Marine Aquaculture, Renewable Energy, Reefs & Ecotourism for Ecosystem Services (TA 6619)

Strategic Summary of Project Research and Initial Recommendations for Palau

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The summary information presented is a result of the initial analysis made to identify key sectors of interests relating to Palau, to understand local context and prepare ground for further research on potential multi-function marine and maritime projects.

The analysis presented in this summary is a starting point and will help to guide further in-country engagement.

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Abbreviations and Units and Measure

ADB	Asian Development Bank
EEZ	exclusive economic zone
FPV	floating photovoltaic
LCOE	levelized cost of energy
LCOH	levelized cost of hydrogen
MARES	Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services
NREL	National Renewable Energy Laboratory
OTEC	ocean thermal energy conversion
PV	photovoltaic
TA	technical assistance

Units and Measure

GW	gigawatt
GWh	gigawatt-hour
hr	hour
kg	kilogram
km^2	square kilometer
kW	kilowatt
kWh	kilowatt-hour
m	meter
m^2	square meter
m^3	cubic meter
m/s	meter per second
MW	megawatt
Nm^3	Normal cubic meter
TWh	terawatt-hour
W	watt
yr	year

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1.0 Headline overview

Coastal and Small Island Developing States such as Palau can maximize the potential of their vast exclusive economic zones (EEZs) by encouraging multi-function marine projects that combine several capabilities holistically. Such activities will enable nations to tackle the climate crisis and achieve a regenerative marine environment.

The Asian Development Bank's (ADB) technical assistance (TA) project (TA 6619) entitled Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services (MARES)[1] is exploring the combination of marine renewable energy capabilities relevant to Palau with local research of potential in-country sites suitable for multi-function initiatives which can be integrated therein.

The project team has developed a set of criteria to enable the selection of appropriate initiatives that blend marine renewable energy with marine aquaculture; nature-based tourism; alternative fuels and maritime transport, and/or restoration of coral reefs or other ecosystems and regeneration. These criteria combine collectively to define a MARES-type project.

Marine solar energy has been identified as being highly likely to be viable in the waters of Palau; a further four types of marine renewable energy including Ocean Thermal Energy Conversion (OTEC) have been identified as being potentially viable.

Sites within Palau, Melekeok State, Koror State and Peleliu Island have all been identified as having the right range of characteristics to support and benefit from MARES pilot projects.

Palau is well suited for MARES pilot projects There are a number of maturing and scalable innovations that align well to the needs of Palau and its communities. This is especially so as Palau may be a Small Island Developing State but is most definitely a large ocean State.

The project team seeks guidance from the Government of Palau on the further development of this report. The project team will analyze candidate technologies and identify six to eight projects to participate in the ADB High-Level Investor Forum on 7 February 2023 in Kuala Lumpur Malaysia.

2.0 The MARES concept

The world's seas and oceans – and the ecosystems, economies and livelihoods that depend on them – are under great stress. Climate change; ocean acidification; marine pollution; natural disasters; overfishing, destructive fishing and illegal, unreported and unregulated fisheries; coastal and population growth resource pressures; sea level rise; and the collapse of marine ecosystems all present significant issues.

There is growing understanding of the breadth of positive outcomes a well-managed sea-space can support – not just targets related to jobs, economic growth and environmental protection, but broader agenda such as the Sustainable Development Goals and Nationally Determined Contributions for climate change action, among others.

The MARES TA 6619 analyzes how three potential Blue Economy opportunities can be harnessed:

- The first is **the harnessing of marine renewable energy.** The opportunity here is considerable, especially for large ocean states. Studies suggest that wave energy alone could power the entire world but the pace of change is still lagging behind expectation. A review of marine renewable

[1] ADB. Regional. Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services.

opportunities illustrates that there are many ways forward, as technologies mature and more research is undertaken on potential sites for implementation. Governments are also grasping the nettle on policy commitments and creating enabling environments for investment and operational implementation.

