ENERGY TRANSITION PARTNERSHIP

Powering Prosperity and Enabling Sustainability in South East Asia

Marine Renewable Energy in the Philippines: Sustainable Energy from Ocean Spaces and Resources

A Stocktake and Options Report for the Philippines' Department of Energy

1 February 2023

UNOPS | AFD Agence Française de Développement | Federal Ministry for Economic Affairs and Climate Action | Department for Business, Energy & Industrial Strategy | Environment and Climate Change Canada / Environnement et Changement climatique Canada | CIFF Children's Investment Fund Foundation | IKEA Foundation | Sequoia Climate Foundation

This Stocktake and Options Report on Marine Renewable Energy for the Philippines is part of the efforts of the Southeast Asia Energy Transition Partnership in accelerating the shift towards modern energy systems, geared towards economic growth, energy security, and environmental sustainability. This paper aims to provide the necessary information to establish a starting point for the development of Marine Renewable Energy as a future sustainable low-carbon energy source in the Philippines.

This Report sets out and analyzes the following: (1) the various forms of indigenous marine renewable energy resources available in the Philippines, (2) the marine renewable energy technologies (e.g. marine floating photo-voltaics, tidal in-stream energy converters, wave energy converters, ocean thermal energy conversion systems, offshore wind, etc.) that may be suitable for the Philippines, (3) recommendations on the potential pathways, including policy and development support in harnessing clean energy from marine resource, and (4) collaboration opportunities with other forthcoming complementary marine renewable energy investment programs.

This Report is intended for use by the Philippines' Department of Energy.

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The Southeast Asia Energy Transition Partnership (ETP) brings together governments and philanthropies to work with partner countries in the region. ETP supports the transition towards modern energy systems that can simultaneously ensure economic growth, energy security, and environmental sustainability. ETP's strategy is built around four interrelated pillars of strategic engagement that are squarely aligned to address the barriers to the energy transition while contributing to the achievement of the UN's Sustainable Development Goals and the Paris Climate Agreement objectives. These are (i) policy alignment with climate commitments, (ii) de-risking energy efficiency and renewable energy investments, (iii) extending smart grids, and (iv) expanding knowledge and awareness building. ETP supported the development of this report in response to the Department of Energy's request made through the Energy Transition Council's Rapid Response Facility to study new and emerging marine renewable technologies.

Table of Contents

General Abbreviations

AM	Adaptive management
CAPEX	Capital expenditure
COP	The Conference of Parties
COC	Confirmation of Commerciality
CREZ	Competitive Renewable Energy Zone
DOC	Declaration of Commerciality
EBSA	Ecologically or Biologically Significant Areas
ECA	Environmentally Critical Area
ECC	Environmental Compliance Certificate
ECP	Environmentally Critical Projects
EEZ	Exclusive Economic Zone
EMF	Electromagnetic fields
EMP	Environmental Management Plan
EPC	Engineering, Procurement, and Construction
EPIRA	Electric Power Industry Reform Act
ESF	Environmental and Social Framework
ESIA	Environmental and Social Impact Assessment
ESS	Environmental and Social Standards
EVOSS	Energy Virtual One-Stop Shop
FDI	Foreign Direct Invetsment
FIT	Feed-In Tariff
FPV	Floating Solar PV
GAD	Gender and development
GDP	Gross Domestic Product
GEAP	Green Energy Auction Program
GEAR	Green Energy Auction Reserve Price
GEBCO	General Bathymetric Chart of the Oceans
GEOP	Green Energy Option Program
GHG	Greenhouse gas
GIS	Geographical Information System
GVA	Gross Value Added
GW	Gigawatt
GWA	Global Wind Atlas
GWp	Gigawatt Peak
HVDC	High Voltage Direct Current
INDC	Intended Nationally Determined Contribution/s
IRR	Internal rate of return
ISO	The International Standards Organization
LCOE	Levelized Cost of Energy
LGU	Local Government Unit
MDB	Multilateral Development Bank
MPA	Marine Protected Area
MRE	Marine Renewable Energy

MSP	Marine Spatial Planning
MTBO	Mean time between overhaul
MTBR	Mean time between repair
NDC	Nationally Determined Contributions
NREP	National Renewable Energy Program
OCSP	Open and Competitive Selection Process
ODA	Official Development Assistance
O&M	Operations and Maintenance Service
OPEX	Operational expenditure
ORE	Ocean Renewable Energy
OSHS	Occupational Safety and Health Standards
OSW	Offshore wind
PCM	Production Cost Model
PDA	Predetermined Area
PDP	Philippines Development Plan
PDP	Power Development Plan
PDS	Pre-Development Stage
PEISS	Philippine Environmental Impact Statement System
PEP	Philippine Energy Plan
PPA	Power Purchase Agreement
PSA	Power Supply Agreement
PURE	Productive Use of Renewable Energy
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
RESC	Renewable Energy Service Contract
ROI	Return on Investment
RPS	Renewable Portfolio Standard
SDG	UN-defined Sustainable Development Goal
TDP	Transmission Development Plan
TFEC	Total final energy consumption
TISEC	Tidal in-stream energy conversion
TRL	Technology Readiness Level
TPES	Total primary energy supply
UCME	Universal Charge for Missionary Electrification
UNFCCC	United Nations Framework Convention for Climate Change
WACC	Weighted Average Cost of Capital
WESC	Wind Energy Service Contract
WESM	Wholesale Electricity Spot Market

COMPANY AND INSTITUTE ABBREVIATIONS

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BFAR	Bureau of Fisheries and Aquatic Resources
BOI	Board of Investments
DBP	Development Bank of the Philippines
DENR	Department of Environment and Natural Resources
DND	Department of National Defense
DOE	Department of Energy
DOLE	Department of Labor and Employment
DOST	Department of Science and Technology
DOT	Department of Tourism
DOTr	Department of Transportation
DTI	Department of Trade and Industry
EICC	Energy Investment Coordinating Council
EMB	Environmental Management Bureau
EPIMB	Electric Power Industry Management Bureau
ERC	Energy Regulatory Commission
GWO	Global Wind Organization
GWEC	Global Wind Energy Council
IFC	International Finance Corporation
ILO	International Labor Organization
IRENA	International Renewable Energy Agency
MARINA	Maritime Industry Authority of the Philippines
MinDA	Mindanao Development Authority
NASA	National Aeronautics and Space Administration
NCIP	National Commission on Indigenous Peoples
NGCP	National Grid Corporation of the Philippines
NREB	National Renewable Energy Board
OES	Ocean Energy Systems - Environmental
PPA	Philippine Ports Authority
PCG	Philippine Coast Guard
Transco	National Transmission Corporation
UP	University of the Philippines
WBG	World Bank Group

Executive Summary

1 This Stocktake Report provides status of the Marine Renewable Energy (MRE) in the Philippines. It presents the various "readily available" and "emerging" MRE technologies that could help accelerate the country's transition towards clean and renewable energy. In this paper, MRE includes offshore wind (OSW), tidal in-stream, wave, ocean thermal energy conversion (OTEC), and marine solar energy.

2 The report presents the global context of MRE and then analyzes its potential in the Philippine context. The report includes the current status of MRE in the Philippines, a stakeholder map of the MRE sector, and the potential roles of MRE in the country's energy transition. It also discusses the international experience and learnings, which can be applied in the development of MRE in the Philippines especially with tidal in-stream energy. Moreover, this report identifies the opportunities and challenges related to MRE development in the Philippines. Its conclusion examines MRE from technical, economic, social, environmental and financial viability, and considers the institutional frameworks required to make MRE a reality for the Philippines. Finally, the report sets out recommendations and pathways for the development of MRE in the Philippines.

3 The MRE potential in the Philippines presents a strong opportunity based on the untapped resources: 178 GW of OSW potential, 266 GWp of marine floating solar potential (in only 1% of Bays and Coastal Areas), and 40 GW to 60 GW of tidal in-stream energy potential (35 TWh per year) as estimated by Buhali et al. (2012)[1]. Moreover, the World Bank (2005) reported that the Philippines has a potential wave energy resource of 33 kW per meter per year (kW/m/yr) from the Pacific and 35 kW/m/yr from the West Philippine Sea. The development of these potential resources has the opportunity to significantly address the gap between the energy supply and demand identified in the Philippine Power Development Plan (2021). It can also contribute to the target of 35% RE share in the power generation mix by 2030 and more than 50% by 2040 set by the National Renewable Energy Program (NREP) (Department of Energy, 2021). Thus, the potential offered by MRE in the Philippines can have a broad impact.[2]

4 MRE is still a relatively new and emerging technology for the Philippines. In terms of techno-economic feasibility, OSW will likely be the first to be developed, followed by marine solar and tidal in-stream. OSW can now be considered closely as a mature technology, with an individual turbine capacity reaching 15 MW.[3] Meanwhile, marine

[1] Buhali, M., Ang, M. R., Paringit, E., Villanoy, C., & Abundo, M. (2012). Tidal in-stream energy density estimates for pre-identified sites in the Philippines using a tide height difference-based metric. *2012 11th International Conference on Environment and Electrical Engineering*. https://doi.org/10.1109/eeeic.2012.6221450

[2] The NREB (DOE) has issued a Draft Circular Prescribing Amendments to Section 19 of the DC No. 2009-05-008 Entitled, Rules and Regulations Implementing RA No. 9513 for which can provide an opportunity for the inclusion of MRE throughout the document for industry development.

[3] World Bank. (April, 2022). "OSW Roadmap for the Philippines". Pgs 25-31. https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf

floating solar and tidal in-stream technologies are in the pre-commercial to commercial technology readiness levels. The uptake of emerging technologies such as OTEC, wave energy, etc. is expected to follow.

5 Table 1 shows the levelized cost of energy (LCOE) and technological maturity of the MRE technologies based on their Technology Maturity Level (TRL).

Table 1. Information on TRL and LCOE of MRE Technologies

Type of MRE Technology	LCOE (USD/kWh)	Technological Maturity Level
OSW	0.1511-0.15766	TRL 9 *Commercialized; Technology already operational over full range of expected lifetime conditions; Actual system proven through successful operations*
Marine solar	0.04-0.29	TRL 8* to some in TRL 9 **Actual system completed and qualified through test and demonstration in an operational environment*
Tidal in-stream (3 MW to 90 MW)[4] tidal in-stream (~12MW) [14]	0.13-0.28 0.20 – 0.45	TRL 7* to TRL 8 (some TRL 9) **System prototyping demonstration in an operational environment*
Wave (2 MW to 75 MW)[15] Wave (~3 MW) [14]	0.12-0.47 0.30 – 0.60	TRL 5* - 7 **System/subsystem/component validation in relevant environment*
OTEC (100 MW) [15]	0.15-0.28	TRL 4 - 6** ***System/subsystem model or prototyping demonstration in a relevant end-to-end environment*

6 MRE resources can be harnessed for a wide range of applications, including:
- Utility-scale electricity
- Off-grid, distributed power generation, island electrification
- Offshore energy applications, e.g., offshore energy platforms, monitoring stations, navigational systems, fish farms and other aquaculture developments
- Coastal operations and applications, e.g., wave breakers, ports
- Production of alternative fuels e.g., hydrogen
- Desalination and water production
- Green marine and maritime ecosystem development

7 These MRE systems are poised to become significant opportunities (not only for tapping clean energy resources but also for developing new industries, creating jobs, and more) for countries such as the Philippines, which have abundant marine areas with suitable characteristics. However, there are a number of challenges in bringing in these emerging technologies to a developing country like the Philippines. These include logistical challenges, technology awareness and adoption among the peoples of remote areas, and training and development of a new core of technology-capable engineers and

[4] International Energy Agency-Ocean Energy Systems. (2015). *International Levelised cost of energy for ocean energy technologies* https://www.ocean-energy-systems.org/documents/16823-international-levelised-cost-of-energy-for-ocean-energy-technologies-2015-may-2015.pdf/

technicians to support the emerging technologies. Nevertheless, these challenges can be overcome to establish these technologies as viable options for the Philippines.

8 Localized economic opportunities for MRE in the Philippines are considerable for both mature and emerging technologies. High potential locations exist throughout the country, many of which have been specifically identified in this paper. The sites are frequently adjacent to some of the poorest urban and rural regions in the country. The electricity generated by these projects can provide an immediate economic boost to those areas which, in many cases, desperately need enhanced electricity resource availability to improve economic activities. Additionally, MREs can introduce the localities to Productive Use of Renewable Energy (PURE), e.g. a Blue Economy[5] market to develop livelihood potential in aquaculture[6] and other associated industries, which can be a significant addition to the economic potential of the impacted area.[7]

9 In planning the development of the MRE sector by the DOE, there are synergies that can be taken advantage of such as, but not limited to the following: (a) data mapping of resources; (b) operations management; (c) common infrastructure development (e.g. grid connection points/substations for offshore cabling and cable landing); (d) planning and management tools and enabling technologies (e.g. Marine Spatial Planning, technology transfer and international collaboration); (e) sector development (e.g. supply chain, productive use, marine-based applications); (f) policy and regulation development for marine and offshore implementation (e.g. environmental, safety). These issues must be addressed through a comprehensive, coordinated, and holistic approach.

10 From a social perspective, the benefits of developing an MRE sector in the Philippines will have a significant positive impact on society. This includes the improvement in health services as more facilities can be built and adequately powered. MRE, being located in marine environments, presents opportunities for additional value in the otherwise underutilized marine area. For communities located in coasts and small islands in the Philippines, additional power availability could mean improved livelihood opportunities, which in turn can provide for adequate housing and educational opportunities. At a higher level, municipal services can also improve with increased power availability. This can start very simply, for example by providing more effective street lighting, all the way to infrastructure advances and the move of many urbanized areas towards “smart” initiatives. Perhaps the most important social benefit will be the expansion of jobs since MRE utilizes local resources and local labor force, and develops local supply chains. An example for coastal communities being involved in MRE would be the use of local marine vessels to visit MRE installations (e.g. for tourism, for maintenance, or for other purposes).

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[5] Blue economy rehabilitates and preserves marine ecosystems through clean technologies and MREs to sustainably use marine resources for economic activities (WWF, 2015).

[6] PIA (2021). https://pia.gov.ph/press-releases/2021/12/02/da-doe-scale-up-renewable-energy-use-to-boost-agri-fisheries-production

[7] “Aquaculture is the rearing of aquatic animals or the cultivation of aquatic plants for food. When used to produce fish, mussels, oysters, or similar organisms, it can produce high-quality protein with no need for land, fresh water, or fertilizer” (LiVecchi et al., 2019).

11 Utilizing MRE as a clean source of energy will help reduce greenhouse (GHG) emissions while ensuring energy security, and improve local economic and social conditions. In addition, developing MRE sources will have the potential to educate people on the environmental sensitivities of their immediate area. Given the efforts to shift to clean energy, and as they directly experience its benefits, they will be more inclined to take action in increasing their resilience to environmental shocks by making conscious efforts to safeguard and improve their local environment.

12 From a financial perspective, excluding OSW and marine solar, the other MRE options still require some strategic financial support mechanisms to make them financially viable. According to a 2020 Report by IRENA, the LCOE of tidal in-stream and wave technologies is at 0.20 to 0.45 USD/kWh and 0.30 to 0.60 USD/kWh, respectively. This is based on 10 ongoing tidal and wave projects with generation capacities from 1 to 6 MW. However, these projects are planned to be scaled up to capacities of 9 to 80 MW. With this, IRENA estimates that the benchmark LCOE value of 0.11 USD/kWh for tidal in-stream is possible when projects are scaled up to a minimum of 16 to 18 MW. This is due to the economies of scale achieved at these larger capacities, wherein the initial CAPEX can be leveraged across a broader user base. It is important to note that the ongoing portfolio of projects is deemed investable in that these values are expected to be achieved with their expansion to higher capacities.[8]

13 The reducing trends in the initial CAPEX planning requirements of MRE-inclusive projects make it more palatable when considering its applications other than for electricity generation. The electricity from MRE sources could be used for other services – e.g., water desalination, electric vessels, etc. Expanded capacities for ongoing MRE projects demonstrate that with the growth of capacity, greater leverage of CAPEX from pre-expansion phase/scan be achieved. This leads to a consistent global trend of LCOE reductions in upcoming projects.

14 From a policy perspective, the Philippine government and its agencies recognize the need to support the emerging opportunities presented by MRE. Significant legislation has been introduced to support investors in the efforts to encourage the development of the renewables sector. A major effort includes the recent drive by the government to remove the 60/40 law on Foreign Direct Investment (FDI) in the sector. This improvement is seen to increase the opportunity for FDI in the MRE sector.

15 From a national agency perspective, resources have also been mobilized to assist the MRE sector. For example, the National Renewable Energy Program (NREP) is an important driver for MRE. It has a target of 35% RE share in the power generation mix by 2030, and more than 50% by 2040.[9] The activities under NREP shall include programs and projects to facilitate compliance to the renewable portfolio standards (both off-grid

[8] IRENA (2020), Innovation outlook: Ocean energy technologies, International Renewable Energy Agency, Abu Dhabi

[9] Department of Energy. (2021). *Philippine Energy Plan 2020 - 2040*. Department of Energy. https://www.doe.gov.ph/pep/philippine-energy-plan-2020-2040.

and on-grid), conduct open and competitive selection processes for project sites, promote the green energy option program, and implement the green energy auctions.

16 Table 2 summarizes the opportunities, challenges, and next steps to undertake in the development of MRE in the country.

Table 2. Opportunities and challenges to MRE Technology Deployment in the Philippines

MRE Technology	Opportunities	Challenges	Proposed Next Steps
OSW	-178 GW potential -Mature technology -PH has good port infrastructure enabling construction and operation	-Inefficiencies in leasing and permitting -Limited opportunity for grid connection of early projects -Availability and interest of ports not established	-Improve leasing and permitting systems -Further analysis and verification to establish viable sites -Craft environmental and social impact assessment standards
Marine solar	-266 GWp potential (in only 1% of bays and coastal areas) -Mature technology -Hybrid systems with ocean renewable energy already competitive in small islands	-External political or commercial drivers may take precedence in identifying project opportunities for action -Leasing and permitting inefficiencies	-Craft a roadmap and framework for the long-term development of marine solar in the Philippines -Improve leasing and permitting systems
Tidal in-stream	-35 TWh/yr (40-60 GW) -High TRL -General downward trend in costs -Can leverage local shipbuilding and local supply chain	-Logistical challenges -Technological awareness and adaptation among locals -Training and development of tech-able engineers and technicians -Still requires subsidy to make the project financially viable	-Enhance capabilities for spatial assessment, preparation (including permitting and consenting) to the installation of equipment -More local implementation of international projects for learning experiences
Wave	-33 kW/m/yr from Pacific - 35 kW/m/yr from West PH Sea -Predictable energy source -General downward trend in costs	-Logistical challenges to bring in the equipment -Technological awareness and adaptation among locals -Training and development of tech-able engineers and technicians -Still requires subsidy to make the project financially viable	-Research and development and desktop-based studies; developmental and exploratory efforts by Department of Energy (DOE) -Enhance capabilities for spatial assessment, preparation (including permitting and consenting) for installation of equipment -More local implementation of international projects for learning experiences
OTEC	-Abundant for archipelagic areas -General downward trend in costs -Multi-product eco-resort with clean energy,	-Low technological maturity; high capital expenses -Logistical challenges to bring in the equipment	-Enhance capabilities for spatial assessment, preparation (including permitting and consenting) to the installation of equipment

MRE Technology	Opportunities	Challenges	Proposed Next Steps
	freshwater, aquaculture, and air conditioning an attractive concept for tropical archipelagoes using OTEC technology	-Technological awareness and adaptation among locals -Training and development of tech-able engineers and technicians -Tariff required to have acceptable ROI -Lack of reference projects to determine tariff value	-More local implementation of international projects for learning experiences

17 The key recommended next steps to enable and accelerate the development of MRE in the Philippines are as follows:

a. MRE development roadmapping
b. Resource inventory and marine spatial planning
c. Establishment and refinement of market support mechanisms
    i. Improved access to subsidies for off-grid markets
    ii. Opening up access to finance for early-stage projects
    iii. Setting of appropriate rates (e.g., GEAR Price, support rates etc.)
d. Capacity building of financing and investment institutions
e. Appropriate education and training for key stakeholders
f. Whole-of-nation approach

I. Introduction

18 The Philippines is the third largest economy in Southeast Asia with a GDP of $390.4 billion in 2019. Although with a quickly growing population of over 109 million people, its economy has consistently performed well for the past six years at an average of 6.5% growth in GDP per annum.[10]

19 The Philippines faces various challenges related to energy security. The country heavily relies on expensive imports of fossil fuel and coal for power generation. Conventional power plants have increasingly resulted in unnecessary supply interruptions and unplanned shutdowns, which are caused by fluctuating prices among others. Accordingly, efforts have been initiated in its energy transition program to empower renewable and sustainable sources.

20 The Philippines has institutionalized the use of renewable energy (RE) through Republic Act 9513 or the Renewable Energy Act of 2008 in order to: (1) accelerate the assessment and development of renewable energy; (2) increase the utilization of renewable energy; (3) support the development and use of renewable energy resources as tools to lessen harmful emissions; and (4) build necessary infrastructure and mechanisms to support renewable energy development.

21 The national government has been updating its national plans to accommodate RE. One such change is the recent 2021 update on the Power Development Plan (PDP) to incorporate the National Renewable Energy Program (NREP) 2020-2040's ambitious 35% renewable energy share in the power generation mix by 2030 and more than 50% by 2040.[11] The NREP shall include programs and projects such as the Renewable Portfolio Standards (RPS) for both off-grid and on-grid generation, Net Metering, Green Energy Option Program (GEOP), Green Energy Auctions Program (GEAP), and development of 25 competitive RE zones, among others. Other efforts include those from the Electric Power Industry Reform Act (EPIRA), such as the Retail Competition and Open Access (RCOA) initiatives. Finally, it is worth noting the Microgrid Act, which seeks to encourage microgrid development for remote communities without access to power, or those with power available for less than 24 hours. These are all intended to bring a clean energy transition, leading to uninterrupted and stable power supplies from widely accessible and sustainable energy sources.

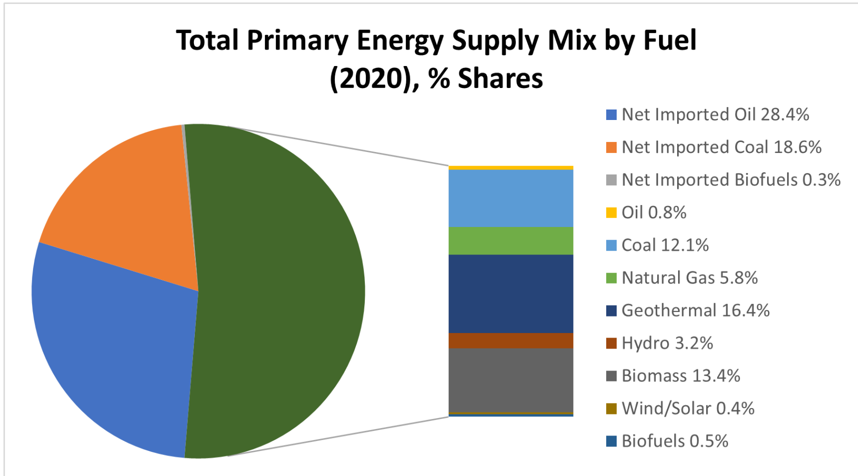
22 Despite such commitments and plans, substantial change is yet to be seen. In 2020, the total primary energy supply (TPES) fell to 56.4 MTOE, which is 5.8% lower than the 2019 level of 59.9 MTOE. This is largely due to the fundamental changes caused to the economy by the COVID-19 pandemic. During this period, coal overtook oil as the

[10] Philippine Statistics Authority (PSA) https://psa.gov.ph/

[11] Department of Energy. (2021). *Philippine Energy Plan 2020 - 2040*. Department of Energy. Retrieved November 10, 2021, from https://www.doe.gov.ph/pep/philippine-energy-plan-2020-2040

country's biggest energy source with 30.8% share, compared to oil's 29.2% share. The image below shows the TPES by fuel share, in percentage.

