Advanced Energy Partnership for Asia

Identifying Potential Candidates for Renewable Energy Zones (REZs) in Bangladesh

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National Renewable Energy Laboratory (NREL)

December 2023

Image: iStock 1041657418

U.S. Agency for International Development (USAID)-National Renewable Energy Laboratory (NREL) Partnership

NREL at a Glance

3,702-person workforce, including:

- 2,721 regular/limited term
- 503 contingent workers
- 205 postdoctoral researchers
- 179 graduate students
- 94 undergraduate students.

—as of 8/21/2023

World-class research expertise in:

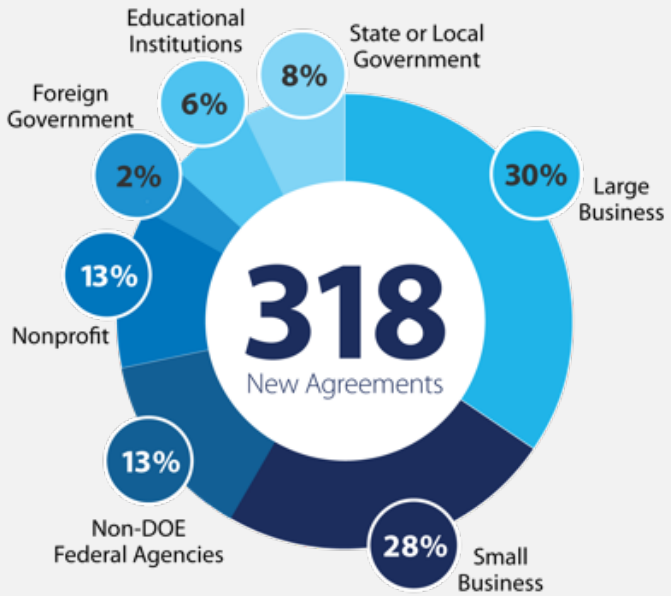
- Renewable energy
- Sustainable transportation and fuels
- Buildings and industry
- Energy systems integration.

Partnerships with:

- Industry
- Academia
- Government.

Four campuses operate as living laboratories.

More Than 1,000 Active Partnerships in Fiscal Year 2022



Agreements by Business Type

Funding by Business Type

The Advanced Energy Partnership for Asia

USAID has partnered with the U.S. Department of Energy's national laboratories to support Asia EDGE, or Enhancing Development and Growth through Energy, and the growth of sustainable and secure energy markets across Asia.

This collaboration, **the Advanced Energy Partnership for Asia**, led by USAID and NREL, helps partner countries transform their energy sectors.

www.nrel.gov/usaid-partnership

What We Do

Utility Performance

Improve energy utility planning and operational practices to increase advanced energy system implementation

Data-Driven Decision-Making

Increase the use and availability of high-quality data to drive energy sector analysis and decision-making

Level Playing Field

Assist governments in fostering more supportive policy, legal, and regulatory environments for private sector deployment and investment in advanced energy systems

Regional Integration

Advance regional energy system planning and operational practices for efficient cross-border energy trade

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Global Technical Platforms

The USAID-NREL Partnership's global technical platforms provide free, state-of-the-art support on common and critical challenges to scaling up advanced energy systems.

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www.re-explorer.org

Greening the Grid

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I-JEDI

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Resilient Energy Platform

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USAID-NREL Support in Bangladesh

Reinforcing Advanced Energy Systems: Phase 1 (2021-2023)

Grid Integration Support

- In-person training on the fundamentals of grid integration of renewables
- Convened Modeling Working Group and provided trainings on grid integration studies and relevant tools
- Supported modeling working group with data processing needs.

Electric Vehicle Support

- Virtual trainings on the building blocks of electric vehicle deployment
- In-person trainings on advanced electric vehicle deployment topics
- Consultation with distribution utility regarding electric vehicle charging station pilot project.

Renewable Energy Zones (REZs)

- Consultation with economic zone on wind and solar resources available for development
- Gathering of initial data and assumptions for REZ analysis
- Update to Bangladesh wind data on Renewable Energy Data Explorer, along with trainings on topic.

Institutional Partnerships

- Organized Energy Fundamentals Course with Bangladesh University of Engineering and Technology
- Provided lectures to Dhaka University's Institute of Energy Studies
- Hosted a study tour of Bangladesh government officials to NREL's campus.

Reinforcing Advanced Energy Systems: Phase 2 (2024-2026):

REZ, electric vehicles, cybersecurity for power systems, wind energy market, institutional partnerships

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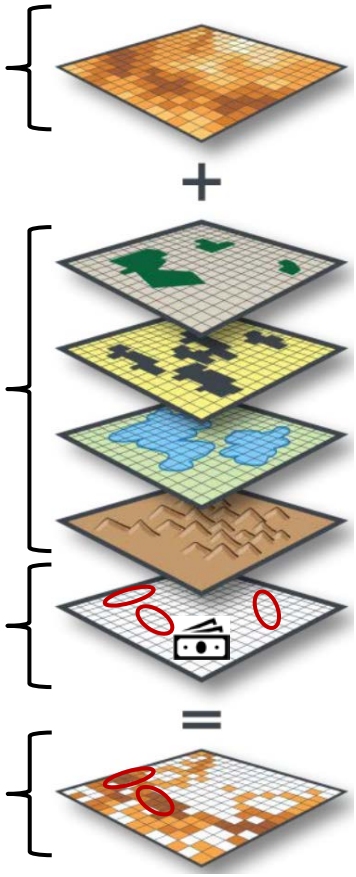
REZ Overview

What Are REZs?

A **REZ** is a geographic area characterized by:

Figure 1. Components of candidate REZs



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

+

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

+

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

=

Candidates for REZs (e.g., technical potential of solar photovoltaics (PV) or wind in candidate REZs, etc.)

Sources: Hurlbut et al. (2016); Joshi and Desai (2023)
Figure: Billy Roberts (NREL), adapted from Lopez (2016)

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What Is a REZ Transmission Planning Process?

A **REZ transmission planning process** is a <u>proactive</u> method of planning, approving, and building transmission infrastructure that connects **high-quality** and **large-scale** renewable resources (e.g., REZs) to the power system.