- The second opportunity is created by the potential of **marine green hydrogen.** This allows large ocean states to utilize their seaspaces not only to meet local energy demands, but also to convert energy to electricity, and then to export that to an entirely new market (a 'Power-to-X' capability). Both policy and commercial drivers are demanding alternative marine fuels, for example, which creates significant new commercial possibilities in this realm. This, then, is the second potential game changer: financial investment will flow into regenerative marine activities because there is a promising market model that simply did not exist before.
- The third set of opportunities is **to develop a much broader set of multi-functional projects** that make the most effective use of available seaspace, to provide the greatest positive effect on local communities (including ensuring that any resulting prosperity is justly transitioned and equitably distributed) and results in the lightest environmental impact.

The MARES follows such approach. There are many exciting emerging innovations in marine aquaculture, cultivated reefs and nature-based marine tourism, but the tangible added benefits when they all come together need to be ascertained and how countries can plan for that.

3.0 What the MARES project is looking for

In order to support Palau and other island states to maximize the potential of their blue economies, the MARES project aims to find capabilities, innovations, technologies or infrastructure that can be combined with one or more technologies and/or infrastructure to create a multi-function capability with a viable, scalable business model. This enables island states to maximize the socio-economic benefits of their blue economies and large EEZ resources to create and equitably distribute greater prosperity for all.

The MARES initiative is seeking to shortlist six to eight candidate projects that:

- Support and align to existing **national aims and objectives**.
- Are **multi-function**, **technically sound** and **scalable**.
- Are **financially viable**.
- Are **sensitive to local conditions and stakeholders**.
- Are **future-proofed**.

4.0 Marine renewable energy options relevant to Palau

Existing electricity infrastructure and operations are undertaken by the Palau Public Utilities Corporation with a network extending over 47 linear miles of connections.[2] This offers primarily diesel-based generators, with minor contributions from solar energy for the remoter Southwest Islands, Tobi and certain main users on Koror and/or Babeldaob Islands. Palau has an ambitious target of achieving 45% of its electricity generation from renewable energy by 2025 and 100% by 2050.

[2] Renewable Energy and Energy Efficiency Partnership. Republic of Palau (2012).

Table 1 provides an overview of ocean energy options potential for Palau (underpinning assumptions for these calculations are available on request). Options are then described in more detail.

*Table 1. Palau Marine Renewable Energy Options and Indicative Estimates (e.g., Potential, Costs, Levelized Cost of Energy (LCOE), etc)**

					Levelized Cost of Hydrogen [LCOH] ($/kg)	
Technology	**Range**	**Potential [Theoretical] Capacity (GW)**	**Capital Cost (Million ($/MW)**	**Levelized Cost of Energy (LCOE) ($/kWh)**	**LCOH (based on LCOE) ($/kg)**	**Reference LCOH by 2030 ($/kg)**
Marine Solar	LOW	17.26[(a)(b)(c)]	1.50	0.1339	11.16	2.5[(i)]
	HIGH	678.68[(a)(b)(c)]	1.88	0.0938	7.81	1.55[(i)]
Wave	LOW	0.1519[(a)(c)(d)]	2.70	0.8657	72.14	Not Available
	HIGH	0.3076[(a)(b)(c)©]	9.10	0.0656	5.46	Not Available
OTEC	LOW	0.10[(a)(b)(c)]	3.00	0.0890	7.42	9.51[(j)]
	HIGH	3.80 [(a)(b)(c)]	13.00	0.0205	1.71	6.79[(j)]
Offshore Wind	LOW	13.84[(a)(b)(c)]	3.00	0.1522	12.68	6.14[(k)(l)]
	HIGH	544.30[(a)(b)(c)]	4.00	0.1142	9.51	3.50[(k)(l)]
Marine Bioenergy	LOW	0.04[(a)(b)(c)]	3.50	0.0514	4.28	Not Available
	HIGH	1.51[(a)(b)(c)]	4.50	0.0400	3.33	Not Available
Tidal/Current	LOW	5.07[(a)(b)(c)]	3.30	0.8524	71.03	Not Available
	HIGH	50.74[(a)(b)(c)]	5.60	0.2511	20.93	Not Available
Salinity Gradient[(m)]	LOW	No data	27.50	No data	No data	No data
	HIGH	No data	35.00	No data	No data	No data

*NB Underpinning assumptions (listed as alphabets in the table) for these calculations are in Appendix.

