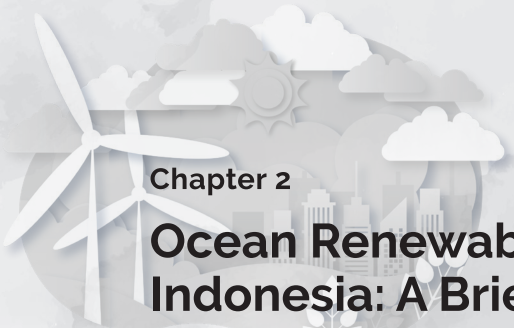

Chapter 2

Ocean Renewable Energy in Indonesia: A Brief on the Current State and Development Potential

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A. Oceans as Potential Alternative Energy Sources

The geographical condition of Indonesia consists of thousands of islands, triggering difficulty in energy distribution and a large disparity in energy prices between the eastern and western parts. The disparity affects production and manufacturing costs and implies investment distribution. Additionally, the impact of climate change on the oceans, such as rising sea temperatures, rising sea levels, reducing oxygen levels, changing ocean currents, increasing ocean stratification, and increasing storm frequency, can cause problems for marine ecosystems (Brierley & Kingsford, 2009; Harley et al., 2006; Moreno et al., 2014).

However, most solutions to problems come from the root of the problem itself. As an archipelagic country, Indonesia faces numerous energy challenges, but definitely, Indonesia's ocean also provides

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the solution. Ocean renewable energy is developed as an alternative solution to mitigate climate change.

Movement and the physicochemical characteristics of saltwater are the primary sources of ocean energy. The tides, ocean currents, and wave phenomena are all examples of the movement of water masses. Technologies for energy conversion have been developed to use the mass motion of saltwater to power generators and turbines. The salt and heat content of the saltwater column are the physicochemical characteristics that can be an energy source. The osmosis principle can turn salt into a source of electrical energy. Based on the laws of thermodynamics, the heat of saltwater, defined as the difference between the temperature of the water at the surface and that at a particular depth, can be transformed into electricity.

Ocean energy in Indonesia, including tides, waves, wind, and ocean thermal, has the potential to be developed (Langer et al., 2021). Marine energy's theoretical and technical potential in Indonesia is estimated at 288 GW and 18-72 GW, respectively (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2016). However, the potential has not been developed. The realization of the potential is zero percent, because, among other things, there are also no policies and regulations regarding ocean energy.

To draw attention, raise awareness, and encourage the development of ocean renewable energy, this paper presents a series of data to be reviewed, which focuses on ocean energy in Indonesia, including the potency, the research progress, the abandonment, and the planned project as a process of extracting marine energy in the fields of ocean thermal energy conversion, offshore wind turbines, ocean tidal, and ocean waves.

B. Ocean Thermal Energy Conversion (OTEC)

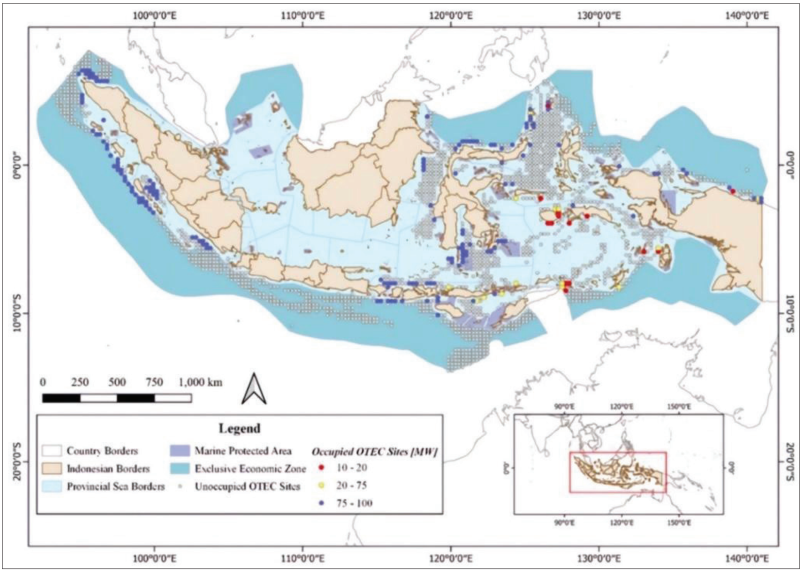
Ocean Thermal Energy Conversion, usually called OTEC, is a method of generating electricity using the temperature difference between the ocean's surface and deeper seawater (Nihous & Vega, 1993). Indonesia has an OTEC energy source that is abundant and regularly renewed when the sun is shining and the ocean currents are naturally present because Indonesia's climate tend to be pretty consistent throughout the year (Koto, 2016). Duxbury et al. (2002) states that in maritime tropical areas, thermal resources from ocean thermocline are one of the most potential sustainable energy sources. Indonesia's theoretical potential is 57 GW of energy sources and 43 GW in practice (INOCEAN, 2012). Langer et al (2021a) has conducted a map of OTEC potential site in Indonesia as shown in Figure 2.1. The aforementioned places include western coast of Sumatra, the southern part of Sulawesi, the northern and southern parts of Papua, and the southern part of Maluku. A study from Syamsuddin et al. (2015) states that potential sites for OTEC power plants are located in North Sulawesi and South Kalimantan at a depth of 500 m. These sites have temperature differences between the surface and deep sea of 21.78°C and 21.11°C, respectively. Using calculation in his paper, he can produce Carnot efficiency of 0.745152 and 0.732385, respectively, and are relatively stable each month.