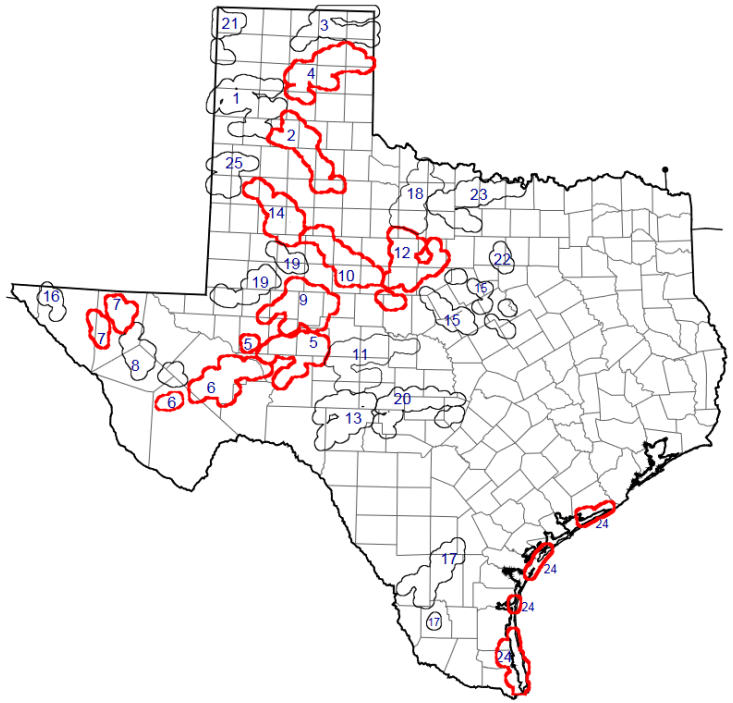


Figure 2. Candidate REZs in Texas (red) from study areas

Sources: Lee et al. (2017); Joshi and Desai (2023)
Figures: Lee et al. (2017); Lee and Barrows (2018)

Step 1. Process Design & Vision Statement

Step 2. Renewable Energy Resource Assessment

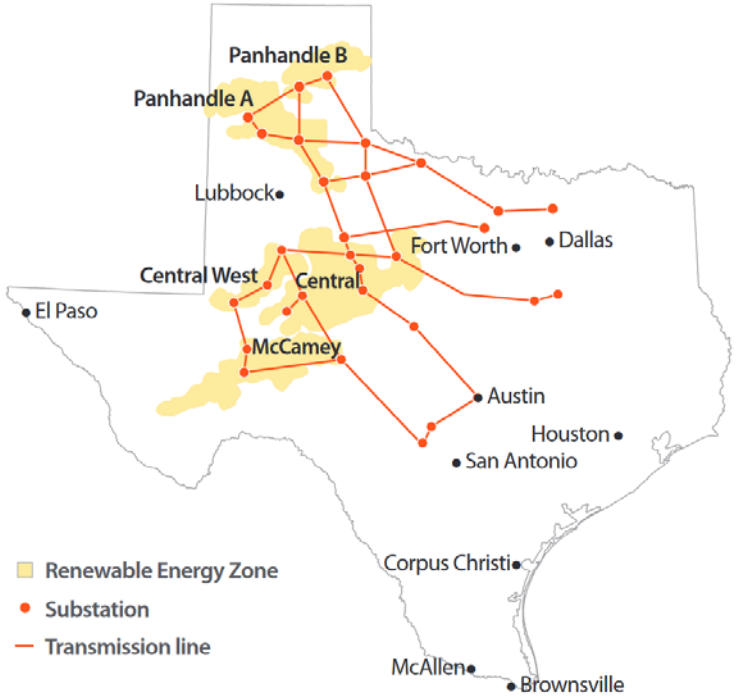
Step 3. Candidate Zones Selection

Step 4. Transmission Options Development

Step 5. Final Transmission Plan Designation

Step 6. Transmission System Upgrade

Figure 3. Transmission expansion plan identified for Texas REZs



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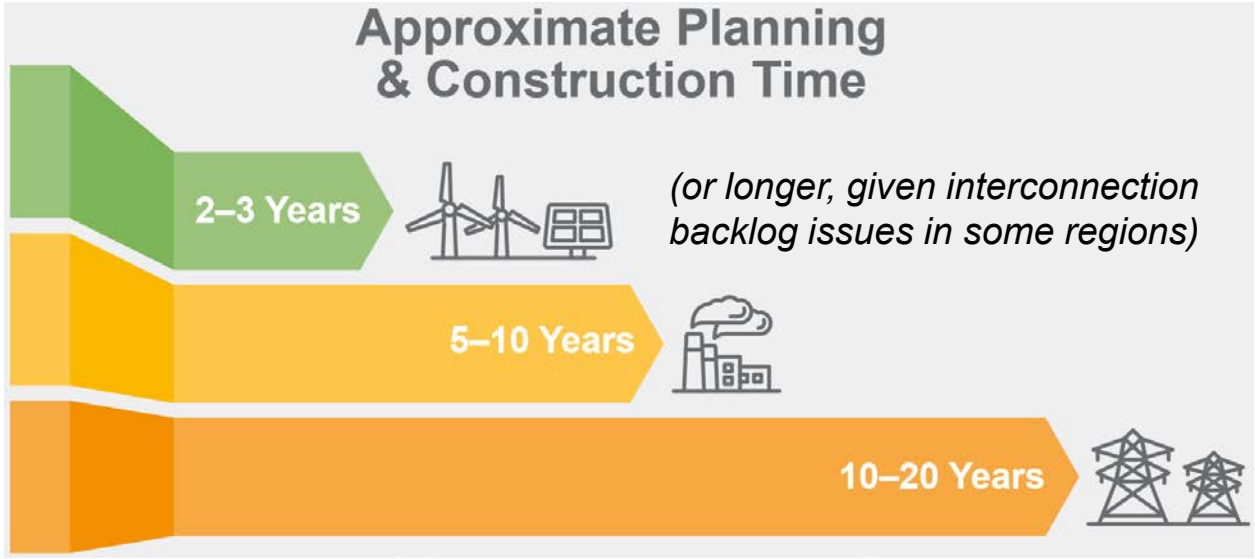
Why Consider REZ Transmission Planning?

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

Figure 4. Circular dilemma

Figure 5. Timescale misalignment



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

Sources and Figures: Lee et al. (2020); Joshi and Desai (2023)

Key Enablers of REZ Transmission Planning

Outline clear and transparent processes for REZ designation, selection, and buildout.