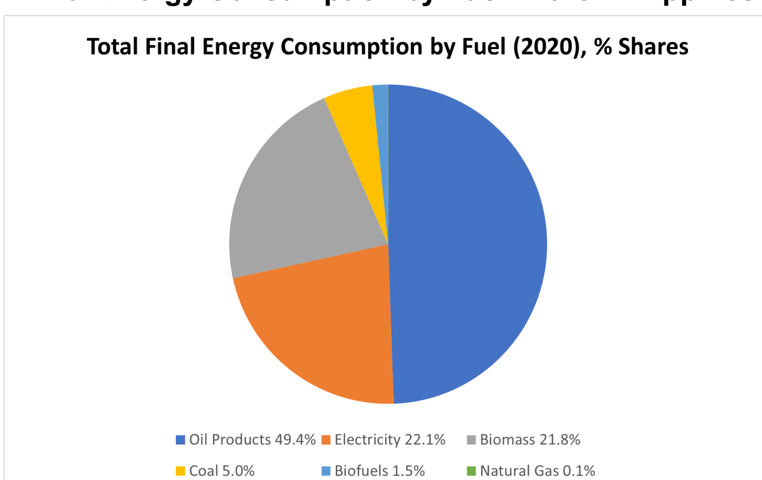
Figure 1. Total Primary Energy Supply Mix by Fuel in the Philippines (2020)



Some important facts about the energy consumption of the Philippines include:

- The total indigenous energy supply of the country reached 29.67 MTOE, equating to approximately 52.6% energy self-sufficiency. The country's net energy imports in 2020 declined by 7.8% due to COVID-19's disruption in global trade.
- The country's total final energy consumption (TFEC) is 32.4 MTOE.
- Oil remained the largest supply of energy, with 49.4% share (16 MTOE) in 2020.
- The 2020 demand for oil was attributed to the country's transport sector.
- After oil, leading demand included electricity with 22.1% (7.2 MTOE) and biomass at 21.8% (7.06 MTOE). Coal was 5% (1.6 MTOE) (see Figure 2).

Figure 2. Total Final Energy Consumption by Fuel in the Philippines in 2020



23 Increasing population will further multiply the country's future energy demand. However, the national grid's capacity has not kept pace with increasing energy demand, resulting in delays in the implementation of renewable energy projects. Consequently, blackouts and power outages are experienced regularly in some parts of the country. Moreover, in contributing to enhanced energy security, further diversification of the domestic energy mix is needed.

24 Despite the above challenges, the Philippines has abundant RE resources due to its geographic location and natural resources. Specifically, its archipelagic feature of over 7,000 islands in Luzon, Visayas, and Mindanao is surrounded by abundant natural resources, including its ocean space. Despite these natural energy resources, the country's energy system is still largely carbon-based, with decarbonization and renewable energy development and innovation moving at a slow pace. This also contributes to the barriers in meeting the country's targets to sustainable development goals.

25 One of the notable efforts that the Philippines has committed, which would support cleaner energy, is its submission of ambitious Nationally Determined Contribution (NDC) targets in accordance with the 21st Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC). The target GHG emission reduction is envisioned at 75%, with 2.71% as unconditional and 72.29% as conditional on international assistance.

26 The Department of Energy (2020) created a new program addressing Energy Investment Opportunities in the Philippines as a way to examine and report the investment opportunities in different energy sectors. For the renewable energy sector, it was reiterated that the NREP was established to increase the renewable energy-based installed capacity of the Philippines. It states that for the period 2020 to 2040, its goals are for 35% renewable energy generation by 2030 and 50% by 2040. Specifically, for OSW energy, the 2040 target is 3GW to 21GW[12]. As of 30 September 2022, there have been 26 OSW service contracts[13] and eight ocean service contracts awarded[14].

[12] The World Bank. (2022). https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf

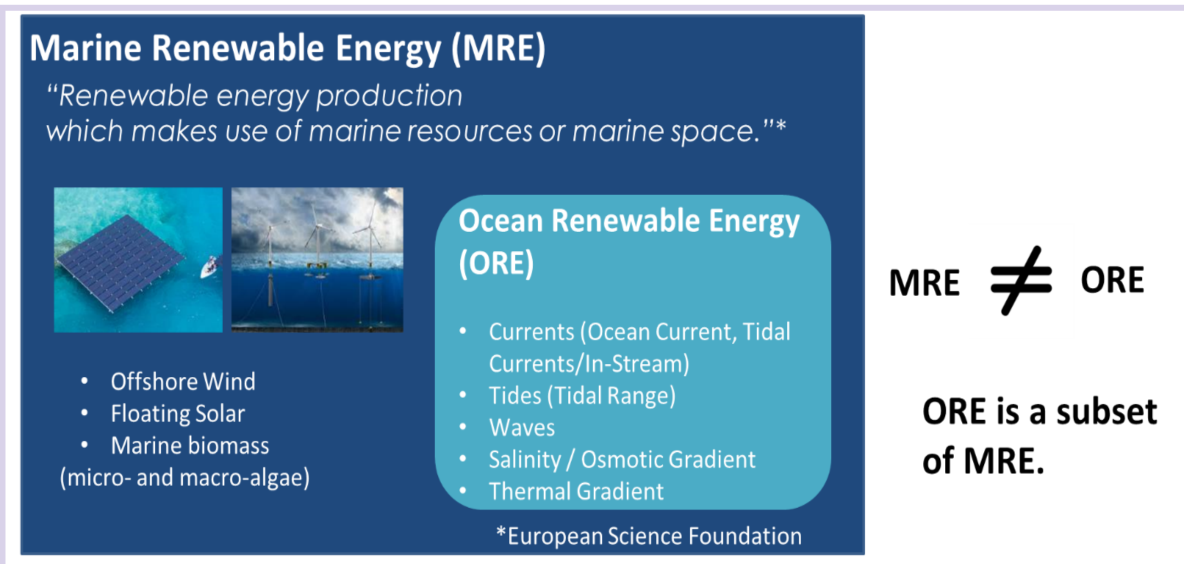
[13] OSW Service Contracts as of September 30, 2022. Retrieved 11 January 2023 from https://www.doe.gov.ph/renewable-energy/renewable-energy-service-contract-resc-application-requirements?q=renewable-energy/awardedwind

[14] Ocean Renewable Energy Service Contracts as of September 30, 2022. Retrieved 11 January 2023 from https://www.doe.gov.ph/renewable-energy/renewable-energy-service-contract-resc-application-requirements?q=renewable-energy/awardedocean

II. Marine Renewable Energy

27 Marine Renewable Energy (MRE) is defined by the European Science Foundation (2010) as "renewable energy production which makes use of marine resources or marine space," (p.4) such as OSW, marine solar, and ocean renewable energy (ORE). As a subset of MRE, all forms of energy that can be derived directly from the resources of the seas and oceans can be collectively called ORE, wherein its technologies include currents (i.e., ocean, tidal in-stream), tidal range, wave, thermal gradient, and salinity gradient. This relationship is shown in Figure 3.

Figure 3. Marine Renewable Energy and Ocean Renewable Energy



Source: Abundo, M. (2021, May 21). Harnessing Marine Renewable Energy. ADB Knowledge Event Repository. http://events.development.asia/learning-events/harnessing-marine-renewable-energy

28 Given the already existing challenges in competing for land space and other developments, utilizing offshore areas has high potential for renewable energy generation. The following are the types of MRE considered in this paper:

a. ***Offshore wind***. Instead of occupying vast land space to develop onshore wind farms, OSW power utilizes offshore/marine areas which are far from any populated or residential areas. In comparing OSW sources with onshore, the former gains "better quality of the wind resource in the sea, where wind speed is usually bigger, even increasing with the distance to the coast, and more uniform (softer), leading to less turbulence effects."[15] The World bank has issued a comprehensive report in April 2022 documenting a development [Roadmap for OSW Energy](https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf).[16] The World Bank study looks at the opportunities and challenges from the perspective of two scenarios, a low growth and a high growth scenario.

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[15] Esteban, M. D., Diez, J. J., López, J. S., & Negro, V. (2011). Why OSW energy? *Renewable Energy*, *36*(2), 444–450. https://doi.org/10.1016/j.renene.2010.07.009

[16] The World Bank. (2022). OSW Roadmap for the Philippines.World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf

Both scenarios have similar timeframes for the roadmap, lasting from 2022 until 2050.

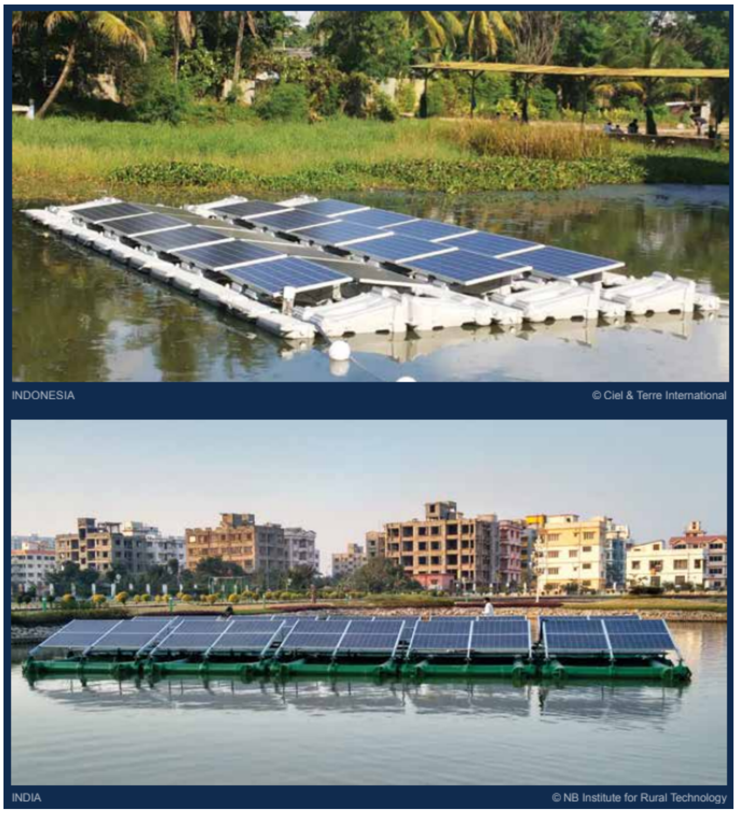
The first scenario is a "Slow Growth" scenario while the second is the "High Growth" scenario. The roadmap considers similar factors needed to enable growth. The difference is in the actions undertaken, finances committed, and the resulting growth which is projected by the end of the horizon. Considering the low growth scenario, the World Bank projects the cost of energy reductions over time, reaching an estimate of US$77 per megawatt-hour for fixed projects in 2030 and US$61 per megawatt-hour for floating projects in 2040, by which time 83 terawatt-hours will have been generated. Considering the high growth scenario, the cost of energy reduces over time, reaching an estimated US$76 per megawatt-hour for fixed projects in 2030 and US$47 per megawatt-hour for floating projects in 2040, by which time an estimated 393 terawatt-hours will have been generated. The 20 percent lower LCOE than in the low growth scenario is due to (a) a faster reduction of the initial costs of starting in a new market, and (b) a lower weighted average cost of capital (WACC) from the expectation of more foreign investment and reduced risk under the high growth scenario.

b. ***Marine solar.*** (e.g. with floating solar PV technology or other marine deployments of solar technologies) harnesses solar energy resources in the marine environment which presents an opportunity for higher efficiencies in terms of power/energy output (i.e. reported >10% improvement) similar to what has been reported and observed in floating solar PV (FPV) deployments on freshwater bodies. It may be fixed (attached to a fixed structure) or floating on the body of water, i.e., similar to the typical solar panel systems, the panels are affixed to a support structure (e.g., fixed pile, floating platform), which may be secured/fixed (e.g. piling, moored, anchored, etc.) onto the seabed layer. Marine installations need more robust infrastructure due to the harsher conditions of open seas compared to rivers and lakes, as well as for protection against marine growth. Wang and Lund[17] noted in their 2022 study that there are many benefits to FPV in the marine environment. However, these advantages come with clear challenges. Wang and Lund note that development work is in progress to adapt PV systems to offshore/marine environments. This includes PV modules and understanding the effect of environmental factors on PV systems. One of the challenges to deploying solar PV offshore, is the variety of harsh and challenging sea conditions, including high humidity, high salt fog, strong corrosion, powerful lightning, and strong typhoons, all of which need to be considered in the framing and anchoring strategies. Wang and Lund note several strategies have already been incorporated around the world to overcome these challenges. However, remedial actions can significantly increase the cost of the development of the offshore PV system. This includes the implementation of breakwaters, grid connectivity systems, and others. The detailed calculation of USD/MWh is in its

[17] Wang, J.; Lund, P.D. Review of Recent Offshore Photovoltaics Development. Energies 2022, 15, 7462. https://doi.org/10.3390/en15207462

infancy, as noted in Ghigo et al, 2022.[18] Nevertheless, they have undertaken a techno-economic analysis using data available from three specific installations in 2022. The findings suggested an average LCOE of 156 USD/MWh. This is then compared to a large-scale grid-connected Solar PV LCOE value of 57 USD /MWh, according to IRENA.[19] According to Wang and Lund, the higher cost is due to a number of factors including the presence of a more complex system, which requires the use of a mooring system and anchors, of the submarine cables and requires more frequent and complex O&M activities, in addition to being a technology not yet consolidated, with a higher level of risk and uncertainties

Figure 4. Marine Solar Technology



Source: World Bank Group; ESMAP; SERIS. Where Sun Meets Water: Floating Solar Market Report - Executive Summary (English). Washington, D.C. : World Bank Group. [*http://documents.worldbank.org/curated/en/579941540407455831/Floating-Solar-Market-Report-Executive-Summary*](http://documents.worldbank.org/curated/en/579941540407455831/Floating-Solar-Market-Report-Executive-Summary)

[18] Ghigo, A.; Faraggiana, E.; Sirigu, M.; Mattiazzo, G.; Bracco, G. Design and Analysis of a Floating Photovoltaic System for Offshore Installation: The Case Study of Lampedusa. Energies 2022, 15, 8804. https://doi.org/10.3390/en15238804

[19] IRENA. Renewable Power Generation Costs in 2020; Technical Report; International Renewable Energy Agency: Abu Dhabi, United Arab Emirates, 2021. Available online: https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

c. ***Ocean Renewable Energy***

i. *Currents* (e.g., ocean currents, tidal streams) in this system, energy is extracted from the currents by placing in-stream energy conversion systems such as hydrokinetic turbines. The energy conversion/production process is similar to wind turbines where the kinetic energy of the fluid is converted into mechanical energy and subsequently electrical energy as the turbine rotates.

- *Tidal in-stream* The movement of ocean water volumes, caused by the changing tides, creates tidal current energy. Tides cause kinetic movements, i.e., reversing current flows, which can be accelerated near coasts, where there is constraining topography, such as straits between islands.[20] tidal in-stream has a global potential of more than 800 TWh/yr.

- *"Ocean currents* are generated from a combination of temperature, wind, salinity, bathymetry, and the rotation of the earth. The sun acts as the primary driving force, causing winds and temperature differences that impact currents. Because ocean currents are fairly constant in both speed and flow and carry large amounts of energy, there are many suitable locations for deploying energy extraction devices such as turbines.[21]"

- *Deep Ocean Current* is a new system that utilizes the continuously flowing deep ocean currents. This allows for the development of larger tidal turbines since the turbines can be installed in the deep sections of the oceans.[22]

Figure 5. Ocean current energy Technologies

Sources: Sustainable Marine, https://www.sustainablemarine.com/ (left); Altum Green Energy, https://altumgreenenergy.com/ (second left); Andritz Hydro Hammerfest, https://www.andritz.com/resource/blob/31444/cf15d27bc23fd59db125229506ec87c7/hy-hammerfest-data.pdf (third left); Nova Innovation, https://www.novainnovation.com/about-nova/nova-innovation/ (right).

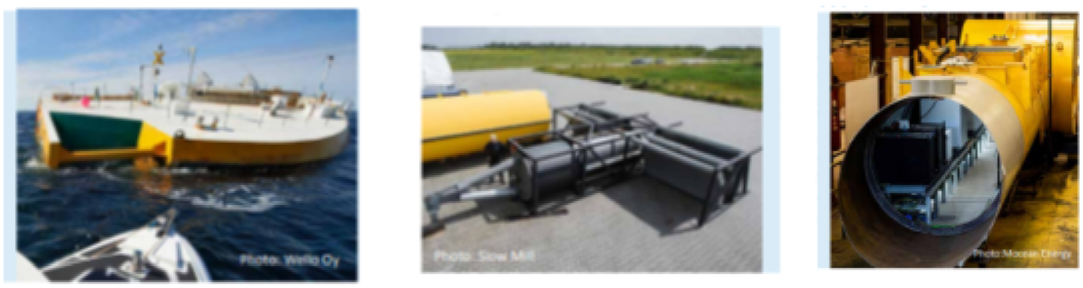
[20] OES. (2021). https://www.ocean-energy-systems.org/documents/42658-tidal-current-energy-highlights-april-2021.pdf/

[21] OES. (n.d.). https://tethys.pnnl.gov/technology/ocean-current

[22] International Energy Agency. (2021). *What is Ocean Energy*? Ocean Energy Systems - International Energy Agency. https://www.ocean-energy-systems.org/ocean-energy/what-is-ocean-energy/.

- *Wave* energy systems utilize the movement of the ocean surface caused by wind systems. Resulting pressure fluctuations from below the ocean surface can also be exploited. Due to the development of floating wave energy converters, the potential of this system increases rapidly since it can be deployed anywhere on the surface of the world's ocean where wave resources are present (Global potential: 80,000 TWh/yr).[23] Full-scale prototypes have been tested and verified.[24,25]

Figure 6. Wave Energy Technologies



Source: Ocean Energy Europe. (2022). Ocean Energy Key Trends and Statistics 2021.

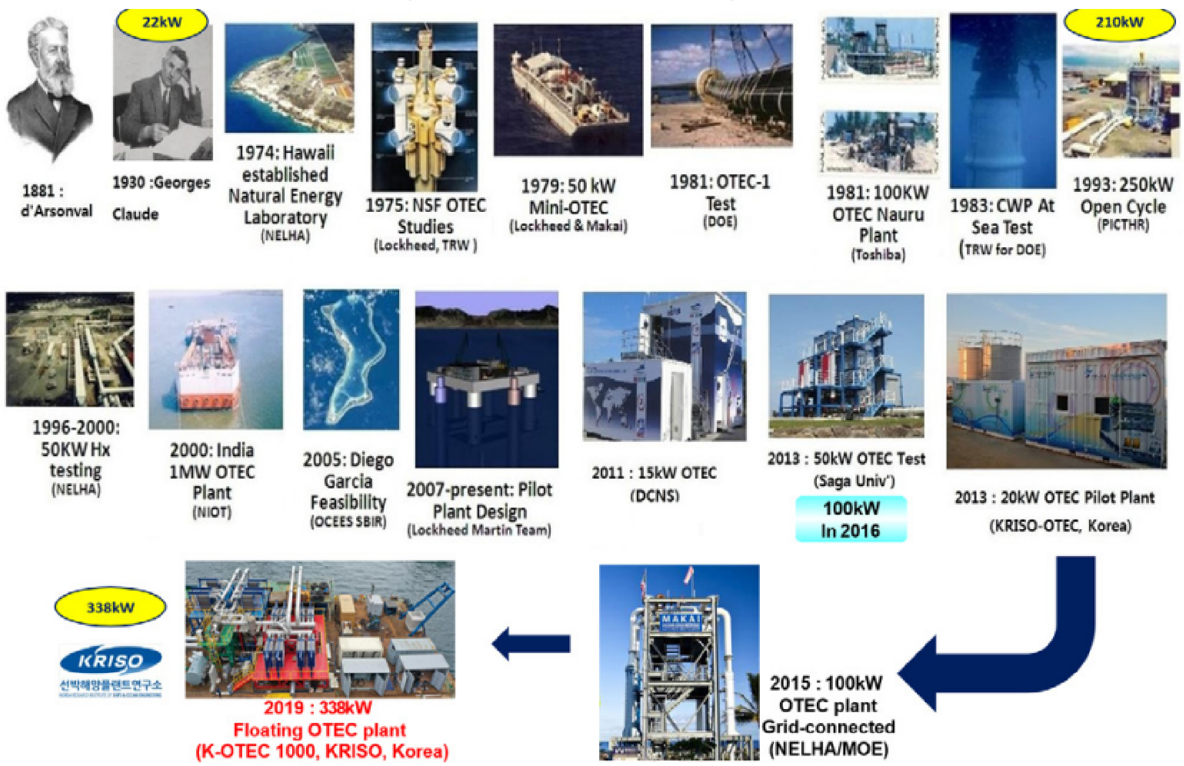
[23] International Energy Agency. (2021). *What is Ocean Energy*? Ocean Energy Systems - International Energy Agency. https://www.ocean-energy-systems.org/ocean-energy/what-is-ocean-energy/.

[24] IRENA. (2014). Ocean energy: Technology readiness, patents, deployment status, and outlook. International Renewable Energy Agency. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/IRENA_Ocean_Energy_report_2014.pdf.

[25] IRENA. (2020). Innovation outlook: Ocean energy technologies. International Renewable Energy Agency. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Innovation_Outlook_Ocean_Energy_2020.pdf

ii. *Ocean Thermal Energy Converters (OTEC)* use the temperature difference between the ocean surface (warm) and the deep seawater (cool), which can be used to drive a heat engine (Global potential: 10,000 TWh/yr).[26] Power is generated based on the thermodynamic principle of a Rankine cycle. In addition to generating electricity, the OTEC power cycle can also be configured to produce freshwater during the energy generation process. The figure below presents an overview of the development pathway of OTEC applications through time.

Figure 7. OTEC Technologies



Source: OES (2021), White Paper on OTEC (OTEC). IEA Technology Programme for Ocean Energy Systems (OES), www.ocean-energy-systems.org.

[26] IRENA. (2020). Innovation outlook: Ocean energy technologies. International Renewable Energy Agency. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Innovation_Outlook_Ocean_Energy_2020.pdf

iii. *Tidal Range/Barrages* uses a large dam-like structure that houses tidal turbines. The structure, called a barrage, allows water to enter and exit the turbines with the ebb and flow of water due to the nature of tides (Global potential: 300+ TWh/yr).[27] Although already commercially installed and economically viable in certain geographies with >4m tidal range (e.g. Canada, France, UK, South Korea), the development and deployment of projects involving tidal range/barrage technology have not been progressing because of its potential adverse impacts on the environment.

Figure 8. Tidal Range Technology: Rance Tidal Power Station in Brittany, France

Source: https://modernize.com/wp-content/uploads/2015/12/Tidal-Barrage.jpg

iv. *Salinity Gradient* uses the difference in salt concentration between seawater and freshwater (chemical potential) to allow ion movements from high to low concentration (Global potential: 10,000 TWh/yr).[28] Deployment and use of salinity gradient technologies have been limited to energy recovery and co-application use because of the associated costs for the current stage of technology.

(*Note: Tidal Range/Tidal Barrage and Salinity Gradient technologies are not discussed further in this paper since both technologies are still in the early stage in terms of Technology Readiness Level to be substantially considered for the Philippines.)*

[27] IRENA. (2020). Innovation outlook: Ocean energy technologies. International Renewable Energy Agency. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Innovation_Outlook_Ocean_Energy_2020.pdf.

[28] Ibid.

III. Technology Readiness, Economics, and Environmental Effects

29 MRE resources can be harnessed for a wide range of applications, including:

a. Utility-scale electricity;
b. Off-grid, distributed power generation, island electrification;
c. Offshore energy applications, e.g., offshore energy platforms, monitoring stations, navigational systems, fish farms and other aquaculture developments;
d. Coastal operations and applications, e.g., wave breakers, ports;
e. Production of alternative fuels e.g., hydrogen;
f. Desalination and water production; and,
g. Green marine and maritime ecosystem development.

30 One of the most important considerations in assessing the viability of MRE technologies is their technological readiness. As will be discussed in the next subsections, technology readiness is viewed critically on a global basis. As such, it would be expected that the technologies suitable for implementation in the Philippines would be those demonstrating with the highest level of maturity, as assessed by IRENA from a global perspective. This includes technologies with either demonstrated commercial implementation, or those with very near-term prospects for demonstrating commercial implementation.

A. Technology Readiness Levels of Various MRE Technologies

31 Technology Readiness Level (TRL) is a system to estimate the maturity of technology. It is popularly used by the National Aeronautics and Space Administration (NASA), R&D institutions, and technology developers. This phased approach uses a scale from 1 to 9, with 9 being the most mature level. The use of this system enables consistent and uniform assessment of technical maturity across different types of technology.[29]

32 Moving from one phase to the next requires increased deployment, leading to technological and economic improvements. To assess and analyze the different steps to industrial roll-out, Table 3 shows the phases with the corresponding indicators identified.

