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Integrating Offshore Wind Into Competitive Renewable Energy Zones (CREZ) for the Philippines

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Photo: Dennis Schroeder, NREL 40481

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Introduction

- Competitive Renewable Energy Zones
- Background Information
- Project Motivation and Scope

Renewable Energy Zones (REZ) Overview

A **Renewable Energy Zone (REZ)** is a geographic area characterized by:

Figure. Components of Candidate Renewable Energy Zones

1. High-quality renewable energy (RE) resources — e.g., solar irradiance, wind speed, etc.

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2. Suitable topography exclusions — e.g., exclusions for protected environmental areas, urban areas, waterbodies, terrain features, etc.

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3. Strong commercial interest — e.g., economic development areas, demonstrated developer interest etc.

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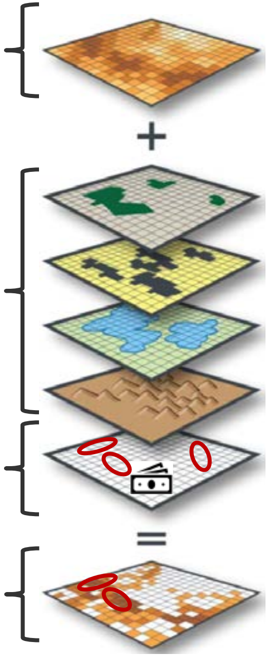
Candidates for REZs — e.g., technical potential of solar PV or wind in candidate renewable energy zones, etc.



Source: Lee et al. (2017)
Image: Billy Roberts (NREL) adapted from Lopez (2016)

Transmission Planning Barriers Addressed by Renewable Energy Zones

Traditional transmission planning might miss the best resources due to the **circular dilemma** and/or **timescale misalignment**:

Figure. Circular Dilemma

Figure. Timescale Misalignment

The REZ transmission process can address these barriers by **proactively coordinating RE generation and transmission expansion**. The REZ process is particularly **applicable for RE expansion that is constrained by transmission capacity**. It may not be as suitable if other reasons are primarily limiting RE development or if adequate transmission exists.

Source and Figures: Lee et al. (2020)

Select REZ Case Studies

The REZ process has been implemented to varying degrees throughout the world, including in the Philippines, and has been tailored to each country or region's particular resource mix, geography, and electricity industry structure.

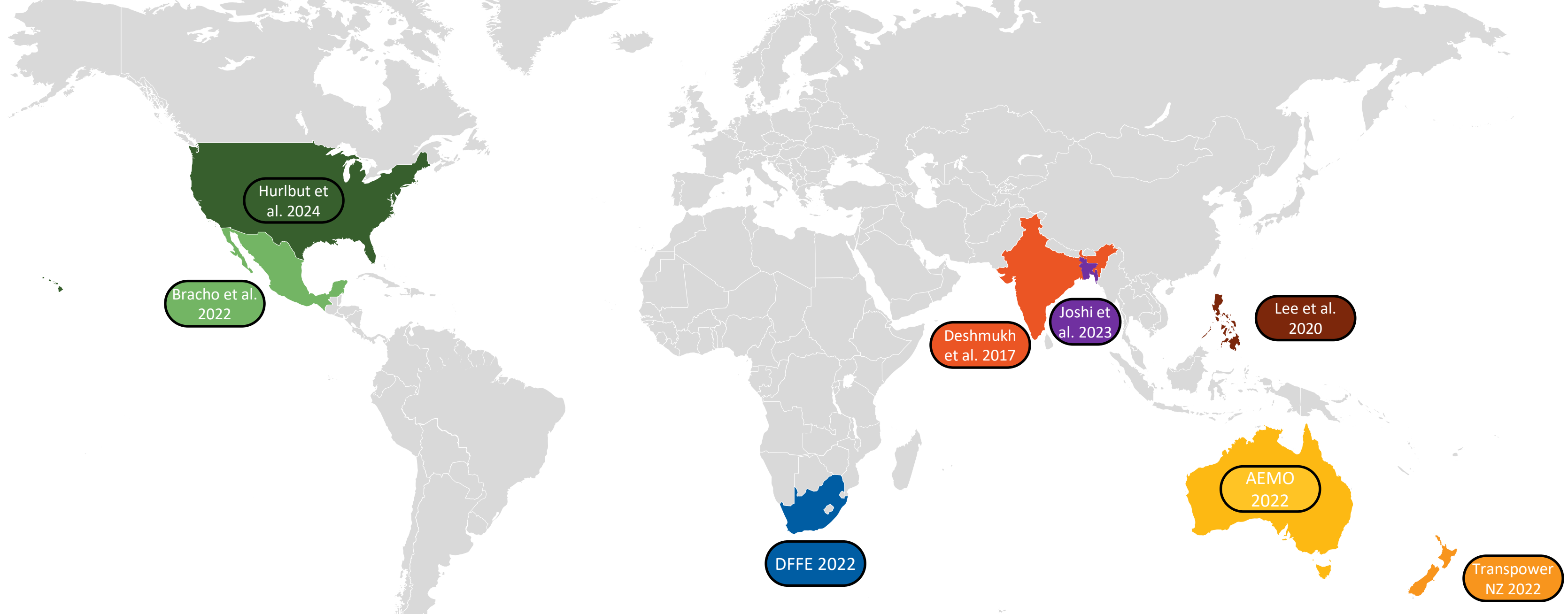
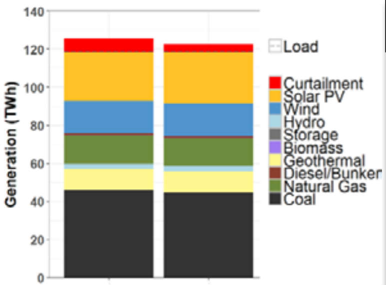