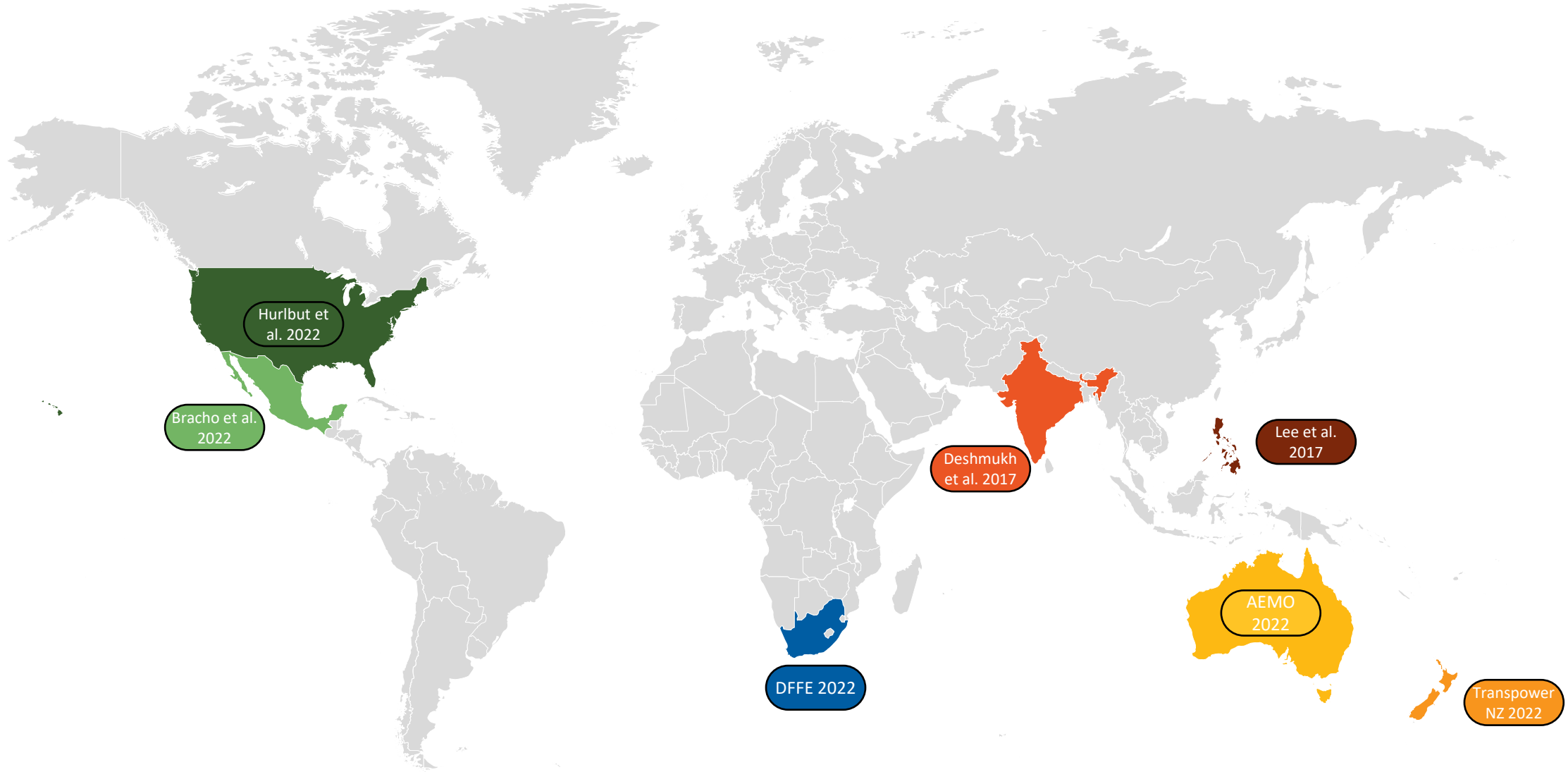
Engage all relevant stakeholders, including private developers, landowners, and government ministries.

Base decisions using the highest-quality resource, land-use, and economic data available.

Ensure that the REZ transmission process ultimately feeds into the regulatory process to build transmission projects.

Source: Joshi and Desai (2023)

Select REZ Case Studies



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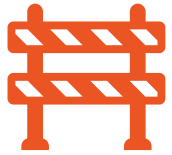
Bangladesh Context for REZ

Challenges



- Land availability for solar PV and wind capacity expansion
- Transmission grid congestion
- Growing electricity demand.

Sources: Tetra Tech (2020); Rose and Joshi (2021); Bangladesh Ministry of Power, Energy and Mineral Resources (2023)

Goals

- 40% of electricity generation capacity from clean energy by 2041
- Developed country by 2041
- Development of special economic zones.

Study Objectives

- Apply REZ methodology to Bangladesh
- Identify potential candidates for REZ development
- Key recommendation of USAID report on barriers to renewable energy in Bangladesh and potential input to long-term planning.

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Bangladesh REZ Analysis: Methodology

Workflow

Technology Performance Assumptions

Cost Assumptions

Land Exclusions (Moderate)

Solar and Wind Resource Data

Renewable Energy Potential (reV) Model

https://www.nrel.gov/gis/renewable-energy-potential.html

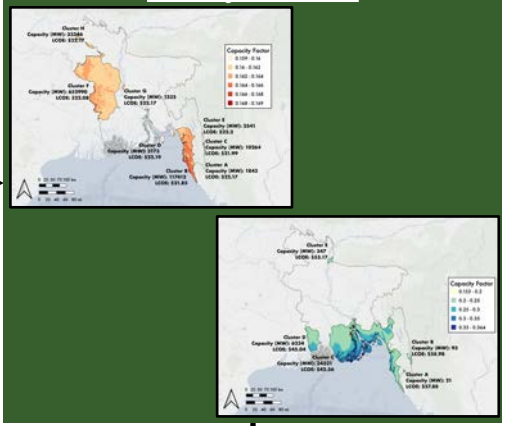
Technical Potential:

- Capacity [MW]
- Site-based levelized cost of electricity (LCOE) [$/MWh]
- Supply curves (site-based LCOE vs. capacity).

