Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services (MARES)

Financial Modelling Report

November 2023

Prepared by

Dr Ralph Chami

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Executive Summary

The Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services (MARES) concept is all about the optimal implementation of the blue economy in partnership with nature to deliver more than the sum of its parts. MARES demonstrates how making a transition from extractive practices to regenerative practices creates healthier ocean ecosystems within which sustainable societies and economies can thrive. MARES should be considered as an enabler to the establishment of blue economies with a particular focus on the ocean energy economy.

This report endeavours to start the process of quantifying the diverse benefits of the multi-functional MARES solutions. The report looks at the potential energy generation, at two different locations, Dinagat Island and Surigao City, and Balut and Sarangani Islands. Site analysis identifies the potential available power production through the various MARES blue energy technologies that are implemented in partnership with the restoration of marine natural assets, seagrass beds, and mangroves.

Four MARES scenarios are developed, including a low ambition proposal, which retains some traditional, carbon-based energy solutions. A high-ambition proposal for both 2030 and 2050. The high-ambition scenarios have a much greater commitment to MARES/marine renewable energy (MRE) solutions. These scenarios describe how energy supply chains can be invested in and created. Those supply chains are placed in the context of the projected energy demands as described in the Mindanao Energy Plan 2018 – 2040.

Analysing the most optimistic outcome modelled for 2050 it has been shown that the potential MRE generation can exceed the energy demand for Dinagat Island and Surigao City but a factor of x17. If this surplus energy were to be used in the generation of hydrogen it would generate $3.85 billion (bn) in annual revenue for a cost of between $1.29bn and $3.19bn depending, the cost of green hydrogen production.

However, the analysis also explores wider effects and finds that compared to the benchmark with the existing energy mix, the cost of carbon emissions drops from $21.15 per gigawatt-hour (GWh) to $3.56 per GWh with the restoration of seagrass and mangroves alone contributing more than 25,000 tonnes of carbon dioxide (CO_2) sequestration per year by 2050.

Equally beneficial, the creation of a new industry sector generates significant employment opportunities in direct, and even more so, indirect jobs.

However, it is not just a story of energy and social or environmental benefits, it also makes sense economically, resulting in a Levelised Cost of Energy (LCOE) per GWh of energy generation a factor of over x2.5 less than the cost of relying on oil and coal [2050 low growth scenario (LGS) annual energy generation of 1,918 GWh for a LCOE of $439m; 2050 (high growth scenario (HGS) + MARES High annual energy generation of 42,667 GWh for LCOE of $3,790].

The story is repeated in Balut and Sarangani Islands, and also in the less ambitious scenarios too, in each case the energy demand is more than met, and the surplus can be put towards a diverse range of energy-driven industries.

This report demonstrates that the blue economy, when implemented with the thought and guidance outlined in the MARES Handbook, will deliver material social, environmental, and economic benefits to the region.

Table 1 below makes a simple comparison between the levelized cost of energy based on extractive methods and renewable methods placed within the MARES approach. Such a comparison provides a clear indication that the MARES approach offers a clear and substantial economic benefit.

	2020	2030 LGS (BAU)	2030 LGS + MARES Low	2030 HGS + MARES High	2050 LGS (BAU)	2050 LGS + MARES Low	2050 HGS + MARES High
LCOE - Energy Intensity ($/ kWh)	0.229	0.229	0.217	0.146	0.229	0.157	0.089

Table 1 Comparison between business as usual to fuel growth and BAU with MARES augmentation

Abbreviations: BAU = business as usual; HGH = high-growth scenario; kWh = kilowatt-hour; LCOE = levelized cost of energy; LGS = low-growth scenario

Acknowledgements

This report was prepared for the Asian Development Bank under Regional Technical Assistance (TA) 6619: Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services. The authors recognise with thanks the support of the Mindanao Development Authority. I would like to extend my sincere thanks to Dr Mike Abundo though the MARES TA- and Dr Roger Ilse for their support in both the collation of data and the analysis and modelling. Furthermore, I would also like to recognise the support from the wider NLA International Team.

1.0 Introduction

Extractive industries have been the mainstay of our economies and power generation. Thankfully, we are learning that just taking from the natural world is not sustainable. It is not sustainable for our environment or for our economies –placing nature, climate, and our own existence at risk. The Marine Aquaculture, Reefs, Renewable Energy, and Ecotourism for Ecosystem Services (MARES) programme explores what is needed to switch to regenerative technologies that would ensure sustainable and inclusive future for all.

Using two pilot projects, namely Dinagat and Surigao City, and the Islands of Balut and Sarangani in the Mindanao region of the Philippines, the MARES team explores the impact of introducing technologies and innovations that rely on the natural world to produce cost-effective energy and resources whilst regenerating the ocean ecosystem – a system we humans sometimes forget we are part of.

The two pilot projects showcase the roles of science, engineering, high-tech as well as "nature-tech" to deliver cost-effective and nature and people-friendly services.

ADB's *The Ocean-Energy Economy: A Multifunctional Approach* – published in October 2023, outlines types of marine renewable energy sources and how they may be realized into affordable energy for all.

Figure 1 The Ocean-Energy Economy A MULTIUNCTIONAL APPROACH

The report provides a first approximate economic perspective of the technologies and the planning scenarios to aid decision makers in making appropriate technology choices prior to performing more in-depth site-specific analysis to validate initial findings.

The emergence of the blue economy has changed the way governments think about our ocean. Developing planning scenarios, increasing awareness through capacity building, and capturing the cross-benefits of related technologies and business approaches are the key themes of the MARES report. It seeks to put some order and common sense to the confusing array of potential solutions that compete for marine spaces.

The MARES project proposes a realistic roadmap. The challenge now is to apply it and in doing so to unlock the potential of a combination of infrastructure and natural capital solutions in a way that makes them compelling, inspiring, and perhaps even investable.

The report walks the reader through two regional scenarios where the MARES approach is applied and showcases the findings. The areas of interest are Dinagat Island and Surigao City, and the Islands of Balut and Sarangani in Mindanao region, Philippines.

The results below clearly show that the MARES approach can not only be used to meet current and expected future demands for energy, but it does so in a cost-effective manner that is also nature-positive, while delivering social and health benefits.

Figure 2. Location 1: Dinagat Island and Surigao City; Location 2: Balut and Sarangani Islands, Philippines

2.0 MARES Scenarios for Dinagat Island and Surigao City

The locations were analysed for their potential to produce marine energy and two scenarios, a high- and low-ambition outlook, were designed for 2030 and 2050. The earlier date of 2030 was chosen to demonstrate what could already be achieved in a comparatively short time horizon, whereas 2050 allows for more ambitious scenarios that demonstrate the untapped potential of marine renewable energy (MRE).

The 2030 low-ambition scenario (Table 2) achieves most of its power generation through marine solar being a comparatively mature technology solution with the highest potential for energy generation in the region. Offshore wind is excluded in the low-ambition scenario to reduce potential capital expenditure (capex), while tidal, wave and ocean thermal energy conversion (OTEC) technologies are implemented as sizeable pilot projects. The 2030 high-ambition scenario scales these solutions to a higher power generation, in particular upgrading OTEC to 100 megawatt (MW) and initiating a 10 MW offshore wind farm.

The 2050 scenarios (Table 3) are altogether more ambitious, in the low-ambition scenario scaling up wind power and the more nascent technologies such as tidal and wave energy. For the high-ambition scenario the significant potential for MRE generation in the region is beginning to emerge; in particular marine solar reaches 20,000 MW while offshore wind and OTEC technologies bring 2,000 MW and 1,000 MW respectively. Even at these high power-generating capacities, the MRE solutions remain at or below the potential for the region shown in Table 4.

2030 Scenarios	2030 Low ambition	2030 High ambition
	Power (MW) (efficiency (%))	Power (MW) (efficiency (%))
Marine solar	100 MW (15%)	200 MW (15%)
Offshore wind	0 MW (30%)	10 MW (30%)
Tidal currents	5 MW (35%)	10 MW (35%)
Wave energy	5 MW (30%)	10 MW (30%)
OTEC	10 MW (90%)	100 MW (90%)

Table 2 2030 Marine Energy Scenarios

2050 Scenarios	2050 Low ambition	2050 High ambition
	Power (MW) (efficiency (%))	Power (MW) (efficiency (%))
Marine solar	200 MW (15%)	20,000 MW (15%)
Offshore wind	200 MW (30%)	2,000 MW (30%)
Tidal currents	50 MW (35%)	200 MW (35%)
Wave energy	50 MW (30%)	200 MW (30%)
OTEC	100 MW (90%)	1,000 MW (90%)

Table 3 2050 Marine Energy Scenarios

MARINE RE Resource Estimates (Potential Installed Capacity)	
	Power (MW) (efficiency (%))
Marine solar	160,000 MW (15%)
Offshore wind	4,000 MW (30%)
Tidal currents	200 MW (35%)
Wave energy	700 MW (30%)
OTEC	1,000 MW (90%)

Table 4 Dinagat Island and Surigao City - Potential marine renewable energy limits for the region

2.1 Energy Production Meeting and Exceeding Demand

The total annual energy demand for the region is derived from the Mindanao Energy Plan 2018 – 2040 [1], that includes two scenarios, a high-growth scenario (HGS) and a low-growth scenario (LGS). The reported values have been scaled to Dinagat Islands and Surigao City and extrapolated to 2050. The existing total energy demand includes fuel (e.g. for transport) and all forms of energy generation, used by all sectors, including electricity generation.