Figure. Select REZ Case Studies Implemented Throughout the World

Prior Renewable Energy Zones and Offshore Wind Work in the Philippines

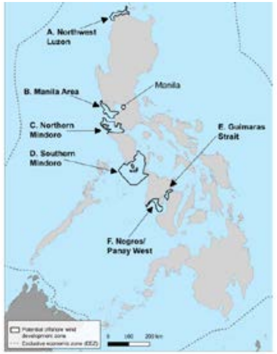
Renewable Energy Zones

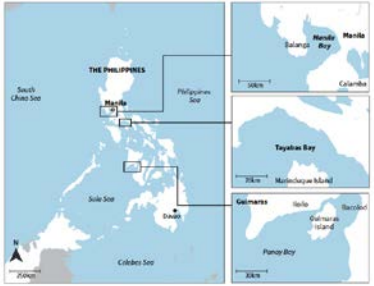
Offshore Wind



2017: RE Grid Integration Study (USAID & NREL)

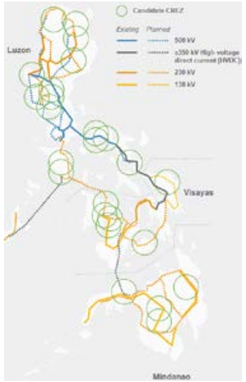
2022: Offshore Wind Roadmap (World Bank)





2024: Pre-Feasibility Analysis (RMI)

2020: CREZ Phase I (USAID & NREL)



2023: CREZ Phase II (USAID, LBNL & NREL)

2025: CREZ Phase III (NREL)

This project links the offshore wind development zones to the CREZs.

Sources: Barrows et al. (2017), Lee et al. (2020), World Bank (2022), Zhou et al. (2023), Buescher et al. (2024)

Project Scope and Outputs

Offshore Wind Zones (A-G)

- Technical potential capacity of offshore wind in each zone, disaggregated by fixed-bottom and floating turbines.
- Hourly capacity factors of offshore wind for each grid cell (3 km x 3 km) in each zone over multiple weather years (2009 – 2021).
- Average levelized cost of electricity (LCOE) of offshore wind for each grid cell (3 km x 3 km) in each zone, including and excluding transmission interconnections.

CREZs (L6-Py2)

- Impacts of offshore wind generation on the renewable energy profile, including solar PV and onshore wind, of each CREZ.
- Capacities of offshore wind that could be interconnected to each CREZ based on least-cost capacity expansion under different future growth scenarios.

The goal of this project is to integrate offshore wind into the Philippines CREZ process to support national transmission planning.

Figure. Potential Offshore Wind Development Zones and Onshore Renewable Energy Zones

Offshore Wind Resource Assessment

- Methodology
- Data and Assumptions
- Results

Study Methodology

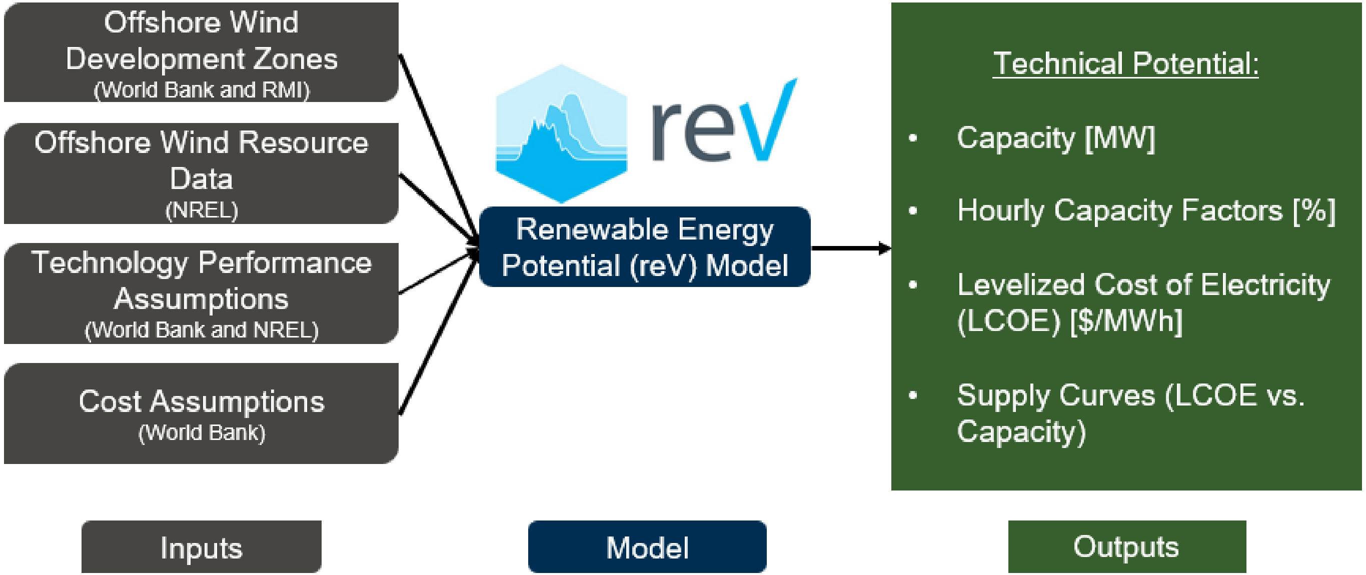


Figure. Schematic of Modeling Methodology Used in This Offshore Wind Resource Assessment for the Philippines

Source: Maclaurin et al. (2021)

Offshore Wind Zones

Table. Details of Offshore Wind Zones

Offshore Wind Zone	Name	Turbine Type	Area (km²)	Capacity Density (MW/km²)	Source
A	Northwest Luzon (NL)	Fixed & Floating	1,571	2.25	World Bank
B	Manila Area (MA)	Fixed & Floating	2,281	0.65	World Bank
C	Northern Mindoro (NM)	Fixed & Floating	3,606	1.80	World Bank
D	Southern Mindoro (SM)	Fixed & Floating	11,669	2.40	World Bank
E	Guimaras Strait (GS)	Fixed	689	0.75	World Bank
F	Negros/Panay West (NPW)	Fixed & Floating	1,534	1.65	World Bank
G	Tayabas Bay (TB)	Fixed & Floating	1,335	1.58	RMI