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Abbreviations: GW = gigawatt, GWh = gigawatt-hour, kg = kilogram, kWh = kilowatt-hour, LCOE = levelized cost of energy, LCOH = levelized cost of hydrogen, MW = megawatt, OTEC = ocean thermal energy conversion

Sources: ADB.2014. *Wave Energy Conversion and Ocean Thermal Energy Conversion Potential in Developing Member Countries*. Manila; A. S. Kim and H. J. Kim, eds. 2020. *Ocean Thermal Energy Conversion (OTEC) Past, Present, and Progress*. London; Central Intelligence Agency. The World Factbook; Pacific Islands Ocean Observing System. Global Wind Atlas; IRENA. 2022. *Global hydrogen trade to meet the 1.5°C climate goal: Part III – Green hydrogen cost and Potential*. International Renewable Energy Agency. Abu Dhabi, 2022; N. Dinh. 2022. *Projections of levelised costs of hydrogen (LCOH)*. MARES Report. Manila. ADB. S. Banerjee, M. N. Musa and A. B. Jaafar. 2017. Economic assessment and prospect of hydrogen generated by OTEC as future fuel. *International Journal of Hydrogen Energy.* Volume 42, Issue 1. pp 26-37. The World Bank. 2021. The Offshore Wind Roadmap for the Philippines.

4.1 Marine solar (high likelihood of viability in Palau)

Marine solar systems may be attached to a fixed structure or floating on the body of water. A review of studies suggests that this is perhaps the most promising of all the types of marine renewable resources available to Palau.

The average solar potential is at 5-6 kilowatt-hour per square (kWh/m^2) per day.[3] A separate study by the Palau government puts the estimate of solar energy capacity at over 5.5 kWh/m^2

[3] National Renewable Energy Laboratory. RE Data Explorer.

per day.[4] The government of Palau is active in pursuing renewable energy development based on their policies on energy and sustainability. Palau has implemented a successful on–grid rooftop solar program. As of December 2020, there is an approved Asian Clean Energy Fund floating solar project amounting to $2 million to assess the potential and feasibility, develop a roadmap, and build institutional capacity to deploy floating photovoltaic (FPV) projects. The Republic of Palau has also proposed a 13-megawatt (MW) floating solar project. By using only 1% of the EEZ of Palau, an estimated ~600 gigawatt (GW) of marine/offshore solar photovoltaic (PV) can be potentially installed.

4.2 Wave energy (potentially viable in Palau)

Wave energy utilizes the movement of the ocean surface caused by wind systems and the resulting pressure fluctuations from below the ocean surface can also be exploited. Due to the development of floating wave energy converters (attenuator devices), the potential of this system increases rapidly as it can be deployed basically anywhere on the surface of the world's ocean where wave resources are present (Global potential: 80,000 terawatt-hour per year [TWh/yr]).

A 2-kilowatt per meter (kW/m) wave energy potential was assessed for Palau.[5] On the other hand, another source mentions that the wave energy resource is estimated to be in the 10–15 kW/m (kilowatt per meter) range in the Republic of Palau making it likely viable.[6] However, no commercial wave energy technologies have yet been tested specifically for Palau, making it unlikely to be used in the near future.[7] Nevertheless, the potential for wave energy exploitation is clear and since the wave energy resource is present in Palau, further investigation may lead to possible projects. In the past few years, more innovative efforts and technological innovations have surfaced, especially in combination with other sources.

