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# Assessing Tidal Energy Potential in the Visayas: Viability of the San Bernardino, San Juanico, and Cebu Straits

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***Abstract*— By laying the groundwork for sustainable tidal energy infrastructure, this study contributes to advancing the Philippines' renewable energy portfolio and supports the global transition to clean energy solutions. With the country's extensive coastline and rising energy demands, tidal energy presents a largely underutilized yet promising resource that can address both local and global energy challenges. Tidal energy is highly predictable, stable, and environmentally friendly, offering a reliable alternative to conventional energy sources like coal and natural gas, which are often subject to price volatility and environmental concerns. The study focuses on the Visayas region, a prime candidate for tidal energy development due to its dense population centers, major seaports, and high energy consumption. Integrating tidal energy into the national grid could reduce the Philippines' reliance on fossil fuels and lower carbon emissions. This research explores tidal stream turbines' potential, addressing challenges like maritime traffic and environmental considerations, while suggesting strategies for overcoming these obstacles. Ultimately, this study supports the transition to a cleaner, sustainable energy future.**

***Keywords—tidal energy, renewable energy systems, site viability assessment, Philippine Straits, marine energy potential***

## I. Introduction

With the rise of renewable energy the past decade, the world is shifting farther and farther away from fossil fuels. One promising renewable technology is Ocean Wave Energy, wherein it harnesses the energy from the waves and translates it to gears, which is then converted into electrical energy. According to Mørk et. al. the theoretical power production of wave energy is around 3.7 TW [1]. By utilizing at least 10% to 15% of that, it would be sufficient to meet the world's energy demands [2]. A way to utilize said energy is by converting the kinetic or potential energy of waves into mechanical energy via turbines. A sample diagram of a wave energy converter can be seen below.

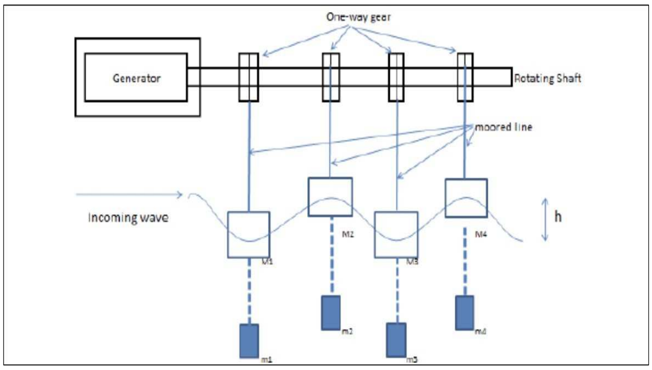


Fig. 1. One-way Gear Sea Wave Converter [2]

As one can see in Fig. 1 above, the force produced by the waves is used to move a pair of counterweights. These counterweights then rotate a one-way rotating shaft, thereby producing electricity via a generator.

Given that the Philippines is an Archipelago with the Eastern side bordering the Pacific Ocean, and the Western side, the West Philippine Sea, the coasts of the Philippines provide an untapped energy resource. A study conducted by Mindanao State University estimates that the potential ocean resource is around 170 GW [3]. Relative to other forms of renewable energy, tidal energy is predictable and stable compared to wind and even solar [4]. Thus, when applied at a larger scale, it can serve as a reliable source of clean energy.

## II. Literature Review

The viability of tidal wave energy systems has become a priority as countries like the Philippines collaborate with the world to meet energy needs while upholding environmental requirements. The Visayas region, with its extensive shoreline resources, holds significant potential. This section presents related literature on tidal energy systems, including key studies and their relevance to the Philippine context.

Khan, Moshref, and Bhuyan developed a dynamic modeling framework for ocean wave and tidal current energy conversion systems [5]. Building such systems is complicated because their approach is primarily theoretical and lacks site-specific information needed for regional evaluations. Jiala and Wu examined Fujian Province's coastal tidal energy resources, providing Philippine-applicable methods. Since their research focused on foreign coastal habitats, it ignored Visayas' unique hydrodynamic conditions [6].