- Offshore wind zones divided into grid cells: 3 km x 3 km

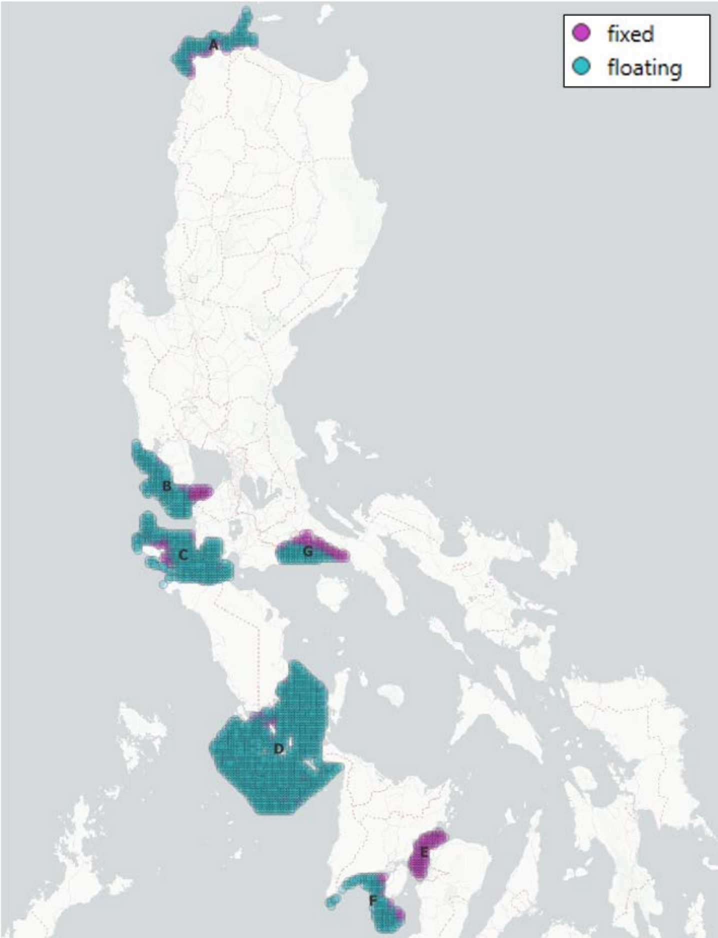
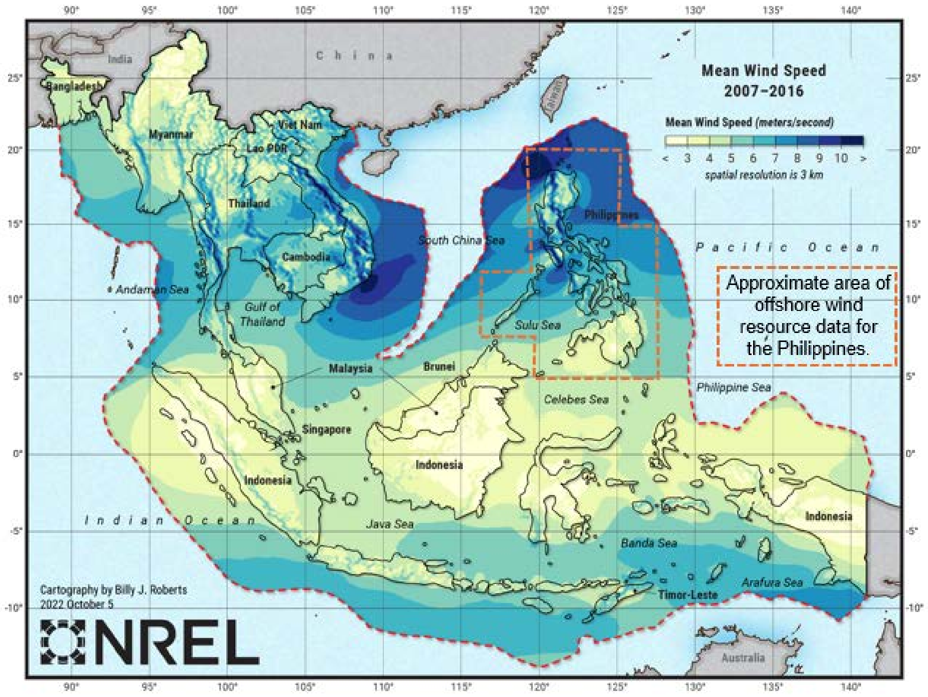


Figure. Grid Cells in Offshore Wind Development Zones, Separated by Fixed and Floating Turbine Foundation Areas

Offshore Wind Resource Data

Figure. Southeast Asia Wind Resource Data



Source: NREL (2023), Image: Billy Roberts (NREL)

Spatial resolution: 3 km x 3 km

Temporal resolution: 15-minutes

Years used: 2009-2021

Technology Performance and Cost Assumptions

Table. Offshore Wind Technology Performance Assumptions

Technology Type	Turbine Rating (MW)	Turbine Rotor Diameter (m)	Turbine Hub Height (m)	Losses (%)	Water Depth (m)	Distance to Shore (km)
Fixed Foundation	20	252	168	15	≤ 50	< 200
Floating Foundation	20	252	168	15	> 50, < 1000	< 200

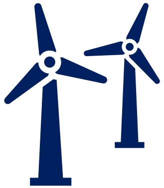
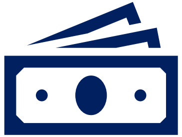


Table. Offshore Wind Cost Assumptions

Technology Type	Capital Cost (USD/MW)	Fixed O&M Cost (USD/MW-year)	Grid Connection Cost: Offshore Cables (USD/km-MW)	Grid Connection Cost: Onshore Cables (USD/km-MW)
Fixed Foundation	$2,463,870	$64,430	$1,619.05	$1,580.50
Floating Foundation	$3,871,980	$76,657	$1,619.05	$1,580.50



Source: World Bank (2022)