4.3 Ocean Thermal Energy Conversion (potentially viable in Palau)

OTEC uses the temperature difference between the ocean surface (warm) and the deep seawater (cool), which can be used to drive a heat engine (Global potential: 8,000 GW (footnote 5); 10,000 to 87,600 TWh/yr.[8] The tropical oceans act as a vast solar collector and the OTEC process allows this to be converted to clean electricity without interruption, 24/7. A-10 MW floating OTEC is considered to be technically achievable in locations such as Japan and Hawaii but not yet fully commercial. However, the present state of proven pipeline technology is such that an island-based 2.5 to 5 MW system is considered achievable today and 10 to 50 MW by 2050 if not sooner.

A 100-MW OTEC plant is estimated to generate 1,460 gigawatt-hour per year (GWh)/yr) (footnote 7). A more specific study estimated a 30-MW OTEC potential across seven identified sites, with a pilot project on the first site starting with 3-MW with expected significant freshwater

[4] UN Climate Technology Centre & Network. 2013. Republic of Palau (2012).
[5] A. Lauranceau-Moineau,2019. *Blue Energy: Renewables in the Pacific Ocean.* Presented during the workshop on Incorporating the Ocean in NDCs. Fiji. 9 May 2019.
[6] ADB. 2014. *Wave Energy Conversion and Ocean Thermal Energy Conversion Potential in Developing Member Countries*. Manila.
[7] IRENA. 2013. *Pacific Lighthouses: Renewable energy opportunities and challenges in the Pacific Islands region*. Palau Abu Dhabi. International Renewable Energy Agency.
[8] IEA Ocean Energy Systems. 2020. *Ocean Energy in Islands and Remote Coastal Areas: Opportunities and Challenges*. IEA Technology Collaboration Programme for Ocean Energy Systems. www.ocean-energy-systems.org

and hydrogen production.[9] The spray flash method is used for desalinated water at 1,000 cubic meter (m^3) per day and 1 normal cubic meter per hour (Nm^3/hr) of hydrogen per cycle.

Table 2 below shows the potential OTEC locations and sizes in Palau. The steep slope on the eastern side provides the temperature difference needed to operate OTEC technology.

Table 2. Assessment of potential OTEC locations in Palau

Potential OTEC Site	Size of OTEC plant
Melkeok	3MW x 2 + 4MW x 1 = 10MW
Airai	3MW x 2 + 4MW x 1 = 10MW
Ngarchelong	2MW x 1 = 2MW
Ngaraard	2MW x 1 = 2MW
Ngiwal	2MW x 1 = 2MW
Peleliu	2MW x 1 = 2MW
Angaur	2MW x 1 = 2MW
Total	**30MW**

Abbreviations: MW = megawatt, OTEC = ocean technology energy conversion

Source: G. Decherong. 2002. *The Project for Ocean Thermal Energy Conversion (OTEC) and its Multi-purpose Utilization in the Republic of Palau*. Prepared for the forum on Desalination using Renewable Energy. Palau. 15-16 October Palau.

OTEC, however, is becoming significantly more viable in Palau than previous studies may suggest. Unlike solar energy, it also offers potential to be reliable nocturnally. At present, the biggest barrier to more widespread adoption of OTEC technology is financial, not technical, particularly at a scale below 10 MW. The electricity generation process system is simple and has proven to be reliable at both the Hawaii Natural Energy Laboratory and the Okinawa Deep Seawater Research Center. What is missing is the financial guarantee to move beyond small demonstration plants to pre-commercial prototype units.

4.4 Tidal flows and currents (potentially viable in Palau)

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. tidal stream energy has a global potential of more than 800 TWh/yr.

Palau is listed among the developing nations in the Pacific Ocean that could receive significant benefits from tidal energy. In addition, efficient technology to capture tidal energy is asserted to be already cost-effective.[10] Certain lagoons, channels, and areas could have possible exploitable tidal flows and currents but further investigation is needed. According to the United States Insular Areas Energy Assessment Report,[11] the most promising opportunities for Palau include doing a basic survey of lagoon/open sea passages for possible tidal flow generation.