Han et al. assessed Chudao Island's tidal and wave energy resources using high-resolution simulations to locate energy potential [7]. However, the study's findings cannot be generalized to the Philippines.

In another Philippine investigation, Abundo et al. constructed the tidal in-stream energy potential meter for a few sites. Due to its focus on Luzon and Mindanao, this investigation also neglected the Visayas [8].

Alquiza, Recto, Loresco, and Villalobos compared offshore wind converters and wave energy converters in the Philippines, including the Visayas. The viability and challenges of Visayas tidal wave energy systems, which may be used to evaluate renewable energy technology, were not addressed [9]. In another recent Philippine renewal energy study, Caballa and Recto examined solar system sustainability using life-cycle assessment methods. However, this method may not work for tidal energy research [10].

On the policy side, Recto, Gamara, and Neyra looked at the post-pandemic changes in ASEAN countries' energy consumption, economic expansion, and emission reduction on a larger scale. Their research emphasizes the interdependence of the sustainability, fairness, and security aspects of the energy trilemma, highlighting the significance of renewable energy sources like tidal energy [11], [12]. Additionally, in order to optimize tidal wave energy systems, Recto, Escoto, and Hernandez stressed the significance of quality improvements in power converter designs [13].

Indeed, the literature exposes several limitations in spite of these scholarly efforts. The distinctive features of Philippine coastal regions are not adequately captured by the generic models or international contexts used in many research. Localized assessments are hampered by the lack of data unique to the hydrodynamic and geological characteristics of the Visayas. Furthermore, whereas life-cycle studies and sustainability indicators have been used for other renewable energy systems, little is known about how they may be used for tidal wave energy. This study intends to fill in these gaps to further the conversation about renewable energy in the Philippines, especially in underserved areas like the Visayas.

## III. Geographical Analysis

Given the 266,000 km$^2$ of coastal area [14], the Philippines boasts a large coastal area that is important for fishing and trade. However, its vast coastal areas have not yet been harnessed for its energy production potential. To start off, an analysis of the geography must be taken to determine the best place to put tidal energy converters. The best scenario would be a place that not only has high tidal energy potential but is particularly close to a large coastal settlement, particularly one with a seaport as this can be an indicator of high energy demand.

Looking at the Fig. 2, one can see a large concentration of ports around the Visayas Island Group. This suggests increased maritime activity and higher populations around these areas. Thus, energy is an essential resource as it's used to power heavy equipment, lighting, transportation, etc. Another point of consideration would be the frequency of cyclone storm surges as constant variations in water height leads to variations in power generation from tidal converters [16].


Fig. 2. Philipppine Seaport Map [15]

Superimposing cyclone surge frequency with seaport data, the Fig. 3 shows that most seaports are protected from cyclone surges.

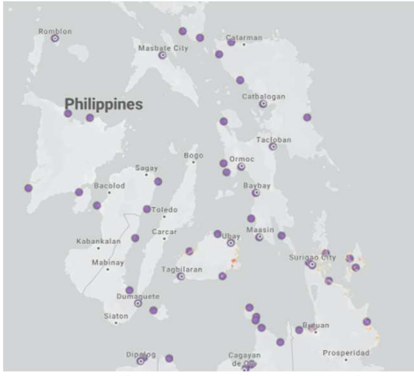


Fig. 3. Seaports vs. Cyclone Surge Frequency in Visayas Region [3]

With a majority of the Visayas region protected from cyclone surges, it is possible to put tidal wave energy systems around a majority of the coasts. Looking at the Fig. 4, the Department of Energy has outlined possible sites (blue areas) that can be used for tidal energy systems. However, more data and research is required to determine the viability of these sites. More specifically, the water current speeds at varying depths.

