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A techno-economic assessment of wave energy resources in the Philippines

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ABSTRACT

The Philippines is currently addressing its growing concerns on how to meet its ballooning energy demand in parallel on having a good energy mix in terms of its renewable and non-renewable resources. As of 2016, according to the Department of Energy (DOE) of the country, roughly 76% of the Philippines' sources of energy came from fossil fuels and the remaining percent was mainly attributable to the renewables. Interestingly, ocean energy is still not part of the current energy mix.

The main focus of the study is to see the technical and economic feasibility of harnessing energy coming from waves. Specifically, this work intends to point out and quantify the potential sites to deploy Wave Energy Converters (WECs) relative to the resource profile of specific locations situated in the five coastal regions of the Philippines. Three WECs were assessed such as AquaBuoy, Pelamis and Wave Dragon in consideration of their advance Technology Readiness Level (TRL). Furthermore, data needed for estimating the resource potential of each site came from Surf-Forecast – a website providing wave profile forecast based on National Oceanic and Atmospheric Administration (NOAA) Wave Watch 3 (WW3) model. Data were gathered for one year on a 3-h interval per day. Meanwhile, prior to assessment, the data were first validated by the hindcast data of MetOceanView – a high resolution web-based weather forecasting tool using MetOcean Solutions Ltd WW3 Tolman Chalicov (MSL WW3 TC) wave model and NOAA Climate Forecast System Reanalysis (CFSR) for the wind model.

Results revealed that there is around 10 − 20 kW/m of wave energy flux scattered in various coastal areas of the Philippines. Lastly, the economic impact of developing wave project has been assessed considering base case, optimistic and pessimistic scenarios to be able to account for any possible uncertainties.

1. Overview of energy industry in the Philippines

The creation of Republic Act No. 9513, otherwise known as Renewable Energy (RE) Act of 2008 [1] has made a great impact on the Philippine energy sector. The law breathed life into the RE industry in meeting the ballooning energy demand of the country while decreasing its dependence on fossil fuels as a major source of energy.

However, as promising as it may seem, even after the formation of the RE Law, the country's reliance on fossil fuels is still evident and significantly higher in comparison with the renewable energy resource [2,3]. Nevertheless, there is still an increasing trend of REs in the installed capacity of the Philippines in spite of its continuous reliance on fossil fuels. In fact, the Philippine government is now on its way on how to further its advocacy on promoting clean energy resources as seen on the installation targets of the National Renewable Energy Program (NREP) for 2030 [4]. As reflected in NREP projections, the country is eyeing to tap more renewable resources, approximately 16 GW of installed capacity for hydro, biomass, wind, solar and ocean, which is three times its capacity on the year of 2010. Yet, ocean energy still seemed to be delayed in development in terms of MW capacity as compared with other renewables. As of the moment, the Department of Energy (DOE) has released official maps (Fig. 1) where different sites for Ocean Thermal Energy Conversion (OTEC), tidal-in-stream and wave energy have been identified.

In a study made by Mindanao State University, the resource potential for marine renewables in the Philippines is estimated to be 170,000 MW [5]. This was further studied by research groups from Marine Science Institute and the College of Engineering of University of the Philippines. They have started working together for the uptake of ocean renewable energy in the country by identifying potential sites for wave energy as seen in Fig. 2 [6]. But, it failed to quantify the resource potential of each identified locations.

Clearly, Figs. 1 and 2 explicitly show that there are gaps that need to be addressed in boosting the development of wave energy in the country. Such gaps resulted to lack of understanding on how it would impact the current energy mix which is dominated by fossil fuels. Some

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Nomenclature

a	amplitude (m)
ADB	Asian Development Bank
CAPEX	Capital Expenditure (USD)
CFSR	Climate Forecast System Reanalysis
DOE	Department of Energy
ERC	Energy Regulation Commission
ECMWF	European Centre for Medium Range Weather Forecasting
FiT	Feed-in-Tariff
f	frequency (s^{-1})
g	gravitational acceleration (m/s^2)
g_c	conversion factor ($kg\,m/N\,s^2$)
H_s	wave height (m)
IRR	Internal Rate of Return (%)
LCOE	Levelised Cost of Energy (USD/MWh)
MSL	MetOcean Solutions Ltd
NOAA	National Atmospheric Administration
NREP	National Renewable Energy Program
NPV	Net Present Value (USD)
NREP	National Renewable Energy Program
OPEX	Operational Expenditure (USD)
OSW	Oscillating Water Column
OTEC	Ocean Thermal Energy Conversion
PhP	Philippine Peso
RE	Renewable energy
ST	wave period (s)
TC	Tolamn Chalikov
TRL	Technology Readiness Level
USD	US Dollar
WEC	Wave Energy Converter
WW3	Wave Watch 3
λ	wavelength (m)
ρ	density (kg/m3)