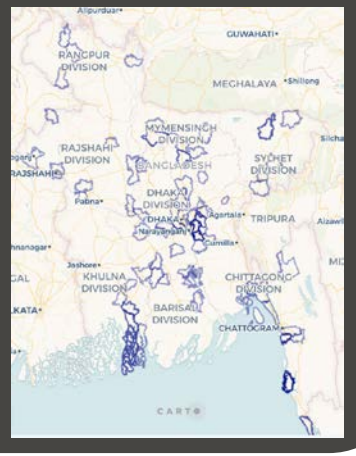
1. Remove grid cells in the bottom 75% of capacity factors for wind and solar.

2. Create clusters using DBSCAN algorithm.

Study Areas:



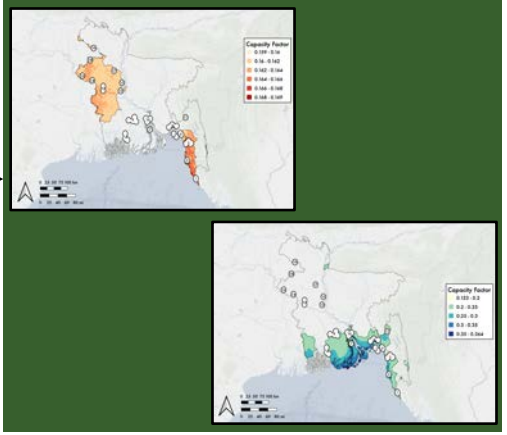
Economic Zones:



1. Economic zones within study areas are designated as candidate REZ.

2. Individual REZs are joined together if within 10 km.

Candidate Zones:



Inputs

Methods

Results

Sources: Maclaurin et al. (2021), Ester et al. (1996)

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Cost, Technology, and Land Exclusions

Utility-Scale Solar PV: Fixed-Tilt

Scenario	Protected Areas[1]	Waterbodies	Forested Areas	Urban Areas	Agricultural Areas	Slope Exclusion
Relaxed	Exclude	Exclude	Include	Exclude	Include	None
Moderate	Exclude	Exclude	Exclude	Exclude	Include	> 5% Slope
Restricted	Exclude	Exclude	Exclude	Exclude	Exclude	> 5% Slope

Technology and Cost Assumptions[2]

- 1.3 DC-AC ratio
- 0.55 ground cover ratio
- 96% inverter efficiency
- 14.08% losses
- Capacity density of 36 MW_{dc}/km^2

- $594,018.46 capital expenditures per MW
- $4,276.93 operating and maintenance expenditures per MW per year.

Utility-Scale Wind: Onshore

Scenario	Protected Areas[1]	Waterbodies	Forested Areas	Urban Areas	Agricultural Areas	Slope Exclusion
Relaxed	Exclude	Exclude	Include	Exclude	Include	None
Moderate	Exclude	Exclude	Exclude	Exclude	Include	> 20% Slope
Restricted	Exclude	Exclude	Exclude	Exclude	Exclude	> 20% Slope

Technology and Cost Assumptions[2]

- 5.5-MW turbine
- 120-m hub height; 175-m rotor diameter
- 11.8% losses
- Capacity density of 3 MW/km^2

- Starting capital expenditure of $5,198,224.075 per turbine (scaled depending on total size of wind farm after exclusions)
- $178,911.48 operating and maintenance expenditures per year.

[1] Protected areas refer to protected environmental areas (e.g., national parks, wildlife sanctuaries, conservation sites, etc.), culturally important sites (e.g., world heritage sites, tourist areas, etc.), and infrastructure (e.g., roads, airports, etc.).

[2] Cost assumptions based partially off assumptions used in the Regional Energy Deployment System (ReEDS™) India Model and technology assumptions based on standard reV configurations and stakeholder input.

"Moderate" land exclusion scenario is used for the analysis.

Sources: Rose et al. (2020), Lee et al. (2020)

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Solar and Wind Resource Data

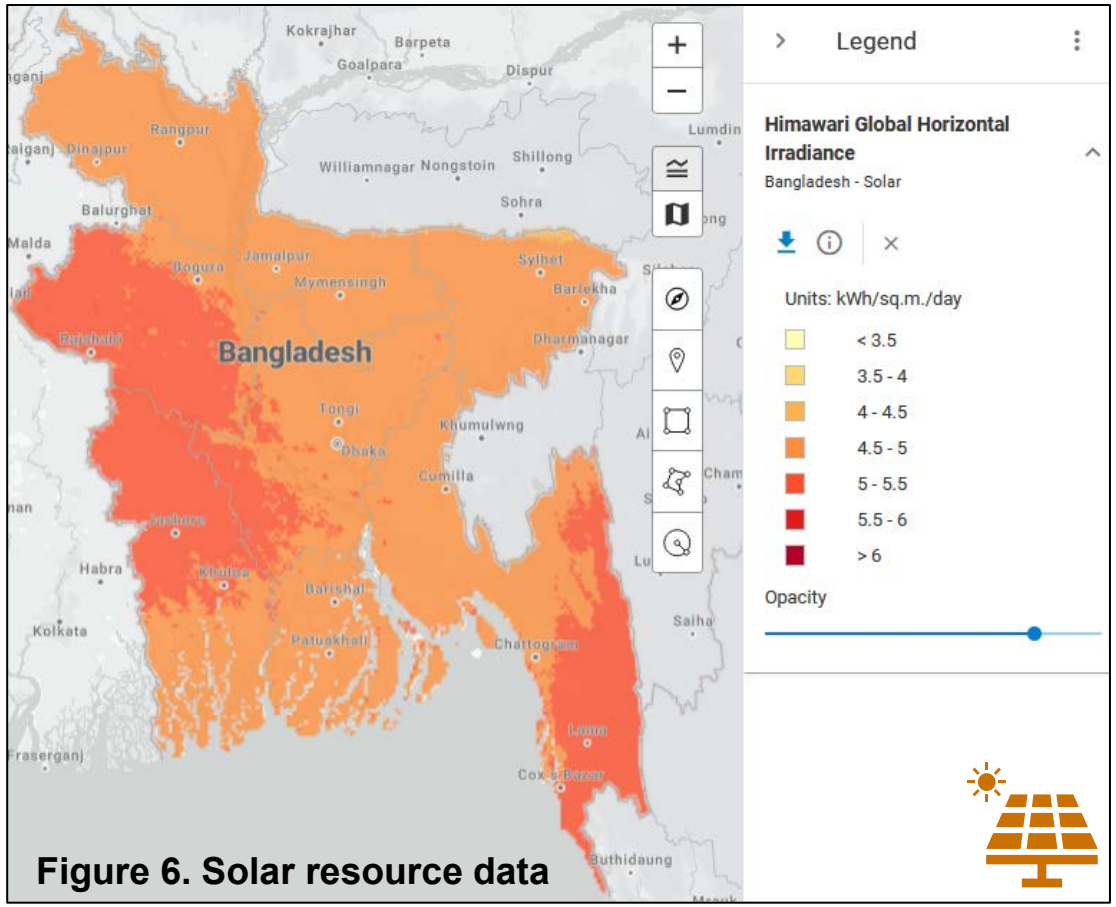

Figure 6. Solar resource data

Spatial resolution: 2 kilometer by 2 kilometer
Temporal resolution: 10 minutes
Timespan: 2015-2019