> The Mindanao Energy Plan was developed with two demand scenarios in mind – the High-Growth Scenario (HGS) and the Low-Growth Scenario (LGS). The LGS adopted the region's share to the national economic growth rate (Real GDP) target, while the HGS used the Mindanao 2020 regional growth rate target, according to the Department of Energy Philippines in 2017.

Overall, a total of 7 scenarios are modelled and outlined in Table 5. In the scenarios without a MARES scenario the energy demand is met by the existing mix of energy generation solutions. In the scenarios with the MARES solution the energy production becomes a mix of existing plus MARES blue energy solutions. For example, in the "2030 LGS + MARES Low" observed in Figure 3, the 2030 Low Ambition MARES energy production, as reported in Table 1, is integrated into the scenario. As the blue energy solutions come online, they replace first the coal-powered electricity generation and then the oil-powered energy generation down to a base load of about 2 GW oil-based electricity generation. Any additional energy generated by MARES solutions is surplus and thus can be put to work elsewhere, either sold back to the grid or fed back into the local economy. The "2030 HGS + MARES High" then looks at how the Mindanao HGS plan can be more than met by the MARES renewable energy solutions where the value of the MARES concept starts to be demonstrated as more surplus energy becomes available to drive regional economic growth.

Modelled Energy Scenarios							
Scenario Name	2020	2030 LGS	2030 LGS + MARES Low	2030 HGS + MARES High	2050 LGS	2050 LGS + MARES Low	2050 HGS + MARES High
Mindanao Energy Demand	2020	2030 LGS	2030 LGS	2030 HGS	2050 LGS	2050 LGS	2050 HGS
MARES Energy Production Scenario	-	-	2030 Low Ambition	2030 High Ambition	-	2050 Low Ambition	2050 High Ambition

Table 5 Modelled energy scenarios - Mindanao energy plan and MARES scenarios

The “2050 LGS” scenario provides a future benchmark that scales the 2020 energy production to the Mindanao 2050 LGS demand. This is followed by the “2050 LGS + MARES Low” ambition scenario that produces almost double the energy demand. Finally, the “2050 HGS + MARES High” scenario demonstrates the immense potential of marine energy solutions in the region with energy production reaching 17 times the energy demand. Annual surplus energy exceeds 40 terawatt-hour (TWh) that can either be used to drive a growing regional energy-based industry such as hydrogen production, fed back into the grid, or exported.

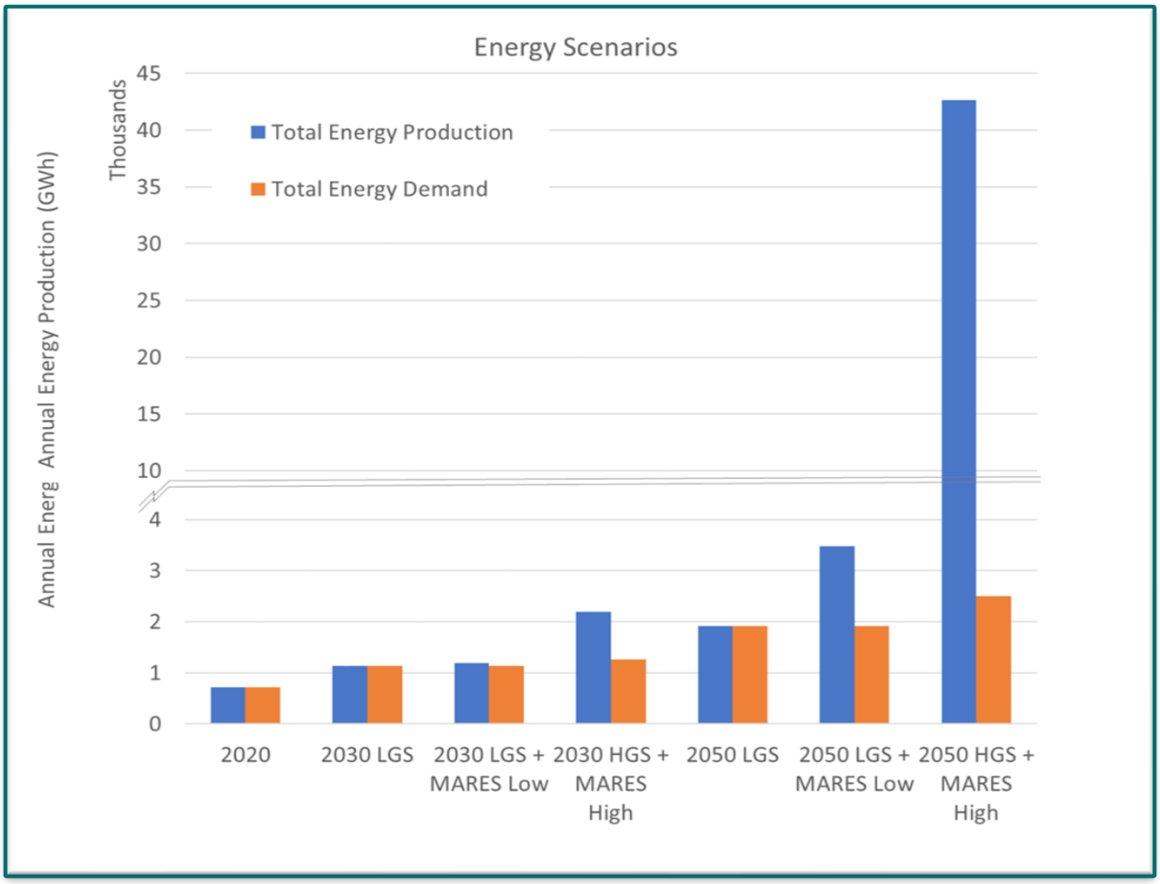

Figure 3 Dinagat Island and Surigao City - Total Energy Demand against Total Energy Production

2.2 Current state In Dinagat and Surigao

The existing energy production in 2020 is used as a base which is scaled to meet the total energy demand in 2030 according to the Mindanao Low-Growth Scenario. The current state is an important baseline that considers how power is generated now, while using the Mindanao Energy Plan 2018-2040 to describe future power needs within the boundaries of a low-growth scenario and a high-growth scenario. These are non-blue energy solutions such as coal, natural gas, and oil, whereas blue energy solutions or MARES-type solutions are marine solar, wave, OTEC, offshore wind and tidal/current power generation.

The region could maintain the current production ratios of oil- and coal-based solutions with some renewable to meet that demand but doing so may prevent us from reaching the region's full potential. The region of Dinagat Island and Surigao City has a glide path for energy demand. Figure 3 demonstrates how that demand can be met by a blend of energy supply and solutions. Then comparing that with a mix that has a bias towards renewables and away from coal and oil. i.e., maintaining minimum level of oil and meeting growth in demand using MARES solutions.

Mindanao has a 2030 target to produce 50% of energy from renewable sources. The data shows that that is more than achievable if we leverage the ocean as a resource and the learning from MARES.

The scenarios moving to include MARES energy production show the way that supply can be shaped to meet that demand. These scenarios quickly exceed demand and, in those scenarios, an opportunity presents itself to generate revenue through the sale of surplus energy or to use that energy to produce a commodity such as green hydrogen.

2.3 Looking to the Future of Energy Generation

The MARES energy production is driven mainly by marine solar and OTEC in both the LGS and HGS projections in 2030 which easily displaces the oil and coal electricity generation.

It is important to model the entire energy system, however, rather than just electricity generation, as a large proportion of energy demand is driven by the transport sector. In the modelling of the scenarios the MARES energy production has been offset against the electricity generation by the burning of coal and oil, however, there is a large opportunity here to transition the regional transport system from oil to be powered entirely by marine renewable energy.