Table 3. Phases of Technology Readiness Levels (TRL)

Development Phase	TRL	Indicators
R&D	1-4	Small-scale device validated in the lab Component testing and validation Small/medium-scale pilots
Prototype	3-6	Representative single-scale devices with full-scale components

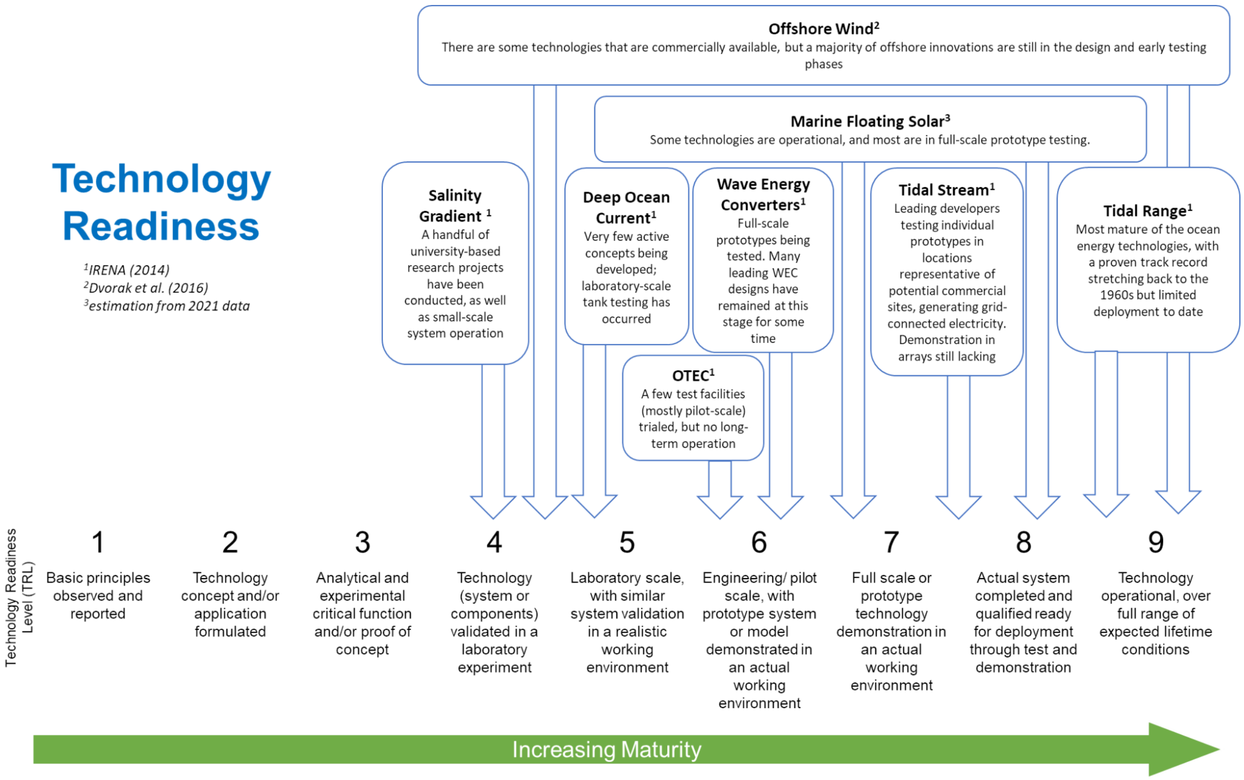
[29] IRENA. (2020). *Innovation outlook: Ocean energy technologies*. *International Renewable Energy Agency*. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Innovation_Outlook_Ocean_Energy_2020.pdf.

Development Phase	TRL	Indicators
		Deployed in relevant sea conditions Ability to evidence energy generation
Demonstration	5-7	Series or small array of full-scale devices Deployed in relevant sea conditions Ability to evidence power generation to Grid
Precommercial	6-8	Medium-scale array of full-scale devices experiencing interactions Grid connected to a hub or substation (array) Deployed in relevant/operational sea conditions
Industrial roll-out	7-9	Full-scale commercial ocean energy power plant or farms Deployed in operational real sea conditions Mass production of off-the-shelf components and devices

Source: Neill, S. P., & Hashemi, M. R. (2018). Fundamentals of Ocean Renewable Energy: Generating electricity from the sea. Elsevier Academic Press.

33 While all of these MRE technologies are classified to have the potential to be viable energy systems in the future, not all of them are currently commercially available and fully operational. The International Renewable Energy Agency (IRENA) presented a Technology Readiness chart in 2016, which has since been appended with OSW and marine solar PV as shown in Figure 9. It classifies the TRL of the different MRE technologies together with their current availability. The context of this assessment is in consideration of the global status, that is, how are these technologies advancing from a global perspective. Given this perspective, IRENA reports that only four technologies have reached maturity level 8 or 9, signifying that these are completed and operational. These more mature technologies include Marine Solar (floating solar PV), OSW, some tidal in-stream systems, and tidal range. Wave energy and OTEC are currently in the prototype stages while deep ocean current and salinity gradient are still in the experimental stages.

Figure 9. Technology Readiness of Marine Renewable Energy



34 Capacity factor is the measure of how often a power plant runs or performs for a specific period of time. It's expressed as a percentage and calculated by dividing the actual unit electricity output by the maximum possible output. Typical capacity factors of selected MRE technologies are summarized in Table 4.

Table 4. Capacity Factors of Selected MRE Technologies

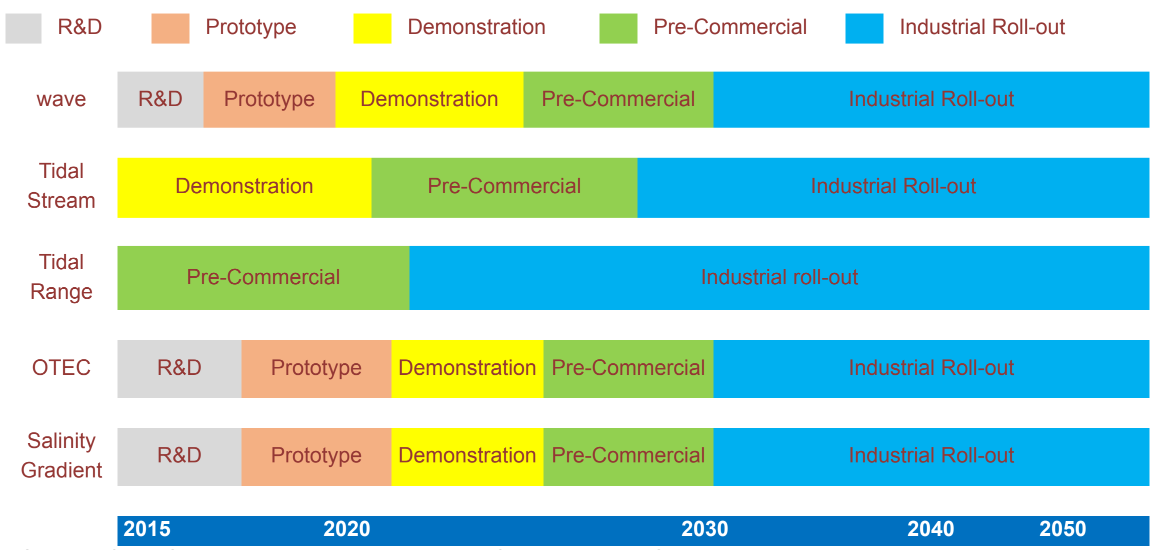
Technology	Typical Plant Capacity Factors[30]	References
Solar PV	16.1% to 20.8%	https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf
OSW	30% to 50%	https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf
Tidal Range (e.g., Barrage)	Typically 25%	https://tethys-engineering.pnnl.gov/publications/tidal-energy-technology-brief
Tidal Stream	25% to 40%	https://www.mdpi.com/1996-1073/10/9/1251/pdf https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/Tidal_Energy_V4_WEB.pdf
Ocean Current (e.g., Gulf Current in Florida Strait)	Up to 70%	https://www.osti.gov/servlets/purl/1378253

[30] Note: these are dependent on other factors such as: site, resource, technology, and other project parameters

Technology	Typical Plant Capacity Factors[30]	References
Wave	32% to 40%	https://www.mdpi.com/1996-1073/10/9/1251/pdf https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/wave-Energy_V4_web.pdf
OTEC	90% to 95%	https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/Ocean_Thermal_Energy_V4_web.pdf

35 A timeline for the development of ocean energy technologies throughout the TRL phases (Figure 10) was developed by the Ocean Energy Forum in 2016. This provides guidance on where the current technologies are and their projected phases of development. It should be noted that this is dependent on the level of support provided by the technology developers and of public support offered by the different countries in terms of policies and incentives.

Figure 10. Timeline for the Development Phase of Ocean Energy Technologies



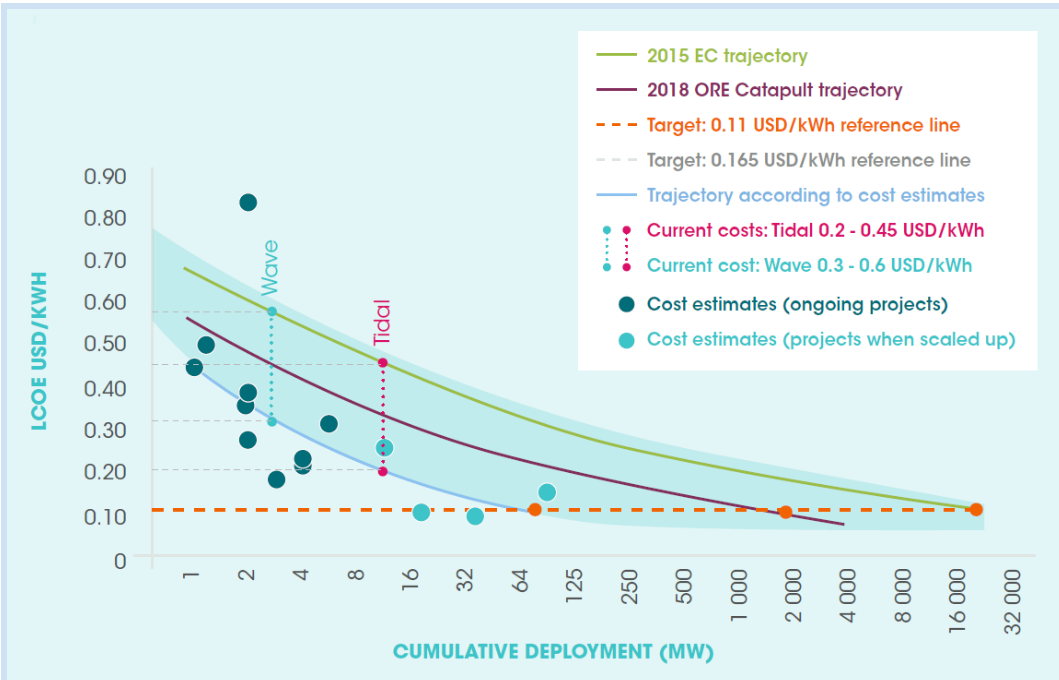
Source: from Ocean Energy Forum. (2016). *Ocean Energy Strategic Roadmap 2016, building ocean energy for Europe*. *Maritime Forum*. European Commission. Retrieved November 10, 2021, from https://webgate.ec.europa.eu/maritimeforum/sites/default/files/OceanEnergyForum_Roadmap_Online_Version_08Nov2016.pdf.

B. Economics of Ocean Renewable Energy, Levelized Costs of Energy, and Cost Reduction

36 Cost reductions are expected to occur in the coming years due to an increase in the installed capacity (economies of scale), reduction in technology prices due to innovation (e.g. more cost effective materials, increased efficiency in power output/conversion systems, etc.), and improved commercial terms (e.g. better interest rate for financing instruments, performance-based leasing, etc.) and policies leading to cost parity with other renewable energy sources. An example of technology innovation includes the integration of new stronger and lighter materials into the various components, extending the efficiency and life of key components in tidal in-stream turbines. This is anticipated to

provide reduced operating costs and higher mean times between repair (MTBR) or mean time between overhaul (MTBO) standards. This translates to lower operating costs and lower CAPEX costs as newer materials are also likely to be more cost effective. Currently, major cost reductions are expected through the increased installed capacity. Figure 11 presents the cost reduction curve of LCOE with respect to cumulative installed capacity. It can be seen that most ORE projects are above the target reference of $0.11/kWh but have the potential to drop costs when scaled up.

Figure 11. Target Cost Reduction Curve and Recent ORE LCOE estimates



Note: From IRENA. (2020). Innovation outlook: Ocean energy technologies. International Renewable Energy Agency. International Renewable Energy Agency. Retrieved November 10, 2021, from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Innovation_Outlook_Ocean_Energy_2020.pdf.

37 ORE technology costs are predicted to decrease as more deployments happen and as the technology matures. The decrease in costs makes these technologies more viable for commercialization. Accordingly, countries leading the ORE market[31] continue to develop projects due to the greater benefits they can provide for local communities and businesses. As compared to onshore renewable energy sources, some ORE provides a "predictable" source of energy since its movements can be measured through astronomical frequencies. With its predictability, as well as wave Energy lasting longer than wind speeds[32] (IRENA, 2020; Nik et al., 2008), ORE technologies can maintain a stable and reliable energy supply.

[31] *According to IRENA (2020), countries leading the ocean energy market include Finland, France, Ireland, Italy, Portugal, Spain, Sweden, United Kingdom, Australia, Canada and the United States. These countries conduct the most ocean energy technology projects.*

[32] *Wave energy is available 90% of the time, as compared to the 20-30% availability of wind and solar energy sources.*

38 In planning offshore development, it is beneficial to look at potential synergies that could arise in terms of common requirements in infrastructure (e.g. ports, grid, connection points, cable landing, substations, etc.), permits/consents/clearances (e.g. maritime lanes, marine zones, protected areas, etc.), support services (e.g. emergency response), supply chain (e.g. offshore work boats, special vessels, instruments/devices, marine & offshore sector service providers such as surveyors, salvage services, etc.) and other project aspects and sector developments (e.g. skills, insurance, etc.).

39 Marine space caters to multiple uses such as fishing/aquaculture, maritime shipping and other crafts/vessels, recreational activities, and energy generation, among others. As such, marine spatial planning (MSP)[33] is important when looking at the productive and synergistic use of marine spaces. In addition, increasing interest in Blue Economy clusters, which are enabled by the presence of an ecosystem of infrastructure, services, energy, and end-use applications (such as food production, desalination, etc.) will require proper planning and management using the appropriate tools (such as Geographic Information Systems, etc.).

40 It is important to recognize that all of the work in developing technology, building processes, and building renewable energy capabilities in a certain locality are valuable. However, the Blue Economy and how it is enabled by the MRE sector must work within a comprehensive construct that builds a self-supporting ecosystem. The World Bank defines Blue Economy as the "sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health."

41 Table 5 presents a range of costs (Capital Expenditures - CAPEX, Operational Expenditures - OPEX) associated with certain project capacities for early stage deployments (first array/project, second array/project, and first commercial-scale project). This provides an indication of the wide range of costs (reflecting some overdesign or uncertainty mitigation measures) for the first projects and the expected change in costs (i.e., reduction both in average cost and in terms of range of costs) as the projects move to the first commercial scale stage.

42 The general downward trend in costs is observed not only for one type of technology, but for all of the three types considered (wave, tidal in-stream, and OTEC). The same downward cost trend is shown in Figure 12 below where wave and tidal in-stream costs decrease as more capacity (addressing more mainstream markets) is reached. In contrast, the variation/fluctuation of fossil fuel cost should signal that in the long term, true sustainability and stability can only be reached with renewable energy. As more projects are developed and more capacity is installed, the costs of projects will follow a cost reduction curve as this is a general trend for most technology development pathways. A similar trend is expected in the Philippines.

[33] Marine Spatial Planning Global (MSP) is "a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that are usually specified through a political process."

Table 5. Summary Data Averaged for Each Stage of Deployment by Technology

Deployment Stage	Variable	Wave		Tidal in-stream		OTEC		OSW*
		Min	Max	Min	Max	Min	Max	Typical
First array/ First project	Project Capacity (MW)	1	3	0.3	10	0.1	5	
	CAPEX ($/kW)	4000	18100	5100	14600	25000	45000	
	OPEX ($/kW per year)	140	1500	160	1160	800	1440	
Second Array/ second project	Project Capacity (MW)	1	10	0.5	28	10	20	
	CAPEX ($/kW)	3600	15300	4300	8700	15000	30000	
	OPEX ($/kW per year)	100	500	150	530	480	950	
	Availability (%)	85%	98%	85%	98%	95%	95%	
	Capacity Factor (%)	30%	35%	35%	42%	97%	97%	
	LCOE ($/MWh)	210	670	210	470	350	650	
First Commercial-scale Project	Project Capacity (MW)	2	75	3	90	100	100	
	CAPEX ($/kW)	2700	9100	3300	5600	7000	13000	
	OPEX ($/kW per year)	70	380	90	400	340	620	
	Availability (%)	95%	98%	92%	98%	95%	95%	
	Capacity Factor (%)	35%	40%	35%	40%	97%	97%	
	LCOE ($/MWh)	120	470	130	280	150	280	
Subsequent Commercial Scale Project/s	CAPEX ($/kW)		1985[e,f]		2967[e,g]		11579[e]	3750[a]
	OPEX ($/kW per year)		41.36[e,f]		62[e,g]		362[e]	70 - 80[a]
	Availability (%)	95%	98%	92%	98%	95%	95%	80.2[d]
	Capacity Factor (%)	12%[i]	47%[i]	35%	42%	90%	95%	34.5[d]
	LCOE ($/MWh)	200[h]	450[h]	300[h]	550[h]	40[j]	290[j]	95[a,b] to 160[a,c]

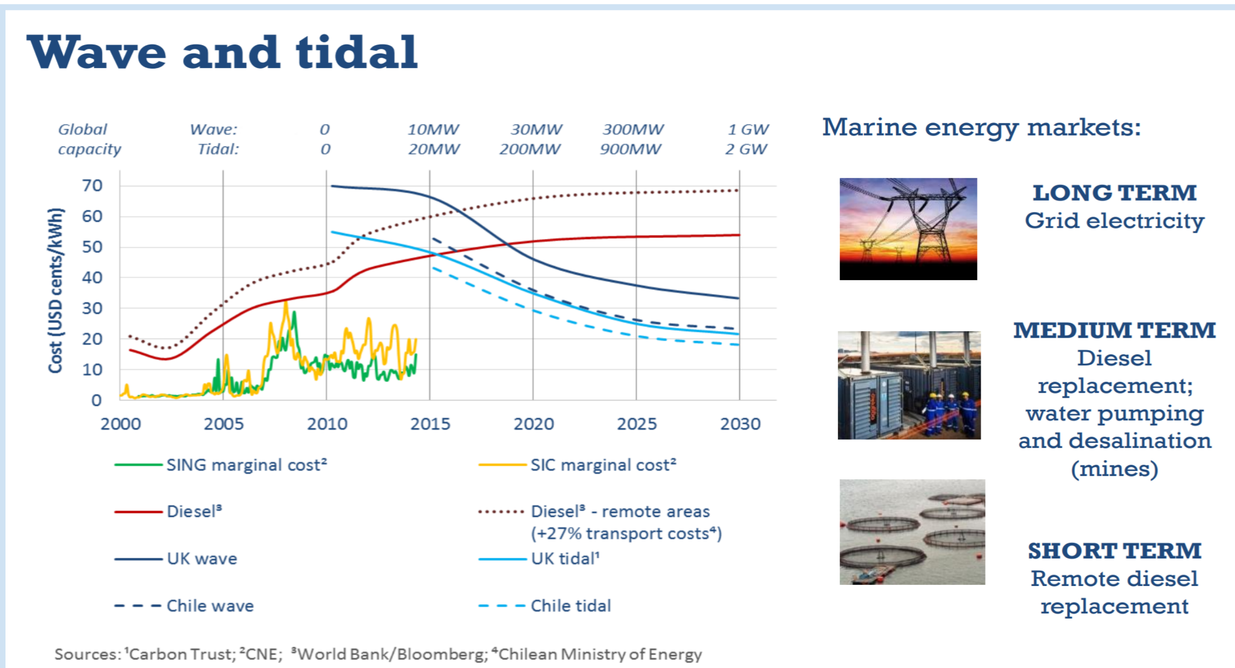
Notes:
**OSW data for "First array/First Project" , "Second array/Second Project" and "*First Commercial- scale Project" are not that relevant since OSW is already a very mature technology (TRL 9) and it is highly likely that the parameters (e.g. CAPEX, OPEX, etc.) will be closer to the "Subsequent Commercial Scale Project/s" data.

Main table from IEA-OES. (2015). International levelized cost of energy for ocean energy technologies: An analysis of the development pathway and levelized cost of energy trajectories of waves, tidal and OTEC technologies. Ocean Energy Systems - International Energy Agency. Ocean Energy Systems - International Energy Agency. Retrieved November 10, 2021, from https://www.ocean-energy-systems.org/documents/57387-cost-of-energy-for-ocean-energy-technologies-may-2015-final.pdf/ . [a] 2020 values. US Department of Energy. Office of Energy Efficiency & Renewable Energy. (2021). OSW Market Report: 2021 Edition. Retrieved November 22, 2022, from https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf. [b] LCOE of fixed-bottom OSW turbines. [c] LCOE of floating OSW turbines. [d] Crabtree, C. et al. (2015). Wind Energy: UK experiences and offshore operational challenges. Proceedings of the Institution of Mechanical Engineers Part A Journal of Power and Energy. DOI:

10.1177/0957650915597560. [e] Values are for TRL 9; European Union. (2018) Market Study on Ocean Energy. doi:10.2771/89934. Retrieved November 23, 2022 from https://www.oceanenergy-europe.eu/wp-content/uploads/2018/07/KL0118657ENN.en-1.pdf. [f] Values are for 20-250 MW project capacity. [g] Values are for 90-410 MW project capacity. [h] IRENA (2020), Innovation outlook: Ocean energy technologies, International Renewable Energy Agency, Abu Dhabi. Retrieved November 22, 2022 from https://www.irena.org/publications/2020/Dec/Innovation-Outlook-Ocean-Energy-Technologies.[i] Asian Development Bank. (2014). wave Energy Conversion and OTEC Potential in Developing Member Countries. https://doi.org/10.1007/BF02929925.
[j]https://tethys-engineering.pnnl.gov/sites/default/files/publications/oes-white-paper-on-otec.pdf

43 Figure 12 provides a synopsis in the short, medium, and long term on how cost reductions for wave and tidal in-stream development may proceed.

Figure 12. Wave and Tidal Energy Market



Note: From Aquatera Ltd. (2014). Recommendations for Chile´s Marine Energy Strategy – a roadmap for development. Aquatera Ltd. Aquatera. Retrieved November 10, 2021, from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/310035/Recommendations_for_Chile__s_Marine_Energy_Strategy_-_a_roadmap_for_development___online_version.pdf .

44 As a general observation, we expect the markets to follow a gradual reduction of fossil fuel energy. Globally, the short term market for wave, tidal in-stream, and other pre-commercial MRE technologies is the displacement/replacement of diesel-based power generation. This is especially for remote locations where the logistics involving sourcing and delivery of fuel is expensive and/or complex. The medium term markets will involve other end-use applications of energy and electricity e.g. water pumping, desalination, specialized applications, etc. In the long term, the market is the main grid energy/electricity supply. In the Philippines, this is supported by the various national plans including the Philippine Development Plan[34] as well as the specific energy sector plans by the DOE.

[34] NEDA. (2023). https://neda.gov.ph/philippine-development-plan-2023-2028/

C. Environmental and Social Effects of Marine Renewable Energy Development Around the World[35]

45 Marine energy developments can give rise to a range of effects on a number of ecological, human and physical receptors. There are a number of international programs and initiatives focused on better understanding these potential effects and how they can be managed at a strategic and project level as the MRE sector develops. One of the key initiatives is Ocean Energy Systems (OES) Environmental, part of the wider Ocean Energy Systems Collaboration Programme, which an intergovernmental collaboration between countries that operates under framework established by the International Energy Agency[36]. OES Environmental synthesizes information and scientific research about MRE and the environment on a global scale into collaborative reports and documents. Additionally, OES Environmental hosts workshops and webinars to bring researchers together around environmental effects research and supports environmental effects tracks at international conferences.[37] One of the key OES Environmental publications is the State of the Science Report, which reflects the most current and pertinent published information about interactions of MRE devices and associated infrastructure with the animals and habitats that make up the marine environment. It has been developed and reviewed by over 60 international experts and scientists from around the world.[38]

46 An overview of some of the key observations made in the 2020 OES Environmental State of the Science report[39] is provided below:

a. Electromagnetic Fields (EMFs) emitted from power cables from a single or small array of MRE devices are expected to have limited impact on the marine environment. Marine animals living near the MRE devices and export cables are not likely to be affected nor harmed by the EMFs emissions.

b. Evidence to date suggests that underwater noise emissions from operational MRE devices do not cause physical harm or significantly affect the behavior of the marine animals in the vicinity. Noise during construction is also widely accepted to pose no significant risk to marine wildlife, assuming that no percussion piling and equivalent activities are required. The potential effects of underwater noise should be considered in any project level impact assessment. This assessment should draw as much as possible on data from other projects

[35] . OES-Environmental. (2020). https://www.osti.gov/servlets/purl/1632878

[36] OES. (n.d.). https://www.ocean-energy-systems.org/about-us/

[37] OES. (n.d.). https://www.ocean-energy-systems.org/oes-projects/assessment-of-environmental-effects-and-monitoring-efforts-for-ocean-wave-tidal-and-current-energy-systems/

[38] Ibid

[39] OES-Environmental. (2020). https://tethys.pnnl.gov/sites/default/files/publications/OES-Environmental-2020-State-of-the-Science-Report_final.pdf

and assessments to ensure that effort and cost remain proportionate to the potential effect.

c. Uncertainty around the potential for marine wildlife to collide with operating tidal turbines remains one of the key issues facing the tidal energy sector around the world. There have been no observations of any marine mammal, fish or seabird colliding with a tidal turbine at sea to date. However, this will remain an important area of study for the sector as first mover projects progress and the sector begins to scale up and install larger arrays. A 'deploy and monitor' approach has been recommended as a potential solution in the short term, which facilitates the development of first mover projects whilst allowing monitoring and research to be conducted around operational projects in real-world conditions. Thisin turn provides essential data to inform future project planning and design activities. The development of robust, transparent project level environmental mitigation and monitoring plans (or similar) in collaboration with key stakeholders is an essential part of this process.

d. The impacts of MRE installations on benthic habitats will be similar to those resulting from other marine infrastructure developments. Direct impacts on benthic habitats will be dependent on the type of support structure used for a project e.g., drilled monopile (which will have a highly localized and small footprint) versus a large gravity foundation (which may have a slightly larger but still localized footprint).