Fig. 4. Potential Tidal Energy Sites [17]

Given the time and resource limitations of this study, water current speeds can be inferred via water temperature maps as warmer waters tend to foster higher wind speeds and thus, higher surface current speeds [18]. Looking at Fig. 5, the Philippine seas boast high surface temperatures with peaks being seen in the Visayas Region. These areas also coincide with the proposed sites seen in Fig. 5.

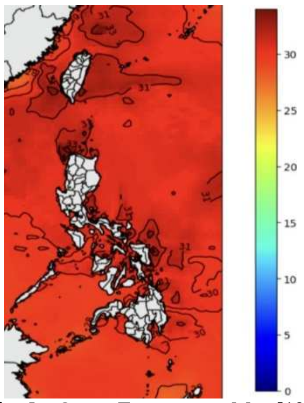


Fig. 5. Ocean Temperature Map [19]

Despite this, the tidal technology that can be applied by inferring temperature data is limited as it only accounts for surface current speeds. Peng et. al. states that the relationship between surface temperature and deep ocean currents remain inconclusive [18]. Thus, using temperature data to infer deep ocean current speeds may prove unreliable.

Lastly, the grid must also be considered, as it would be preferred if the proposed tidal energy system is closer to high energy demand areas such as deep seaports and metropolitan areas. Fig. 6 below shows areas in the Visayas Region with high energy usage density. The thicker the lines, the denser the electrical grid is and thus, higher energy demand.

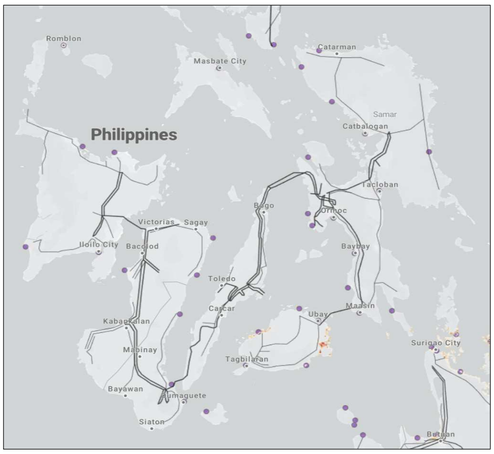


Fig. 6. Electrical Grid Map of Visayas Region [15]

As one can see, the Negros, Cebu, and Panay islands boast dense electrical grids. Furthermore, referring back to Fig. 4, one potential site outlined by the DOE is situated at the Cebu Strait. Thus, given the proximity to a large metropolitan area, a dense electrical grid, and being already marked as a potential tidal energy site, the Cebu strait can be a viable source of tidal energy.

However, despite its potential, constructing a tidal energy system in this area poses significant challenges. One key issue is the high volume of maritime traffic, largely due to the area's proximity to a major metropolitan hub and the port of Cebu. As shown in marine traffic data [20], much of the vessel movement in the Visayas passes through this strait, making it less suitable for tidal infrastructure deployment. More viable alternatives may include areas near Tacloban, the San Bernardino Strait, or the waters off North-Eastern Mindanao, based on the Department of Energy's outlined potential sites, their lower traffic density, and proximity to dense electrical grids.

## IV. Tidal Energy Systems

With the geography in mind, the next step is to identify the type of tidal energy system to be used. Currently, the two prominent types of tidal wave energy technologies are (1) tidal barrage and (2) tidal stream turbine.

### A. *Tidal Barrage*

Looking first at Tidal Barrages, the main premise of these systems consist of putting a dam-like structure in estuaries that experience high tidal currents. (See Fig. 7.) They utilize the potential energies of high tide currents falling down to low tide. The subsequent falling turns the turbines, thus generating electricity. Given that they are essentially dams at estuaries, they require substantial amounts of capital, resources, and environmental planning [22]. With the low number of estuaries present in the Visayas region, tidal barrages would not be suitable for capturing tidal wave energy.