The potential of the Makassar Strait as a suitable location for OTEC installations has been recognized due to its unique geographic characteristics and strategic positioning. Studies, such as the one conducted by Ilahude and Gordon (1996), have revealed that the area consistently exhibits high temperatures, particularly at the surface. This thermal profile makes the Makassar Strait an ideal candidate for harnessing ocean thermal energy. Furthermore, extensive research by Hammad et al. (2020) has identified a total of 17 promising sites within the Makassar Strait where floating OTEC stations could be deployed. These sites showcase an average temperature difference of 23.57°C, indicating the presence of substantial thermal gradients that can be utilized for power generation.

In terms of efficiency, the average Carnot efficiency at these identified locations is estimated to be 7.7%. While there is room for further optimization, this figure signifies the potential for converting a significant proportion of the available thermal energy into usable power through OTEC technology. Considering power generation capabilities, the envisioned OTEC stations in the Makassar Strait have the capacity to generate an average gross power output of approximately 177.66 MW, with a net power output of around 13.85 MW. This represents a substantial energy yield that can contribute to the regional power supply. Among the 17 potential locations in the waters of the Makassar Strait, the station situated at coordinates 01°01’51”N-120°13’21”E stands out as particularly promising. Its selection is based on a combination of factors, including favorable geographical conditions, ocean currents, proximity to the nearest coastline, and notable power generation capacity.

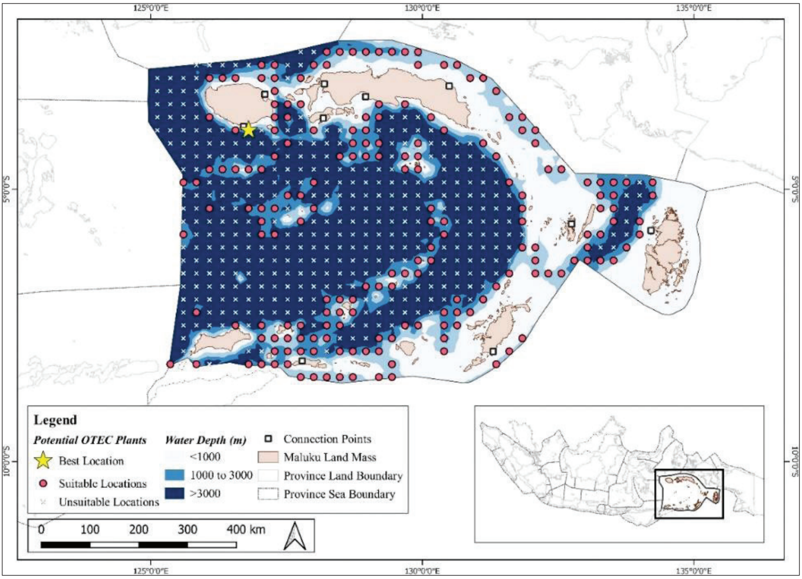
In east Indonesia, the northern region of Bali emerges as a promising location for the implementation of OTEC systems. Researchers, such as Ilahude et al. (2020), have conducted studies specifically focused on the potential for OTEC installations in North Bali. By utilizing annual temperature data obtained from HYCOM and employing (Uehara & Ikegami, 1990) equation to develop a temperature model, Ilahude’s research reveals that the North Bali area exhibits a significant contrast in sea surface temperature compared to the deeper sea, ranging between 22°C and 25°C. Notably, through the analysis, it was determined that the location with the highest net power potential for OTEC deployment is situated in Tedjakula, Buleleng, boasting an impressive net power output estimated at 71,109 MW. This finding underscores the substantial energy potential that the northern part of Bali holds for OTEC applications in the country.