Results: Capacity Factors

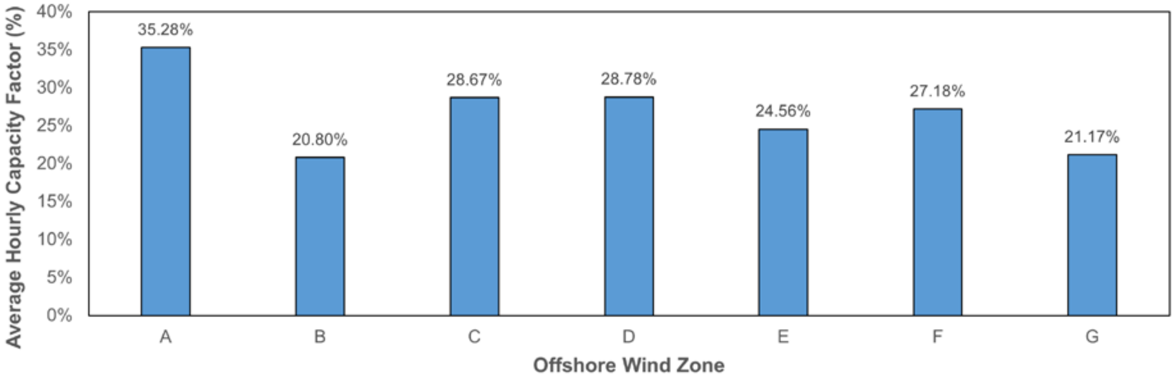


Figure. Average Offshore Wind Capacity Factors (%) for Each Offshore Wind Zone (2009-2021)

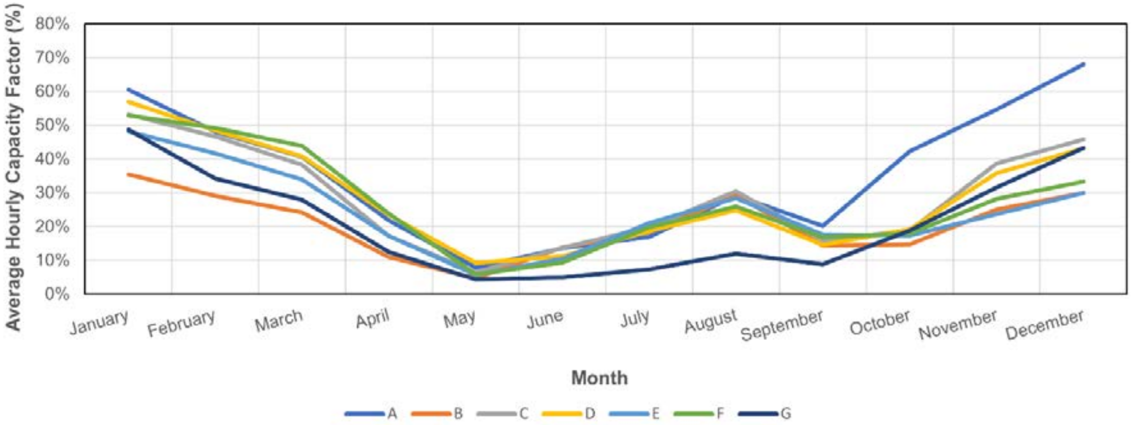


Figure. Average Offshore Wind Capacity Factors (%) Per Month for Each Offshore Wind Zone (2009-2021)

Results: Capacity and Levelized Cost of Electricity

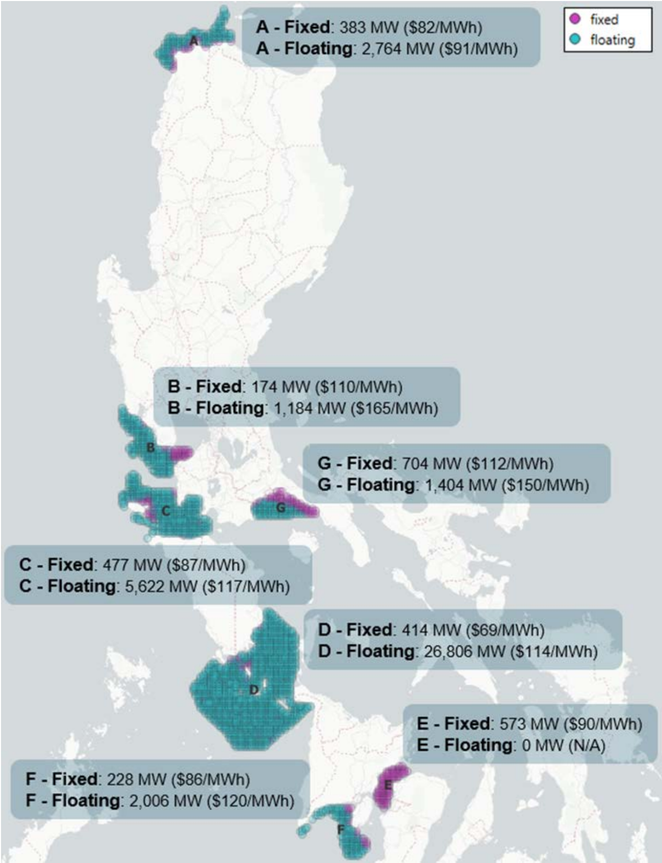


Figure. Technical Potential Capacity (MW) and Average Total LCOE ($/MWh) for Each Offshore Wind Zone

- The average total levelized cost of electricity (LCOE) includes both the cost of developing the site and the cost of interconnection to the nearest onshore CREZ.
- The LCOE calculation is based on the average wind resource data from 2009-2021 and the 2022 assumptions for capital, O&M, and grid connection (accounting for distance to CREZ) costs.
- The LCOE values are anticipated to decline in the future as underlying costs decline due to maturation of technology, industry, and supply chains (including localization of supply chain).
- These estimated LCOE values do not account for the cost of potential port or grid infrastructure upgrades that could be necessary to support offshore wind deployment in the offshore wind zones and CREZs.

Source: GWEC (2024)