Fig. 7. Example of Tidal Barrage Technology in La Rence, France [21]

### B. *Tidal Stream*

The next type is the Tidal Stream. (See Fig. 8.) This system makes use of the kinetic energy produced by the movement of underwater currents. These are like windmills, but instead of using wind currents, they use underwater currents to produce force in the turbines [23]. Compared to tidal barrages, they produce less power. However, given that these systems are formed in clusters, like wind turbine farms, they have less ecological impact as opposed to building a big, dam-like structure at an estuary [22]. Ecological issues may arise in their operation affecting the local marine life.

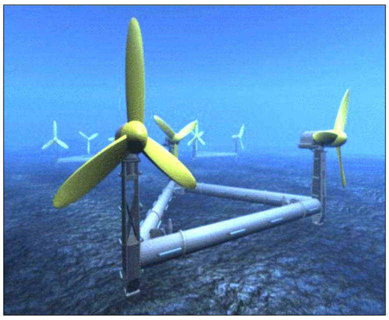

Fig. 8. Example of Tidal Stream Teachnology in the United Kingdom [21]

### C. *Use Cases in the Visayas*

Looking at a recent case, a new 1 MW tidal stream energy system is being installed near the island of Capul along the San Bernardino Strait. This system will be used to replace the off- grid, diesel generators used to power the small island town [24]. This system will utilize the HydroWing System, a bidirectional tidal turbine system [24]. (See Fig. 9.)

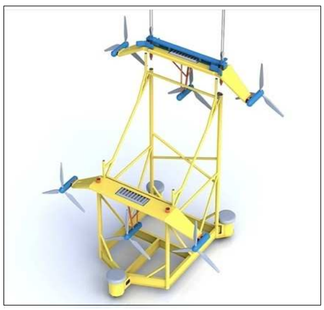

Fig. 9. HydroWing System, image via Tocardo [24]

The San Bernardino Strait, according to Blue Energy in 2004, is estimated to have a potential of 2.2 GW [25]. Given that Capul, at maximum demand, only requires 427 kW [24], the 1 MW tidal stream energy would be sufficient enough for the small island town.

Looking at the analysis conducted by Benitez and Danao, the current diesel engine has a cost of 24.01 Php/kWh. Contrast this with the various tidal stream turbines used in the analysis, the lowest cost system was only able to produce at 25.82 Php/kWh per unit while the most expensive yielded a cost of 64.47 Php/kWh per unit. However, with more installations, the LCOE will decrease further [3].

Comparing the LCOE of tidal energy systems with solar and wind, Ahmed et. al. shows the LCOE of solar PV between 2.5 Php/kWh and 5 Php/kWh and wind at 2 Php/kWh and 5 Php/kWh [26]. In terms of cost, the cheapest tidal energy system is roughly 5 to 10 times more expensive than solar and wind. The high costs can be attributed to the novelty and operation of tidal energy systems.

### *D. Proposed System*

Based on the preceding analysis, the San Bernardino Strait, the San Juanico Strait–San Pablo Bay near Tacloban City, and the Cebu Strait emerge as viable candidates for the deployment of grid-connected, submerged tidal energy systems. The viability criteria are as follows: Water Current Speeds, Proximity to shore and large-grids/population centers, and Proximity to maritime activity. All candidate areas have high water current speeds as inferred from Fig. 5.

Looking at the San Bernardino Strait, it is in a relatively low traffic area given that it is far away from a large metropolitan area. On one hand, this can serve advantageous as the installation and maintenance of a large-scale system will be easier. Meanwhile, given its distance from a large metropolitan area, a lot of the energy that it can produce will be wasted due to transmission loss. Outside of the stated criteria, this site shows greater social impact as it provides remote communities access to electricity.

Another viable site would be around the San Juanico strait or San Pablo Bay near Tacloban city. It is near a far more populated area, which helps reduce transmission loss, but also makes it harder to repair and maintain. One particular advantage that it has is that it is situated in between the two large islands of Samar and Leyte. Despite being the two biggest islands in the Visayas region, the combined usage of the two lags behind Panay, Negros and Cebu with a peak power consumption of 344 MW back in 2023 [27].