Using the method carried out by Langer et al. (2021b) in their research, it is estimated that there are 1,021 sites on the border of Indonesian provinces which are technically and economically suitable for OTEC. It implies that OTEC can be run almost throughout the Indonesian maritime region, where only the northern and southern regions of Sumatra, southern and western Kalimantan, northern Java, and the southern part of Papua do not have areas suitable for OTEC installation. Langer et al. (2021b) also stated that the best site for an OTEC plant is 13 km from Namrole and Maluku, as shown in Figure 2.2. This is in line with Indonesian Ocean Energy Association (INOCEAN)'s statement that mapping areas with temperature gradients above 20°C (Rahayu & Oktaviani, 2018). With a potential electric production of around 0–16 TWh, OTEC can cover about 6% of Indonesia's electricity needs in 2018 (Ministry of Energy and Mineral Resources, 2019). In another study, Langer et al. (2022) simulated an OTEC Enhancement Model considering the fulfillment of electricity needs and the global relevance of OTEC. The study states that an OTEC power plant with a capacity of 45 GW can be built and can cover 22% of the national energy needs in 2050. From Sutopo (2018), the economic potential of OTEC in Indonesia varies between 318 TWh and 3691 TWh with the economic potential of OTEC between provinces varying between 253 and 904 TWh. Differences in temperature and distance have the greatest influence on LCOE, followed by CAPEX values.



Source: Langer et al. (2021a)

Figure 2.1 Potential Site of the Ocean Thermal Energy Conversion in Indonesia



Source: Langer et al. (2021)

Figure 2.2 Site Map of Ocean Thermal Energy Conversion in Namrole, Maluku

The development of OTEC in Indonesia is currently not yet at the stage of installing power plants, either prototypes or commercially. In the world, OTEC power plants have been installed in several locations, e.g., Saga and Kumejima in Japan, with respective energy outputs of 30 kW and 100 kW. OTEC is still in the pilot project stage for several reasons, one of which is the problem with the cold water pipe (CWP) component (Adiputra & Utsunomiya, 2019). Indonesia had also made several plans for the development and research of OTEC. One was the plan to build a pilot plant in collaboration with Saga University in Japan. The pilot project of the OTEC power plant installation was planned to be built on Bali Island with an energy output of 5 MW (Martosaputro & Murti, 2014), yet no progress has been made up to now.

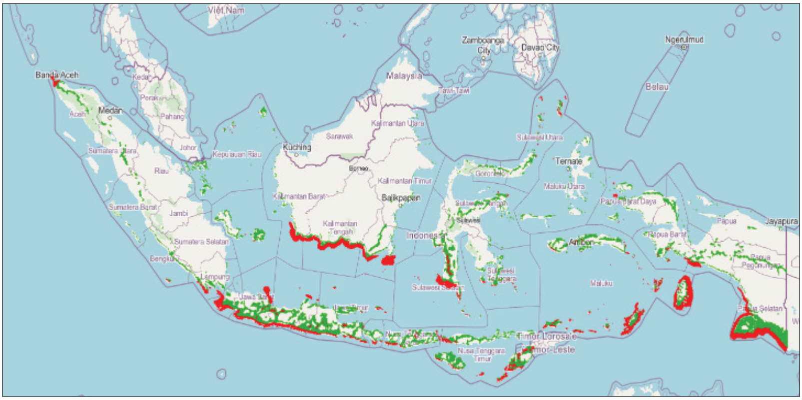
In the endeavor to develop OTEC in Indonesia, setting the site in Mentawai Island, Adiputra et al. (2020) proposed a preliminary design of OTEC to convert oil tanker ships into OTEC floating structures to reduce the capital cost of OTEC installation. Considering the problem in the CWP component, Adiputra and Utsunomiya (2019) also conducted research on the design of CWP components with a stability-based approach based on internal flow effect (IFE). Adiputra draws the conclusion that, in light of the findings, installing clump weights is important to limit motion displacement, FRP is the most suitable material, and the pinned joint at the top is preferred to lessen applied stress. Further, Adiputra and Utsunomiya (2021) then analyzed the CWP stability, imposing internal flow effect using the Galerkin and Frobenius methods on the frequency domain. In a recent study, the stability analysis was enhanced using the Finite Element Method in the time domain. The analysis shows that the instability occurs on 4.5–4.8 m/s fluid velocity (Adiputra & Utsunomiya, 2022).