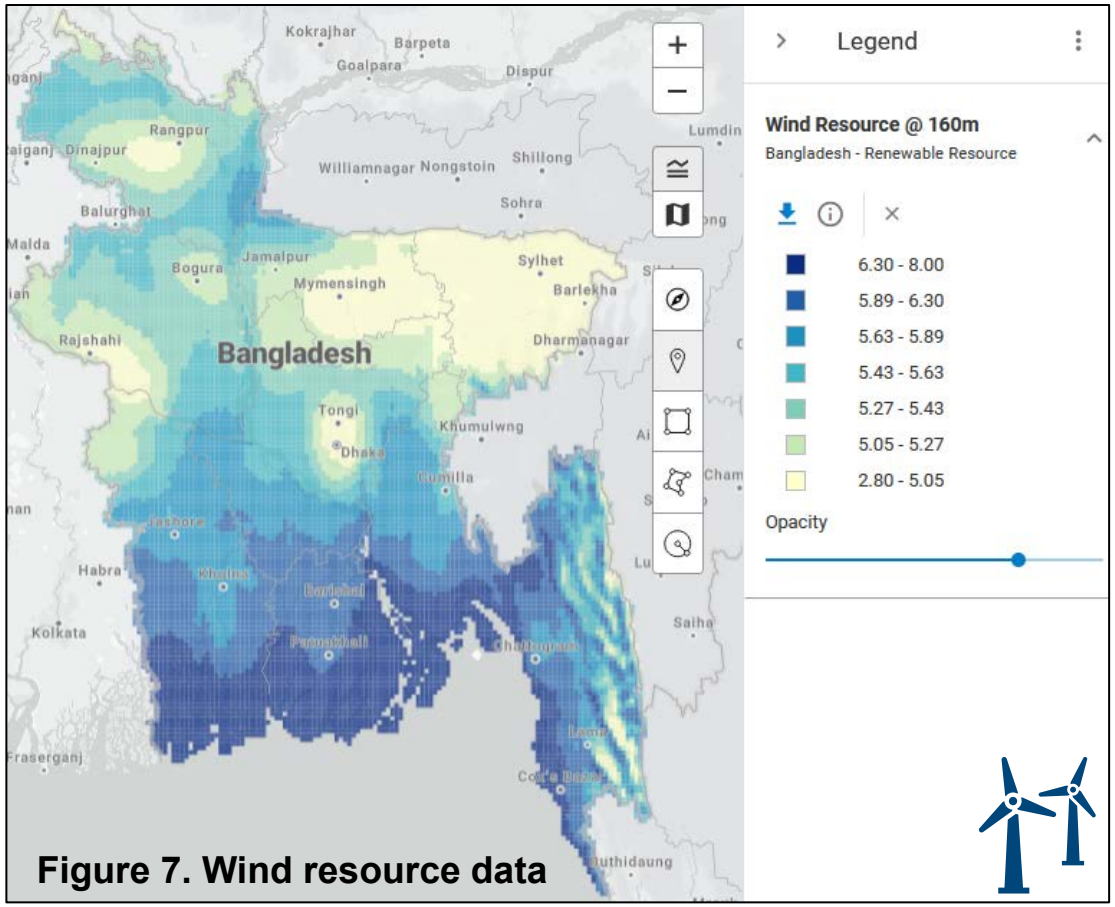

Figure 7. Wind resource data

Spatial resolution: 3 kilometer by 3 kilometer
Temporal resolution: 15 minutes
Timespan: 2014-2017

Sources: Maclaurin et al. (2022); NREL (2023)

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Technical Potential: Fixed-Tilt PV