   Effects on pelagic habitats may come from the installation of mooring lines, transmission cables, and mechanical moving parts in the water column.

   Structures on the seafloor or in the water column may act as artificial reefs that could lead to a change in the presence or behavior of marine animals. Biofouling organisms may create habitat on the MRE systems and attract fish or other marine animals. The attraction of fish may also boost fish populations in nearby areas.

   Overall, the effects of MRE devices in benthic and pelagic habitats are likely to cause a low risk to animals and habitats if the projects are carefully planned and sited to avoid rare or fragile habitats. Assuming that protected and vulnerable areas are avoided (through preconstruction seabed surveys/data review), no significant effects from small scale or demonstration projects are expected.

   The potential effects on benthic habitats will be considered in any project level impact assessment, which will most likely require seabed survey data to ensure that sensitive/vulnerable areas can be avoided as far as possible.

   MRE developments with components floating on the surface or positioned in the water column, will have mooring lines which allow them to maintain their position. In an array, cables are also used to carry power from multiple devices to a single power export cable installed on the seabed. OES Environmental[40] states that "the potential for these lines and cables to become a hazard for marine animals that may become entangled or entrapped in them is uncertain but has been raised by stakeholders".

Concerns raised have mostly focused on large marine animals being entangled in a loose/slack line that can 'loop' around an animal. These concerns have largely been raised due to historical and ongoing issues associated with entanglement and fishing gear. However, compared to fishing gear, mooring lines and cables associated with MRE developments are never sufficiently slack to create a loop, nor are there loose ends to give rise to an entanglement risk. Given this, and the ability of some marine animals to detect such mooring systems and cables, OES Environmental states that "the probability of entanglement of marine animals with mooring structures or cables associated with single MRE devices is likely to be low."

e. Potential changes to oceanographic systems are assessed using numerical models. As larger commercial arrays are planned, field data will become important to inform numerical models and impact assessments for those projects. However, the impact of demonstration projects and small arrays on oceanographic systems is generally very low.

f. Cable landfall and onshore infrastructure will be required to support any offshore MRE development. Consideration of effects on coastal and terrestrial habitats and species will be managed through normal planning and impact assessment processes. MRE arrays may consist of transmission cables for interconnection of the devices or to connect to offshore substations.

g. ORE developments can create direct opportunities for local communities through employment and engagement of the local supply chain. Indirect benefits are also realized through activity within the local community such as use of accommodation, retail and other local businesses. Small arrays and demonstration projects are unlikely to put any significant pressure on local businesses and supply chains during the construction phase (as can occur with larger developments in small communities if not managed properly). These projects are also highly unlikely to result in any significant effect on local recreation/tourism. The projects may increase opportunities in these areas, as has been the case for a number of onshore wind projects in the Philippines. This can be enhanced with the creation of local visitor centers and other complimentary facilities, such as that created at the Fundy Ocean Research Centre for Energy (FORCE) tidal site in Canada. The European Marine Energy Centre has also received 1000s of visitors since its establishment in the early 2000s. Impacts on these receptors, positive and adverse, should be considered during the project design and impact assessment process. Close collaboration

[40] OES-Environmental. (2020). https://tethys.pnnl.gov/sites/default/files/summaries/Entanglement-Risk-SSS.pdf

with local communities and other relevant stakeholders is essential to properly understand and manage effects and opportunities.

h. Small arrays and demonstration projects will have a relatively small offshore footprint, and as such, will have limited impact on the area(s) available for fishing. However, offshore infrastructure will create an offshore area to be avoided in most cases so close consultation and collaboration with local stakeholders will be essential. The potential effects on local fisheries should be considered during project design and impact assessment. Education and outreach activities will be necessary to ensure that the local fishing community is appropriately engaged in each project from the outset and expert support should be engaged to facilitate this process in each location.

i. Small-scale projects will have a limited impact on the area(s) available for safe navigation. There are standard practices and guidance available to ensure that any impacts on shipping and navigation receptors are mitigated and managed appropriately. A navigational risk assessment should be undertaken at a project level, which is proportionate to the likely level of risk and in line with relevant legislation and regulations. There is extensive experience of this within the industry from previous deployments at test sites around the world (such as EMEC) and other demonstration sites.

j. Consideration of effects on land use and landscape and seascape will be managed through normal planning and impact assessment processes.

k. Small arrays and demonstration projects will have a relatively small offshore footprint, and as such, will have limited impact on any local marine archaeology and cultural heritage interests. The potential effects on marine archaeology and cultural heritage interests should be considered during project design and impact assessment for example, avoiding known sensitive areas and interests such as wrecks, etc.

l. It is widely accepted that small scale MRE projects will not have significant impacts on marine physical processes including sediment transport, but that useful data may be collected during operation to inform future impact assessments for larger scale projects. A high-level assessment of potential effects should be included during the impact assessment process. Research and monitoring of these effects can be built into a project research strategy to inform future projects.

m. Accidental events and poor waste management practices could impact local water and sediment quality. However, it is assumed that robust waste management and health and safety protocols will be produced for each project in collaboration with the relevant authorities which will result in these potential impacts being managed within normal protocols for offshore activities. Any site-specific issues should be addressed through the standard planning and consenting process.

n. There are no significant effects expected from small-scale development projects in relation to geology, hydrology, and hydrogeology. Any site-specific issues should be addressed through standard planning and consenting processes.

47 Adaptive Management (AM) has the potential to support the sustainable development of the MRE industry by enabling projects to be deployed incrementally in the face of uncertainty about potential effects and to assist in closing knowledge gaps through rigorous monitoring and review. AM is an iterative process, also referred to as "learning by doing," that seeks to reduce scientific uncertainty and improve management through periodic review of decisions in response to the knowledge gained from monitoring. AM has been used to guide the implementation of MRE monitoring programs and has successfully allowed a number of projects worldwide to progress. If information from routine monitoring shows that the level of an effect is likely to cause an unacceptable impact, corrective actions can be taken. Conversely, if monitoring information indicates that risks have been overestimated, monitoring and mitigation requirements may be reduced.

48 The growth of MRE will result in the increasing use of marine space, which can cause conflicts with existing ocean uses. However, this issue can be partially addressed through the implementation of Marine Spatial Planning (MSP). Itseeks to manage competing marine uses while balancing environmental, social, and economic interests to support the sustainable development of the oceans. MSP has the potential to increase transparency and certainty for industry, improve environmental protection, reduce sectoral conflicts, and provide opportunities for synergies. Alongside MSP is the engagement of other marine users through education, training and increasing their involvement if MRE technologies are to be deployed. This could increase the likelihood of acceptance and long-term adoption of such technologies as other marine users, e.g., fishing communities, are aware of their benefits and risks. Engagement of other marine users may also create a marine ecosystem where MRE technologies could benefit users not only in terms of energy access but address their other socio-economic needs.

49 A current study on risk argues that "risk retirement does not take the place of any existing regulatory processes, nor does it replace the need for all data collection before or after MRE device deployment. Regulators may request additional data collection to verify risk retirement findings, to add to the growing knowledge base, or to inform assessments of site-specific environmental effects. By appropriately applying existing learning, analyses, and monitoring, datasets from one country to another, among projects, and across jurisdictional boundaries, regulators may be able to make monitoring requirements less stringent, reducing costs to the MRE industry over time. As a means of facilitating the consenting of a small number of MRE devices, a risk retirement pathway has been developed to evaluate the potential risks of specific stressor-receptor interactions. Preliminary evidence indicates that the risk of underwater

noise and EMF from small numbers of MRE devices could be retired. As larger MRE arrays are developed, these stressors may need to be reassessed."[41]

50 The OES Environmental State of the Science Report, states that "the body of knowledge about potential effects of MRE development should be used to help streamline and accelerate consenting processes and support the responsible development of MRE through the implementation of strategies such as marine spatial planning, adaptive management, and risk retirement. How these management strategies may support consenting and management of MRE project needs to be considered through these lenses:

a. Data collection, analysis, and reporting for consenting must be proportionate to the size of the MRE project and the likely risk to marine animals and habitats.

b. Both MSP and AM can play critical roles in assessing whether sufficient evidence has been gathered to evaluate the potential risks of MRE development to the marine environment. AM also provides a framework to manage the deployment of devices while uncertainty about effects remains. MSP and AM could be implemented alongside other marine users' engagement to ensure the acceptability and long-term adoption of MRE technologies.

c. Knowledge gained from consented MRE deployments, along with lessons learned from analogous offshore industries and research projects, can be evaluated to determine their applicability to inform the permitting and consenting process and activities at new MRE sites. Data transferability, within the risk retirement pathway, can make the routine transfer of evidence more efficient.

d. A fully data-supported risk retirement process can help determine which interactions have sufficient evidence and where significant uncertainties remain. By retiring specific issues for smaller projects, resources can be directed towards examining the most challenging stressor-receptor relationships and addressing associated evidence gaps.

[41] OES-Environmental. (2020). https://tethys.pnnl.gov/sites/default/files/publications/2020-State-of-the-Science-Report-LR.pdf

IV. Marine RE in the Philippines: Resources, Activities, and Benefits

A. Offshore Wind and Marine Solar Renewable Energy Resources in the Philippines

51 Table 6 provides the OSW and marine solar potential in the Philippines. Meanwhile, Figure 13 shows a map of the Philippines' estimated technical potential for fixed and floating OSW[42]. There are three areas identified to be suitable for floating OSW development, and these are in north Luzon and north and south of Mindoro Island. There are other areas around the country are suitable for OSW (e.g. with floating turbines) but with lower wind speeds.

Table 6. Offshore Wind and Marine Solar Energy Potential

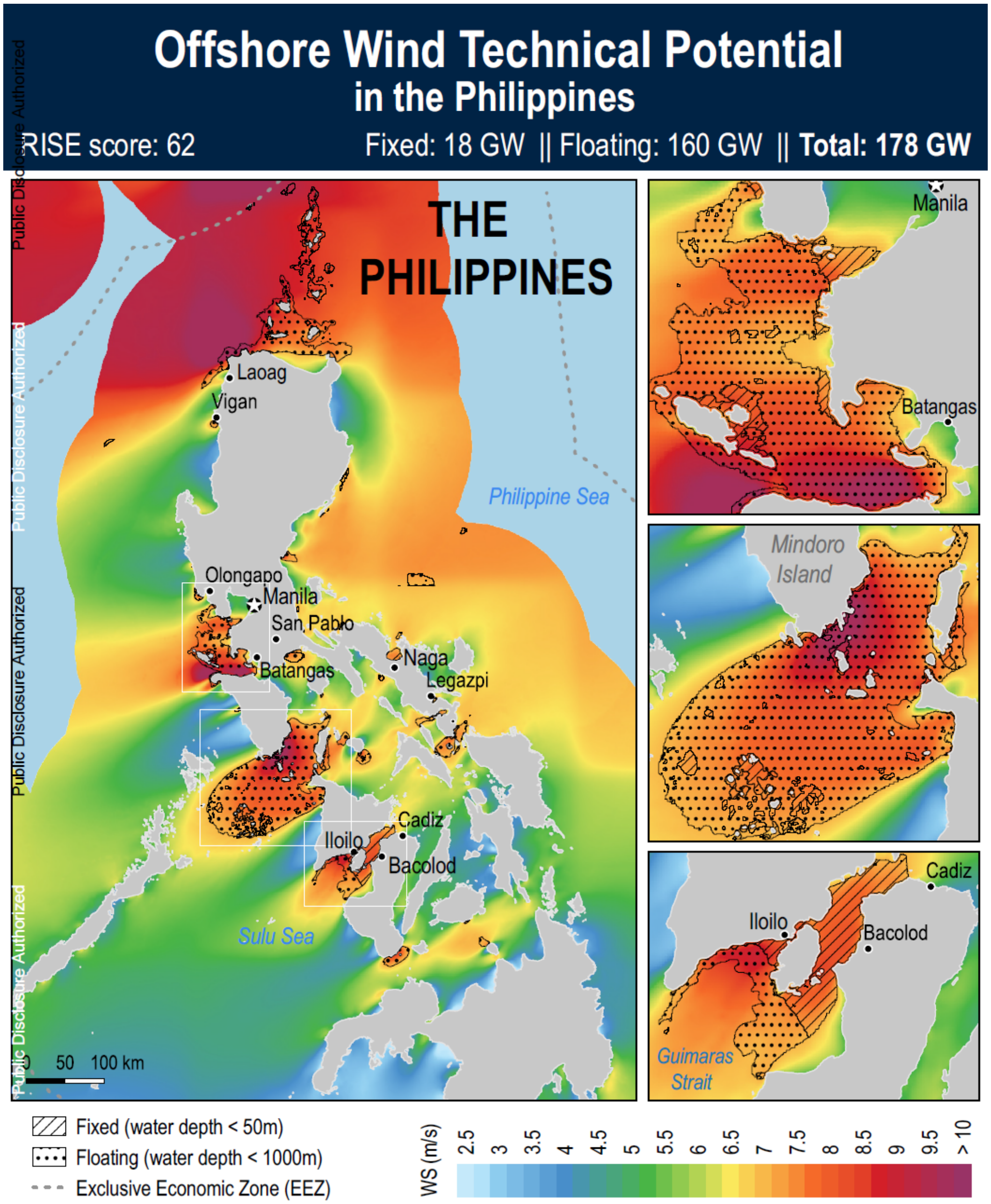
Type of MRE	Potential
Offshore Wind Energy	178GW (World Bank[43]) - Fixed: 18GW - Floating: 160GW
Marine Solar	Estimated[44] to be 266 GWp Huge potential for near-shore and calm bay areas.

[42] Energy Sector Management Assistance Program. (2019, October). *Going global: Expanding Offshore Wind to emerging markets*. World Bank Group.
https://documents1.worldbank.org/curated/en/716891572457609829/pdf/Going-Global-Expanding-Offshore-Wind-To-Emerging-Markets.pdf

[43]The World Bank. (2020)
https://documents1.worldbank.org/curated/en/519311586986677638/pdf/Technical-Potential-for-Offshore-Wind-in-Philippines-Map.pdf

[44] 100 Watt-peak per square meter of floating Solar PV (Worldbank/ESMAP/SERIS
https://openknowledge.worldbank.org/bitstream/handle/10986/31880/Floating-Solar-Market-Report.pdf?sequence=1%26isAllowed=y)
multiplied by 1% of 266,000 km² Coastal and Bay Areas of the Philippines (http://www.wepa-db.net/policies/state/philippines/seaareas.htm)

Figure 13. Offshore Wind Technical Potential in the Philippines



Note: From Energy Sector Management Assistance Program. (2019, October). Going global: Expanding Offshore Wind to emerging markets. World Bank Group. Retrieved January 26, 2022, from https://documents1.worldbank.org/curated/en/716891572457609829/pdf/Going-Global-Expanding-Offshore-Wind-To-Emerging-Markets.pdf

B. Ocean Renewable Energy Resources in the Philippines

52 According to a study conducted by the Mindanao State University[45], the counry's ocean energy potential is estimated to be over 150 GW. Separately, the Department of Energy has estimated this to be at least 170 GW. Buhali et. al. (2012)[46] have estimated that around 40 to 60 GW+ are practically extractable from tidal currents / tidal streams alone.

53 Figures 14 and 15 show potential sites for harnessing ocean renewable energy - tidal stream energy on the left, wave energy at the center, and OTEC on the right. Researchers from the University of the Philippines (UP) and Nanyang Technological University have estimated the theoretical potential of the Philippines for tidal stream energy to be 200 GW, of which 40 – 60 GW is technically and economically feasible. Table 7 shows a match of where there are ORE resources and the location where electrification is most needed. Research groups from UP's Marine Science Institute and the College of Engineering have begun to work together on developing ORE in the Philippines, starting with proper resource estimates from existing data to identify and prioritize sites for development.

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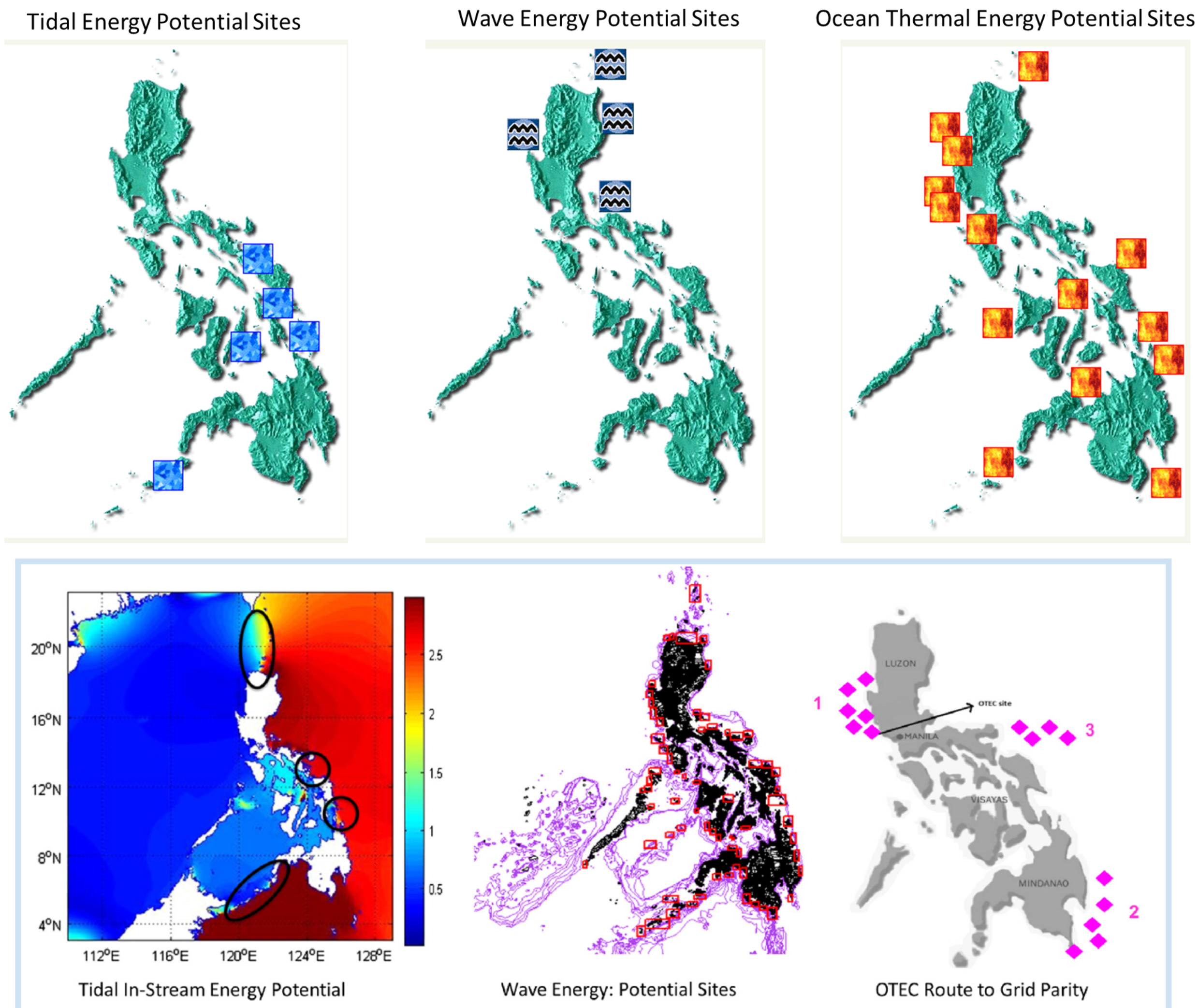
[45] Quirapas, M. A., Lin, H., Abundo, M. L., Brahim, S., & Santos, D. (2015). Ocean Renewable Energy in Southeast Asia: A Review. *Renewable and Sustainable Energy Reviews*, *41*, 799–817. https://doi.org/10.1016/j.rser.2014.08.016

[46] Buhali, M., Ang, M. R., Paringit, E., Villanoy, C., & Abundo, M. (2012). Tidal Stream energy density estimates for pre-identified sites in the Philippines using a tide height difference-based metric. *2012 11th International Conference on Environment and Electrical Engineering*. https://doi.org/10.1109/eeeic.2012.6221450

Figure 14. Potential Ocean Energy Sites in the Philippines



*Note: **Top -** from the Philippines Dept. of Energy; **Bottom** - from Quirapas, M. A., Lin, H., Abundo, M. L., Brahim, S., & Santos, D. (2015). Ocean Renewable Energy in Southeast Asia: A Review. Renewable and Sustainable Energy Reviews, 41, 799–817. https://doi.org/10.1016/j.rser.2014.08.016*

Figure 15. Philippines' Tidal Stream and Wave Energy Potential

Note: From Deloitte Consulting, & OceanPixel SEA. (2017). Marine Renewable Energy: Unlocking The Hidden Potential Southeast Asia (Sea) Market Assessment. OceanPixel.

Table 7. Electrification rate and population of Philippine regions with tidal stream and wave energy potential shown in Figures 14 and 15

No	Province/Region	Electrification Rate	Population (million)
1	Cagayan / II	91.8%	1.20
	Catanduanes / V	88.7%	0.26
2	Sorsogon / V	88.7%	0.79
	Northern Samar / VIII	87.2%	0.63
3	Southern Leyte /VIII	87.2%	0.42
	Surigao del Norte / XIII/CARAGA	93.8%	0.49
4	Basilan / ARMM	38.7%	0.35

No	Province/Region	Electrification Rate	Population (million)
	Sulu / ARMM	38.7%	0.82
	Tawi-tawi / ARMM	38.7%	0.39
5	Palawan / IV-B	82.2%	0.85
6			
7	Batangas / IV-A	96.3%	2.69
	Occidental Mindoro / IV-B	82.2%	0.49
	Oriental Mindoro / IV-B	82.2%	0.48

Note: From Deloitte Consulting, & OceanPixel SEA. (2017). Marine Renewable Energy: Unlocking The Hidden Potential Southeast Asia (Sea) Market Assessment. OceanPixel.

