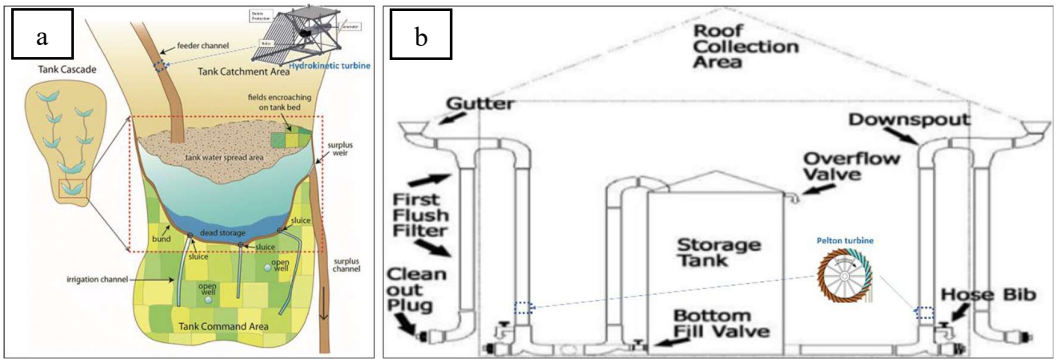

Figure 1. (a) Agriculture RWH (Modified from Meter *et al.* [17]);
(b) Domestic RWH (Modified from PB et al. [19]) in SAIL

More than ninety percent of food in Indonesia is traded on the open market. This shows that only a small part of the food is grown and consumed by the people themselves. Many islands have to rely on internal or international trade to feed their population. Nevertheless, a number of cases show how difficult it is for islanders to reach the mainland to get food due to their isolation [25]. Irrigation water is very important in supporting food security [26]. Therefore, drought-tolerant crops were often considered the only answer to unpredictable rainfall in drought-prone regions [27].

Most of Indonesia's primary energy supply comes from non-renewable sources (coal, oil, and natural gas), with coal being the largest contributor. Nevertheless, energy scarcity remains a widespread problem in Indonesia. Providing energy, especially renewable energy, to islands and archipelagos is difficult. The majority of small islands rely on imported fossil fuels to meet their energy needs, especially for transportation and power generation. Due to their remote location, infrastructure and energy costs on a number of islands are three to four times higher than on the mainland [28].

3.2. Expected Contribution to WEF Nexus Index

The WEF nexus framework developed in this study to analyze the interlinkages between the three components of water, energy, and food as an expected contribution of the implementation of SAIL (Figure 2). The structure of the nexus concept was developed to show the flow of the resources sector to other sectors.

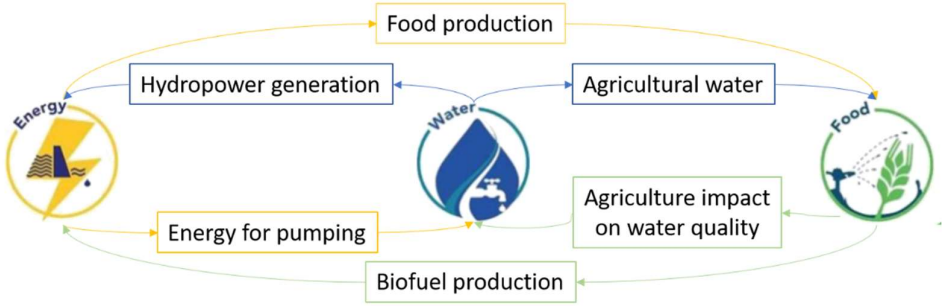

Figure 2. WEF Nexus of SAIL Implementation

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The modified RWH technology in the SAIL program can provide an additional amount of water not only for domestic use but also for agriculture. According to Ghimire & Johnston [29], the use of RWH in agriculture offsets the consumption of surface and groundwater for irrigation by fifty percent and can therefore even lead to increased surface water availability for downstream ecosystems. Although the agricultural sector is primarily responsible for water pollution from nitrates, phosphorus, pesticides, soil sediments, salt, and pathogens resulting from crop and livestock production, it can also play a role in improving water quality by performing a water purification function in certain agricultural practices [30].

Water is an excellent source of energy. Its potential and kinetic energy can be used to drive a turbine, which can then be converted into electrical energy [31]. At SAIL, hydrokinetic energy in a water feeder channel and a pico-hydropower system placed downstream of the downpipe can generate electrical energy from water. This energy can be used as a source of energy for pumping the water. In agriculture, this energy can be used as a source of power to pump water to irrigation areas.

The introduction of RWH technology in SAIL may also lead to changes in cropping patterns, such as the introduction of new crops, improved tillage practices, and the simultaneous cultivation of two or more crops [27], including the production of biofuel crops. Based on Hasnah et al. [32], *Pongamia pinnata* (Pongamia) is a legume tree with oil- and fatty acid-rich seeds that can be cultivated on the Indonesian island. Due to its deep roots and drought tolerance, it is found in coastal locations, along limestone and rocks, at the edges of mangrove forests, tidal creeks, and rivers. All the energy potentially generated on SAIL is renewable. It could also be used as an energy source for food production. The WEF nexus index consists of a collection of 21 indicators. However, it is difficult to reduce the status of a nation's integrated resource management to a single number [33]. This article does not measure the index due to limited access to data, but it does highlight the possibility of improving the availability and accessibility of water, food, and energy through the implementation of SAIL, which is associated with an increase in the WEF nexus index.

4. CONCLUSION

SAIL has been introduced as an effective strategy to increase Indonesia's WEF nexus index. The SAIL program entails the adoption and modification of RWH sustainable technology that provides low-cost, energy-efficient water for agricultural and residential use. The effects of SAIL on the WEF nexus have been identified and investigated. In addition, the government should provide aid and incentives to encourage the installation of RWH systems.

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