C. Offshore Wind Turbine

Offshore wind turbines are basically energy from wind that flows over offshore areas. By definition, this technology can be included in wind energy, but here this technology is included in this section. Currently, Indonesia has a total installed capacity for onshore wind energy of 140 MW, separated into two locations, Jeneponto Wind Farm and Sidrap Wind Farm, with an output of 65 MW and 75 MW (National Energy Council, 2019). Developing wind energy power plants in Indonesia is still slow and focused on land-based power plants. According to the Ministry of Energy and Mineral Resources (MEMR)'s Handbook of Energy and Economic Statistics of Indonesia (HEESI) in 2021 (Ministry of Energy and Mineral Resources, 2021), wind energy can only supply 1,070,935 BOE. This is very far from hydro energy, which produces 45,947,523 BOE. The Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik—RUPTL) of State Electricity Company of Indonesia (Perusahaan Listrik Negara—PLN) targets 255 MW of wind energy in 2025. Still, only 135 MW of new power plants were installed by the end of 2021. Specifically for offshore wind turbines, Indonesia does not yet have offshore power plants, although the potential is quite large. Offshore wind projects can provide a larger energy supply than onshore projects because they can exploit Indonesia's vast ocean territory. In addition, offshore wind projects can also accelerate the transition to green energy.

In comparison to other nations, such as Denmark and the United Kingdom where wind speeds are around 8.5 m/s, Indonesia has a less windy source with an average wind speed of about 4 m/s (Global Wind Atlas, n.d.). This is also supported by research from the Hydrodynamic and Ocean Energy Laboratory of Hasanuddin University, which states that wind speeds in Indonesia vary but are generally classified as moderate, so it is recommended to build mobile rather than fixed system power plants (Mahmuddin et al., 2015). With such wind conditions, Indonesia can still produce energy with a significant output. According to Janis Langer, low-speed offshore wind turbines still have a high potential for profitability, with a technological capacity of more than 6,816 TWh annually and a levelized cost of electricity (LCOE) value of 20 US¢ (2021)/kWh (Langer et al., 2022). The Indonesian Wind Energy Association states that the total potential for wind energy power plants in Indonesia is 154.88 GW, with about 58.25% coming from offshore power plants (EMD International A/S, 2017).

In Indonesia, there is a lot of room for wind energy. Wind energy resources are scattered throughout Indonesia and are available on the southern coast of Java, the eastern region, including Maluku and East Nusa Tenggara, and the southern section of Sulawesi Island. In addition, some areas in Kalimantan, Sumatra, and Papua, especially in the archipelago, also have wind energy sources that can be converted into electrical energy and distributed, especially in remote and difficult-to-access areas with access to main electricity facilities (Martosaputro & Murti, 2014). This is in line with the potential mapping for wind energy sources from the Ministry of Energy and Mineral Resources (MEMR), which can be seen in Figure 2.3.



Source: Ministry of Energy and Mineral Resources (2021)

Figure 2.3 Map of the Wind Energy Potential in Indonesia

The green part indicates wind speeds of 4–6 m/s, and the red part indicates wind speeds above 6 m/s. According to Figure 2.3 (ESDM One Map, n.d.), the regions with the greatest potential for wind energy resources are the southern portions of Java and Kalimantan, the southern portion of Sulawesi, the eastern portion of Indonesia, including Maluku and East Nusa Tenggara, and the southern portion of Papua Island.