C. Status of MRE Initiatives in the Philippines

54 Listed below is a summary of projects and efforts (2016-2021) contributing to the uptake of MRE in the Philippines:

- Offshore Wind Roadmap Development (DOE and World Bank) launched in April 2022
- DOE and Climate Change Commission (CCC) NAMA Support Project – Detailed Preparation Phase: Tidal Stream + PV Hybrid for Off-grid market (EUR 20 million grant incentive program for private sector)[47]
- Mindanao Development Authority working with partners (i.e. Altum Green Energy and OceanPixel Pte Ltd) for Blue Economy development in Mindanao enabled by Marine Renewable Energy (MOU signed during Presidential state visit in Singapore, September 2022)
- EU-Access to Sustainable Energy Program (ASEP)-Clean Energy Living Laboratories (CELLS) - for strategic RE options for the Philippines, including MRE
- Innovate UK-funded project for off-grid island energy transition including MRE options (inventory/database, and multi-aspect analysis) - with Aquatera Ltd, OceanPixel Philippines Inc., University of the Philippines, Ateneo de Davao University, and Silliman University
- DOST-funded ORE R&D Project with the Mindanao Renewable Energy R&D Center (MREC) of Ateneo de Davao University (2019 to 2022)[48]

[47] NAMA Facility. (n.d.) https://www.nama-facility.org/projects/philippines-decarbonisation-of-electricity-generation-on-philippine-islands-using-tidal-stream-a/

[48] Ateneo de Davao. (2019). http://sea.addu.edu.ph/mrec-launch/

- ADB - Technical Assistance: Promoting Sustainable Energy for All in Asia and the Pacific - Renewable Energy Mini-Grids and Distributed Power Generation (1 Ocean Energy Expert)[49]
- DOE Forum with ORE Project Developers and Technology Providers (Dec 2020)
- UNDP Development for Renewable Energy Applications Mainstreaming and Market Sustainability (DREAMS) Project
- DOE Capability Development (Internal) - Training and Special Equipment Procurement
- DOST Philippine Sites for Harnessing Ocean Renewable Energy (PhilSHORE) Project[50]
- Private sector activities including marine renewable energy pilot and demo projects (e.g. Altum Green Energy demo in Davao City)

55 A summary of the ongoing works by relevant agencies is presented in Table 8.

Table 8. Stocktake Summary

Type of MRE	Potential	Activities / Relevant Updates	Lead Agency/ies
Offshore Wind Energy	178GW [51] - Fixed: 18GW - Floating: 160GW	World Bank-supported Offshore Wind development roadmap preparations since June 2021, launched in April 2022. 42 WESCs, 20 OSW developers. Marine spatial planning tool and permitting supported by ETP.	Solar and Wind Energy Management Division (SWEMD) Renewable Energy Management Bureau (REMB), DOE
Marine Solar	Estimated[52] to be 266 GWp. Huge potential for near-shore and calm bay areas.	Exploratory activities (by R&D entities, Technology providers, and some project developers)	SWEMD, REMB, DOE
Ocean Renewable Energy	At least 170 GW[53] (DOE)	i. Nationally-Appropriate Mitigation Action (NAMA)	i. DOE and CCC

[49]ADB. (2020). https://www.adb.org/projects/48435-002/main

[50] PhilSHORE. (2016). https://philshore.github.io/

[51]World Bank. (2020). https://documents1.worldbank.org/curated/en/519311586986677638/pdf/Technical-Potential-for-Offshore-Wind-in-Philippines-Map.pdf

[52] 100 Watt-peak per square meter of floating Solar PV (Worldbank/ESMAP/SERIS https://openknowledge.worldbank.org/bitstream/handle/10986/31880/Floating-Solar-Market-Report.pdf?sequence=1%26isAllowed=y) multiplied by 1% of 266,000 km² Coastal an Bay Areas of the Philippines (http://www.wepa-db.net/policies/state/philippines/seaareas.htm)

[53] M. Quirapas, H. Lin, M. Abundo, S. Brahim, D. Santos; Ocean renewable energy in Southeast Asia: A Review; Renewable and Sustainable Energy Reviews, 41 (2015), pp. 799-817 https://doi.org/10.1016/j.rser.2014.08.016

Type of MRE	Potential	Activities / Relevant Updates	Lead Agency/ies
a. Tidal Stream b. Wave c. Ocean Thermal d. Salinity Gradient	a. At least ~40 to 60 GW[54] of practically extractable resource	Support Project (Hybrid Tidal + PV) green-lighted for detailed preparation phase ii. At least 4 project developers and at least 2 technology developers are involved in pre-development stages of sites/projects with DOE Renewable Energy /Ocean Energy Service Contracts. iii. ORE R&D Project developing a small-scale field lab a. Some early exploratory activities by at least 4 project and/or technology developers b. 1 OTEC Project (10 MW) previously planned (with DOE RE Service Contract); proposed Feed-in Tariff at ~PhP17/kWh (~USD0.37/kWh) which was deferred[55]	ii. Hydro and Ocean Energy Management Division (HOEMD), REMB, DOE iii. Mindanao Renewable Energy Center, Ateneo de Davao University (funded by the Dept. of Science and Technology) a. HOEMD b. HOEMD

56 Figure 16 shows a projected Ocean Sector Roadmap for 2020 to 2040 for the DOE. This roadmap includes key policy and program objectives designed to enable MRE towards a practical and efficient future as a meaningful part of the Philippines energy generation mix. The roadmap begins in 2020 with a clear policy objective formulation, including the creation of special rates for ocean energy and capacity building for the DOE to increase their level of expertise. Key milestones have been defined for the period 2020 to 2025. The initial roadmap culminates in 2040 with the completion of major ocean energy projects leading to the achievement of 70.5MW target installed capacity.

[54] M. L. Buhali Jr., M. R. C. O. Ang, E. C. Paringit, C.Villanoy, and M. L. S. Abundo, "Tidal Stream energy potential of the Philippines: An initial estimate", in 1st Asian Wave and Tidal Conference,2012.
[55] Eco-business. (2016). https://www.eco-business.com/news/tariff-issues-stall-philippine-ocean-energy-project/

Figure 16. Ocean Sector Roadmap for 2020 to 2040

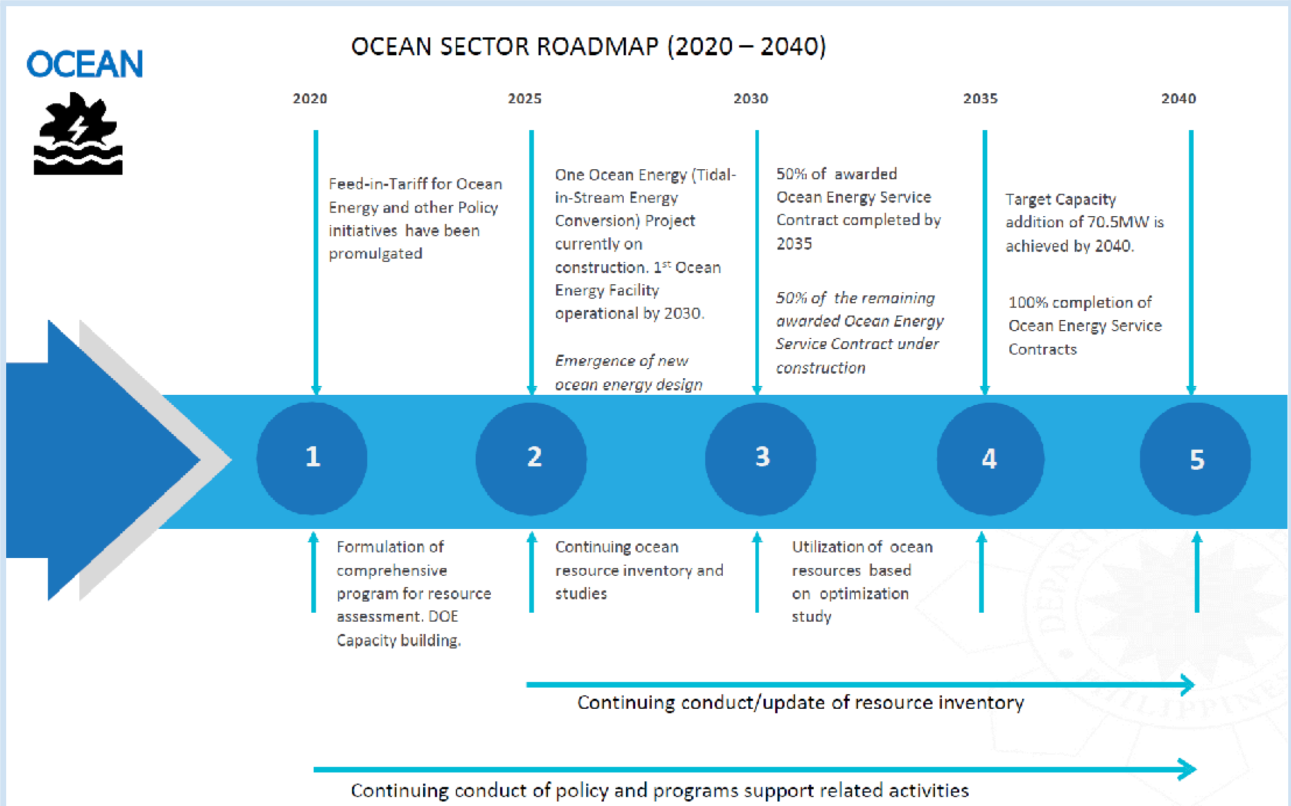
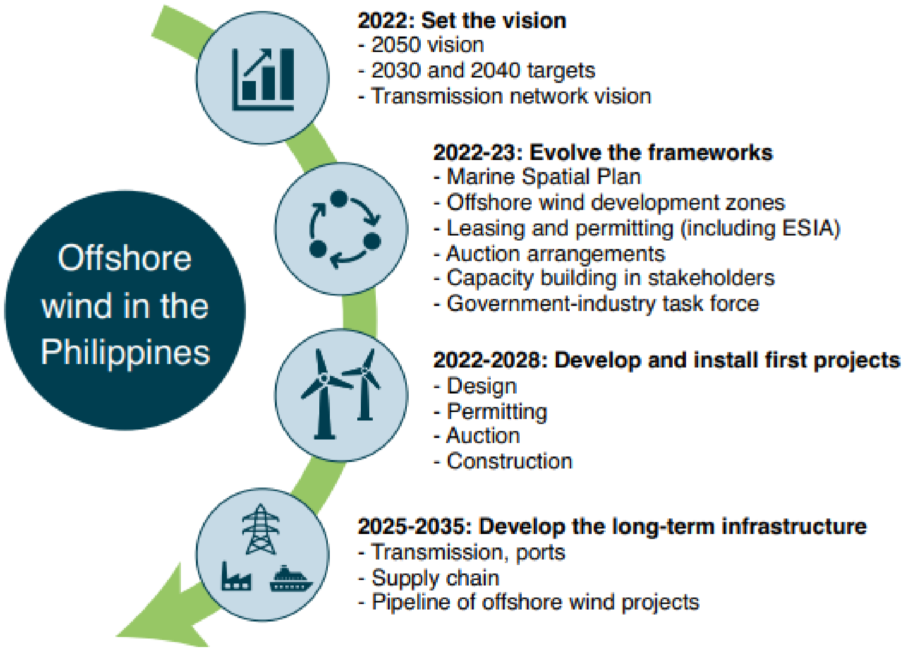


Figure 17. Offshore Wind Roadmap



Note: From the World Bank. 2022. Offshore Wind Roadmap for the Philippines. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO Retrieved November 25, 2021, from *https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf*
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D. Project Development - Stakeholder and Process Mapping

57 From pre-development of an MRE project up to construction and operation, several stakeholders are involved in registration, regulation, and compliance. The DOE is the central government agency responsibile for administering, reviewing, and approving applications for MRE projects (leading to RE service contracts) up to commercialization. The CCC is the respective lead policy-making body of the government for climate change programs. An overview of the processes involving DOE, CCC, and other relevant authorities is shown in Appendices A, B and C.

58 The Philippine government is aware of the complexity of the procedures associated with planning and developing MRE projects and is planning to streamline them in order to reach and enable the required and planned RE investments envisioned in the Philippine Energy Plan 2020 – 2040. In the PEP, DOE ensures compliance to the Energy Virtual One-Stop Shop (EVOSS) Act and Ease of Doing Business (EODB) Act of 2018 in order to build favorable market conditions. A “whole-of-government approach” shall be implemented in order to improve and speed-up regulatory procedures. One of the envisaged measures that will be considered is the enhancement of the Energy Investment Coordinating Council (EICC) in DOE, under the Energy Policy and Planning Bureau with institutionalized linkages with the other

government regulatory agencies. More of the Next Steps and Recommendations are found in Section VIII.

E. Benefits of MRE

60 Developing MRE resources will also create beneficial impacts on other key political, economic, environmental, sociological, technological, legal, and environmental factors in the Philippines, particularly in coastal areas.

a. ***Political***. Given that MRE development will mostly be located in local coastal areas, local government units (LGUs) can initiate efforts to transition to clean energy and develop energy security for their own constituency. LGUs will have direct access to the benefits of having predictable and steady energy supply at a lower cost compared to fuel-based energy options. With the involvement of their local stakeholders, they will be able to better measure the gaps, costs, and the local resources needed to facilitate MRE development and better electrification for their LGU.

b. ***Economic***. MRE development can boost the economic condition of local areas by providing access to electricity for LGUs with insufficient or non-existent electrification. The presence of commercial grade, working MRE energy projects will encourage investors to set up businesses in the area, which in turn will attract tourism and stimulate further economic activity. Additionally, MRE development can introduce localities to the Blue Economy[56] market to create livelihood potential in the works of aquaculture, green tourism, among others.[57] The Philippines can study and potentially replicate the Blue Economy Cooperative Research Center of Australia's work into an integrated and planned approaches to managing Blue Economy supply chains.

c. ***Sociological***. The transition to RE sources can provide significant social benefits, including improvement in public health and creation of work opportunities for coastal and island community residents, including women and other marginalized groups. There is also the need to highlight the role of women and other marginalized groups in bringing in localized solutions for a just energy transition. These are typically instituted by these projects through their Gender and Development (GAD) initiatives to empower women, the economically disadvantaged, and persons with disabilities (PWDs).

d. ***Technological***. Implementation of MRE programs across the country enables Philippine-based businesses to partner and create joint ventures with business leaders in the development of MRE projects, systems, components and services. One such opportunity is to establish and develop local manufacturing and service companies in

[56] Blue Economy rehabilitates and preserves marine ecosystems through clean technologies and MREs to sustainably use marine resources for economic activities (WWF, 2015).

[57] "Aquaculture is the rearing of aquatic animals or the cultivation of aquatic plants for food. When used to produce fish, mussels, oysters, or similar organisms, it can produce high-quality protein with no need for land, fresh water, or fertilizer" (LiVecchi et al., 2019).

the field. This typically begins with service centers for components, then advances into component manufacturing, culminating in the development of a new industrial sector focused upon MRE. The completion of this objective is due to the collaboration of both international and local efforts in the development of technologies and skills needed. The unique situation of having 7,000+ islands, many of which are not grid connected, provides an opportunity to become leaders in the production, implementation, and deployment of viable and commercially ready technologies for non-grid connected island communities. These technologies and solutions have the potential to be applied in similar locations around the world.

e. ***Environmental.*** MRE is a clean energy source that can reduce GHG emissions while ensuring energy security, increase economic growth, enhance social inclusion in an environmentally sustainable manner. MRE deployment, through proper planning and engagement with other marine users, could provide a pathway towards creation of a Blue Economy, where there is a recognition of sustainable and regenerative use of marine space among its users and stakeholders. Coordination with other marine stakeholders could also streamline legal and regulatory processes that are needed to utilize the marine space sustainably.

61 In addition to the above, generating MREs will have the potential to educate communities in matters around sustainable development and environmental management. This may help them take action to increase their resilience to environmental shocks by making conscious efforts to protect and improve the environment.

V. Application of International Experiences and Learning in the Philippine Context

63 The Philippines can learn from international experiences and initiatives in the development of its MRE sector. General observations in relation to these can be applied to support the development of the MRE sector followed by the related technologies.

64 Besides OSW and marine solar technologies, which have had significant traction globally, there is also evidence to suggest that the development of MRE ecosystems has been catalytic, instrumental, and synergistic in supporting the growth of the MRE sector in many parts of the world. The development of the supporting ecosystem is critical to the overall success of MRE implementation. The UK is the most successful hub for MRE development to date, with attention paid to the critical need for a supporting ecosystem for project development. As an example for ORE, the UK based European Marine Energy Centre (EMEC) has been instrumental in developing the global tidal in-stream and wave Energy sectors and is now at the forefront of research and innovation around ORE, including the generation of clean hydrogen.

65 Beyond EMEC, a number of other test sites/facilities around the world have also become the catalyst for the journey of various countries to embark on ORE sector. Examples of other test sites include the Fundy Ocean Research Centre for Energy (FORCE) in Canada, the Dutch Marine Energy Centre (DMEC), the Pacific Marine Energy Center (PMEC) in the United States of America, And the National Ocean Technology Center (NOTC) in China, among others.

66 Other research, development, test bedding, demonstration, pilot, and scaling-up activities globally have also looked into marine solar technologies e.g.: Wang and Lund[58] have highlighted four different models of floating PV for the marine environment. These include (a) Fixed Pile Floating Voltaic Systems, with an example (2021, Zhejiang, China) covering 3 km^2 of coastal mudflats delivering 300 MWp; (b) wave-proof floating voltaic, in development since 2016 with various degrees of success versus wave energy, as documented in studies in Malta by Grech et. al.[59]; (c) floating platform PV systems, with continuous development and innovation in this area by firms such as the SwimSol Corporation of Australia and the Norwegian Moss Maritime corporation; and finally (d) Floating Thin Film PV Systems. These are still under development, for example by firms such as the Norwegian Ocean Sun, with a theoretical wave and wind robustness able to withstand super typhoon events with winds up to 275 km/h.[60]

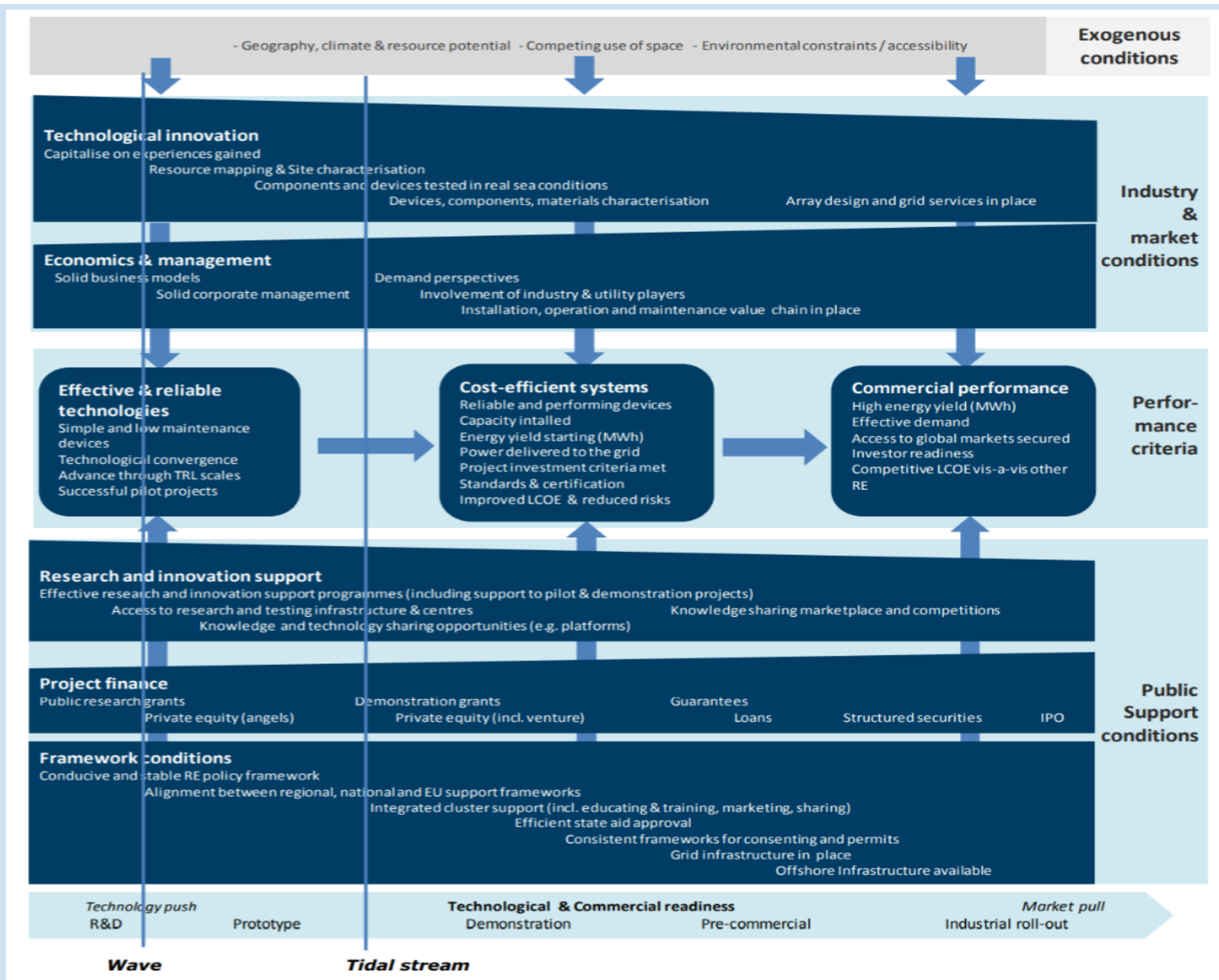
[58] Wang, J.; Lund, P.D. Review of Recent Offshore Photovoltaics Development. Energies 2022, 15, 7462. https://doi.org/10.3390/en15207462

[59] Grech, M.; Stagno, L.M.; Aquilina, M.; Cadamuro, M.; Witzke, U. Floating photovoltaic installations in Maltese sea waters. In Proceedings of the 32nd European Photovoltaic Solar Energy Conference and Exhibition, Munich, Germany, 20–24 June 2016; pp. 1965–1968.

[60] Solar Energy Research Institute of Singapore; World Bank Group; Energy Sector Management Assistance Program. Where Sun Meets Water: Floating Solar Market Report. 30 October 2018. Available online: https://openknowledge.worldbank.org/handle/ 10986/31880

67 These example studies capture the lessons learned globally that the Philippines can leverage and apply appropriately in the local context. Looking at the issue broadly, we can examine a useful framework the country can use to develop its MRE sector as shown in Figure 18. This diagram documents a typical journey of emerging technologies, from low to high technology and commercial readiness levels that highlight the importance of a holistic view of various roles such as innovation, economics, R&D support, project finance and other conditions that enable the uptake of emerging technologies in the combined environment of technology push and market pull.

Figure 18. Framework for an integrated approach to ocean energy technology development



Note: From European Commission (2017, April). Study on Lessons for Ocean Energy Development. European Commission. Retrieved November 10, 2021, from *http://publications.europa.eu/resource/cellar/03c9b48d-66af-11e7-b2f2-01aa75ed71a1.0001.01/DOC_1*

68 Localizing the experience of other countries with their progressive development, not only of the technology, but also of the supply chain, project facets, and the wider ecosystem, will prove to be a significant yet important challenge as the Philippines looks to apply international experiences and learning in the Philippine context.

69 To be successful, the Philippines can look at synergizing different efforts that could be strategic for the country's sustainability agenda (e.g., energy-food-water nexus, Blue Economy development, etc.) and not just focus on energy security for traditional power generation.

70 Various enabling tools from international initiatives (e.g. Marine Spatial Planning, Toolkits, Environmental and Social Impact Assessment methodologies, etc.) could also be investigated for suitable application in the Philippines in order to help facilitate the sustainable development of the MRE sector.

A. Tidal in-stream Energy Conversion Technology

71 To harness the hydrokinetic energy from tidal currents / tidal streams, tidal in-stream energy conversion (TISEC) technologies are used. In the Philippine context, TISEC can be used to extract energy from tidal currents which are present in a lot of straits and channels around the archipelagic nation. The following figure demonstrates examples of some TRL 6 - 8 (i.e., near commercial/commercial) TISEC Systems (various sizes and types: seabed, floating, submerged, etc.), shown in Figure 19. These can form an important basis for technology development and implementation which projects in the Philippines can learn from. For instance, looking at a trajectory of technology development that starts with smaller systems (i.e., in the <100 kW range) may be better than starting with units in the >250 kW range because the capabilities and capacities of different players in the ecosystem (e.g., the supply chain), especially in a new geography and market, can be developed alongside.

Figure 19. Tidal Stream Energy Conversion Technologies

Note: Images from: Orbital Marine Power. (2021). Orbital. Orbital Marine Power. From https://orbitalmarine.com/o2/.; Sabella. (2018). Sabella. From https://www.sabella.bzh/en.; Sustainable Marine Energy. (2019). Sme. Sustainable Marine. From https://www.sustainablemarine.com/plat-i.; Envirotek. (2017). Envirotek. ENVIROTEK. http://www.envirotek.sg/. Guinard Energies Nouvelles. (2018). Guinard. Guinard Energies Nouvelles. https://www.guinard-energies.bzh/en/guinard-energies-2/.; SIMEC Atlantis Energy. (2016). Simec. SIMEC Atlantis Energy. From https://simecatlantis.com/services/turbines/.; Nova Innovation. (2020). Nova. Nova Innovation. https://www.novainnovation.com/products/ ; Minesto. (2018). Minesto. https://minesto.com/products. https://minesto.com/.; Mako Energy. (2019). Mako. Mako Energy. From https://www.mako.energy/technology.

72 For first projects in the Philippines, supply chain capability and any need for large specialized vessels to handle the installation of large and heavy systems which are not currently present in the Philippines will need to be a key consideration. As such, floating technologies and smaller TISEC technologies that are a particularly good fit with local manufacturing capabilities (e.g., shipbuilding) and the wider local supply chain will be most suitable for the Philippines in the short term.

B. Tidal Stream Energy Investment and Project Economics

73 The investment required to tap the potential of tidal in-stream in the Philippines will vary from project to project and from one site to another. Table 9 provides an overview of a number of reference projects that are useful for the Philippines' context, including information around cost, and the relevant rates (be it the Feed-in Tariff, Power Purchase Agreement, or LCOE). Each of these projects has been highlighted due to their existing or near-term expectations for viable, affordable electricity for their target market. All of these projects have mid- and long-term project lives, extending up to 20 or more years. Each of the project studies referenced includes a managed increase of capacity during the project duration, and it has demonstrated a

reduction in the LCOEs for each project. Ultimately, this is shown in each project to improve its viability and affordability.