[9] G. Decherong. 2002. *The Project for Ocean Thermal Energy Conversion (OTEC) and its Multi-purpose Utilization in the Republic of Palau*. Prepared for the forum on Desalination using Renewable Energy. Palau. 15-16 October.
[10] A. Takhar. 2010. *Tidal energy Overview*.
[11] Pacific Centre for Renewable Energy and Energy Efficiency. 2006. *United States of America Insular Areas Assessment Report: An Update of the 1982 Territorial Energy Assessment*.

4.5 Offshore wind (potentially viable in Palau)

Offshore wind energy is powered via wind turbine-based propulsion, similar to onshore systems but with fixed or floating windmill-based technology infrastructure out at sea. Instead of occupying vast land space to develop onshore wind farms, offshore wind power utilizes the marine coastal landscape which is far from any populated or residential areas.

Based on the global wind atlas,[12] Palau has estimated wind resources at an average wind speed (at 50 m height) of 3.1 to 6 m/s (towards the northern offshore region). Palau's Renewable Energy Roadmap indicates that utility-scale onshore wind (20 MW to 24 MW) is possible to contribute towards a 100% RE scenario.[13] Detailed wind resource assessment should be done if further consideration is to be given to wind power.

4.6 Marine bioenergy (may be unviable in Palau)

Bioenergy refers to organic derived, electrical energy being produced from sources such as algae (macro and micro); seaweed; kelp; algae; biomass, bacteria and other compounds. Production processes involve harvesting, extraction, pyrolysis, gasification, liquification, processing and anaerobic digestion. No studies have been undertaken measuring the marine bioenergy resource potential as well as its use in Palau.

4.7 Salinity gradient (may be unviable in Palau)

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 [footnote 5]). There is no specific literature for salinity gradient energy potential and its use for Palau.

4.8 The potential of green Hydrogen

In order to reduce reliance on fossil fuels, electricity energy can now be converted into hydrogen, which can thus be viewed as another form of energy carrier. Hydrogen can be produced using various methods; from use of conventional energy sources like natural gas or coal, from nuclear energy and, most importantly, from renewable energy sources like wind, solar and biomass

Currently the most basic industrial process to produce the purest form of hydrogen is water electrolysis, the process of splitting water molecules to give hydrogen and oxygen by circulating electricity directly through it. Hydrogen produced with electrolysis using the electricity made from renewable energy sources has low global warming potential. The most important advantage of electrolysis of water is the production of extremely pure hydrogen, with the only by-product being oxygen. There is potential to create a new global commercial opportunity where excess marine renewable energy is converted to exportable hydrogen which could unlock the financing required to speed up adoption of these technologies and secure a key regenerative cornerstone of many nations' Blue Economies.

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[12] Global Wind Atlas. Palau.

[13] IRENA. 2022. Republic of Palau: *Renewable energy roadmap 2022-2050*. Abu Dhabi. International Renewable Energy Agency.

5.0 Potential investable projects

Innovations investigated by the MARES team that are potentially relevant to Palau include:

- **A 'digital living reef'** that mimics the natural barrier behavior of coral reefs (i.e., reducing the power of larger waves that are typically bad for the shoreline), at the same time as accelerating regenerative coral growth and converting wave power to energy.[14]
- **A floating offshore OTEC** system designed to be affordable and manageable within coastal and smaller island states, to help decarbonize at a lower cost than incumbent fossil fuels.[15]
- **A floating offshore solar energy system** that provides clean, hybrid photovoltaic electricity for ports and coastal communities, including nearshore aquaculture farms.[16]
- A project testing how **locally produced hydrogen can be used as fuel for a ferry** that runs between the mainland and local islands, to shift from diesel power to renewable energy.
- **An aquaculture project** that is working with the local coastal community so that it **can be featured as an eco-tourism asset**, rather than a disturbance. It has done so by specifically designing its infrastructure to be a destination for scuba diving tours.[17]

Further investigation of down-selected initiatives will continue.

6.0 Potential pilot sites in Palau

The site selection process aimed to identify the top three project areas in Palau that would best support the testing of each technical concept to provide sufficient evidence for full commercial scalability of solutions. The target activities in the pilot sites will generally pertain to renewable energy, marine aquaculture, nature-based marine tourism and coral reefs.