Results: Supply Curve

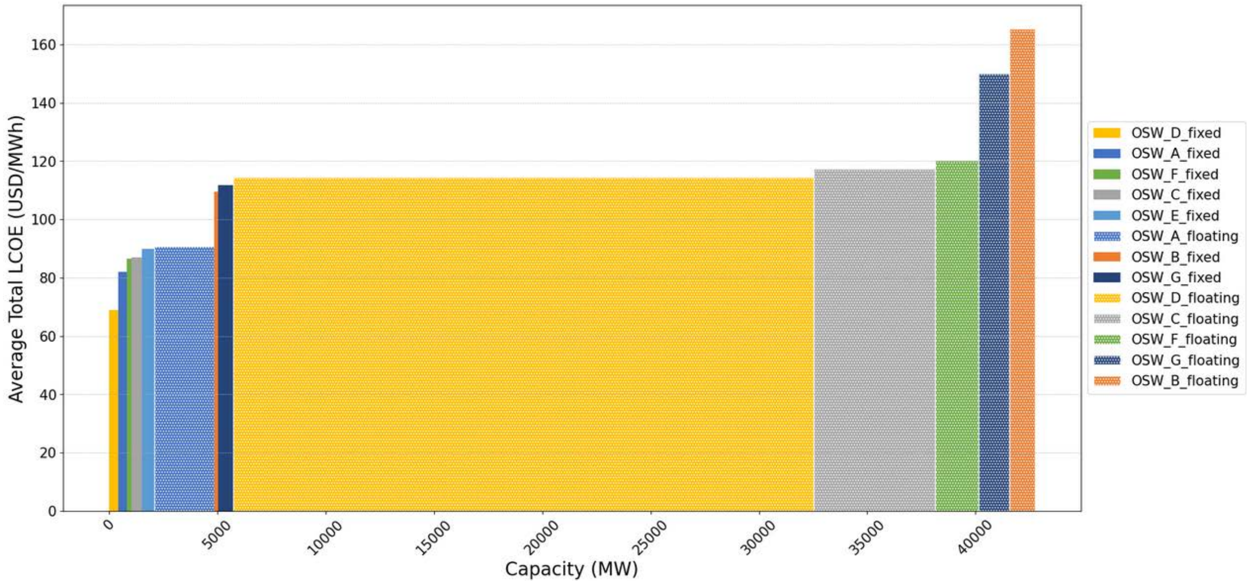


Figure. Supply Curve for Offshore Wind Zones, Disaggregated by Turbine Type

- Most of the technical potential capacity across all zones consists of floating turbines (almost 40 GW, approximately 93%) compared to fixed-bottom turbines (almost 3 GW, approximately 7%).

Offshore Wind Transmission Planning

- Frameworks
- CREZ Impacts
- Potential Infrastructure Impacts

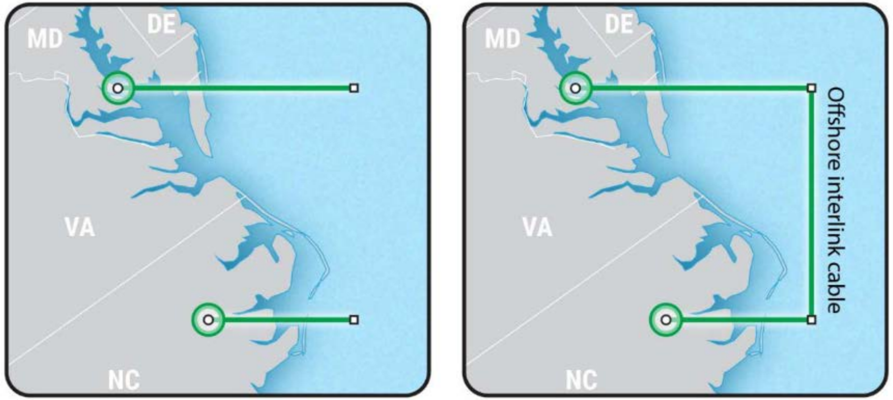
Offshore Wind Transmission Planning Frameworks

- Renewable energy zone processes have not typically included offshore wind as a resource, given its unique transmission considerations.

- This study aims to link the Philippines' offshore wind zones to onshore CREZs, supporting efficient and coordinated transmission investments for both onshore and offshore renewable energy resources.

- An emerging consideration for offshore wind transmission planning is the development of an offshore transmission network to connect resource hubs (out of the scope of this study, which just considered a radial topology).

Figure. Diagram of Radial (Left) Versus Networked (Right) Offshore Transmission in the U.S. Atlantic Offshore Wind Transmission Planning Study



Source: Brinkman et al. (2024)

CREZs Impacted by Offshore Wind Zones

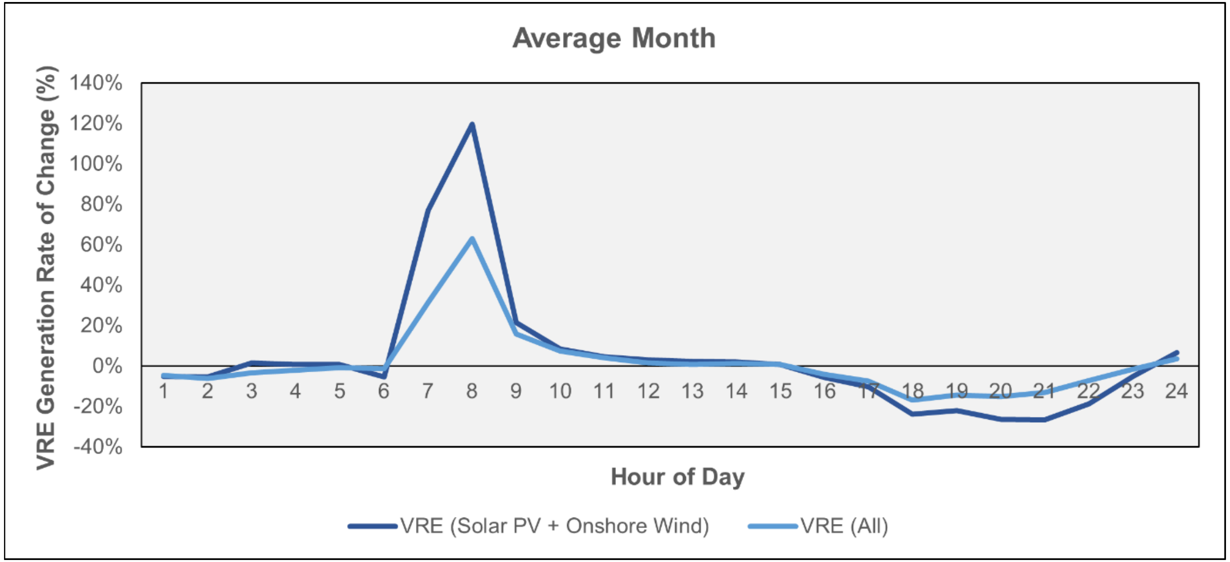
Table. Details of CREZs Linked to Offshore Wind Zones