Table 9. Reference Rates and Costs of Tidal Stream Energy Projects

Project/s Size and Location	Technology	Feed-in Tariff (FIT) / Power Purchase Agreement (PPA) Rate or LCOE and term	Notes/Remarks
22MW, Canada [2]	Tidal Stream	(a) FIT: CAD530/MWh (~PhP19.63/kWh), 15 years (b) FIT: CAD420/MWh (~PhP15.56/kWh), 15 years	FIT rates are developmental rates called "COMFIT" or Community FIT. Lower rate for projects producing >16,640 MWh
9MW, Canada 2020 [3]	Tidal Stream	CAD530/MWh (~PhP19.63/kWh), 15 years	Project Cost: ~PhP4.34B
~1-2MW, Indonesia (West Papua) 2017 [1]	Hybrid Tidal Stream, Solar, Diesel	Diesel-only LCOE: USD0.5 to USD 1.00 / kWh (~PhP24.06 to PhP48.12/kWh) Hybrid (Tidal+Solar+Battery+Diesel) Case Study LCOE: USD 0.25 to USD 0.368 /kWh (~PhP12.03 to PhP 17.71/kWh), 20 years	Phase 1 (Test): Tidal + Diesel – completed in 2017
600kW to 5MW, 2020-21 Philippines	Hybrid Tidal Stream, Solar, Diesel	Diesel-Only True Cost of Generation Rate: ~PhP 13.5 to 24.83/kWh Hybrid (Tidal+Solar+Battery+Diesel) LCOE: (~PhP12.03 to PhP 17.71/kWh), 20 years	Various Off-Grid Studies – i.e., Tawi-Tawi, Dinagat, San Antonio (N. Samar) *Estimated/Indicative Project Costs:* PhP75m-100m (600kW, no OpEx) PhP125m-150m (1.2MW, no OpEx) ~PhP500m (5MW, no OpEx)

Note:
[1] Deloitte Consulting and OceanPixel SEA (2017). Marine Renewable Energy: Unlocking The Hidden Potential Southeast Asia (SEA) Market Assessment, Singapore: OceanPixel.
[2] Nova Scotia, Canada. (2015). Developmental tidal feed-in tariff program. Department of Energy and Mines. Retrieved November 11, 2021, from https://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit.
[3] Offshore Energy. (2020, April 2). Canada awards C$30 million for 9MW Tidal Energy Scheme. Offshore Energy. Retrieved November 11, 2021, from https://www.offshore-energy.biz/canada-awards-c30-million-for-9mw-tidal-energy-scheme/.

74 Although tidal in-stream focused, the information in Table 9 provides a good starting point for projects in the Philippines (at various scales) in terms of LCOE and pricing/rates and terms of such rates to encourage the private sector and other participants to undertake and progress first-mover projects and beyond.

75 Figure 20 provides some indicative estimates of Internal Rate of Return (IRR) and Return of Investment (ROI) for Low, Medium, and High Project CAPEX and corresponding LCOE scenarios with the corresponding tariff rate.

Figure 20. Economics of Grid-Connected Tidal Stream Energy Projects

100 MW	Total Project (20-Years)					
	~USD 378M		~USD 560M		~USD 984M	
	CapEx = $ 233.2M	OpEx = $6.63M/yr	CapEx = $ 406.5M	OpEx = $6.63M/yr	CapEx = $ 810.2M	OpEx = $6.63M/yr
FIT (PhP/kWh)	USD 2M/ MW (LCOE = $ 0.11/kWh)		USD 4M/ MW (LCOE = $ 0.17/kWh)		USD 8M/MW (LCOE = $ 0.3/kWh)	
10	ROI = 95% Profit = ~USD 358M	IRR = 14% Payback = ~6.5 yrs	ROI = 32% Profit = ~USD 177M	IRR = 6% Payback = ~11 yrs		
13.5	ROI = 163% Profit = ~USD 616M	IRR = 21% Payback = ~5 yrs	ROI = 78% Profit = ~USD 434M	IRR = 11% Payback = ~7.6 yrs	ROI = 1% Profit = ~USD 9M	IRR = 3% Payback = ~16.2 yrs
17	ROI = 232% Profit = ~USD 873M	IRR = 28% Payback = ~3.5 yrs	ROI = 124% Profit = ~USD 691M	IRR = 15% Payback = ~6.3 yrs	ROI = 27% Profit = ~USD 267M	IRR = 5% Payback = ~12 yrs

200 MW	Total Project Cost (20-Years)					
	~USD 753.5M		~USD 1,117.3M		~USD 1,966.3M	
	CapEx = $ 465.3M	OpEx = $13.25M/yr	CapEx = $ 811.8M	OpEx = $13.25M/yr	CapEx = $ 1,620.3 M	OpEx = $13.25M/yr
FIT (PhP/kWh)	USD 2M/ MW (LCOE = $ 0.11/kWh)		USD 4M/ MW (LCOE = $ 0.17/kWh)		USD 8M/MW (LCOE = $ 0.3/kWh)	
10	ROI = 95% Profit = ~USD 718M	IRR = 14% Payback = ~6.5 yrs	ROI = 35% Profit = ~USD 354M	IRR = 6% Payback = ~11 yrs		
13.5	ROI = 164% Profit = ~USD 1,233M	IRR = 21% Payback = ~4.5 yrs	ROI = 78% Profit = ~USD 869M	IRR = 11% Payback = ~7.6 yrs	ROI = 1% Profit = ~USD 20M	IRR = 3% Payback = ~16.2 yrs
17	ROI = 232% Profit = ~USD 1,748M	IRR = 28% Payback = ~3.5 yrs	ROI = 124% Profit = ~USD 1,384M	IRR = 15% Payback = ~6.3 yrs	ROI = 27% Profit = ~USD 535M	IRR = 5% Payback = ~12 yrs

Source: OceanPixel Philippines Inc and OceanPixel Pte Ltd sensitivity analysis

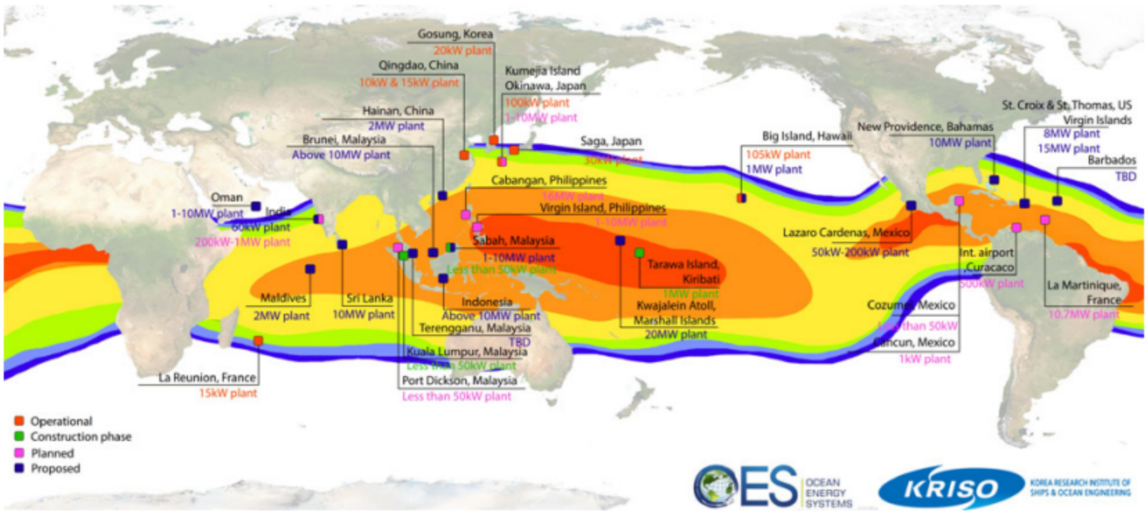
76 From Figure 20, it can be concluded that the required or appropriate rate reduces for large scale tidal power projects. This illustrates that for first mover projects, a higher rate is needed. As the number of installed capacity increases, which translates to a lower cost (due to economies of scale and because of the learning captured), the rate becomes lower. In the tropical region, a reduction of at least 30% of the costs can be expected because there are cheaper labor and less stringent regulatory requirements. The now more commercial, high TRL, MRE projects started from USD 8 M/MW more than a decade ago and now have gone down to USD 4-6 M/MW internationally. It is anticipated that ORE can reach USD 2.5 - 5/MW which gives the project developer some flexibility to accept rates that may be slightly lower. The recommendations to achieve these cost reductions are found in Section VIII Recommendations.

77 Including productive use of renewable energy (e.g., water desalination, aquaculture applications, green hydrogen, etc.) in the scoping and development of MRE energy projects may potentially have positive implications on the economics of the project.

C. Ocean Thermal Energy Conversion Technology

78 Figure 21 shows the several OTEC projects in different project stages.

Figure 21. Present and future planned OTEC/SWAC projects around the world



Note: Image from: OES (2021), White Paper on OTEC (OTEC). IEA Technology Programme for Ocean Energy Systems (OES), [*www.ocean-energy-systems.org*](http://www.ocean-energy-systems.org)

79 According to the OTEC white paper by the IEA OES (2021)[61], an island-based 2.5 MW system is achievable. It also states that building a 10 MW floating OTEC plant is technically, but not yet commercially, feasible. This is due to significant technical developments in the oil and gas industries in the past 15 years, where OTEC demonstration could learn from. In increasing the capacity further to 100 MW, the main challenge is "the confidence that large diameter cold water intake pipes can be installed and will prove reliability over time." A key barrier to commercialization of OTEC technologies is the high estimated CAPEX. Table 10 shows the LCOEs of OTEC.

[61] IEA-OES. (2015). *International levelized cost of energy for ocean energy technologies: An analysis of the development pathway and levelized cost of energy trajectories of waves, tidal and OTEC technologies*. *Ocean Energy Systems - International Energy Agency*. Ocean Energy Systems - International Energy Agency. https://www.ocean-energy-systems.org/documents/57387-cost-of-energy-for-ocean-energy-technologies-may-2015-final.pdf/.

Table 10. Estimated LCOE for OTEC plants[62]

Energy Technology (unsubsidized)	LCOE (USD, 2018/kWh)
10 MWe OTEC (original interest rate)	0.15
10 MWe OTEC (adjusted interest rate)	0.20 - 0.67
100 MWe OTEC (original interest rate)	0.03 - 0.22
100 MWe OTEC (adjusted interest rate)	0.04 - 0.29

80 An island-based 2.5 MW is applicable to archipelagos such as the Philippines. OTEC co-products include freshwater, nutrients from deep ocean water, and still cool water. These co-products provide opportunities and more incentives to further develop the technology. Tropical locations can benefit from the supply of freshwater, especially in summer months. The nutrients from deep ocean water can help in aquaculture operations. The cool water products can be used for large-scale air conditioning as well as for temperature-controlled agriculture. A multi-product eco-resort with clean energy, freshwater, aquaculture, and air-conditioning is an attractive concept for tropical archipelagos, including the Philippines. However, strategic financial support mechanisms will be required, and an appropriate tariff rate is required for the system to have an acceptable return on capital investment.

[62] Langer J., et al., "Recent progress in the economics of ocean thermal energy conversion: Critical review and research agenda" Renewable and Sustainable Energy Reviews, 130, 2020.

VI. Opportunities and Challenges of MRE in the Philippines

81 Quirapas et. al. (2015) enumerate several opportunities and challenges faced by ORE development in SEA (Table 8). The Nationally Appropriate Mitigation Action (NAMA) Support Project Proposal on Decarbonization of Electricity Generation on Philippine Islands (using Tidal Stream & Solar PV) of September 2020 contains a barrier analysis which corresponds largely to the challenges analyzed by Quirapas and peers and may apply to most ORE which may also be relevant to other MRE technologies.

82 Through the development of MRE, there is a technical opportunity to incorporate inter-industry knowledge from more mature energy sectors (such as oil, gas, and OSW). Collaborative platforms can lead to the creation of MRE best practices that can be applied to local and regional circumstances. For example, the recent OSW Roadmap recognizes that partnerships and inter-sector platforms are important and suggests creating a long-term official government-industry Task Force that includes local and international project developers and key suppliers. The Task Force will help realize the roadmap's recommendations and promote collaboration to ensure successful offshore industry growth. Additional technical/technological opportunity is hybridizing RE systems with MRE - Marine Solar (floating solar PV), OSW with tidal in-stream etc., also the potential for microgrid systems especially for off-grid areas. More of the recommendations and next steps are found in Section VII.

83 Socio-economic opportunities associated with developing MRE include job creation and energy security wherein developers can reduce costs while uplifting the livelihoods of the community. Additional and alternative access to renewable electricity could enable long-term sources of income for communities, specifically those located in isolated and remote areas.

84 As a source of cleaner and renewable energy, MRE can displace conventional power generation and help mitigate GHG emissions and meet wider environmental sustainability targets.

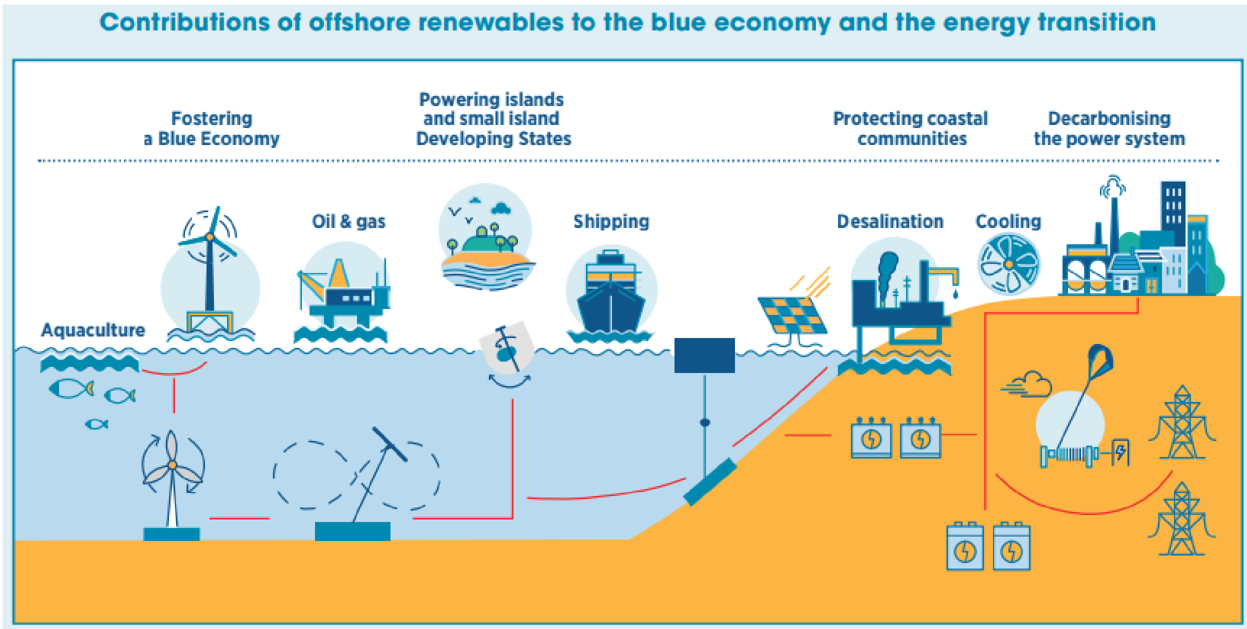
85 Policies in support of MRE development will help in addressing the issue of energy access in rural and off-grid areas. This will also provide an alternative source of energy as the population grows and consumers' energy demands continue to increase. When planned and implemented effectively, the introduction of MRE technologies could bring about blue economy growth that ensures sustainable and regenerative usage of marine space.

86 Blue economy growth can be developed through blue ecosystems. An example of this is the transition to inter-island marine vessels enabled/powered by renewable energy. The use of MRE in the context of an electric vessel 'ecosystem' is a step towards the blue economy. More combinations of applications and services in support of sustainable development are being

explored, crafted, and implemented globally. The MARES[63] project of the ADB looking at regenerative marine industries by which it catalyzes the blue economy with marine renewable energy).

87 Figure 22 illustrates the different MRE technologies applied within the blue economy.

Figure 22. Marine Renewable Energy and the Blue Economy



Source: IRENA (2021), Offshore renewables: An action agenda for deployment, International Renewable Energy Agency, Abu Dhabi.

88 Aside from opportunities, there are some important challenges preventing the development of MRE in the Philippines. Financial constraints and regulatory and procedural gaps are the two most pressing barriers for MRE development.

a. Financial barriers: High up-front capital costs; high risk perceptions of local banks associated with RE projects due to a limited national track-record of MRE prevent banks from providing debt financing; high risk perceptions by investors because of currency risk (costs are in hard currency while revenues are in local currency).

b. Regulatory and administrative barriers: These hurdles are still high for any perceived-as-emerging RE (such as MRE) project developer/investor and contribute to a high-risk perception by investors. The need for streamlined, coordinated, and proportionate procedures is generally recognized by DOE. In addition, the guidelines for incentives and other benefits for MRE are not yet clearly defined by DOE. Thus,

[63]Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services. 2021. https://events.development.asia/learning-events/adb-data-room-marine-aquaculture-reefs-renewable-energy-and-ecotourism-ecosystem

discussions must be undertaken with the DOE for these projects, to better understand the emerging policy framework and the consequent benefits applicable.

89 Technical challenges include:

a. Installation of MRE infrastructure is limited to appropriate weather and sea conditions and requires professionals that have technical expertise.

b. The cost of deployment, maintenance, and repair of the MRE technologies can be relatively high in comparison to other more established technologies.

c. Infrastructure must be able to withstand high energy offshore conditions over a long period of time to have minimal repairs and replacement in the future.

d. While there is potential MRE resource that can be harnessed, the physical infrastructure may not be readily available to support deployment, especially in remote, off-grid areas where grid systems are not present.

90 Economic challenges include:

a. Relatively high CAPEX for MRE technology deployment.

b. The competitiveness of MRE as a source of energy is also a concern due to the wide preference for fossil fuels in the Philippines. This preference for fossil fuels is due to several factors, including its lower capex, equipment suppliers and support existing throughout the country, as well as the knowledge base of qualified personnel already available in the Philippines to install and service this equipment. However, recent (i.e. the past two years) price volatility of fossil fuels have triggered various players and stakeholders to seriously consider the more sustainable alternative of renewable energy.

c. Thus, MRE's main targets in the short-term are Philippines off-grid areas that are not reached by current energy service providers.

91 A key social challenge arises from MRE being relatively new and hindrances from policy decision-makers, local government units, and the community itself may arise in the project development. MRE projects must be active in the area at the earliest stages to generate support from all the stakeholders involved by making sure that it will benefit the entire community. Project proponents must engage in active outreach with stakeholders to ensure that policy decision-makers and community end-users are aware of, engaged with and supportive of the MRE projects, to increase acceptance of target community groups. To be

successful, acceptance and long-term adoption of MRE technologies require consistent engagement with various marine and community stakeholders.

92 The key environmental challenge for the MRE sector is that there remains uncertainty regarding possible impacts on marine wildlife and habitats, the wider natural environment, and other users of marine space. Although current research indicates that minimal impacts are to be expected from small arrays and demonstration projects, it is important to consider this on a project-by-project basis. Developers must ensure that there is cooperation among other users of marine space (such as fishermen and ships) and that potential impacts are mitigated and managed appropriately. These issues will be managed through the pre-development planning process, including strategic and project specific environmental assessments.

93 Political, legal, and institutional challenges may also arise in MRE development, especially in demographic and geographic aspects. There are political hurdles such as burdensome bureaucratic procedures for acquiring necessary permits, managing corruption, and appeasing social acceptance issues. These challenges constrain the country and the developer's potential to maximize MRE sources. In addition, while supportive policies are in place for RE development in the Philippines, implementing rules and regulations need to be consistent and transparent to various stakeholders. This is to ensure that there is accountability and transparency throughout the project development and implementation.

Table 11. Opportunities and Challenges in the Philippines

Dimension	Opportunities	Challenges
Economic	A combination of ORE and solar/wind is already competitive today on small islands so far depending on diesel generators and leads to cheaper and 24 h stable energy supply for the population.	High up-front capital costs reduce perceived competitiveness of MRE.
Financial	Government financing and support schemes such as encouraging Foreign Direct Investments (FDI) for RE are in place, they can be easily applied to MRE.	High risk perceptions associated with RE projects and a limited national track-record of MRE lead to unfavorable financing offers by national banks. Currency risks increase investors' risk perception.
Political/legal/ institutional	Supportive MRE policies could address the issue of energy access on rural islands, provide an alternative energy source to address increasing energy demand, and reduce dependence on fuel.	Burdensome, time-consuming and untransparent bureaucratic procedures for deployment and setting up a business increase the risks to investors.

Dimension	Opportunities	Challenges
	Policies, financing and support schemes for RE are in place but need to be adapted to cover MRE.	The legal environment for MRE is also still developing, for example considering the benefit programs applicable.
Technical or Technological	Incorporating inter-industry knowledge and learning from more mature sectors, such as oil and gas, and marine & offshore, in the MRE sector. Creating innovative MRE solutions applicable to the local and regional conditions, e.g., MRE as an off-grid solution for small tropical islands such as in the Philippines and Indonesia. Can leverage local shipbuilding and local supply chain manufacturing industries.	Successful installation of MRE infrastructure requires good weather and sea conditions, as well as technical expertise and knowledge to carry out the installation and address possible installation problems. The upfront cost of the installation, maintenance and repair of MRE technologies remains expensive and is not yet competitive in comparison to fossil fuel at a larger scale. For grid-connected solutions, grid infrastructure is often not sufficiently developed, or the capacity may need to be increased.
Social	Creation of an MRE sector could lead to job creation and security; to regional supply chains that could reduce MRE cost; and to uplifting the livelihoods of rural communities.	Policy decision-makers and community end-users need to be aware of and on board on MRE projects, to increase acceptance of target groups.
Environmental	MRE, as a source of cleaner and renewable energy, can help mitigate the impact on climate change.	Addressing the impact on marine life and environment, and other users of marine space. Special protected areas must be excluded and typhoon risks must be limited.

Note: Adapted from Taeihagh, A, Quirapas, M. (2021-03-01). Ocean renewable energy development in Southeast Asia: Opportunities, risks and unintended consequences. Renewable & Sustainable Energy Reviews 137. ScholarBank@NUS Repository. https://doi.org/10.1016/j.rser.2020.110403

VII. Conclusion

A. Vast Potential for Marine Renewable Energy Development in the Philippines

94 This report focuses on laying out the potential for MRE for the Philippines in terms of energy resources, technology options, project development pipeline, and other considerations for the following opportunities: offshore wind, marine solar, tidal in-stream, wave energy and OTEC. The Philippines will most likely adopt OSW technologies first (with large-scale grid-connected projects), then marine solar (e.g., floating PV in marine environments) and tidal in-stream technologies (starting with small-scale island micro-grid scale projects), before wave energy and OTEC.

1. Offshore wind

95 Offshore wind has a capacity potential of 178 GW in total for the Philippines[64]. This includes a fixed bottom capacity potential of 18 GW and a floating capacity potential of 160 GW. The activities currently underway to support the development of these resources includes a World Bank-supported OSW Roadmap that details the various steps to create a successful OSW industry in the Philippines by 2035, which was released in April 2022. In addition, there are project developers actively pursuing large scale development opportunities.

96 The DOE has already awarded OSW service contracts close to 20 OSW developers, and this involves around 42 awarded OSW energy service contracts with an equivalent of about 31.5 GW of potential capacity as of this writing. Government agencies are taking an active role in these opportunities. The relevant agencies include the Solar and Wind Energy Management Division (SWEMD) and the Renewable Energy Management Bureau (REMB), both from the Philippine Department of Energy.

2. Marine solar

97 Marine solar has high potential in the Philippines, with most of the focus areas for development found in the multitude of near-shore, calm bay and reservoir areas. The Philippines has an estimated 266GWp of Marine Solar potential that could be realized by utilizing only 1% of the available offshore space in bays and coastal areas. Given the geography of the Philippines, with more than 7,000 islands, the total potential is extremely difficult to quantify. Nevertheless, efforts to quantify this potential are ongoing amongst R&D entities, technology providers, and some project developers. It is likely that other constraints, such as external, political, or commercial drivers will take precedence in identifying and initiating specific project

[64] The World Bank. (2022). https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf

opportunities for action. REMB and SWEMD are leading the efforts in marine solar development.

3. Ocean energy

98 For the Philippines, the quantified potential for ORE sources amounts to at least 170 GW, as estimated by the Philippine Department of Energy. This consists of at least approximately 40 to 60 GW of practically extractable tidal in-stream energy resources, as presented at the Asian Wave and Tidal Energy Conference (2012). The potential for OTEC and wave energy has yet to be quantified.

99 Tidal in-stream activities in the Philippines have included three key developments:

a. The Nationally Appropriate Mitigation Action (NAMA) Support Project (Hybrid Tidal and Solar PV), "Decarbonization of Electricity Generation on Philippine Islands" has been given the green light for a detailed preparation phase. The lead agencies on this are the Climate Change Commission (CCC) and the Department of Energy.

b. At least five project developers and at least two technology developers are involved in pre-development stages of sites/projects with DOE Renewable Energy/Ocean Energy Service Contracts (total of seven service contracts). The lead agencies on this are the Hydro and Ocean Energy Management Division (HOEMD), the Renewable Energy Management Bureau (REMB), and the Department of Energy (DOE).

c. An ORE Research and Development Project is developing a small-scale field lab. The leading organizations for this are the Mindanao Renewable Energy Center and the Ateneo de Davao University. The lab is funded by the Philippine Department of Science and Technology (DOST).