The 2050 HGS MARES High ambition scenario is over 60% powered by marine solar with an annual energy generation of 26 TWh generated by 20 GW of solar arrays, still well below the total exploitable marine solar potential of 160 GW. Most of the rest of the energy production is made up by offshore wind and OTEC energy production. Note that although OTEC technology solution is half of that for offshore wind, 1 GW to 2 GW respectively, due to the much greater efficiency of OTEC, 90% vs 30% for wind, it exceeds the energy production of offshore wind.

The model assumed current levels of efficiency for MARES technologies and projected forwards, but it would be reasonable to assume that the technology would advance and become more efficient and therefore in the future it is likely that more energy could be extracted from the same level of input power. The levels of efficiency modelled on are in the % on the key table in the chart.

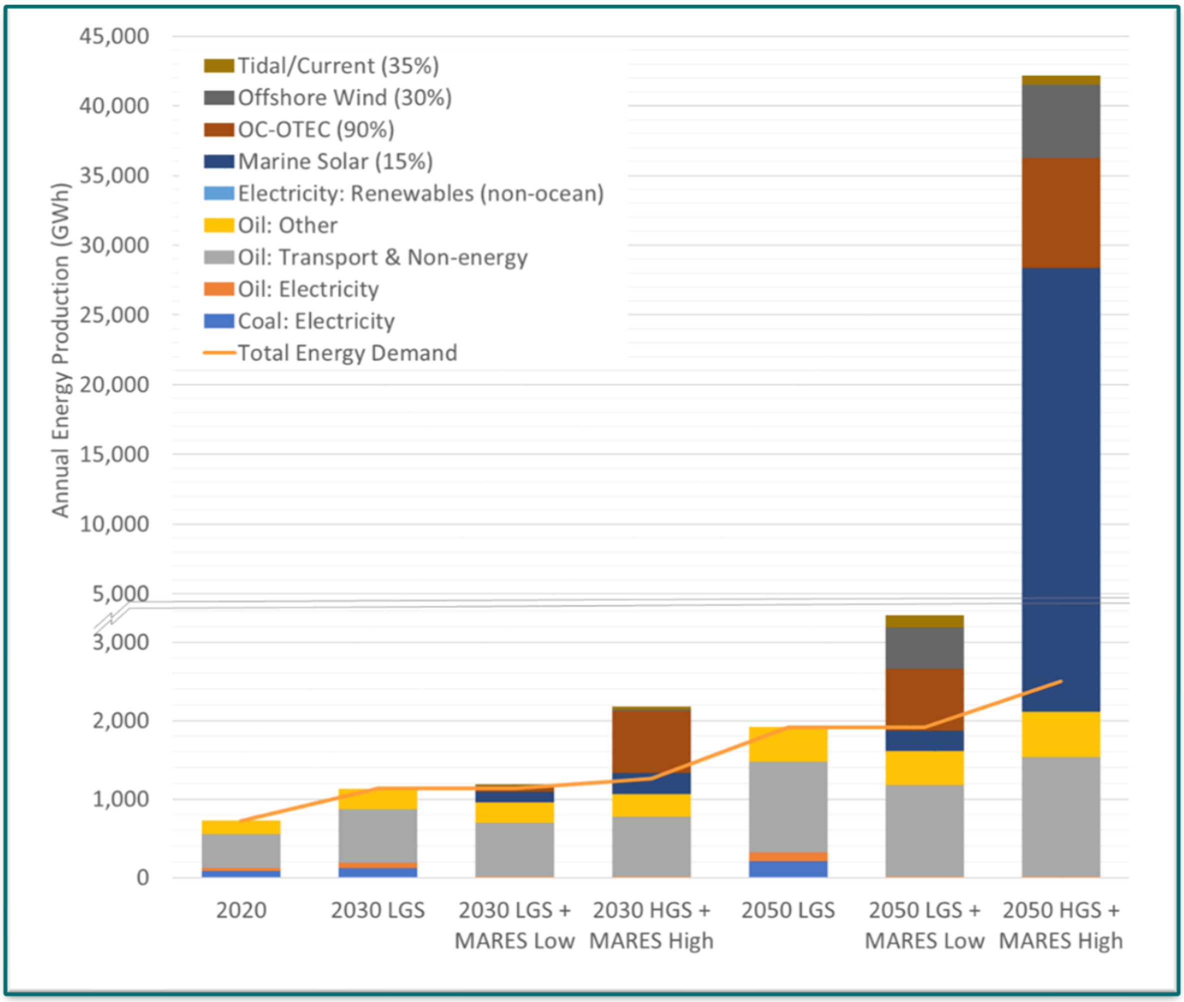

Figure 4 Dinagat Island and Surigao City - Total energy demand and generation mix by scenario

2.4 Cost Benefit Analysis

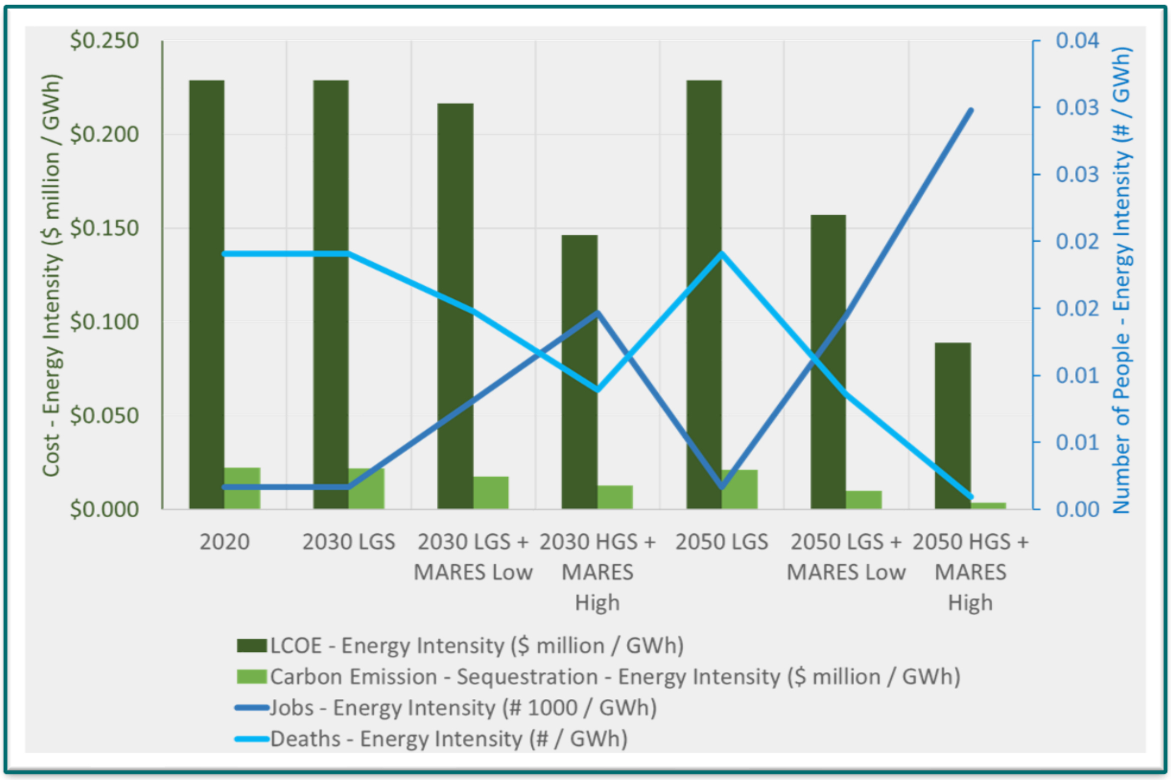

Figure 5 Dinagat Island and Surigao City - Cost benefit for MARES scenarios

Analysis of the levelized cost of energy for the different energy solutions (Appendix 2 – Levelised Cost of Energy) reveals that the blue energy solutions have a lower lifecycle cost per unit of energy generation making them economically attractive alternatives to non-blue energy solutions. In addition to looking at costs, analysis of carbon emissions [2] [3] has also been considered explicitly. Unsurprisingly, transitioning from conventional energy production to MARES solutions reduces the carbon intensity from $22.23 per GWh (2020 scenario) down to $3.56 per GWh in 2050 (2050 HGS + MARES High scenario) based on today's one-month future price on the EU Exchange Traded System (ETS) which corresponds to $85.28 per CO2 equivalent per year[1].