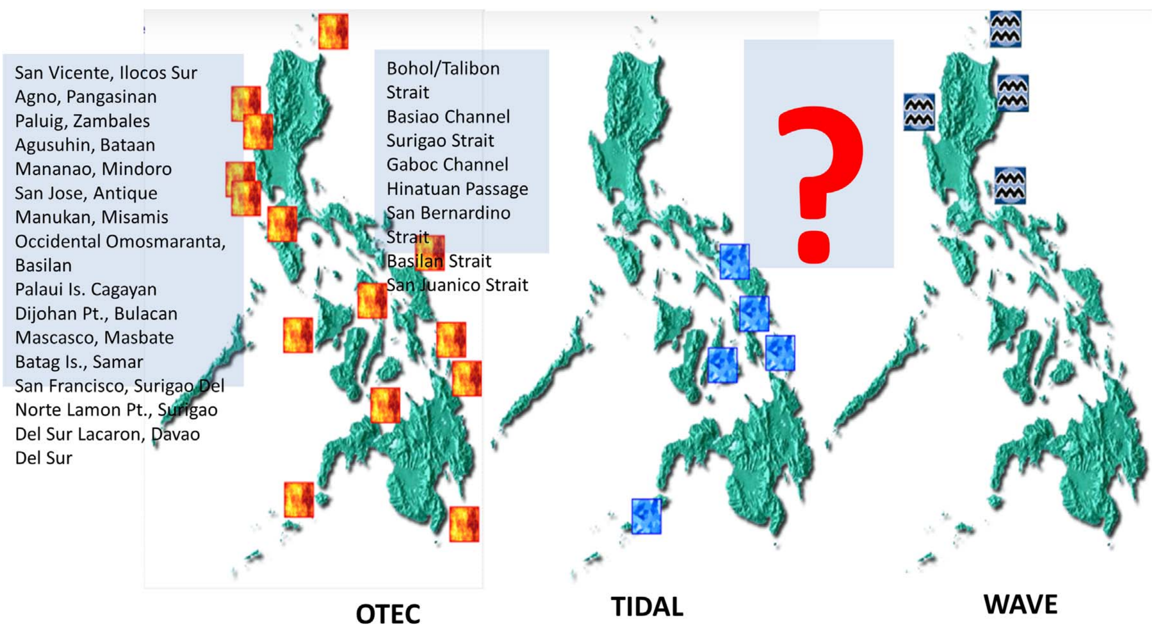

Fig. 1. Ocean energy resource map of the Philippines from the DOE.[1]

of these gaps are the following:

1. Methods for estimating the wave resource potential in a given location should be identified and accounted for applicability and replicability.
2. Current wave energy resource map is not sufficient to locate and estimate the wave potential of the country.
3. Wave resource variability needs to be considered and identified.

This study aims to be a springboard in quantifying and updating the previous studies stating the viability of ocean wave energy in the Philippines. Specifically, it aims:

1. To define a wave resource assessment methodology in estimating the resource potential in a given location;
2. To identify wave energy sites with an initial estimate of the energy that can be captured using a particular type of Wave Energy Converter (WEC);
3. To assess the economic viability of wave farm projects.

2. Review of wave energy

This section presents previous and current studies being conducted for the development of ocean wave energy, both in the Philippines and in an international level.

2.1. Wave energy resource

Basically, ocean wave energy is considered as a concentrated form of solar energy. Due to winds created because of the pressure differences in the earth's atmosphere, waves are produced. Said pressure differences are a product of differential solar heating.

In theory, wave energy is both functions of kinetic and potential energy. According to [7], the energy transferred from wind to water is a form of potential energy (mass of water in wave above sea level) whereas kinetic energy is the movement of water molecules in which the amount of energy transferred is dependent upon three factors such as the wind speed, the amount of time the wind is blowing and the distance over which the wind excites the waves, also known as “fetch”. Study shows [7] that the power potential of waves can be described as units of power per meter of wave crest length.