Analysis of the potential of offshore wind turbines in Indonesia produces different results by some researchers. The most influencing factor is wind speed, where the measured wind speed can differ. According to Fauzy et al.'s study (2021), which evaluates the possibilities for offshore wind farms in tropical nations, particularly Indonesia, the mean annual wind speed offshore Jeneponto and Water Island in 2015 was 8.51 m/s and 8.04 m/s. Additionally, each location's wind energy capacity factor and field availability indicate strong potential for the generation of wind energy. A high-capacity factor is obtained when using turbines with low cut-in and rated wind speeds, demonstrating that these characteristics may increase the effectiveness of offshore wind turbine power production. In addition, increasing the wind farm size can increase energy production and reduce the LCOE.

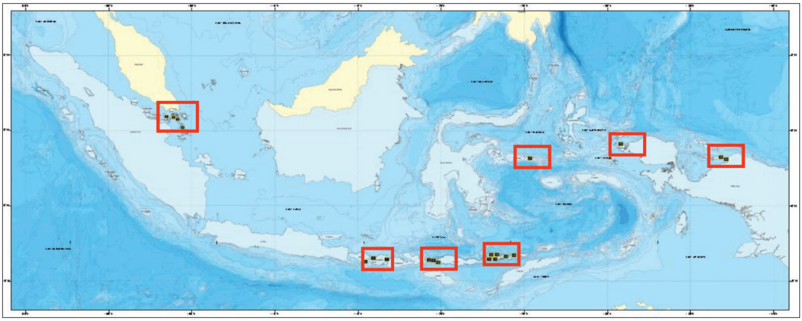
According to Nurlatifah et al. (2021), Indonesia is a promising location for the construction of offshore wind projects due to its average wind speed of 4–7 m/s. This value exceeds the cut-in value of the turbine, which is generally only 3–4 m/s. However, with such wind speed, the wind is unlikely to pass the rated speed. Thus, making the turbine unable to produce the maximum capacity. In terms of cut-off speed, no wind speed exceeds the cut-off speed. The recommended areas for offshore wind projects are Aceh, Southern Java, and South Papua because the seasonal monsoon circulation passes these areas. Indonesia's predominantly shallow waters show the economic viability of offshore wind turbine installations. According to Bosch et al. (2018), Indonesia has a potential of more than 2000 TWh/year in shallow water and 2000 TWh/year in transitional water. As for the total potential obtained (combining shallow, translational, and deep water), Indonesia has an offshore wind energy potential of 8318 TWh/year. This indicates that Indonesia has favorable conditions for developing affordable offshore wind turbines. Gernaat et al. (2014) estimated that the offshore technical potential of Indonesia is 53 EJ or equivalent to 4668 GW. However, it needs to be explained why the potential is so high, considering that the water depth is only limited to 80 m with a distance to shore of 139 km.

Other research by Pawara and Mahmuddin (2017) produced wind power density maps in the Maluku and Sulawesi areas each month in one year. The research found that in the Maluku and Sulawesi areas, the highest wind potential was in July, with a maximum energy density of between 416–463 watt/m^2 in the southern area of Maluku (Pawara & Mahmuddin, 2017). Another study by Purba et al. (2014) calculated the potential wind energy at several island points in Indonesia, namely Rondo, Berhala, Anambas, Biawak, and Miangas. These islands were chosen to represent the sea conditions where the islands are located. It was found that the maximum wind speed was on Rondo Island, with an average speed of 4.6 m/s and a maximum wind speed of 8.49 m/s. The power generated using a NEG Micon 2750 kW/92 m turbine is 1.5 MW (Purba et al., 2014). MEMR has identified several potential locations for building offshore wind turbines, including the Tanimbar Islands, Kupang, Sukabumi, and Jeneponto, with an estimated annual production of between 4–6 GWh (Balai Besar Survei dan Pengujian Ketenagalistrikan, Energi Baru, Terbarukan, dan Konservasi Energi, 2021).

D. Tidal Energy

The flow that happens in Indonesian region is caused by the "Great Ocean Conveyor Belt" or the thermohaline circulation since Indonesia is physically situated between the Pacific Ocean and the Indian Ocean. With a speed of 0.2–0.4 m/s, the global circulation travels over the Indonesian islands of Sulawesi, Kalimantan, Bali, and Nusa Tenggara (MEMR & INOCEAN, 2014). The thermohaline circulation causes a subcirculation on the Indonesian islands called the Indonesia Through Flow (ITF). This type of current, although small, can affect tidal energy sources considerably. Larantuka Strait and Boling Strait are examples of straits traversed by ITF currents (Firdaus et al., 2017).