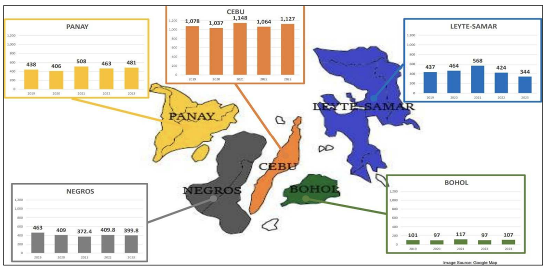


Fig. 10. Visayas Subgrid Electric Consumption [26]

Given that Leyte and Samar boast the lowest electrification rate amongst all the islands in the Visayas region, future efforts to bring it to complete electrification can be assisted by the tidal-stream energy systems. (See Fig. 11.)

Furthermore, given that the more turbines that are installed, the lower the LCOE, the addition of more units can greatly improve the energy equity in the area by lowering electricity prices.

Lastly, the Cebu strait also poses a viable site for a large scale, grid-connected tidal energy system. Similar to the San Juanico strait, the site is also close to a large metropolitan area, Cebu City. Given that Cebu City is the larger city, this means that the site will also experience larger maritime traffic. In addition to this, the site also needs to be larger in scale given that it powers a larger electricity consumer.

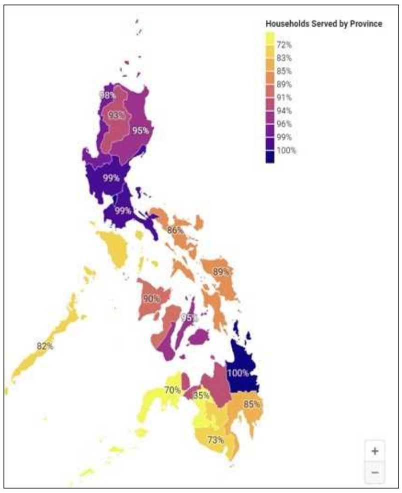


Fig. 11. Electrification Heat Map of the Philippines [28]

Taking all sites into account, the San Bernardino Strait offers wide space and low maritime traffic, making O&M easier, but its remoteness means high transmission losses. It is best suited for powering nearby communities such as Capul, serving as a test case for tidal technology before scaling to larger grids. The San Juanico Strait, near Tacloban, has lower transmission losses and could improve electrification in Samar and Leyte. The Cebu Strait, while facing heavier maritime traffic, is adjacent to a major urban center with high demand; tidal energy here could reduce electricity costs and support economic growth.

**Table I.** Comparative Analysis of Tidal Stream Sites

| Site | Current Speeds | Proximity to Cities/Grid | Proximity to Maritime Activity |
|---|---|---|---|
| San Bernardino | High | Low | Low |
| Cebu | High | Very High | Very High |
| San Juanico | High | High | Low-Medium |

## V. Conclusion

This study has identified the San Bernardino, San Juanico, and Cebu straits as promising candidates for tidal-stream systems based on key site characteristics and early feasibility indicators. It establishes a foundation for integrating small-scale tidal systems in Philippine coastal waters, with the HydroWing installation in Capul Island serving as a real-world reference for potential implementation. While further site-specific data and technical validation will enhance future deployment, the groundwork laid here demonstrates the practical potential of tidal energy as a less intrusive alternative to land-based renewable systems like solar PV and wind turbines.

## VI. Future Work

For future work, a more comprehensive multi-criteria analysis should be conducted. Additional criteria should not only focus on specific technical requirements such as water currents, transmission losses, but also focus on the policy side such as Marine Protected Areas and ecological impact of tidal stream systems, ensuring that they are not only a reliable and viable source of energy, but a sustainable one as well.

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