6.1 Melekeok State

Melekeok is on the main island of Babelbaob which is the second largest, and least developed, land mass in all of Micronesia. It is a target area for special economic zone development and largely inhibited with large open flat areas denuded of forest. The existence of an industrial quality pier, the deep channel to the open sea, strong tidal currents, and large waves for wave energy equipment testing all make this area an ideal marine renewable energy location.

MARES consultants currently consider this area as being able to support a number of renewable energy and eco-tourism projects, potentially operating in close proximity.

6.2 Koror State

Located in the center of Palau's central business, tourism and population centers, Koror is the closest connection the main electric grid and where the majority of Palau's energy is being used.

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[14] ADB. 2022. *Paddling to Create Cultured Reefs for New Habitats and Coastal Protection*. ADB Knowledge Events. Manila. 6 May.

[15] ADB. 2022. *Ocean Thermal Energy Conversion (OTEC) Viability as a Catalyst for Transformative Island Development*. ADB Knowledge Events. 30 September.

[16] ADB. 2022. *ACEF 2022 Deep Dive Workshop: The Future of Ocean Energy and Hydrogen - Just Transition to a Safer World*. ADB Knowledge Events. 16 June.

[17] ADB. 2021. *How Singapore is Modernizing Fish Farming with Low Carbon Alternative Methods?* ADB Knowledge Events. 6 August.

For this area consultants have identified at least three potential projects that cover tidal energy, FPV, aquaculture, and ecotourism.

6.3 Peleliu Island

Peleliu is one of Palau's sixteen states, located 26 miles south of Koror. The third most populated state in Palau, Peleliu Island has 13 square kilometers of landmass surrounded by mangroves, shallow sea grass covered sand flats and coral reefs. The island has approximately 500 residents in 135 households, powered almost exclusively from diesel-fueled generators. The island has an international airport, three small resorts, world class scuba diving, is a breeding ground for cornerstone marine species, and has a strong deep cold ocean current suitable for sea water air conditioning. The proposed site is 50 meters from the entrance of a World War II-era unused man-made harbor.

Initial projects being explored for this area include the creation of a 'fossil fuel free zone' where homes and transport run exclusively on renewable energy and an aquaculture incubator facility.

7.0 Conclusion and next steps

Marine solar energy is highly likely to be viable in Palauan waters; wave energy, OTEC, tidal flows/currents and offshore wind are all potentially viable. Marine bioenergy and salinity gradient are not currently considered suitable for Palau. Melekeok State, Koror State and Peleliu Island have been identified as having the right characteristics for MARES pilot projects. The project team seeks guidance and approval to:

- Review local legislations and regulations to recommend enabling action, if any.
- Review social and cultural aspects of RMI and how multi-modal projects might be suitable with appropriate safeguards and capacity development.
- Progress towards prefeasibility review of select multi-function projects.
- Provide comment on thresholds and triggers for feasibility for such projects including innovation in financing structures, colocation of downstream activities and opportunity for enhance viability through colocation.

Appendix

These estimates relate to Table 1.

(a) The area of computation for the Low Scenario is 1% of the total available area (10% of the total available area for the High Scenario). For tidal/current, low scenario is 0.5 m/s in 0.1% of the total available area while high scenario covers velocities 1 m/s in 1% of the total available area.

(b) The perimeter of the EEZ of Palau is 475,077 km^2 (EEZ US and associated territories data from http://geo.pacioos.hawaii.edu/geoexplorer/). The value for the EEZ No-take zone is 80% of the EEZ.

(c) The rated output used are the following: marine solar energy – 7 sqm/kW; wave energy – 10 MW/km; OTEC – 0.8 MW/km^2 (https://library.oapen.org/bitstream/handle/20.500.12657/43849/external_content.pdf?sequence=1); offshore wind – 114.57 W/m^2 (wind atlas @ 100 m; globalwindatlas.info); marine biomass – 2,500 MWh/km^2-yr (annual yield); tidal/current – 42 MW/km^2.