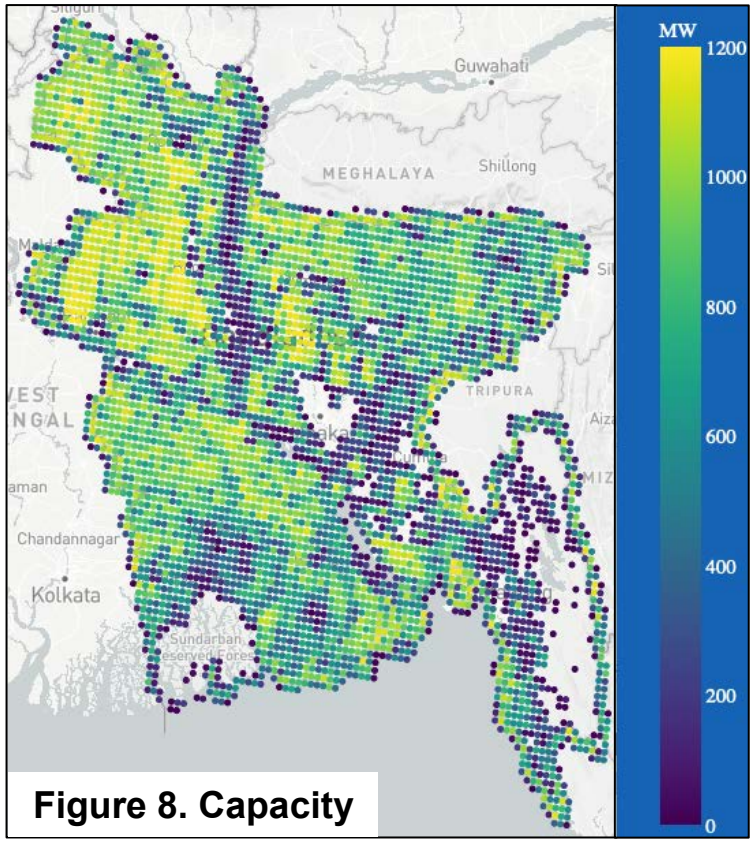


Figure 8. Capacity

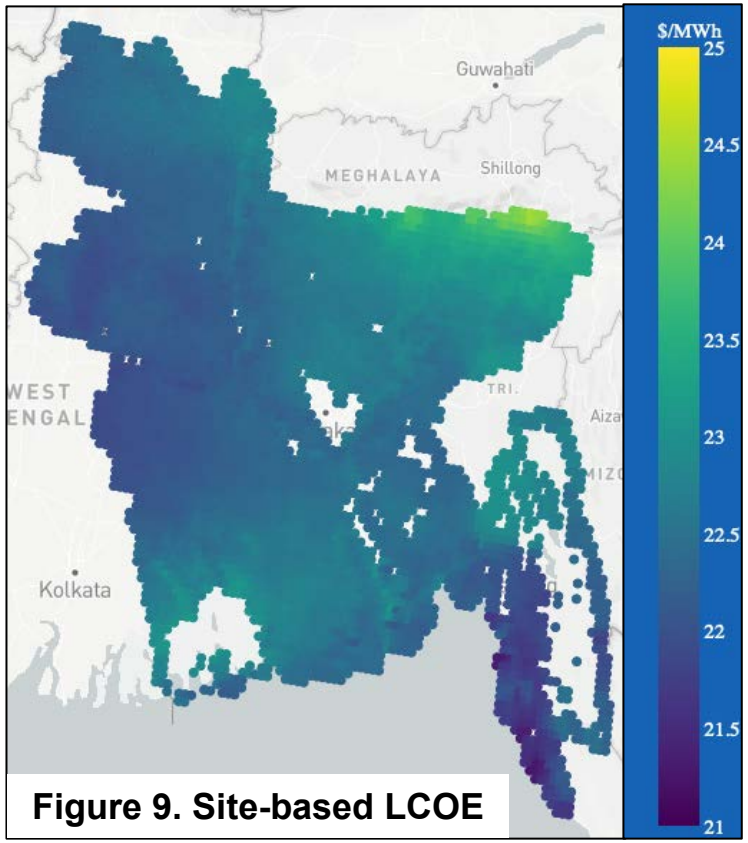
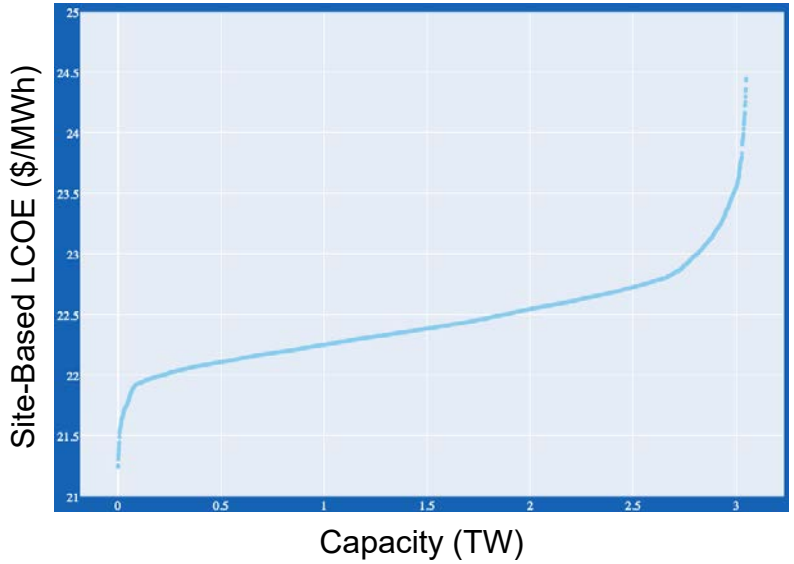


Figure 9. Site-based LCOE

Figure 10. Supply curve



Size of Each Installation: 1.2 GW | **Size of Each Grid Cell**: 5.76 km x 5.76 km | **Number of Sites**: 4,655

Total Power Capacity: 3.0 TW | **Average Site-Based LCOE**: 22.45 $/MWh

"Moderate" land exclusion scenario

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Technical Potential: Onshore Wind