100 Wave energy development activities in the Philippines have been much less extensive to date. There have been some early exploratory activities by some project and/or technology developers. R&D and desktop-based studies have been on-going and some developmental and exploratory efforts have also been spearheaded in collaboration with HOEMD and DOE.

101 OTEC activities in the Philippines have not progressed significantly over the past decade because of the deferred Feed-in Tariff (FiT) rate for this specific technology. This decision of the Energy Regulatory Commission (ERC) stems from the lack of information on commercially operating OTEC technologies to serve as reference in calculating for the rate.

102 Other emerging technologies and trends related to the development and uptake of MRE include the following.

a. Seawater-based energy storage systems

Seawater-based energy storage systems are a feasible and sustainable alternative to lithium-ion batteries using abundant seawater.[65] By direct utilization of saltwater as a source for the conversion of electrical and chemical energy, seawater batteries are distinctive energy storage technologies for sustainable renewable energy. The first Seawater Pumped Storage facility was constructed in Japan. The peak power output of the facility was estimated by the University of Strathclyde in a 2018 study to be 2.1 % of Okinawa's maximum power demand. In the Philippines, a 500 MW pumped storage hydropower project in the province of Rizal and 1.4 GW project located in Pakil Laguna, both under the supervision of Prime Infra, will be constructed. With mountainous topography along coastal areas, some areas in the Philippines can have water pumped storage as a suitable solution for energy storage.

b. Sea water air conditioning (SWAC)

Tropical, coastal areas with narrow continental shelves are good sites for the implementation of Seawater Air Conditioning (SWAC), a renewable and low CO_2 emission cooling process. SWAC is a base load district cooling technology that uses deep cold seawater that can be as cold as 3–5 °C, even in the tropics. SWAC offers a solution to reduce the amount of energy in producing air conditioning through renewable cold seawater. The implementation of SWAC in tropical coastal areas in the Philippines can be feasible and will reduce the impact of GHG emissions.

c. Electrification of Vessels

The electrification of vessels/boats in the Philippines is an upcoming trend. To date, there has been some support deployed to not only explore (i.e., in terms of R&D) but also undertake pilot projects with electric boats (e.g., in Pasig River, Sangat), with support from entities such as USAID, DOE, and DOST.

d. Blue Economy

Sustainable development projects, such as those involving marine renewable energy, food production, aquaculture, water production (e.g., desalination), electrification of vessels, marine environment monitoring, and other productive use of renewable energy for the Philippines, will form part of the development of the Blue Economy of the Philippines. The Mindanao Development Authority (MinDA), in partnership with OceanPixel Pte Ltd (Singapore) and Altum Green Energy Operations (Australia), is looking at the possibility of using "blue energy" as an alternative source of power supply in Mindanao to enable the development of the Blue Economy. An MOU has been signed with the government with the purpose to "promote and accelerate the Blue Economy and energy" in this part of the country.

[65] Arnold, S., Wang, L., & Presser, V. (2022). Dual-Use of Seawater Batteries for Energy Storage and Water Desalination. *Small*, 2107913.https://doi.org/10.1002/smll.202107913

B. Viability in terms of Technological, Financial, and Socio-Economic

103 The report has provided details of the viability of MRE considering the technological, financial, and socio-economic factors. These are summarized as follows.

1. Technical Viability

104 From a technology perspective, OSW and marine solar are the most advanced and as such, the uptake of these technologies is expected to accelerate rapidly in the short term (three to five years). This is due to the availability of proven and transferrable technologies and the significant progress being made internationally, particularly in the OSW sector.

105 Tidal in-stream, wave, and OTEC technologies are expected to follow respectively. Realizing key opportunities will depend upon the incorporation of inter-industry knowledge and learning from more mature sectors, such as oil and gas, OSW, shipbuilding etc. In addition, creating innovative ORE solutions applicable to the local and regional conditions will be critical. Key challenges involve the enhancement of capabilities in the Philippines for strategic sectoral planning (e.g., Marine Spatial Planning), project preparation and permitting (which will require Environmental Impact Assessment and other tools), and understanding of the technologies, especially with respect to installation and maintenance of the equipment. Successful installation, operations, and maintenance of ORE infrastructure require good weather and sea conditions, as well as technical expertise and knowledge.

106 However, international projects as well as local implementations are demonstrating key processes and capabilities needed to overcome the challenges. With this in mind, no stringent limitations for MRE - OSW, marine solar, ORE development in the Philippines from a technical perspective are anticipated. The OSW roadmap mentions the considerations below (which are applicable to advance the development of all MRE projects):

a. Clear and long-term electrification strategy;
b. Clear and streamlined permitting policies;
c. Sufficiently large and visible project pipeline to attract investment;
d. Stable and transparent investment environment;
e. Strong and accessible transmission network;
f. Coherent industrial policy;
g. Availability of marine ports, infrastructure and supply chain;
h. Skilled and well-informed public institutions;
i. Confident and competitive environment; and
j. Supportive and engaged public.

2. Financial Viability

107 OSW and marine solar are already financially-viable. For OSW, the indicative LCOE ranges from USD 0.1511 to 0.15766 per kWh for a 25.0372 square-km offshore area.[66] For marine solar, the LCOE is approximately USD 0.09 to 0.13 per kWh.

108 Studies by IRENA of existing projects have shown that the financial viability of ORE is still a challenge. For OTEC, the LCOE could be as low as USD 0.156/kWh for a 100 MWe power plant.[67] Ten on-going wave and tidal in-stream projects with generation capacities between 1 to 6 MW have LCOE rates of 0.2 to 0.45 USD/kWh (tidal in-stream) and 0.3 to 0.6 USD/kWh (wave). According to the IRENA study for tidal energy, an LCOE of USD 0.11/kWh is expected to be reached between 2022 and the early 2030s.[68] However, the cost reductions will come only through the economies of scale to be achieved by scaling up the total installed capacity of projects (through project scaling or replication). Moreover, IRENA estimates that benchmark LCOE values of 0.11 USD/kWh are approximated when projects are scaled up to a minimum of 16 to 18MW for tidal in-stream energy projects. Thus, we expect the Philippines to have a similar experience, requiring larger scale projects to provide the economies of scale needed to reduce the initial CAPEX costs per MW for the implementation of these technologies. It is important to note however, that tidal in-stream and wave energy technologies could be cost competitive today in certain markets such as isolated off-grid islands, which depend on fossil fuel imports.

109 Although the target LCOE of USD 0.11/kWh for tidal in-stream energy seems to be still higher than those projected for other renewables, such as Marine Solar and OSW, it can be justified by considering the additional benefits from a system perspective in terms of predictability, higher capacity utilization, and less variability of electricity supply. This will lead to lower system integration costs than in the case of variable renewable energies in terms of lower necessary back-up capacities and reduced balancing costs.

3. Socio-economic Viability and Adaptation of the Legal and Policy Framework

110 The MRE sector presents a huge opportunity for the Philippines. Creation of the sector could lead to the following: 1) job creation and security, 2) development of regional supply chains that could reduce MRE costs and, in turn, LCOE and reduced subsidies (i.e. from the Universal Charge for Missionary Electrification) to support energy services in off-grid communities, 3) the initiation of a higher skilled workforce equipped to advance the state of new technologies in the

[66] Maandal, G.L.D. et. al. (2021).
https://www.mdpi.com/2077-1312/9/7/758/pdf#:~:text=The%20LCOE%20calculated%20for%20a,kWh%20to%20PHP%208.306%2FkWh

[67] Langer, J. et. al. (2021). https://doi.org/10.1016/j.energy.2021.120121

[68] IRENA. (2020).
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Innovation_Outlook_Ocean_Energy_2020.pdf

Philippines, and 4) the uplifting the livelihoods of rural communities. Furthermore, the achievement of clean affordable energy in rural areas will help advance the availability of many social benefits such as improved educational opportunities, health care and related services, as well as safety.

111 From an environmental perspective, moving from a fossil fuel-based sector to one which is based upon clean renewable energy helps to achieve the Philippines commitments in meeting its obligations to the reduction of greenhouse gases and other pollutants, as outlined in its NDC. This will help the Philippines do its part in the mitigation aspects of climate change.

112 To address the broad socio-economic opportunities and ensure the sector is viable, efforts must be made across a broad spectrum of challenges. Policy decision-makers and community end-users and other stakeholders (e.g., marine space users) need to be aware of and be involved in planning MRE projects (including marine spatial planning) in order to lessen the social resistance to the projects. Public consultations and information sharing sessions should be held to increase public awareness and acceptance of the technology and of the projects.

113 Strategic research around the first projects can help improve our collective understanding around the potential effects on marine wildlife, the overall marine environment, and other users of marine space (fishermen, marine sports, shipping and logistics). Other users of the space are a key issue, since there are demographic, commercial, and geographic conditions that need to be considered in the strategic analysis and planning process. This will ensure the project sizing and application are viable and meaningful for the given local environmental and social settings. For example, tidal in-stream projects being explored in Masbate are under consideration but have been hampered by the LGUs' plan of other usage of the geographic areas, including fishing and transport.

114 The policy and legal framework need to be streamlined and simplified as well as adapted for MRE in order to lower project risks. Incentive measures are in place but need to be opened up for MRE. The Philippine government's goal to go for a "whole-of-government-approach" and a "one-stop-shop" for energy investments should be supported in order to allow transparent and calculable project development procedures. This will require technical assistance on different levels of the government and the financing institutions. Alignment with various agencies (through focus group discussions, technical working group discussions, and workshops), following good international industry practices will help MRE development to accelerate the permitting and consenting processes during project development.

115 This report bespeaks that engaging the stakeholders throughout the development process of an MRE project could efficiently address the challenges and barriers expressed above. This is needed to ensure that MRE projects become viable from economic, social, environmental and policy perspectives.

VIII. Recommendations

A. Potential Pathways for Developing the Marine Renewable Energy Sector in the Philippines

116 As we consider the potential pathways for development, it is important to understand the Innovation Journey, and how MRE technologies are established from a high level. The Innovation Journey and technology value chains are important factors when considering the technologies. *How are these technologies going to come to the Philippines? How will they develop? How will technology transfer take place?* These are all key factors when examining these technologies and considering how they can benefit the Philippines. To provide an initial examination of these questions, Pavitt's Taxonomy is used and is described in detail in Appendix H.

117 A contextualized application of Pavitt's Taxonomy accounts for all of the above considerations in assessing MRE technology development. The MRE innovation journey begins with the very early stage of innovation. In this case, the innovation is conceptualized, typically by individuals or teams within smaller science-based or engineering-based firms. In the case of MRE development, its earliest stages are highly focused on the machinery and equipment needed to interact with marine resources to produce energy. These early stages also address the need for supporting technologies, such as instrumentation, controls systems, and associated software. Initial designs are typically created in house, in collaboration with advanced customers for need and environmental condition analysis. This information is submitted to design teams with rapid design cycles and rapid prototyping, in some cases reinforced with very limited field testing.

118 The main thrust of the innovation journey for MRE is identified as the product design and fundamental product development. The type of innovation for the initial stage of the MRE innovation journey is further identified as the initial product conceptualization, design, and development. The smaller and boutique firms with close links to stakeholders will most likely initiate the innovation journey for MRE, such as advanced customers and firms interested in participating in the financing of the innovation. Due to the imperative to reach markets quickly and monetize the investments into the innovation, these firms will use rapid development approaches to quickly design and implement the early versions of the innovation, which are then further refined based on the prototyping and limited field trials.

119 Once the above processes are undertaken, the Innovation Journey for MRE will move to the next stage where the maturity and commercial suitability pathways of the innovation will be developed. This is typically carried out by specialized equipment and systems suppliers, and the core applications are now specialized towards a specific application of MRE. At this stage, MRE begins to formalize with more rigorous and highly managed development and testing processes focusing on early to mid-stage development. The processes are typically driven

from in-house teams focusing on the optimization of the functional, operational, and economic factors of the innovation.

120 Finally, MRE innovation journey moves away from smaller science and engineering firms, and more towards larger firms or consortiums due to the investments required for mid-stage development. In such cases, financing programs with banks or other investment institutions become an important element of the innovation journey for MRE. Larger technology firms may also perform a “buyout” of the technology if it creates a symbiotic relationship with their other business capabilities.

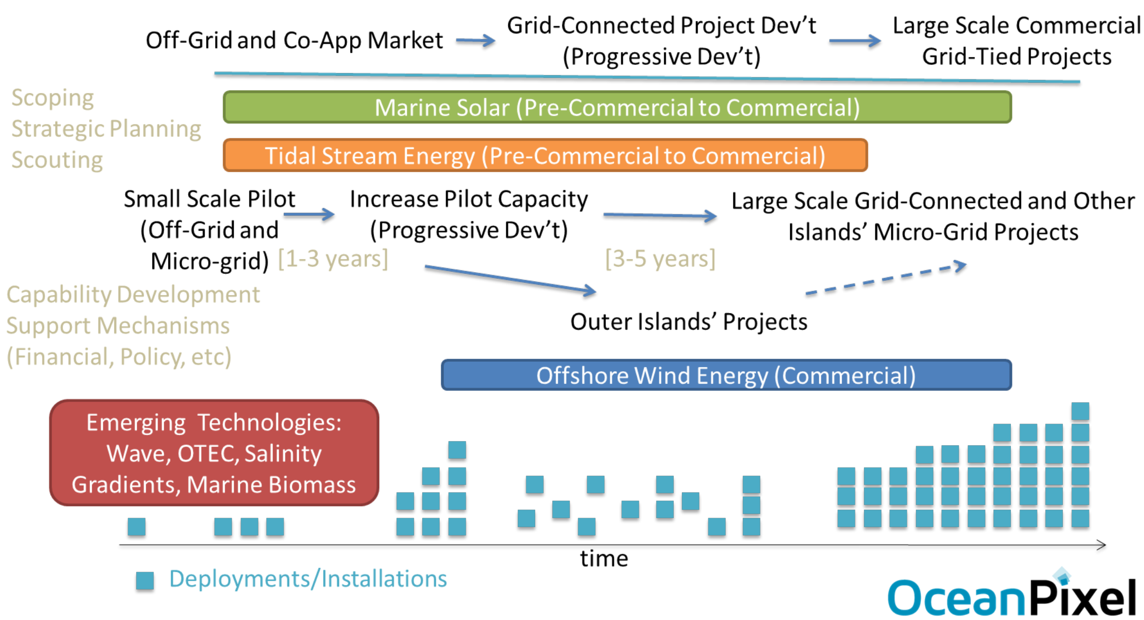
121 The Philippines as an archipelagic country is an ideal partner for the innovation journey of MRE. The unique physical characteristics of the marine environment in the country present vast opportunities to advance the product testing and development, especially at the early stages of the journey. This brief review of the application of Pavitt’s Taxonomy can still be strengthened with more in-depth research.

122 Other important perspectives to consider that will support the innovation journey for MRE based on Pavitt’s Taxonomy are defining supportive strategic financing conditions, amending rules and regulations, developing the industry that accounts for the supply chain and building capability.

123 A progressive approach to commercialization of MRE,especially ORE, starts with first mover projects (e.g., demo, pilot, off-grid, specific applications) and scaling them up into larger arrays or systems, or replicating smaller scale, commercially viable systems – as appropriate.

124 A hybridized system pathway (see Figure 23) is also recommended in order to holistically and strategically develop the MRE sector.

Figure 23. Hybridized MRE Development Pathway



125 As more deployments happen and installed capacity increases, the effective project costs and ultimately the LCOE will also decrease. More mature technologies, such as OSW, typically target the main grid market rather than off-grid areas. These are more advanced in terms of the pathway shown above as such projects need not address being competitive in alternative markets such as islands (e.g., microgrids, water production, electrification of vessels, aquaculture, etc.).

B. Key Factors to Accelerate MRE Development in the Philippines

126 The Philippines can potentially drive the adoption of MRE and related technologies in support of its sustainable development goals while preventing disaster risk reduction. The points below summarize some more of the opportunities which could be enabled by MRE development:

a. Increased Energy Security and Energy Access;
b. Accelerating the Sustainable and Just Energy Transition;
c. Facilitating energy, food, and water security nexus;
d. Addressing climate change by contributing to clean and green alternative energy sources;
e. Socio-economic growth through job creation, economic resilience, inward investment, public-private partnerships;
f. Expertise/capability development leading to export potential through creation of regional supply chain and standards, technology, R&D, financial and business models,

education and skills development, best practices in utilization of marine space and environment;

g. Just energy transition through participation of marginalized groups in the communities like women and indigenous communities along coastal areas; and

h. Catalyzed Blue Economic growth that aims for a sustainable and regenerative use of marine space for long-term.

127 The need for common infrastructure (e.g., transmission and related facilities, i.e., substations for interconnection of offshore capacity) and services (e.g., auxiliary) must also be considered when looking at MRE in an integrated manner. To ensure success, there must be an open and collaborative environment between proponents and other stakeholders such as the National Grid Corporation of the Philippines (NGCP) and distribution utilities. Such an environment can be facilitated by local government units.

128 There is also a need to develop/increase the capability and capacity of various stakeholders to develop a successful MRE sector (more information in Appendix E and Appendix G). Increasing awareness of MRE's benefits, opportunities and risks in the Philippines should be the first step to policy and decision-makers, related industries and potential supply chain providers, technology developers, and end–users.

129 The more MRE technologies will be deployed, the more it will provide accurate estimates of cost from actual conditions, which in effect can enhance local skills and knowledge and may lead to creation of local MRE supply and value chains.

130 To realize the opportunities of developing MRE (and specifically ORE) in the Philippines, the following priority areas (see section C below) need to be addressed in a holistic, cohesive, and properly orchestrated manner through a thorough roadmapping program with relevant stakeholders.

C. Priority action and Next steps To Enable and Accelerate the Development of MRE in the Philippines

131 A spectrum of capability development for the key stakeholders in the MRE ecosystem is needed**.** An integrated and holistic approach involving stakeholder engagement, strategic planning, roadmapping, training, market mechanisms, and other activities will be needed to contribute to the development and growth of a successful and sustainable MRE sector in the Philippines.

132 The prioritized requirements to be addressed through technical and developmental assistance/ intervention (see Appendix G for Summary Table of Needs, Challenges, Assistance, etc.) are as follows:

a. **MRE Development Roadmapping**

The DOE (and various agencies -such as NEDA, DILG, CCC, etc.) need technical assistance, coordination, and expert advisory services to address the gaps in technical expertise and experience. This, in effect, can support a strategic sectoral development roadmap and will enable them to lead the orchestration of MRE development in the Philippines.. It is also important to involve distribution utilities (private and electric cooperatives) during the planning and capacity-building process, especially those having off-grid areas within their franchise areas. Leveraging ongoing activities (such as the OSW roadmap) to serve as inputs and experience to the wider MRE roadmapping is recommended.

An industry roadmap will also facilitate the commercial deployments of MRE in the progressive development framework as discussed in the previous section. It will help enable the development of first mover projects (e.g., demo, pilot, off-grid, specific applications) which can be scaled up into larger arrays or larger systems or replicating smaller scale, commercially viable systems – as appropriate.

b. **Resource Inventory and Marine Spatial Planning**

The DOE (and other stakeholders, e.g., NEDA, NAMRIA, DENR, BFAR, etc.) require technical assistance, capability development, guidance, training, platforms, and tools to address the gaps in capability/expertise. These agencies also require appropriate tools to conduct resource assessment, data management, spatial resource allocation, etc. A critical element of the process is the requirement for support in a multi-stakeholder engagement environment, with alignment of all stakeholders towards a strategic consensus. Similar to the Competitive Renewable Energy Zones (CREZ) project, the same principle may be applied to marine spaces and resources. The use of Marine Spatial Planning principles and tools will help to ensure the efficient allotment of the site to achieve:

- Fair use and resource allocation for all interested stakeholders including fishermen, transportation providers, logistics and shipping providers, etc.;
- Environmental resource assessment and safe use policies and approaches for the project;
- The production of high quality and quantity of energy resources, in keeping with the local / regional requirements of the project spatial area; and,
- The mitigation of negative impacts and alienation of stakeholders especially with regards to utilization of the environment and balancing outside commercial interests.

c. **Market Support Mechanisms**
There is a need to provide support to various stakeholders in terms of technical assistance, coordination, expert advisory; process development and verification, policy and guidelines development, support instruments and mechanisms.

i. **Access to Subsidies for Off-Grid Markets' True Cost of Generation** (e.g., from the UCME)
The uncertainties in revenue models and overly complex processes for New Power Producers to access the same subsidies that fossil-fuel-based generation taps for off-grid markets (e.g., Missionary Electrification) lead to frustration for project developers who wish to hybridize the off-grid markets of the Philippines. Stakeholders such as NPC-SPUG, electric cooperatives, NEA, DOE, and ERC need to improve the transparency and simplicity of certain pathways to allow for more private sector involvement in the energy transition of off-grid areas.

ii. **Enabling / Opening Up Access to Finance for Early-Stage Projects**
Stakeholders such as DOE, Financial Institutions (e.g. DBP, LBP), Board of Investments, NEDA, and others need assistance to design/develop support mechanisms for project developers, supply chain businesses, and other stakeholders to help build the ecosystem needed for MRE projects. This would address the lack of support in terms of funding for the pre-development stage and financing for early small-scale projects.

iii. **Rate (e.g., GEAR price, support rates etc.) Setting**
The ERC (and the DOE) may need more information on appropriate reference projects (especially for ORE). There are also gaps in terms of expertise to assess proposed rates of projects that are attributed to lack of capability in various aspects (e.g., technology) of marine renewable energy. Helping these agencies will enable project developers to attract investment in a more secure and substantial manner since the commercial viability is somewhat secured with the setting of an appropriate support rate for utility-connected projects.

d. **Financing and Investments**
There is a need for technical assistance to strengthen development banks' capabilities in understanding the specifics of MRE projects technologies. In particular, LBP (and/or DBP) staff dealing with risk assessment would need such training. Additional subjects are rules and regulations applicable for ORE and compliance with central bank regulations. Furthermore, clarity on foreign investment into Philippine renewable energy projects/portfolio may need to be addressed and communicated in amicable terms to ensure that investments have adequate returns. *The DOE is already coming up with an updated implementing rules and regulations to RA 9513 that would allow 100% foreign ownership of RE projects in the country.*

In general, MRE in the Philippines is presently taking decisive steps. ORE technology developers and investors are working to take their technologies to a commercial level and international donors like ADB, AFD and NAMA Facility are willing to look deeper into the financing of MRE Projects.

e. **Education and Training of Various Stakeholders**
There is a need to drive more awareness and education especially for policy makers and the off takers, as well as electric cooperatives and communities. The key messages to these stakeholders must include the benefits and challenges of deploying MRE. As mentioned in previous sections, stakeholder education and acceptance must lead to understanding, acceptance, and adoption of MRE technologies as a long-term benefit for all stakeholders.

f. **Whole-of-Nation Approach**
A Whole-of-Nation Approach is needed for the successful realization of long-term MRE benefits. This approach includes coordination among stakeholders, focusing on technical assistance and capacity building. These efforts must address and build understanding of the economic and financial barriers at the earliest stages of MRE development in the Philippines. These efforts must address the most critical challenges as described above, for the successful and sustainable development of an MRE sector to become a reality. Furthermore, as MRE progressively develops, political, social and legal challenges must be addressed by involving and engaging key stakeholders in the planning, capacity-building and implementation of projects. An important first step is the close collaboration between ETP and other donor organizations, the NAMA Support Project for hybrid RE on small islands in the Philippines, potential off-takers and end-users, and other support organizations /initiatives.

g. **Capability Development and Capacity Building for Key Agencies (e.g., DOE)**
There is a need to strengthen the institutions in the forefront of MRE development in the country. Information and experiences on energy roadmapping, resource assessment, marine spatial planning, and project financing are crucial in facilitating the sustainable development of the sector. A whole-of-nation approach is required, from the top offices to the farthest electric cooperatives, support organizations, and communities.