CREZ	Island Name	Centroid Latitude	Centroid Longitude	Linked Offshore Wind Zone(s)
L2	Luzon	15.0320	120.6782	B, C
L3	Luzon	15.3911	120.2106	B
L6	Luzon	18.2851	120.8562	A
L10	Luzon	13.7690	122.4436	G
Mr1	Mindoro	12.9590	121.1469	C, D
Mr2	Mindoro	12.5983	121.1474	D
N1	Negros	10.8809	122.9828	E
N2	Negros	10.6107	122.8897	E, F
Py1	Panay	11.4231	122.8023	D
Py2	Panay	10.9721	122.8000	E

Figure. Onshore CREZs Linked to Offshore Wind Development Zones

CREZ Impacts of Offshore Wind Generation

Figure. CREZ L2: VRE Generation Hourly Rate of Change (%) for an Average Month of 2017, With (All) and Without (Solar PV + Onshore Wind) Offshore Wind Included



For all the impacted CREZs, the addition of offshore wind reduces the variability of renewable energy and therefore supports the grid integration of cleaner sources of electricity, reducing ramping needs of conventional generation.

Scenarios for Future Offshore Wind Deployment in the Philippines

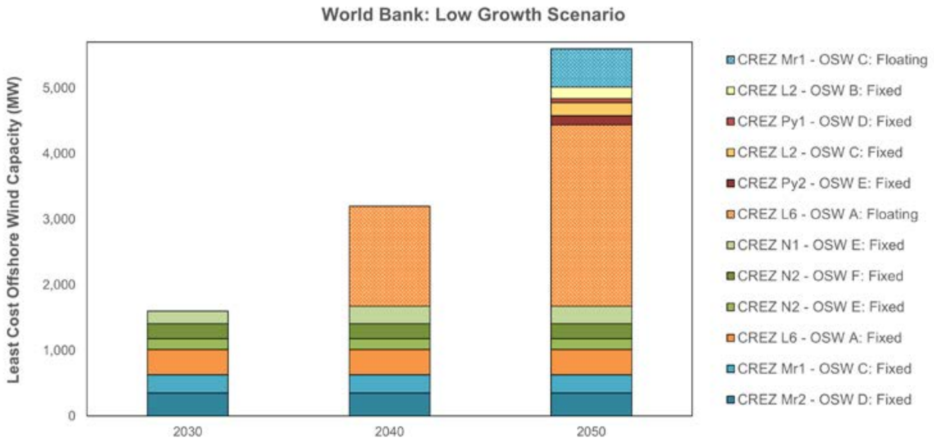
Table. Anticipated Offshore Wind Deployment in the Philippines Under Different Future Scenarios

Source	Scenario	Offshore Wind Capacity (MW)		
		2030	2040	2050
World Bank	Low-Growth	1,600	3,200	5,600
	High-Growth	2,800	20,500	40,500
Philippine Energy Plan	Reference	0	2,500	6,800
	Clean Energy Scenario 1	2,000	5,300	19,500
	Clean Energy Scenario 2	4,000	21,000	50,100

For each scenario of future offshore wind growth in the Philippines, the capacities are allocated to different offshore wind zones and onshore CREZs based lowest cost and technical potential.

Sources: World Bank (2022), PDOE (2023)

World Bank Scenarios for Future Offshore Wind Deployment in the Philippines



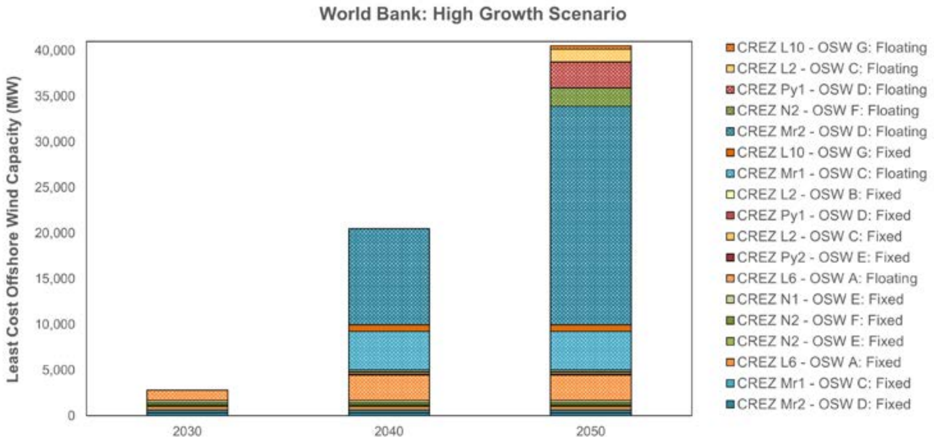


Figure. Least-Cost Offshore Wind Deployment Based on CREZ, Linked OSW Zone, and Turbine Type for the Different World Bank Scenarios

- The stacks are arranged from lower-cost resources (bottom) to higher-cost resources (top).
- The lower-cost resources primarily consist of fixed-bottom wind turbines; however, most of the offshore wind technical potential in the Philippines consists of floating turbines.

Philippine Energy Plan Scenarios for Future Offshore Wind Deployment in the Philippines