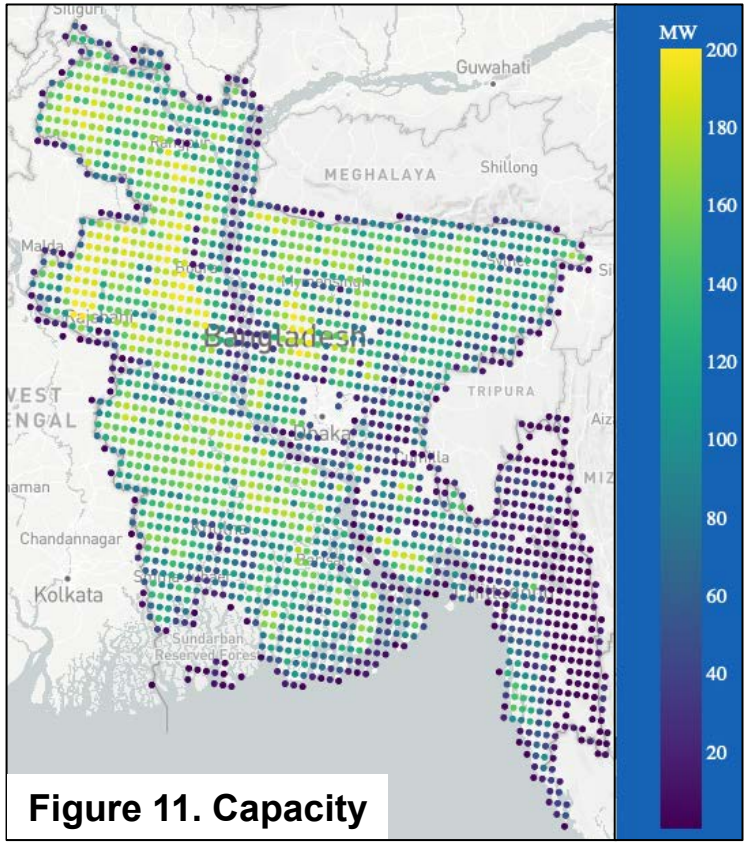


Figure 11. Capacity

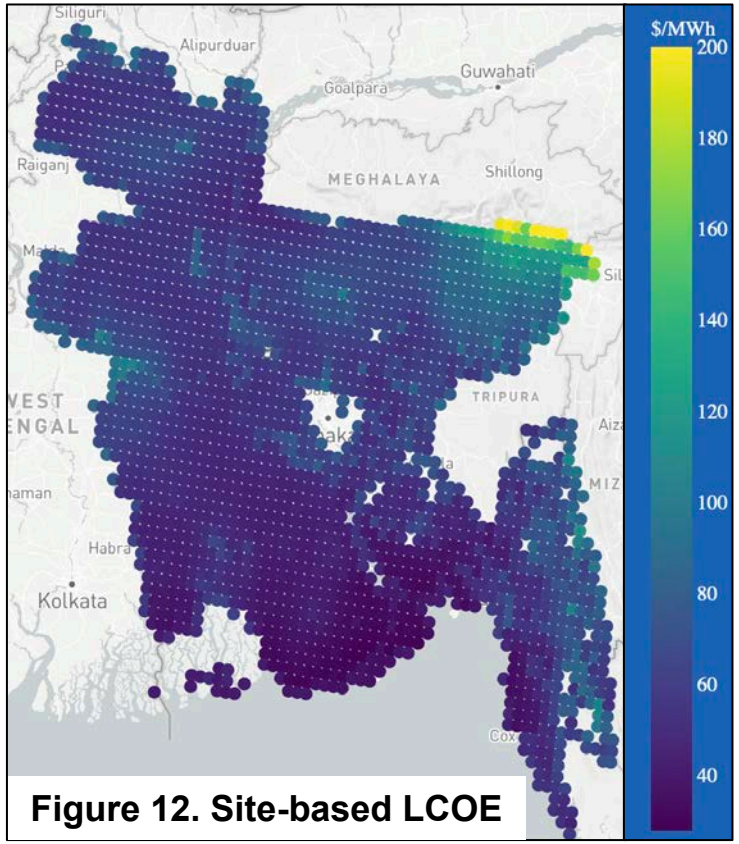
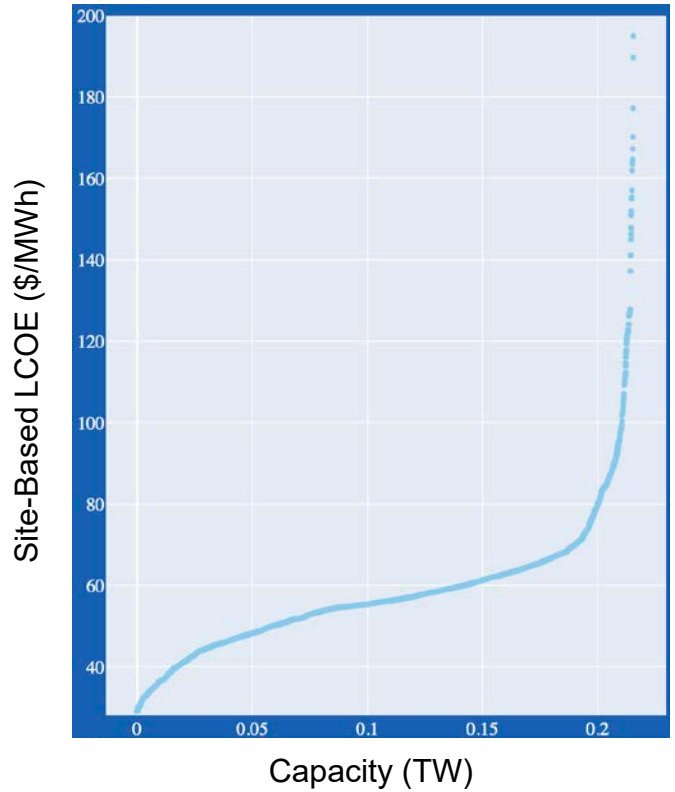


Figure 12. Site-based LCOE

Figure 13. Supply curve



Size of Each Installation: 200 MW | **Size of Each Grid Cell**: 8.2 km x 8.2 km | **Number of Sites**: 2,269

Total Power Capacity: 0.22 TW | **Average Site-Based LCOE**: 58.16 $/MWh

"Moderate" land exclusion scenario

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Study Areas and Economic Zones