133 Table 12 organizes the proposed next steps according to a short-term, medium-term, or long-term timeframe.

Table 12. Timeframe of Proposed Next Steps in MRE Development

Short-Term	Medium-Term	Long-Term
● MRE Development Roadmapping ● Resource Assessment and Inventory ● Marine Spatial Planning ● Capability Development for Key Agencies	● Capacity Building for other Organizations ● Strengthening Market Support Mechanisms (Support Rate Setting, Access to Subsidies and Finance) ● Financing and Investments ● Education and Training of Stakeholders	● Whole-of-Nation Approach (coordination, involvement, and engagement of multi-stakeholders)

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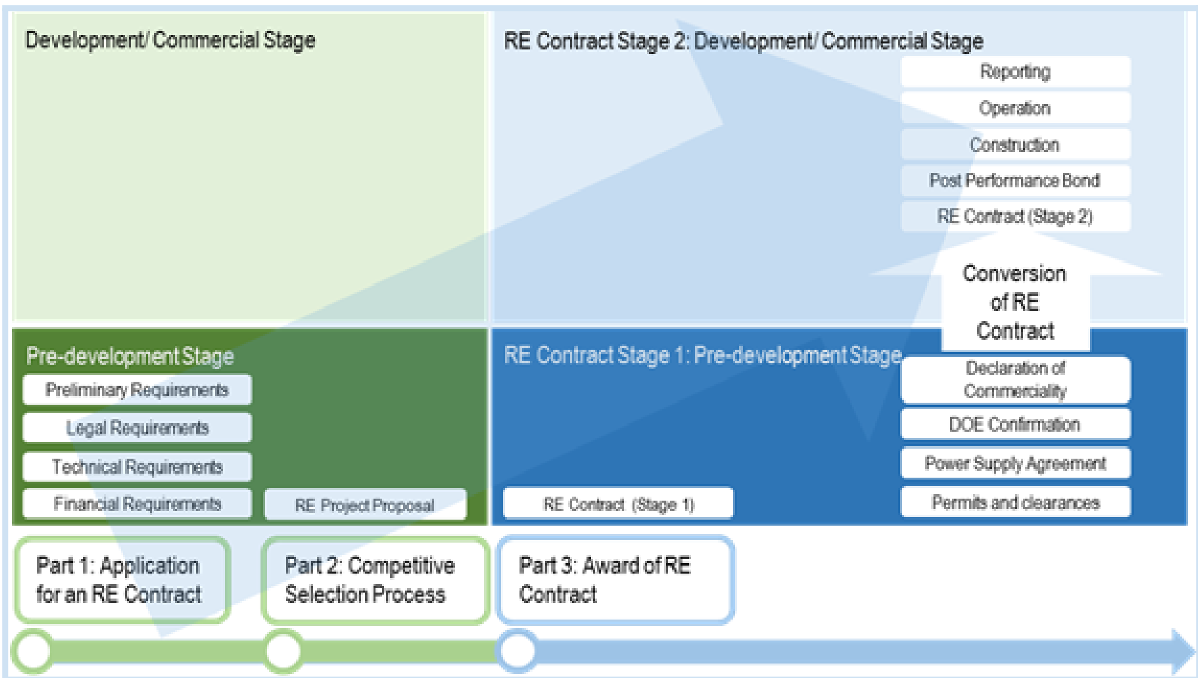
X. APPENDICES

Appendix A
Ocean Renewable Energy Project Development Process

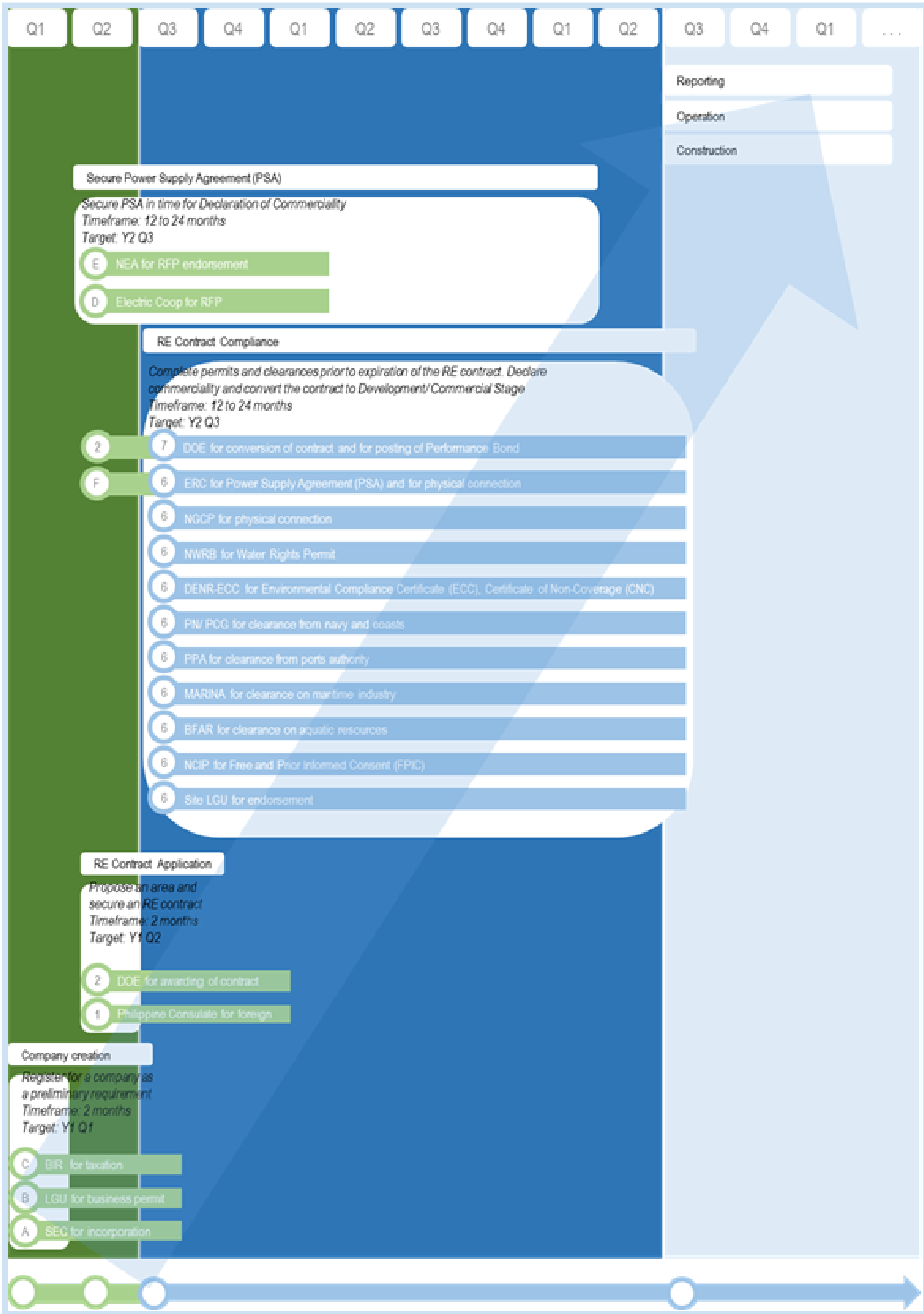
Figure A.1. Overview of the Ocean Energy Project Development Process



Appendix B

Stakeholder and Process Map

Figure B.1. Stakeholder and Process Map
(PSA for Off-Grid; Feed-in Tariff or Equivalent Rate (e.g. GEAR Price) for Grid-connected)



Appendix C
Ocean Renewable Energy Philippine Market Stakeholders and Processes

Table C.1. ORE Philippine Regulatory Processes

Process	Regulator(s)	Inputs	Outputs	Time
Company registration	Securities and Exchange Commission (SEC)	• Articles of Incorporation • General Information Sheet • Accomplished forms • Fees	• Certificate of Incorporation	2 mo
	Local Government Unit (LGU)	• Certificate of Incorporation • Accomplished forms • Fees	• Business Permit • Municipal/Sanitary Permit • Municipal/City Business Permit • Building Permits/Civil/Structural Permits • Locational Clearance/business permit in the localities where the business will be established	1 mo
	Bureau of Internal Revenue (BIR)	• Certificate of Incorporation • Accomplished forms • Fees	• Tax Identification Number • Certificate of Registration • Application for Authority to Use Computerized Accounting System • Application for Registration Information Update	1 mo
	Social Security System (SSS)	• Application	• Employer Registration • Specimen Signature Card	1 mo
	Philippine Health Insurance Corp.	• Application	• Employer Data Record • Member's Data Form	1 mo
	Bureau of Fire Protection	• Application	• Evaluation Clearance-Fire Safety Permit	1 mo

Process	Regulator(s)	Inputs	Outputs	Time
	Home Development Mutual Fund	• Application	• Member's Data Form • Remittance Form *Note: Membership registration for local employees only*	1 mo
Pre-Application	DOE (currently not enrolled in EVOSS but its integration in the system is being studied)	• Letter of Intent • Location Map	• Verification Result from the ITMS • Notice to Apply	
Application for a Renewable Energy (RE) Contract	Department of Energy (DOE) thru EVOSS (also Philippine Consulate Office if applicable)	• Application and processing fees *Legal Requirements* • Certificate from its Board of Directors authorizing its representative • Articles of Incorporation • SEC-certified AOI, By-Laws, and GIS • Business Permit • Organizational Chart *Technical Requirements* • Work Program • Verified Project Site/Area Location Map *Financial Requirements* • Latest Annual Report and/or Audited Financial Statements • Bank Cert • 2-year projected cash flow with supporting document/s • Letter of Undertaking/ Support from parent company duly authenticated by the Philippine Consulate Office (submitted on an as applicable basis (if unable to self-finance))	• RE Contract • Certificate of Registration • Certificate of Endorsement to BOI for Project Registration to avail incentives under RA9513	2 mo

Process	Regulator(s)	Inputs	Outputs	Time
RE Contract Compliance	Site Local Government Unit (LGU)	• RE Contract • Focus group discussions, visits, consultations	• Clearance	12 to 24 mo
	National Commission on Indigenous Peoples (NCIP)	• RE Contract • Focus group discussions, visits, consultations	• Certification Precondition for Energy Service Companies	
	Bureau of Fisheries and Aquatic Resources (BFAR)	• RE Contract • Application	• Clearance	
RE Contract Compliance *(continued)*	Maritime Industry Authority (MARINA)	• RE Contract • Application	• Clearance	12 to 24 mo
	Philippine Ports Authority (PPA)	• RE Contract • Application	• Clearance	
	Philippine Navy (PN) / Philippine Coast Guard (PCG)	• RE Contract • Application	• Clearance	
	Department of Environment and Natural Resources (DENR)	• RE Contract • Application	• Environmental Compliance Certificate (ECC) • Certificate of Non-coverage • Wastewater Discharge Permit	
	National Water Resources Board (NWRB)	• RE Contract • Application	• Clearance	
	National Grid Corporation of the Philippines (NGCP)	• RE Contract • Application	• Mechanism for physical connection	
	Energy Regulatory Commission (ERC)	• RE Contract • Application	• Mechanism for physical connection	
Declaration of Commerciality and Operation	Electric Cooperative	• RE Contract • Proposal	• Power Supply Agreement	12 mo

Process	Regulator(s)	Inputs	Outputs	Time
	Department of Trade and Industry – Board of Investments (DTI-BOI)	• RE Contract • Certificate of Endorsement to BOI to avail incentives under EO 226	• Registration for Availing Incentives under EO 226 or the Omnibus Investment Code	
	National Transmission Corporation (TRANSCO)	• True cost of generation	• PSA rate difference	

Appendix D
Awarded Energy Projects

Table D.1. Awarded Energy Projects as of 31 May 2021

Island/ Grid	Region	Province	Project Name	Company	Stage of Contract	Potential Capacity (MW)
Luzon	III	Zambales	Cabangan Ocean Energy Project	Bell Pirie Power Corporation	Pre- Development Contract	5
	V	Sorsogon	San Bernardino Strait Between Bicol Peninsula and Samar Leyte Corridor (2 sites) - Area 1OP (Tidal Stream Energy Conversion TISEC Project)	H&WB Corporation	Pre- Development Contract	5
Luzon Total						**10**
Visayas	VIII	Northern Samar	San Bernardino Ocean Energy Project - Capul	San Bernardino Ocean Power Corporation	Development Contract	3
			San Bernardino Strait Between Bicol Peninsula and Samar Leyte Corridor (2 sites) - Area 3OP	H&WB Corporation	Pre- Development Contract	5
			TISEC-Project Site (Areas 4&5)	Poseidon Renewable Energy Corporation	Pre- Development Contract	TBD
			TISEC-Project Site (Area 6) (As of March 2021)	Poseidon Renewable Energy Corporation	Pre- Development Contract	TBD
			Northwest Capul Ocean Energy Project (As of March 2021)	Oceantera Energy Corporation	Pre- Development Contract	TBD
Visayas Total						**8**

Island/ Grid	Region	Province	Project Name	Company	Stage of Contract	Potential Capacity (MW)
Mindanao	XIII	Surigao del Norte	Gaboc Channel Ocean Energy Project	Adnama Power Resources Corporation	Pre- Development Contract	6
Mindanao Total						**6**
Grand Total						**24**

Note: From the Department of Energy. (2021). Awarded Ocean Projects as of 31 March 2021. Department of Energy. Retrieved November 11, 2021, from https://www.doe.gov.ph/sites/default/files/pdf/renewable_energy/awarded_ocean_2021-03-31.pdf*. And the Department of Energy. (2021). Awarded Ocean Projects as of 31 May 2021. Department of Energy. Retrieved November 11, 2021, from* https://www.doe.gov.ph/sites/default/files/pdf/renewable_energy/awarded_ocean_2021-05-31.pdf?withshield=1

Appendix E
Gaps Analysis of MRE

Table E.1. Gaps Analysis

Identified Key Needs	Involved Stake-holders	Challenge/ Barrier Detail	Elements that will contribute to the increase in MRE	Assistance Needed
Resource Inventory	DOE	Lack of capability and tools to conduct resource assessment, data management, etc.	Strategic marine renewable energy resource assessment Survey of current human and resource capabilities Industry development roadmap (including supply chain) Marine spatial planning Outreach and awareness program	Technical Assistance, capability development, guidance, training, platform, and tools
MRE Development Roadmapping	DOE	Lack of technical expertise and experience in marine renewable energy to support a strategic sectoral development roadmap.	Strategic marine renewable energy resource assessment Survey of current human and resource capabilities Industry development roadmap (including supply chain) Research and development Outreach and awareness program	Technical assistance, coordination, expert advisory
Marine Spatial Planning	DOE Multi-Agency/ Stake- holder	Lack of appropriate tools and expertise; requires multi-stakeholder engagement and alignment towards strategic consensus	Marine spatial planning Pilot projects and demonstrations Market mechanisms for MRE uptake (e.g. FIT, PSA/PPA) Outreach and awareness program	Stakeholder engagement, technical assistance, capability and tools development
Support Rate Setting	ERC	No appropriate reference project, lack of expertise in assessing proposed rates	Pilot projects and demonstrations Market mechanisms for MRE uptake (e.g. PSA/PPA)	Technical assistance, coordination, expert advisory

Identified Key Needs	Involved Stake-holders	Challenge/ Barrier Detail	Elements that will contribute to the increase in MRE	Assistance Needed
Access to Subsidies for True Cost of Generation (e.g. from the Universal Charge for Missionary Electrification (UCME))	-	Uncertain process for new power producers to access the same subsidies that fossil-fuel-based generation taps for off-grid markets (e.g. Missionary Electrification)	Industry development roadmap (including supply chain) Pilot projects and demonstrations Other support mechanisms (i.e. grant, incentives, financing, etc.)	Technical assistance, process development and verification, policy and guidelines development
Enabling / Opening Up Access to Finance for Early Stage Projects	In preparation phase: NAMA-Facility/ LBP/DBP	Lack of support in terms of funding for pre-development stage and financing for early small-scale projects	Pilot projects and demonstrations Other support mechanisms (i.e. grant, incentives, financing, etc.) Research and development Outreach and awareness program	Need support instruments and mechanisms for emerging technologies, early-stage activities, and small-scale projects

Appendix F
Clean Energy Transition Barriers

Table F.1. Clean Energy Transition Barriers from NAMA Support Project Outline

Category	Identified Barriers	Solutions offered by the NSP
Economic Barriers	High up-front capital costs reduce perceived competitiveness of TSE technologies.	Sizeable cost reductions through economies of scale and learning effects. Incorporation of TSE - PV - Battery Systems (hybrid RE) into the energy mix of hitherto diesel powered mini -grids leads to reduction of average system generation costs with increased reliability of the supply.
Financial and Investment Barriers	High risk perceptions associated with RE projects by local banks and a limited track record of TSE lead to prohibitive lending terms. High risk perception by potential investors lead to low demand for RE hybrid systems.	A tailored financial support for early projects will help build confidence in the financial viability and bankability of RE systems. TSE track-record leads to a more realistic perception of the costs and competitiveness among financial institutions, off-takers, and other stakeholders. Adequate framework conditions for viable business models and financial incentives (through NSP and other development programs) will encourage developers and investors. The existing government incentive schemes are to be made available for hybrid RE generation systems, too.
	Currency risks: major part of the up-front capital costs will be in hard currency while revenues will be in local currency.	Design of an adequate financial support mechanism and equity debt ratio.
	Solvency risk of the off-taker, such as local electricity co-operatives.	PSAs are bankable thanks to NEA taking over all obligations in case of bankruptcy of an EC. However, the financial standing of the off-taker shall be established through implementing partners (e.g. NEA, ECs).
Informational Barriers	Lack of awareness of economic and financial effectiveness of hybrid RE systems on governments, banking sector's and other stakeholders' level.	Information on the comparative advantage of substituting diesel generators by RE will be made available.
Institutional and Regulatory Barriers	Regulatory and administrative hurdles appear high for a first-of-a-kind commercial hybrid RE project and hamper the interest of	Technical assistance shall adjust the legal and regulatory framework, the incentive systems (including a standardized PSA) as

Category	Identified Barriers	Solutions offered by the NSP
	potential investors. A range of promotional RE policies are promulgated by law but need to be opened-up for hybrid RE. Potential conflict between mini-grid implementation and grid extension.	well as streamlining permitting processes. The establishment of a Steering Committee will prevent “sunk cost” investment.
Technical Barriers	Technical barriers are mainly related to insufficient grid infrastructure on the respective islands, possibilities of grid connection, and limited availability of vessels for installation, service and maintenance.	Private developers will demonstrate technical feasibility if installation and reliability of operation including maintenance.
Environmental Barriers	Competitive and conflicting uses of potential sites such as protected areas (e.g. for corals, rare marine animals) and fishing grounds.	Ensure that requirements of maritime protected areas are respected when selecting the project area.
	The project region might be located in an area which is subject to risks from typhoon damage.	The project locations will be selected in areas where the risk of damage is deemed acceptable.

Appendix G

Tabulated Summary of Recommended Next Steps to Enable and Accelerate the Development of Marine Renewable Energy in the Philippines

The table below summarizes the key needs to be addressed through technical and developmental assistance / intervention. A spectrum of capability development for the key stakeholders in the marine RE ecosystem is needed. An integrated and holistic approach involving stakeholder engagement, strategic planning, roadmapping, training, market mechanisms, and other activities will be needed to contribute to the development and growth of Marine Renewable Energy in the Philippines.

Table G.1. Summary of Recommended Next Steps

Identified Key Needs	Involved Stake-holders	Challenge / Barrier Description	Elements that will contribute to the accelerated development of the MRE sector	Assistance Required
Resource Inventory	DOE	Lack of capability and tools to conduct resource assessment, data management, etc.	Strategic marine renewable energy resource assessment Survey of current human and resource capabilities Industry development roadmap (including supply chain) Marine spatial planning Outreach and awareness program	Technical Assistance, capability development, guidance, training, platform, and tools
MRE Development Roadmapping	DOE, NEDA, DILG, etc	Lack of technical expertise and experience in marine renewable energy to support a strategic sectoral development roadmap	Strategic marine renewable energy resource assessment Survey of current human and resource capabilities Industry development roadmap (including supply chain) Research and development Outreach and awareness program	Technical assistance, coordination, expert advisory
Marine Spatial Planning	DOE, NEDA, NAMRIA Multi-Agency/ Stakeholder	Lack of appropriate tools and expertise; requires multi-stakeholder engagement and alignment towards strategic consensus	Marine spatial planning Pilot projects and demonstrations Market mechanisms for MRE uptake (e.g., PSA/PPA) Outreach and awareness	Stakeholder engagement, technical assistance, capability and tools development

Identified Key Needs	Involved Stake-holders	Challenge / Barrier Description	Elements that will contribute to the accelerated development of the MRE sector	Assistance Required
			program	
Support Rate Setting	ERC, DOE	No appropriate reference project, lack of expertise in assessing proposed rates	Pilot projects and demonstrations Market mechanisms for MRE uptake (e.g., PSA/PPA)	Technical assistance, coordination, expert advisory
Access to Subsidies for True Cost of Generation (e.g., from the Universal Charge for Missionary Electrification (UCME))	NPC - SPUG, NEA, DOE	Uncertain process for new power producers to access the same subsidies that fossil-fuel-based generation taps for off-grid markets (e.g. Missionary Electrification)	Industry development roadmap (including supply chain) Pilot projects and demonstrations Other support mechanisms (i.e., grant, incentives, financing, etc.)	Technical assistance, process development and verification, policy and guidelines development
Enabling / Opening Up Access to Finance for Early Stage Projects	DOE, Financial Institutions (e.g. DBP, LBP)	Lack of support in terms of funding for pre-development stage and financing for early small-scale projects	Pilot projects and demonstrations Other support mechanisms (i.e. grants, incentives, financing, etc.) Research and development Outreach and awareness program	Need support instruments and mechanisms for emerging technologies, early-stage activities, and small-scale projects

Appendix H
Pavitt's Taxonomy to describe the Development Journey of Marine Renewable Energy in the Philippines

This is a brief discussion of Pavitt's Taxonomy. While innovation is crucial for the advancement against our renewable energy objectives, the innovation journey must be carefully selected to minimize risk, uncertainty and reduce the time to market of new products. This must be tempered with an eye towards the commercial consideration of optimizing profit. Pavitt hypothesizes that technical change is influenced by technical knowledge which is cumulative and unique to firms, and varied across sectors in origin and direction. Pavitt further states that a technological trajectory is based mostly on the principal activities which are both inside the firm, as well as in the field experiences of the new technology. The resulting taxonomy and associated interpretive theory is based on where the firm sources its knowledge and process technology (e.g. from suppliers, in-house, or from the field), the nature of the innovation (product or process), users' needs (product price or performance), how innovators capture and protect the gains of their activities (e.g. design, skills, secrecy, patents or difficulty to imitate) and the extent and patterns of technological diversity (potential for scale or scope economies, and therefore the size of the firm). Based upon this, Pavitt groups firms into four categories, viz. supplier-dominated firms, science or engineering-based firms, scale-intensive firms and specialized suppliers. While innovation is crucial for the survival of a firm, the innovation path must be carefully selected to minimize risk, uncertainty, and reduce the time to market of new products, in addition to optimizing profits. The sources of technology, the direction of technical change, the type of innovation and the type of firm differs depending on the sectoral category. Pavitt has developed a tabular taxonomy, which we will now apply to Marne Renewable Energy.

The Pavitt Taxonomy allows for all of the above considerations in a tabular approach. Following is the Pavitt Taxonomy for the Marine Renewable Energy sector.

Table H-1.The Innovation Journey for MRE Technology in the Philippines

CATEGORY	TYPICAL CORE APPLICATIONS	MAIN SOURCES OF TECHNOLOGY INNOVATION	MAIN DIRECTION OF TECHNICAL CHANGE	TYPE OF INNOVATION	TYPE OF FIRM AND INNOVATION PATHWAY
Science and Engineering Based Firms	➢ Machinery/ Equipment ➢ Instrumentation ➢ Software	➢ In-House design ➢ Customers & Advanced Users ➢ Rapid Design Cycles reinforced with Field Testing	➢ Product Design ➢ Fundamental Product Development	➢ Initial Product and Equipment Development	➢ Small Design-led and Boutique Firms ➢ Close Links to Customers for Needs/ Financial Parameters ➢ "Skunkworks" and Rapid Application Development pathways
Specialized Equipment and Systems Suppliers	➢ Marine Submersible Turbines ➢ Ocean Current Equipment ➢ Wind Turbines ➢ Salinity Gradient Equipment ➢ Tidal Range Equipment ➢ Wave Energy Equipment ➢ Ocean Thermal Equipment ➢ Marine Solar Equipment	➢ Formal Innovation Processes ➢ Highly Managed Development and Testing Processes ➢ Production Engineering ➢ Suppliers Integration ➢ Logistics Integration ➢ Power Generation System Integration	➢ Incremental Product Development ➢ Improvements in Cost & Reliability	➢ Early to Mid Stage Development Processes Driven from In House ➢ Functional, Operational, and Economic Optimization	➢ Consortiums and Partnerships ➢ Development Program Transfers to Larger Firms through Buyouts etc. ➢ Financing Agreements and Instruments

The table utilizes the major headings as originally developed by Pavitt in 1984, with some minor changes for the MRE requirement:

- CATEGORY – A brief description of the type of firm, according to Pavitt's classification system;
- TYPICAL CORE APPLICATIONS – Refers to the applications the innovation is applied towards;
- MAIN SOURCES OF TECHNOLOGY INNOVATION – Considers the key inspiration and processes used for innovation;
- MAIN DIRECTION OF TECHNICAL CHANGE – Describes the focus areas to which the innovation(s) are applied;
- TYPE OF INNOVATION – Advises the stage of innovation and briefly addresses high level process descriptions; and,
- TYPE OF FIRM AND INNOVATION PATHWAY – Characterization of the firms involved in the innovation pathway, as well as the type of pathway typically used.