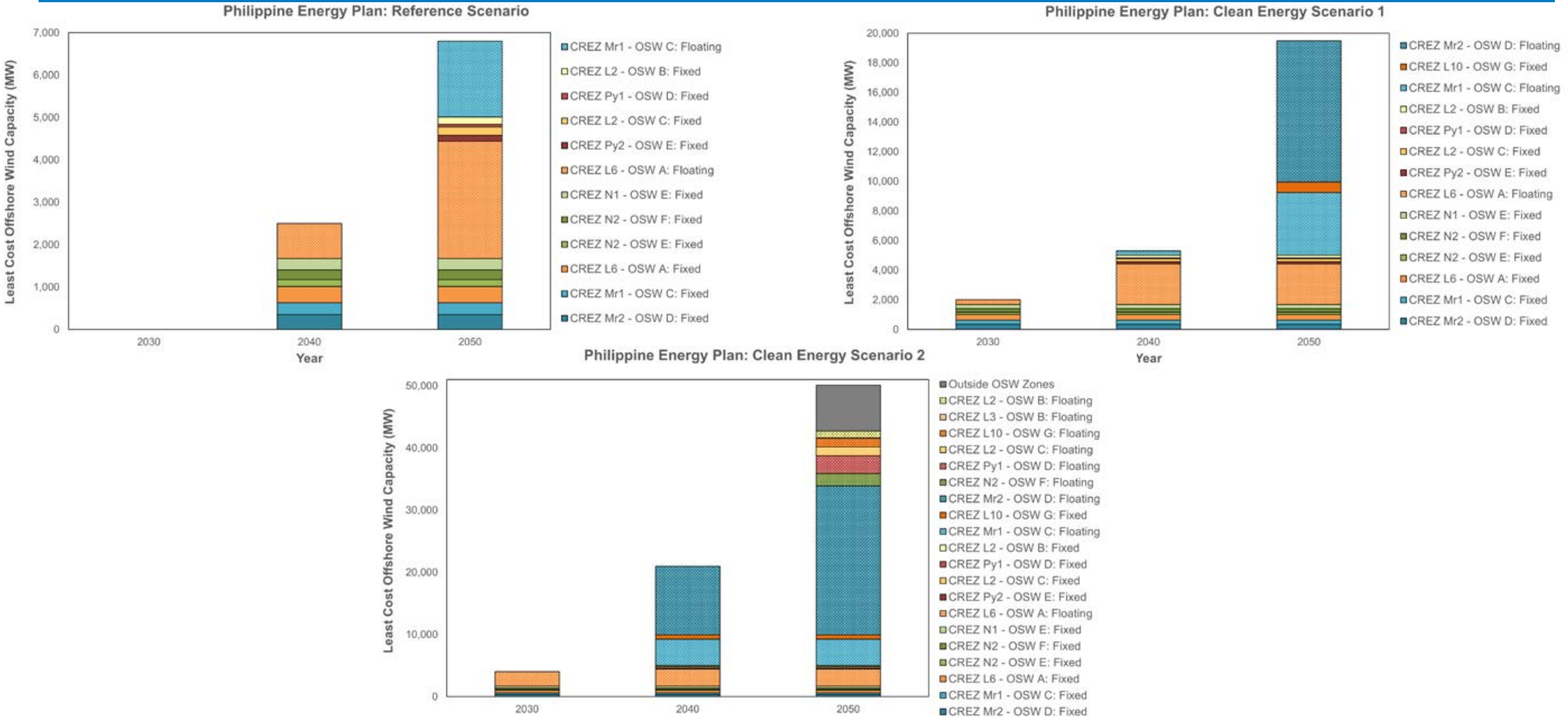


Figure. Least-Cost Offshore Wind Deployment Based on CREZ, Linked OSW Zone, and Turbine Type for the Different Philippine Energy Plan Scenarios

Conclusion

- Key Takeaways
- Next Steps

Key Takeaway #1

Offshore wind has a more stable generation profile compared to onshore wind and solar PV, supporting further grid integration of variable renewable energy (VRE) in the Philippines.

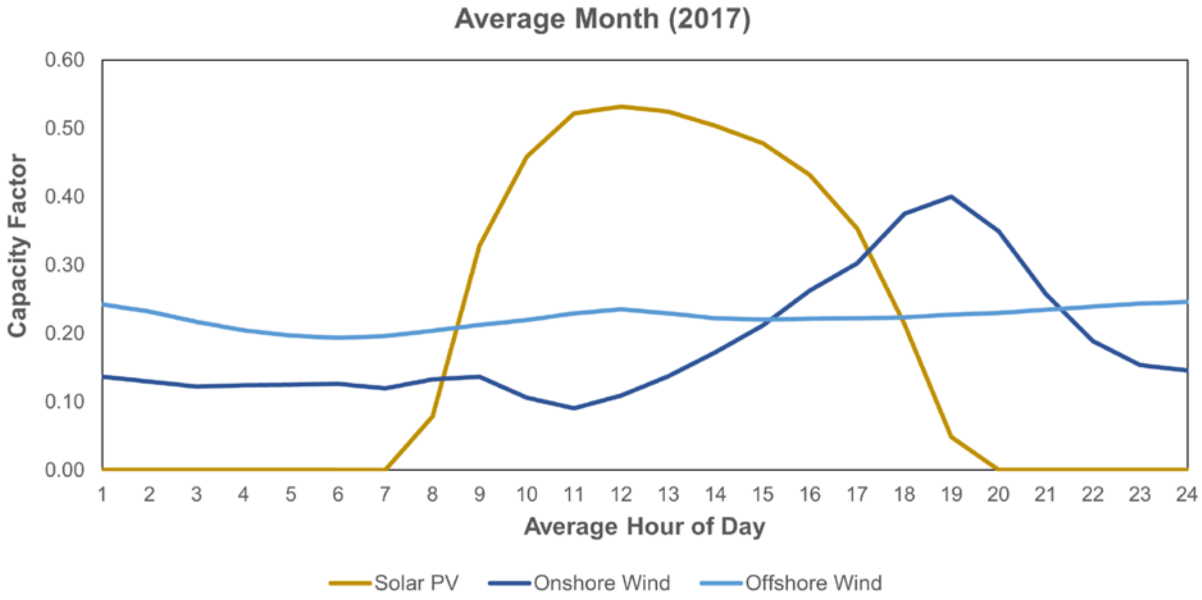


Figure. CREZ L2: VRE Daily Generation Profiles for an Average Month of 2017

Key Takeaway #2

The offshore wind resource in the Philippines is geographically diverse, and the offshore wind zones are primarily suitable for floating turbines.