The Ministry of Energy and Mineral Resource Republic of Indonesia (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2011) stated that the current speed on the coast of Indonesian waters is usually less than 1.5 m/s. However, in some places, for example, in the straits of Bali, Lombok, and East Nusa Tenggara islands, current speeds can reach 2.5 to 3.4 m/s. MEMR also recorded the strongest tides in Indonesia in the strait between Taliabu Island and Mangole Island in the Sula Islands, Maluku Province. Based on the map of the distribution of tidal energy in Indonesia, which can be seen in Figure 2.4, tidal energy in Indonesia is found in several locations, e.g., the Sunda Strait in southern Sumatra, southern Maluku, northern Papua, Riau Islands areas, and eastern Indonesia, such as Bali, Lombok, and East Nusa Tenggara.



Source: INOCEAN (2012)

Figure 2.4 Potential Site of Tidal Energy in Indonesia

Several kinds of research have been conducted to determine the amount of energy that can potentially be extracted from tidal sources in the particular region of Indonesia. One such research is by Orhan et al. (2015), which stated that the potential energy from the tides in the Larantuka Strait in East Nusa Tenggara is around 20 GWh per year, with power densities at some locations reaching 6 kW/m^2 with current speeds of more than 4 m/s. Further research by Orhan and Mayerle (2017) showed an increase in the average power density value to 10 kW/m^2, with an estimated power that can be technically extracted at 200 MW. In western Indonesia, Ikhwan et al. (2022) researched extracting tidal energy in the waters off West Aceh and stated that the total energy that can be converted into electricity in the waters is around 507.36 kWh per day, and it is highly possible to build a tidal turbine power plant.

In 2009, research by Aziz (2009) stated that the Alas Strait has a total potential energy of 329.299 GWh per year that can be extracted from tides with a depth range of 24 to 40 meters and 641.622 GWh with a depth range of 24 to 80 meters. This is in line with other research by Orhan et al. (2017) who studied several straits in Indonesia and stated that the Alas Strait has the potential for energy production, at around 2,258 MW. In the same research, Orhan et al. also stated that the straits studied, e.g., the Bali Strait, Larantuka, Boling, Alas, and others, can produce around 4,800 MW.

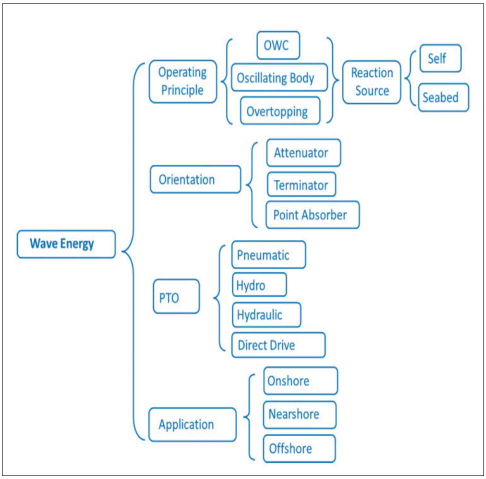
The development of tidal energy extraction in Indonesia is still in the research and prototype stage. Erwandi et al. (2011) conducted numerical ocean modeling to assess the potential of the marine current in several straits of Indonesian archipelago. The results were then used to design the rotor of the marine current turbine which was installed on the first-generation prototype with a capacity of 2 kW tested in Flores, East Nusa Tenggara, in 2010. The prototype was then continued to the second-generation turbine with a capacity of 10 kW and the third-generation with the same capacity (Kasharjanto et al., 2017). Another prototype has been tested by adopting the Gorlov turbine model with a capacity of 0.8 kW/unit (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2011). In December 2018, Indonesia also adopted the Tidal Bridge project in PLN's RUPTL and is in the feasibility study phase for constructing a tidal energy power plant in Larantuka with around 30 MW installed capacity and could generate around 80 GWh/year. Recently, world tidal energy company Nova teamed up with Institut Teknologi Sepuluh November, planning to deliver a feasibility study for 100kW tidal turbine that could further generate 7 MW electricity in Larantuka strait.