The wider purpose of the MARES concept is that the benefits are not just limited to financial but also spill over into social and environmental dimensions. In this respect, the health of the population has been modelled as a function of deaths through accidents and exposure to pollution per GWh of energy produced[2] (

[1] The euro price is the average weekly price from March 6, 2022, to February 26, 2023. Downloaded from https://www.investing.com/commodities/carbon-emissions-historical-data. The conversion to US dollar is found by multiplying the Euro price by the U.S. Dollars to Euro Spot Exchange Rate, U.S. Dollars to One Euro, Daily, Not Seasonally Adjusted from Fred at the St. Louis Federal Reserve website https://fred.stlouisfed.org over the same time period.
2Mortality rates for each energy source in deaths per billion kWh produced. Source Updated (correted data from: World Health Organisation CDC; Seth Godin John Konrad

Appendix 2 – Levelised Cost of Energy

	LCOE ($/kWh)
Coal[1]	0.068
Oil[2]	0.237
Marine Solar[3]	0.094
Wave[3]	0.066
OC-OTEC[3]	0.021
Offshore Wind[3]	0.069
Tidal/Current[3]	0.377

1) Lazards-LCOE plus April-2023
2) Calculation assuming LCOE for 1 MV oil-powered generator over a 30-year lifetime: LCOE - this report
3) The Ocean-Energy Economy A MULTIUNCTIONAL APPROACH, ADB, October 2023

Appendix 3 – Deaths per TWh of Energy Production). Mainly through the reduction in pollution the MARES scenarios have had a marked impact on the number of deaths per GWh of energy produced, bringing it down by over an order of magnitude from today relative to 2050 MARES scenario.

The investment into the blue economy creates many new jobs[2] as new industries spring up to supply the materials, labour and services required for the installation, maintenance and operations of these new technologies. Furthermore, access to surplus energy allows for the expansion of further industries, such as electric shipping and port services, electric vehicles infrastructure, and hydrogen production and export.

OTEC is a great example, not only does it produce energy with a 90% operating percentage, open-cycle OTEC can also be used to produce fresh water. However, the immense additional benefit of OTEC is the provision of nutrient rich deep ocean water (DOW) which can be used in multiple industries such as aquaculture, fisheries, coral restoration, microalgae, oyster farms, cosmetics and spa facilities.

[2] Job creation estimates based on Input-Output analysis of renewable energy industry transition in Indonesia, Global Green Growth: Clean Energy Industrial Investments and Expanding Job Opportunities, The Global Green Growth Institute, United Nations Industrial Development Organization, 2015 [5]

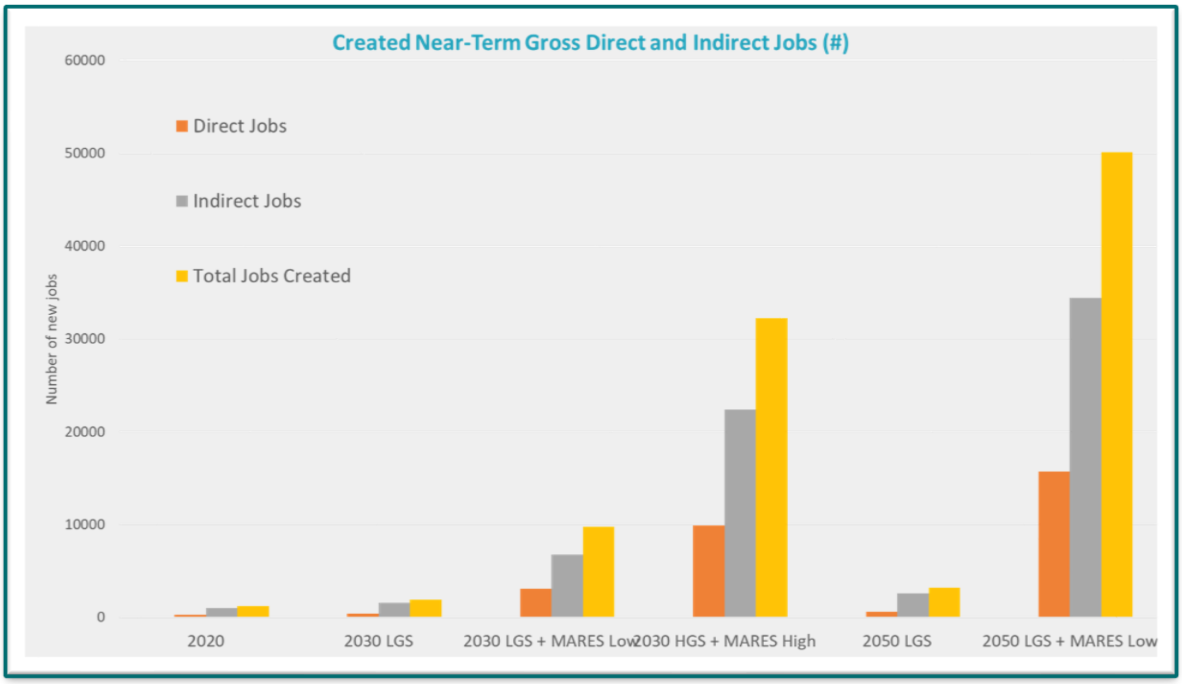

Figure 6 Dinagat Island and Surigao City - Created Near-Term Gross Direct and Indirect Jobs (#)

Surplus energy over existing demand allows for exploration of new economic opportunities to leverage the new source of energy. One such solution is the generation of hydrogen for export. Taking just the surplus energy from MARES it is possible to generate over 700,000 tonnes per year by 2050, with a current market price of approximately $40 million based on today's prices.

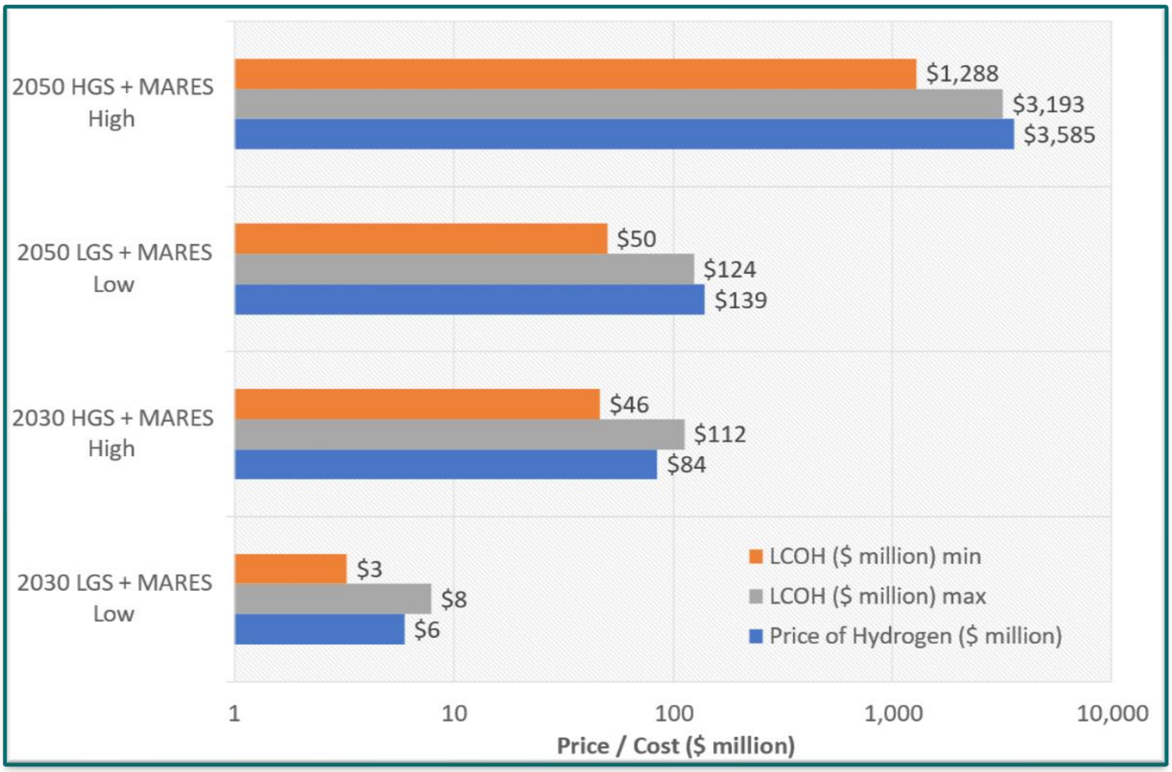

Figure 7 Dinagat Island and Surigao City – Price compared to cost of annual volume of hydrogen production from surplus energy generation[3]

2.5 Valuing Natural Assets

The Philippines is surrounded by nutrient-rich tropical oceans that support a diverse range of marine fauna and fora. However, like many oceans around the world, human activity is putting increasing pressure on the marine environment, that in turn impacts coastal communities that depend upon it, through the degradation of marine ecosystem services. Restoration and conservation of coastal marine ecosystems have a multiplier effect generating many benefits, both natural and economic, some of which are described in Figure 7.