(d) The coastline length is 1,519 km (https://www.cia.gov/the-world-factbook/field/coastline/). The final value used is the value for the low scenario.

(e) The final value used is the value for the low scenario.

(f) The following capacity factor values are used: marine solar – 1,400 (low scenario yield) to 1,600 (high scenario yield) kWh/kWp/yr is used (Decherong, G. (2002). The Project for Ocean Thermal Energy Conversion (OTEC) and its Multi-purpose Utilization in the Republic of Palau); wave energy – 0.12 (low scenario) and 0.47 (high scenario) (Asian Development Bank. (2014). Wave Energy Conversion and Ocean Thermal Energy Conversion Potential in Developing Member Countries. https://doi.org/10.1007/BF02929925); OTEC – 14.60 GWh/MW (annual production) (Asian Development Bank. (2014). Wave Energy Conversion and Ocean Thermal Energy Conversion Potential in Developing Member Countries. https://doi.org/10.1007/BF02929925); offshore wind – 0.3 (https://globalwindatlas.info/area/Palau, IEC Class III); tidal/current – 15% (high scenario) and 7.5% (low scenario).

(g) The capital cost values are used, as listed: marine solar – Under the ADB floating solar project, low installed capacity scenario capital cost uses USD15M/8 MW CAPEX per MW while high installed capacity scenario capital cost uses USD12M/8MW CAPEX per MW; wave energy – USD9.1M/MW CAPEX per MW (low installed capacity scenario capital cost) and USD2.7M/MW CAPEX per MW (high installed capacity scenario capital cost) (USD2.7-9.1M/MW, https://www.ocean-energy-systems.org/documents/16823-international-levelised-cost-of-energy-for-ocean-energy-technologies-2015-may-2015.pdf/); OTEC – USD13M/MW CAPEX per MW (low installed capacity scenario capital cost) and USD3M/MW CAPEX per MW (high installed capacity scenario capital cost) (3-13M USD/MW, https://www.ocean-energy-systems.org/documents/16823-international-levelised-cost-of-energy-for-ocean-energy-technologies-2015-may-2015.pdf/); offshore wind – USD4M/MW CAPEX per MW (low installed capacity scenario capital cost) and USD3M/MW CAPEX per MW (high installed capacity scenario capital cost) (3-5M USD/MW); marine bioenergy – USD4.5M/MW CAPEX per MW (low installed capacity scenario capital cost) and USD3.5M/MW CAPEX per MW (high installed capacity scenario capital cost) (Early TRL Cost of Seaweed farm ($70,000), biomass plant ($3,500,000 to $4,500,000 per MW) but anticipated to become cheaper based on land equivalents, IRENA); tidal/current – USD5.6M/MW CAPEX per MW (low installed capacity scenario capital cost) and USD3.3M/MW CAPEX per MW (high installed capacity scenario capital cost) (https://www.ocean-energy-systems.org/documents/16823-international-levelised-cost-of-energy-for-ocean-energy-technologies-2015-may-2015.pdf/).

(h) Electricity price assumed for revenue: USD0.05/kWh (low scenario turnover) and USD0.10/kWh (high scenario turnover)

(i) IRENA, "Global hydrogen trade to meet the 1.5°C climate goal: Part III – Green hydrogen cost and," International Renewable Energy Agency, Abu Dhabi, 2022.

(j) S. Banerjee, M. N. Musa and A. B. Jaafar, "Economic assessment and prospect of hydrogen generated by OTEC as future fuel," International Journal of Hydrogen Energy, p. https://doi.org/10.1016/j.ijhydene.2016.11.115, 2017.

(k) World Bank, "Offshore Wind Roadmap for The Philippines," World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO, 2021.

(l) N. Dinh (2022), Projections of levelized costs of hydrogen (LCOH), MARES Report: ADB

(m) Salinity gradient research and technologies in Palau need more exploration, investigation, and feasibility studies.