Installation of the existing power plant had been attempted. The specific turbine design ("Kobold") was installed in Lombok with grant support from the Italian government through partnerships as part of the project "Promotion and Transfer of Marine Current Exploitation Technology in China and South East Asia (Pilot Plants)" that promotes a vertical axis marine current turbine technology. Unfortunately, the project failed and was abandoned because there was no clear planning or project document, which resulted in a lack of funds, misalignment, and misunderstandings amongst the parties. The United Nations Industrial Development Organization (UNIDO) independent assessment report (2015) is a detailed report on the project.

E. Wave Energy

Wave energy is an important source of renewable energy. If exploited extensively, it can make a significant contribution to the electrical energy supply of countries with sea-facing coasts (Falcão & Henriques, 2016). In addition to the abundant wave energy potential in Indonesia, wave energy devices are new renewable energy that has high consistency compared to several other renewable energies. Ocean Wave Power Generation is a technology to capture wave movement and use it to create energy which is then converted into electricity. The amount of energy generated depends on the speed, height, and frequency of the waves, as well as the density of the water (Ocean Energy Europe, 2022).

In general, a typical classification for Ocean Wave Power Plant is divided into 4 basic components. Classification is based on (1) operating principle, (2) orientation, (3) power take-off (PTO) type, and (4) application of this wave energy device (see Figure 2.5). Based on several studies related to capacity factor (CF) for wave energy, it has a CF of 25% to around 40%, with a design life of 20 years. This CF is influenced by the type of wave energy conversion used and the potential of its application. One of the parameters to be considered in selecting the type of wave energy device is the level of efficiency of this technology (Qiao et al., 2020).

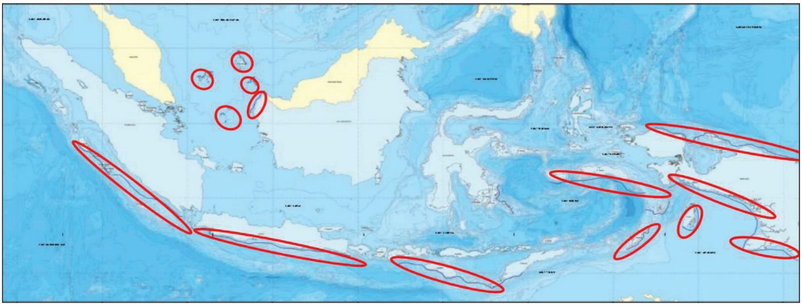


Source: IRENA (2014)

Figure 2.5 Summary in Outline of Typical Classification for Wave Energy

Globally, Asia is the continent with the largest potential for ocean wave energy among other continents, with a potential for 6200 TWh/year of wave energy (Qiao et al., 2020). Indonesia is a country in Asia with a geographical location that is surrounded by two seas, the Indian Ocean and the Pacific Ocean, making it have promising potential for the development of wave energy power plants (see Figure 2.6). The Indonesian waters off the southern coasts of Java and Nusa Tenggara have a potential for wave energy of 10 to 20 kW per meter wave, according to the Medium-Term Development Plan (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, 2015).

With this potential, Indonesia has begun to develop technology and commercialize wave energy extraction. In the early 2000s, the Agency for the Assessment and Application of Technology, Indonesia (BPPT) conducted research. It implemented a medium-scale prototype on Baron Beach in Yogyakarta as an educational vehicle (see Figure 2.7). This project or research project ended in 2006 due to changes in policy or research priorities. This activity was the first large-scale national research in Indonesia.



Source: INOCEAN (2012)

Figure 2.6 Potential Site of Tidal Energy in Indonesia

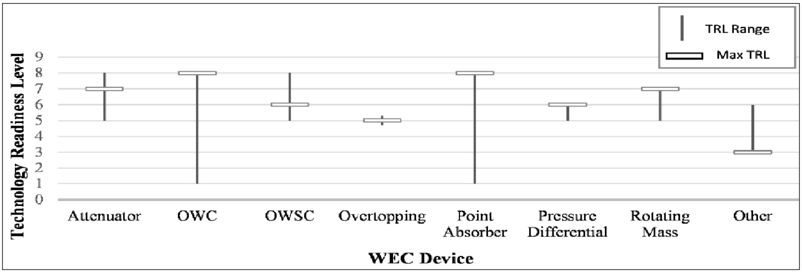
(a) (b)