[3] IEA Global average levelised cost of hydrogen production by energy source and technology, 2019 and 2050; The European Union has launched its first green hydrogen auction with a maximum price of €4.50 ($4.91)/kg. The approved projects will receive subsidies for a decade, alongside revenue from hydrogen sales, and must start production within the next five years.

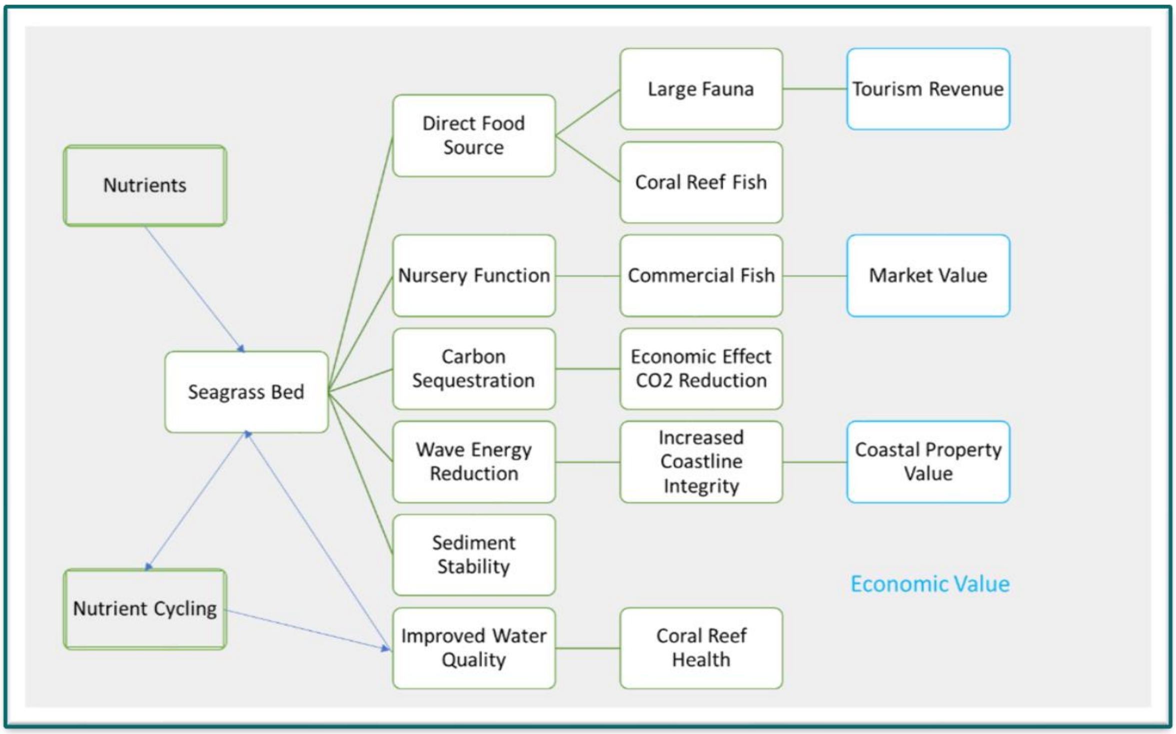

Figure 8 Ecosystem services of seagrass beds and their economic value [4]

Valuing these benefits helps to build the economic case for the restoration of natural assets. Figure 8 shows the potential carbon sequestration through the restoration of seagrass beds and mangroves that generates an annual flow of carbon sequestration that exceeds 25,000 tonnes by 2050, or an annual cash flow with net present value over $1 million.

Appendix 4 provides an overview of the natural capital assets which have been identified and valued in this analysis.

Valuations have been based on type of coverage (mangrove, seagrass and coral) and by area of coverage. This provides an indication of carbon sequestration volumes. No accounting has been applied for broader biodiversity benefits. A more detailed analysis that incorporates biodiversity is likely to reveal the potential of high carbon values.

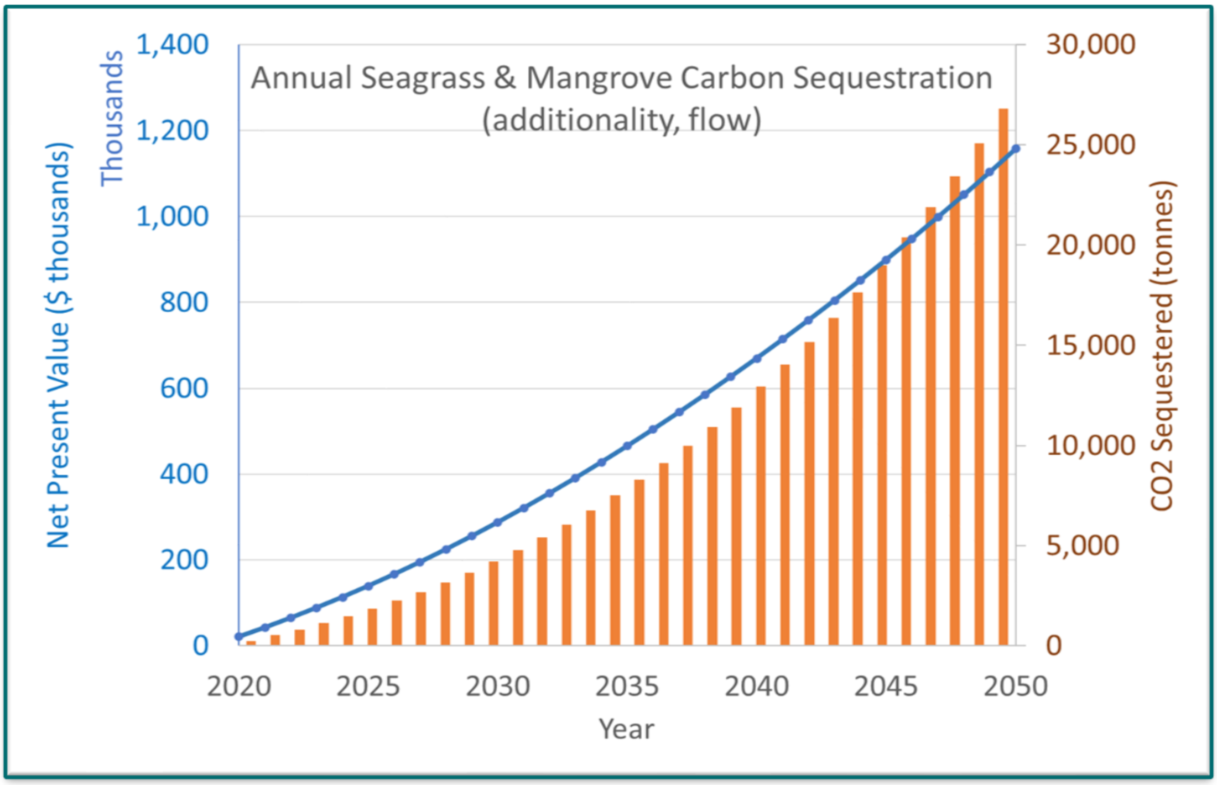

Figure 9 Dinagat Island and Surigao City - Annual seagrass and mangrove carbon sequestration from restoration of lost habitats

3.0 MARES Scenarios for Balut and Sarangani Islands

We have repeated the analysis for Balut and Sarangani Islands and found very similar results as shown in Figure 10. Balut and Sarangani are typical of many of the smaller off-grid islands that are largely powered by oil. MARES offers a great opportunity to replace the local oil-driven economy to build a local 'blue economy' in line with the published intentions of the Mindanao energy plan, that is driven by MRE, creating jobs and having positive social and health impacts.

Other charts and figures for Balut and Sarangani Islands are included in Appendix 1.