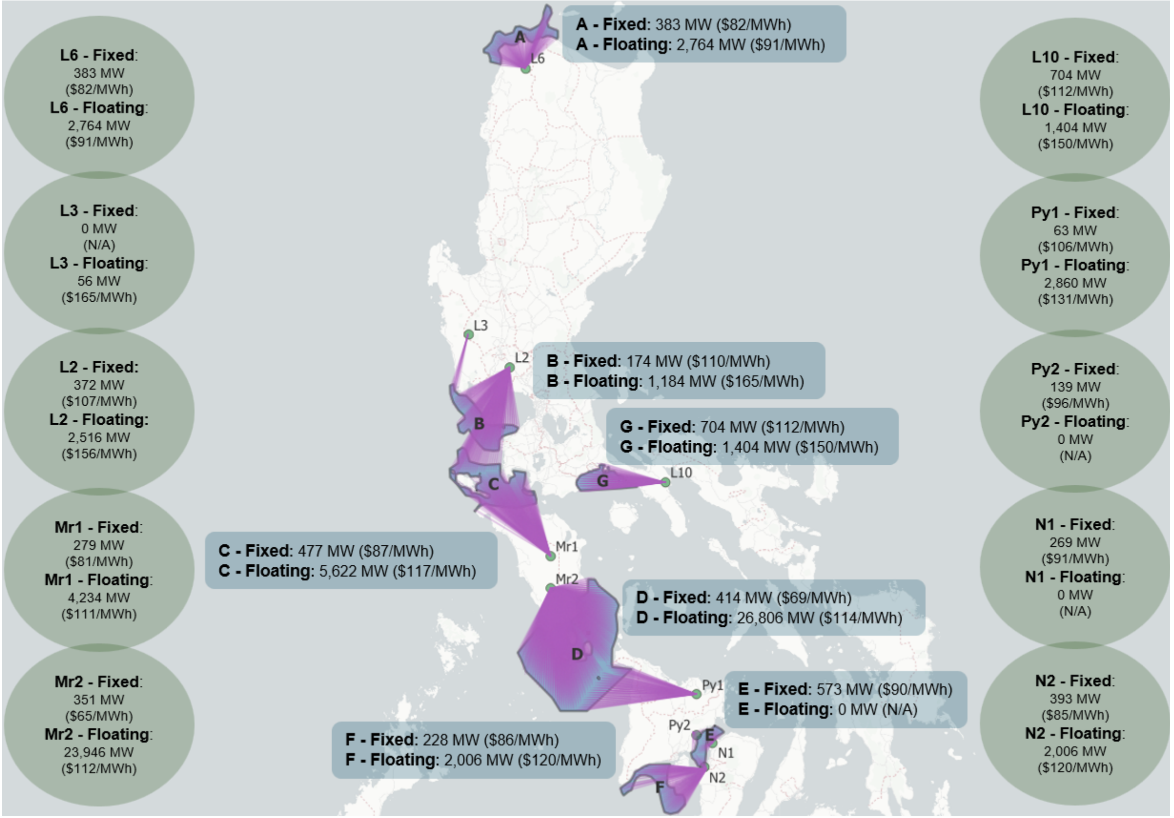


Figure. Technical Potential Capacity (MW) and Average Total LCOE ($/MWh) for Each Offshore Wind Zone and Linked Onshore CREZ, Disaggregated by Turbine Type

Key Takeaway #3

Select onshore CREZs will be impacted by offshore wind, providing opportunities for strategic transmission investments in the Philippines.

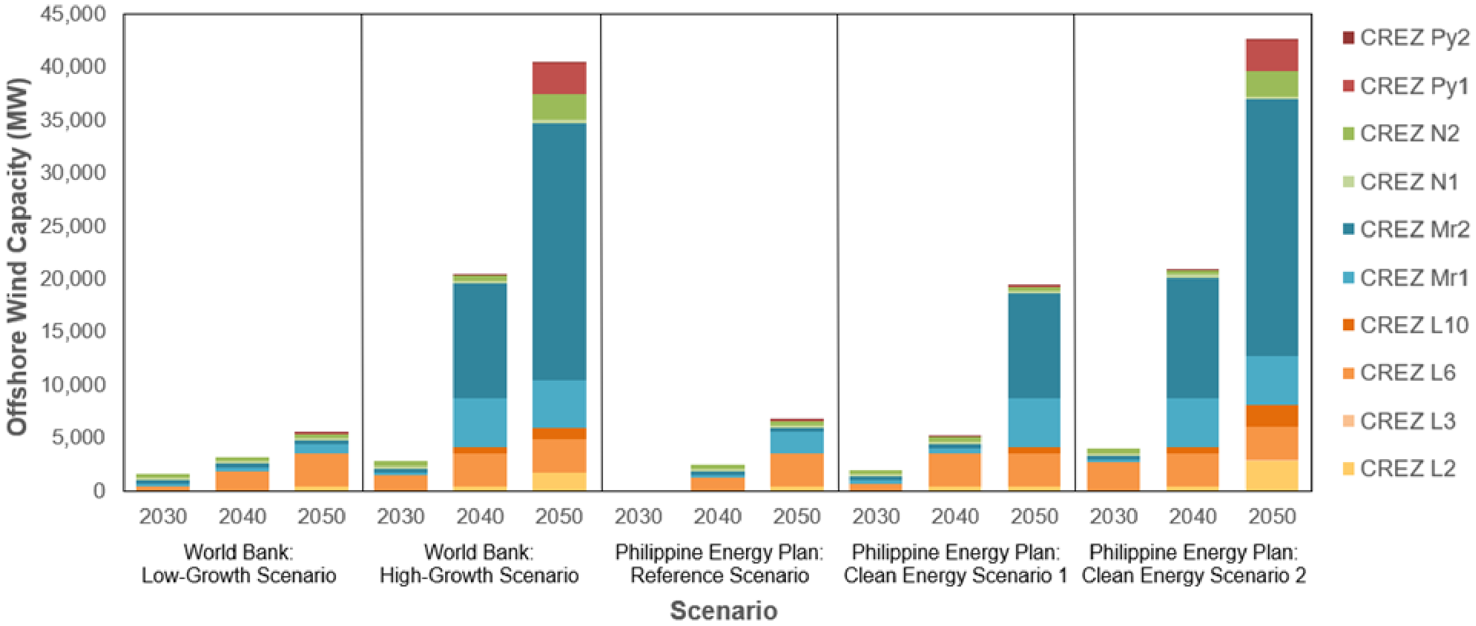


Figure. Least-Cost Offshore Wind Deployment Based on CREZ for the Different Growth Scenarios

Next Steps

Developers:
Can use this information to inform project siting, along with initial cost and generation modeling.

Transmission Planners:
Can incorporate the hourly offshore wind generation data into capacity expansion and production cost models and explore the costs and benefits of networked offshore transmission.

Policymakers:
Can use these findings to support auctions and prioritize transmission and port investments at the onshore CREZ hubs that are most viable for offshore wind integration.

Thank You

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