Note: (a) Full scale trial of PLTGL at Baron Technopark for 2004–2005
(b) Full scale trial of PLTGL at Baron Technopark at 2006
Source: Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi (2016)

Figure 2.7 Testing of Wave Energy Harvesting Instruments by BPPT

Significant progress has been made in wave energy converters in recent years. There is increasing awareness in many countries, especially in Europe, that this technology will be ready for large-scale application in five to ten years (Cornett, 2008). Through PLN, the Indonesian government is considering and reviewing the implementation of sea current and wave energy power plants with potential in Bali, West Nusa Tenggara, and East Nusa Tenggara (PLN, 2021). At the end of 2022, the Swedish wave energy company, Waves4Power, and PLN Indonesia Power signed a memorandum of understanding (MoU) to develop the large-scale wave energy park or so-called WaveEL.

Based on several references, the Technology Readiness Level (TRL) for wave energy devices ranges from 1 to 8 (see Figure 2.8). The OWC and point absorber types of wave energy devices have the highest TRL compared to others. Wave energy devices, such as the OWC-type, which has been in operation for a long time, have demonstrated proven operational capabilities as a wave energy power plant. Therefore, this device can be said to be at TRL 9 (Mayon et al., 2022). The capital expenditure (CAPEX) of wave energy power plant technology is targeted to reach 3350 kEUR/MW in 2025 to enable the technology to meet the Strategic Energy Technology (SET) Plan target (with a capacity factor of 37%). Wave and tidal energy technology has lofty goals according to the SET Plan statement on marine energy. With a five-year delay, wave energy technology is anticipated to achieve the same goal, paying 15 EUR¢/kWh in 2030 and 10 EUR¢/kWh in 2035 (Magagna & Soede, 2019).



Source: Mayon et al. (2022)

Figure 2.8 Wave Energy Device Technology Readiness Level

The levelized cost of electricity (LCOE) for marine energy is lower than initially anticipated. The current wave LCOE is between 0.30 and 0.55 US$/kWh (IRENA, 2020). The results of a recent feasibility study on the development of wave energy technology and its implementation in eastern Indonesia conducted by PT Pembangkitan Jawa Bali (PJB), in conjunction with the Energy Study Center of UGM in 2022, shows that Southeast Maluku, Yamdena Island, has the potential for wave energy with slight to moderate characteristics. Wave energy in eastern Indonesia is typical of wave energy in Mutriku, Spain, or REWEC3, Italy. The study conducted in east Indonesia, focusing on the wave potential at Yamdena Island, Maluku, indicates an LCOE of $38.10 cents/kWh for an installed capacity of 1 MW. The LCOE is expected to decrease with an increase in the installed capacity, reaching cost parity with diesel power plants for installations exceeding 11 MW, at $16.25 cents/kWh. These results are consistent with the study by Australia's National Science Agency for the Wave Swell Energy project in 2021 that the projected LCOE of Wave Swell Energy (WSE) is around 0.5 US$/kWh for an installed capacity of 1 MW, although the potential waves with rough characteristics installed by WSE in King Island, Australia (Hayward, 2021).

E. Closing

This paper discusses Indonesia as an archipelagic country and its development potential to ocean renewable energy resources. As a commitment to help fight climate change, global warming, and carbon waste, Indonesia set a target to reach 23% of the renewable energy mix in 2025 and 31% in 2050. In order to achieve that target, Indonesia needs to maximize its renewable energy source potential. With a vast ocean area, Indonesia has a large amount of ocean renewable energy resources, including ocean thermal energy, offshore wind turbine, ocean wave energy, and tidal energy. Indonesia has several potential locations for OTEC energy, e.g., North Maluku, Mentawai, South Sulawesi, and Sunda Strait, with a total technical energy potential of 43 GW. In terms of offshore wind energy, several locations, e.g., South Sulawesi, West Papua, and East Nusa Tenggara, have promising wind energy potential with around 154.88 GW of energy that can be utilized. Larantuka Strait, Bali, Boling, and the Alor Island have a significant potential for tidal energy with an energy potential of around 4,800 MW. Ocean wave energy can be found along the southern coast of Java and East Nusa Tenggara, with a potential of around 10–20 kW per meter of the wave. Indonesia has also set government rules and plans, such as RUPTL and RUEN, in order to support ocean renewable energy development.

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