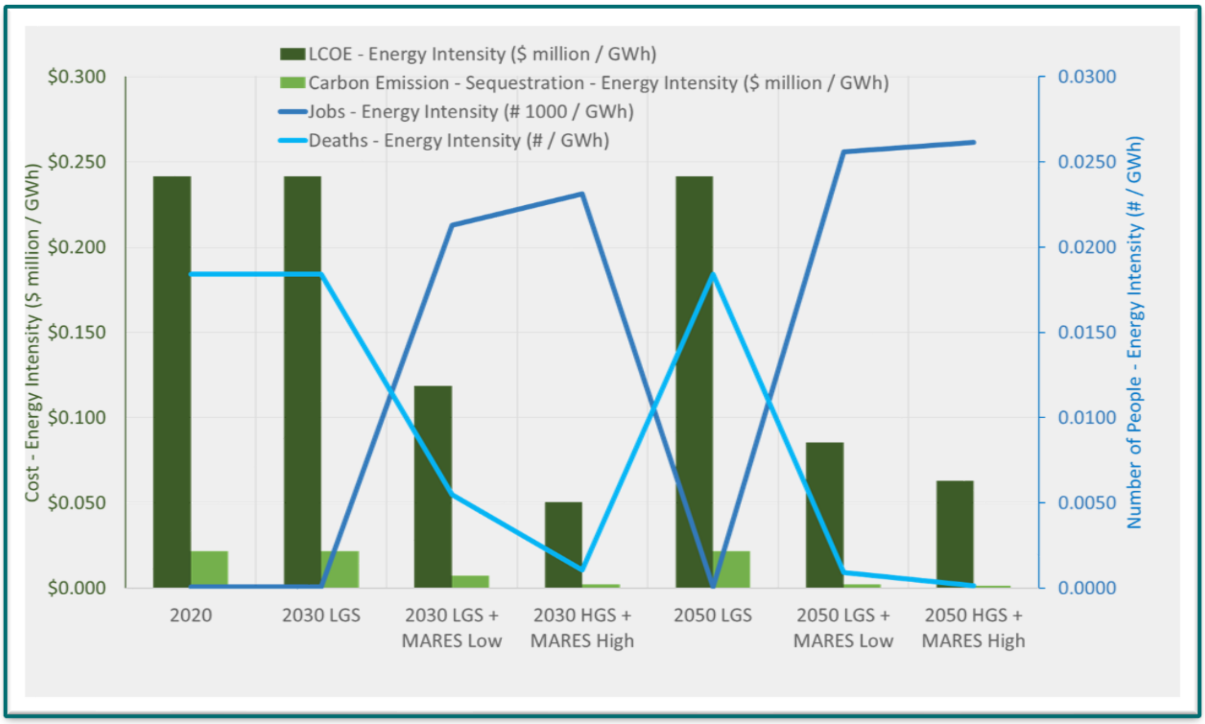

Figure 10 Balut and Sarangani Islands - Cost benefit for MARES scenarios

4.0 Conclusion- Sustainable, Resilient, Economic Growth

MARES solutions will help to create energy security while avoiding exposure to global energy shocks and price volatility which is an increasing trend. They provide an opportunity to restore natural assets and leverage the multiplier effect generated by healthy functioning ecosystems which provide environmental, social, and economic benefits. Many MARES solutions provide the infrastructure to build multi-functional marine spaces that can help restore natural assets while also generating blue energy.

The reason for outlining the benefits of the MARES approach is also to generate opportunities for investment at scale. It has been demonstrated how MARES solutions help to increase sustainability aligned to SDGs while contributing to Nationally Determined Contributions (NDCs) (reduced emissions and increased carbon sequestration). As MARES also supports a wide range of sectors it helps in building economic resilience via a diversified economy while creating direct and especially indirect jobs.

Appendix 1 – Charts for Balut and Sarangani Islands

Table 6 2030 Marine energy scenarios

2030 Scenarios	2030 Low ambition	2030 High ambition
	Power (MW) (efficiency (%))	Power (MW) (efficiency (%))
Marine solar	25 MW (15%)	100 MW (15%)
Offshore wind	0 MW (30%)	10 MW (30%)
Tidal currents	2.5 MW (35%)	5 MW (35%)
Wave energy	2.5 MW (30%)	5 MW (30%)
OTEC	10 MW (90%)	100 MW (90%)

Table 7 2050 Marine energy scenarios

2050 Scenarios	2050 Low ambition	2050 High ambition
	Power (MW) (efficiency (%))	Power (MW) (efficiency (%))
Marine solar	200 MW (15%)	2,000 MW (15%)
Offshore wind	200 MW (30%)	2,000 MW (30%)
Tidal currents	50 MW (35%)	200 MW (35%)
Wave energy	50 MW (30%)	200 MW (30%)
OTEC	100 MW (90%)	1,000 MW (90%)

Table 8 Balut and Sarangani Islands - Potential marine renewable energy limits for the region

MARINE RE Resource Estimates (Potential Installed Capacity)	
	Power (MW) (efficiency (%))
Marine solar	21,000 MW (15%)
Offshore wind	12,000 MW (30%)
Tidal currents	200 MW (35%)
Wave energy	280 MW (30%)
OTEC	1,000 MW (90%)

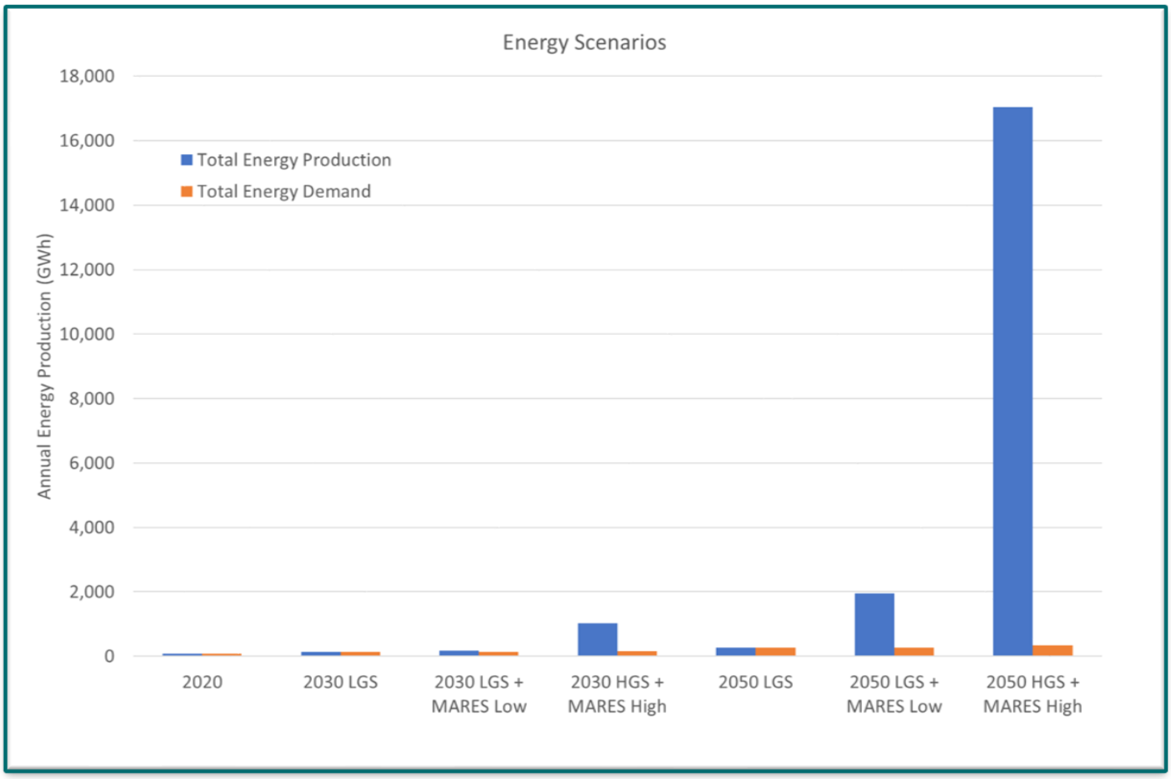

Figure 11 Balut and Sarangani Islands - Total Energy Demand against Total Energy Production

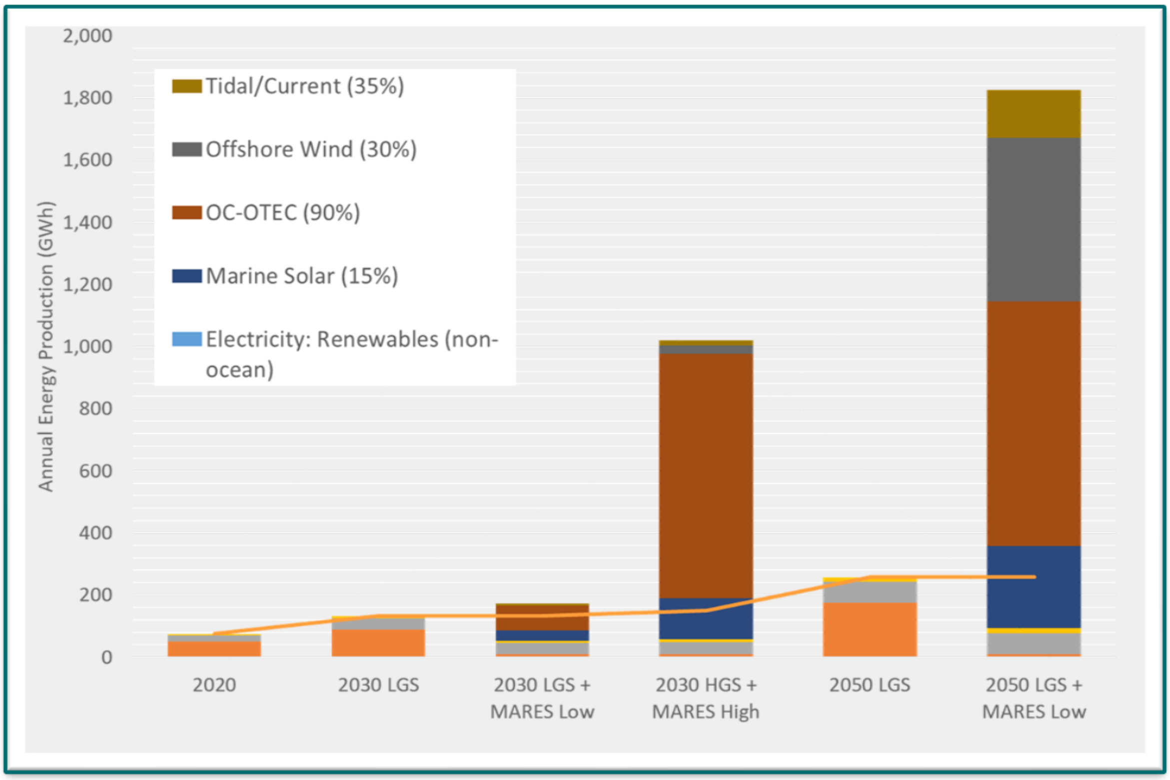

Figure 12 Balut and Sarangani Islands - Total energy demand and generation mix by scenario

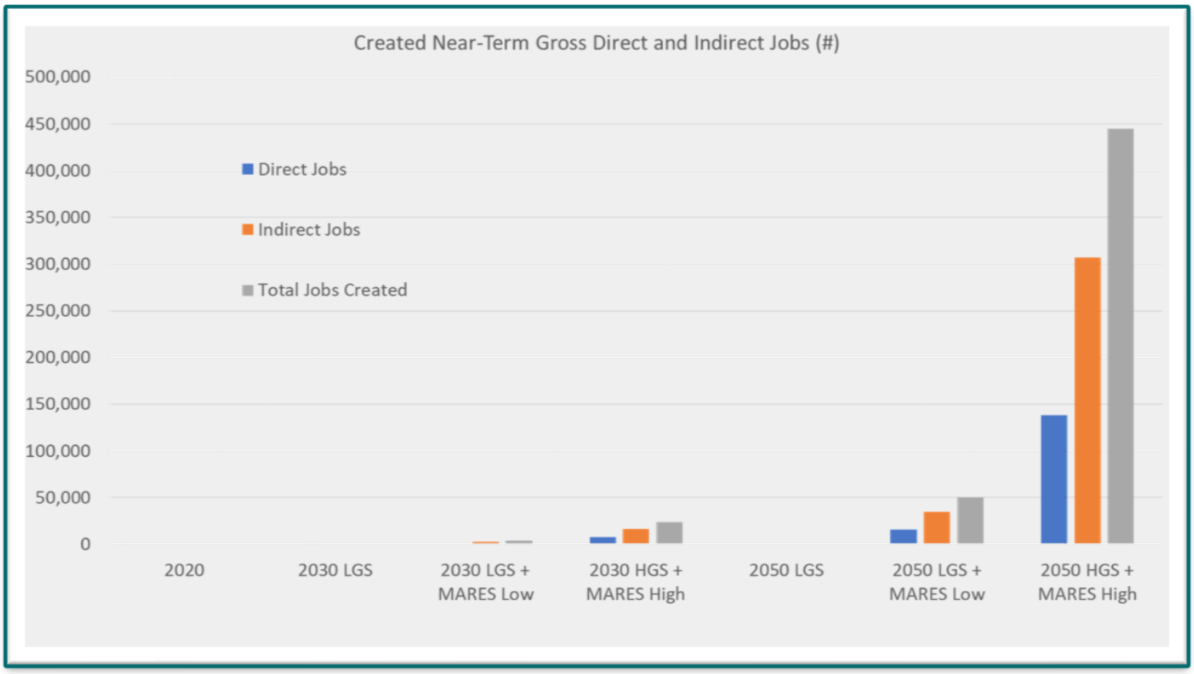

Figure 13 Balut and Sarangani Islands - Created Near-Term Gross Direct and Indirect Jobs (#)

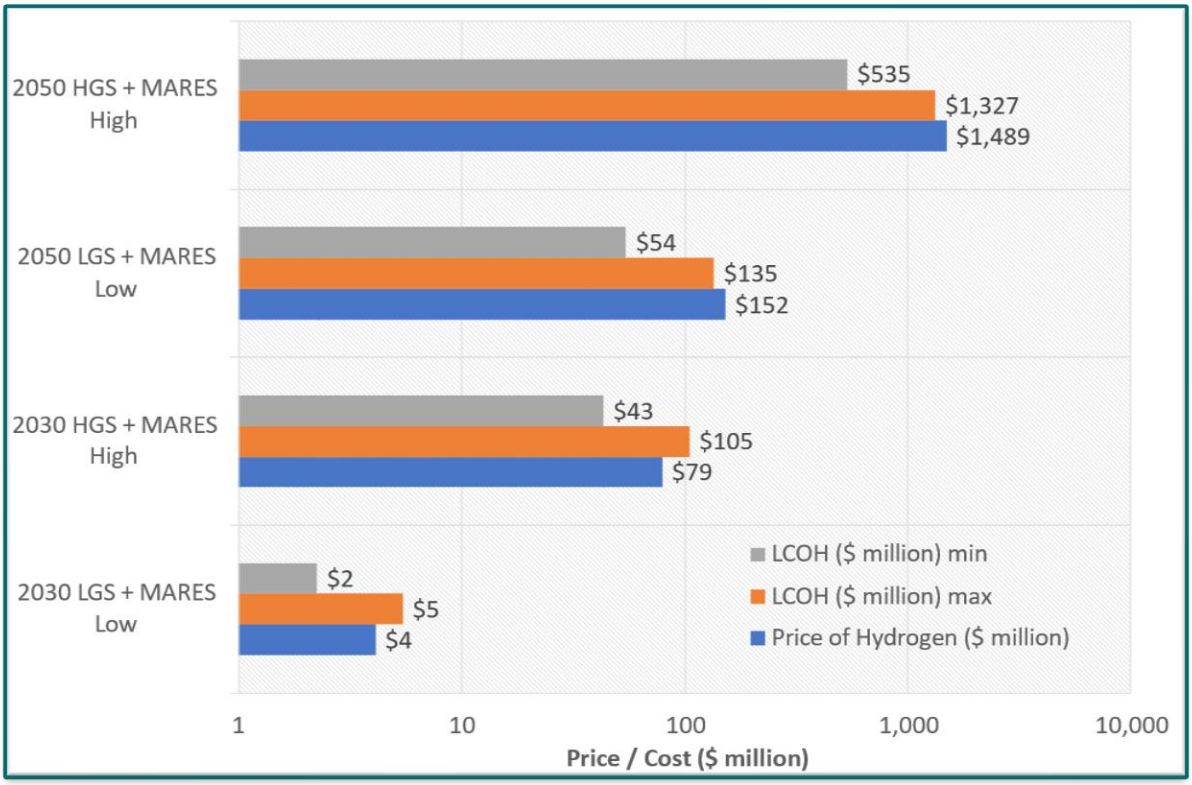

Figure 14 Balut and Sarangani Islands - Price compared to cost of annual volume of hydrogen production from surplus energy generation[4]

[4] IEA Global average levelised cost of hydrogen production by energy source and technology, 2019 and 2050; The European Union has launched its first green hydrogen auction with a maximum price of €4.50 ($4.91)/kg.

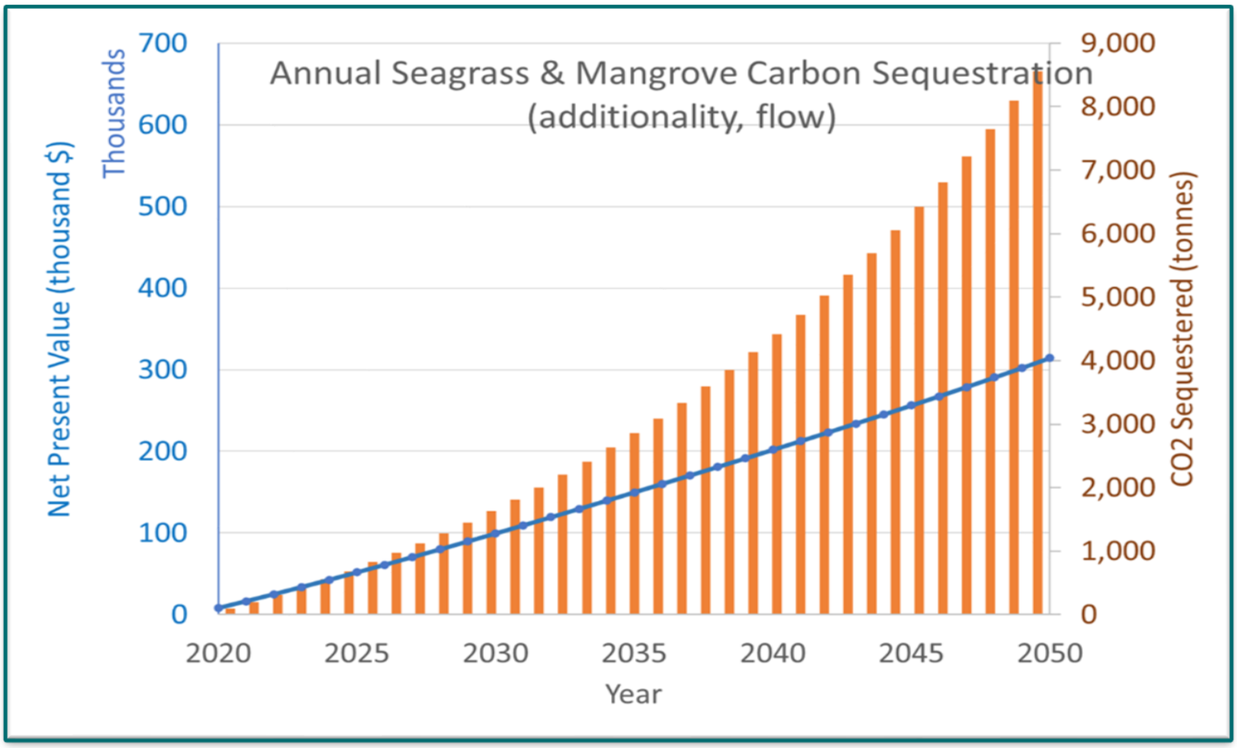

Figure 15 Balut and Sarangani Islands - Annual seagrass and mangrove carbon sequestration from restoration of lost habitats

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The approved projects will receive subsidies for a decade, alongside revenue from hydrogen sales, and must start production within the next five years.

Appendix 2 – Levelised Cost of Energy

	LCOE ($/kWh)
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1) Lazards-LCOE plus April-2023
2) Calculation assuming LCOE for 1 MV oil-powered generator over a 30-year lifetime: LCOE - this report
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Appendix 3 – Deaths per TWh of Energy Production

Deaths per terawatt-hour of energy production Source
Deaths per TWh energy production – processed by Our World in Data Unit deaths per terawatt-hour

Additional information about this data
Death rates from energy production is measured as the number of deaths by energy source per terawatt-hour (TWh) of electricity production.

Data on death rates from fossil fuels is sourced from Markandya, A., & Wilkinson, P. (2007).

Data on death rates from solar and wind is sourced from Sovacool et al. (2016) based on a database of accidents from these sources.

We estimate deaths rates for nuclear energy based on the latest death toll figures from Chernobyl and Fukushima as described in our article here: https://ourworldindata.org/what-was-the-death-toll-from-chernobyl-and-fukushima

We estimate death rates from hydropower based on an updated list of historical hydropower accidents, dating back to 1965, sourced primarily from the underlying database included in Sovacool et al. (2016). For more information, see our article: https://ourworldindata.org/safest-sources-of-energy

The data of this indicator is based on the following sources:

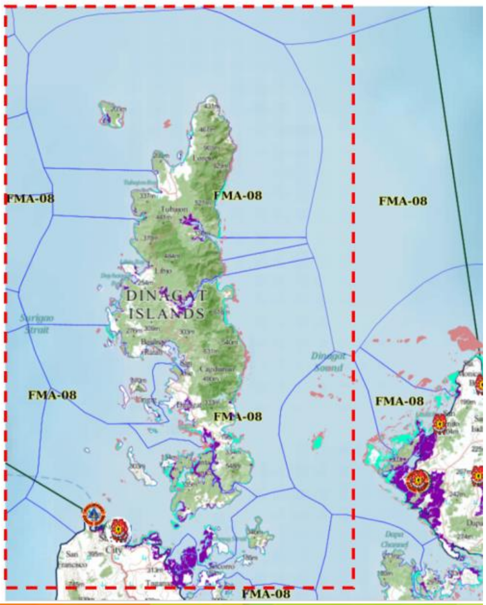
Deaths per TWh energy production
Death rates from energy sources is measured as the number of deaths from air pollution and accidents per terawatt-hour (TWh) of energy production.

Data published by
Sovacool et al. (2016); and Markandya, A., & Wilkinson, P. (2007)

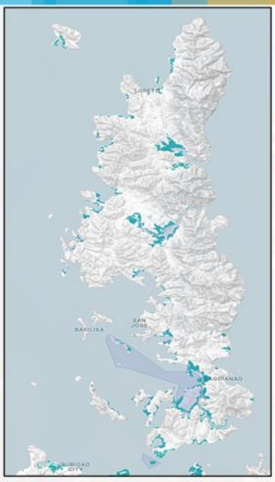
Appendix 4 – Natural capital Assets and Values

Profile	Dinagat Is. Province	Surigao City
LGU Profile	7 Municipal LGUs	1 City LGU
Municipal waters	377,451 Ha.	54,803 Ha.
Mun Water Max Depths	275m offshore West of LGU Basilisa	543m offshore West of Sumilon Is.
Coral Reef	4,919 Ha.	16,003 Ha.
Seagrass meadows	2,422 Ha.	9,591 Ha.
Mangrove forest	2,230 Ha.	14,080 Ha.
Earthquake/ Ground shake	> Intensity 8 in some parts and Intensity 7 in the rest of the island	> Intensity 8 in mainland and Intensity 7 in the islands
Earthquake-induced landslide	Not susceptible	HIGH near mountains and the rest are LOW
Liquefaction vulnerability	HIGH in portions of the coastal area of the province	HIGH in coastal portions of the city
Tsunami	2-5m high in most coastal area	2-5m high in most coastal area
Flood	LOW in general except in some low-lying areas	LOW in general except in some low-lying areas

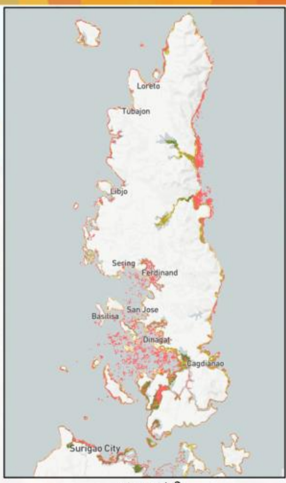
Dinagat & Surigao City AOI



MARES – A Multifunction Approach – Valuing Natural Capital



Mangrove[1]



Coral [2]

Seagrass [3]

[1] https://www.globalmangrovewatch.org/
[2] https://allencoralatlas.org/atlas/#9.71/10.1133/125.6434
[3] https://data-gis.unep-wcmc.org/portal/home/webmap/viewer.html?useExisting=1&layers=aaa46cd3d3d640b2916b8f0a0ffe07cb

Profile	Municipality of Sarangani
LGU Profile	4th Class
Municipal waters	131,741 Ha.
Mun Water Max Depths	3,000m offshore West of Balut Is., but Northside of all Islands has a lot of 1,000m potential.
Coral Reef	3,875 Ha.
Seagrass meadows	133 Ha.
Mangrove forest	84 Ha.
Earthquake/ Ground shake	> Intensity 8 in some parts and Intensity 7 in the rest of the island
Earthquake-induced landslide	Not susceptible
Liquefaction vulnerability	Some portions of Sarangani Is., and none in Balut Is.
Tsunami	3-6m high in most coastal area
Flood	LOW in general, except in some low-lying areas

Balut and Sarangani Islands, Philippines AOI

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[2] National Renewable Energy Laboratory, "Life Cycle Greenhouse Gas Emissions from Electricity Generation: Update," 2021.

[3] D. f. E. S. a. N. Z. a. D. f. B. E. &. I. S. UK Government, "Greenhouse gas reporting: conversion factors 2021," 2021. [Online]. Available: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting. [Accessed 2023].

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