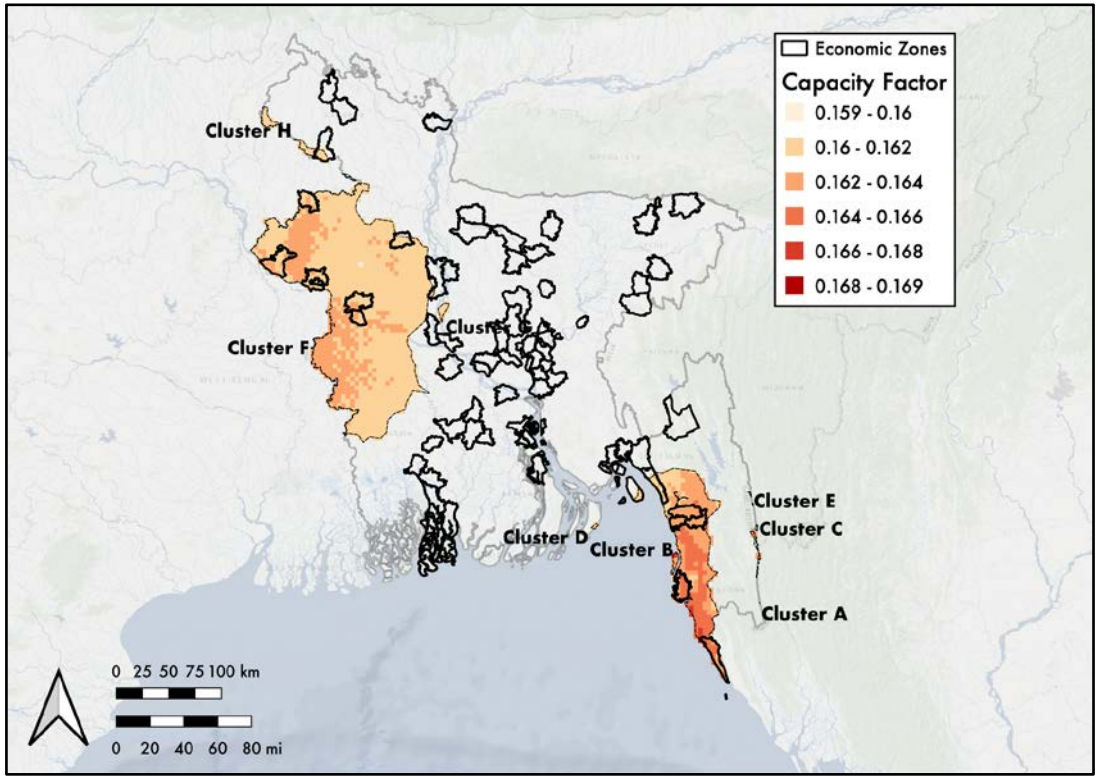


Figure 14. Solar study areas and upazilas containing Bangladesh economic zones

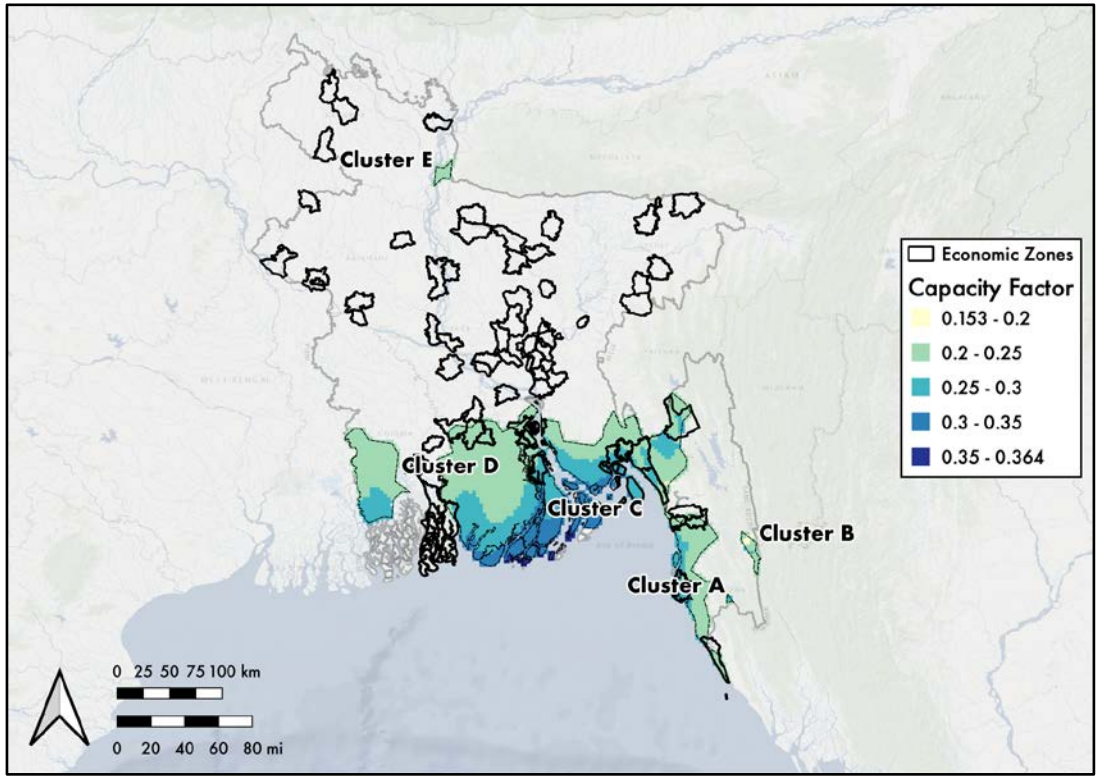


Figure 15. Wind study areas and upazilas containing Bangladesh economic zones

Source: BEZA (2023)

Bangladesh REZ Analysis: Results and Discussion

Potential Candidate Zones

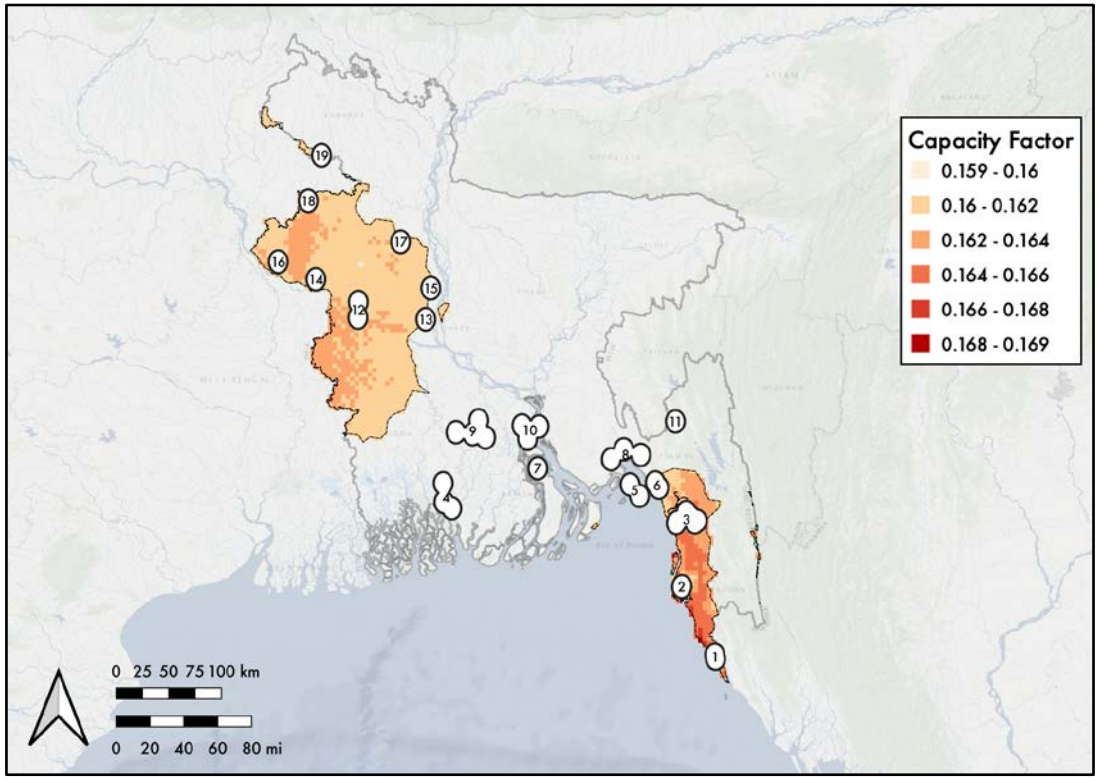


Figure 16. Potential candidates for REZs in Bangladesh compared to solar PV study areas

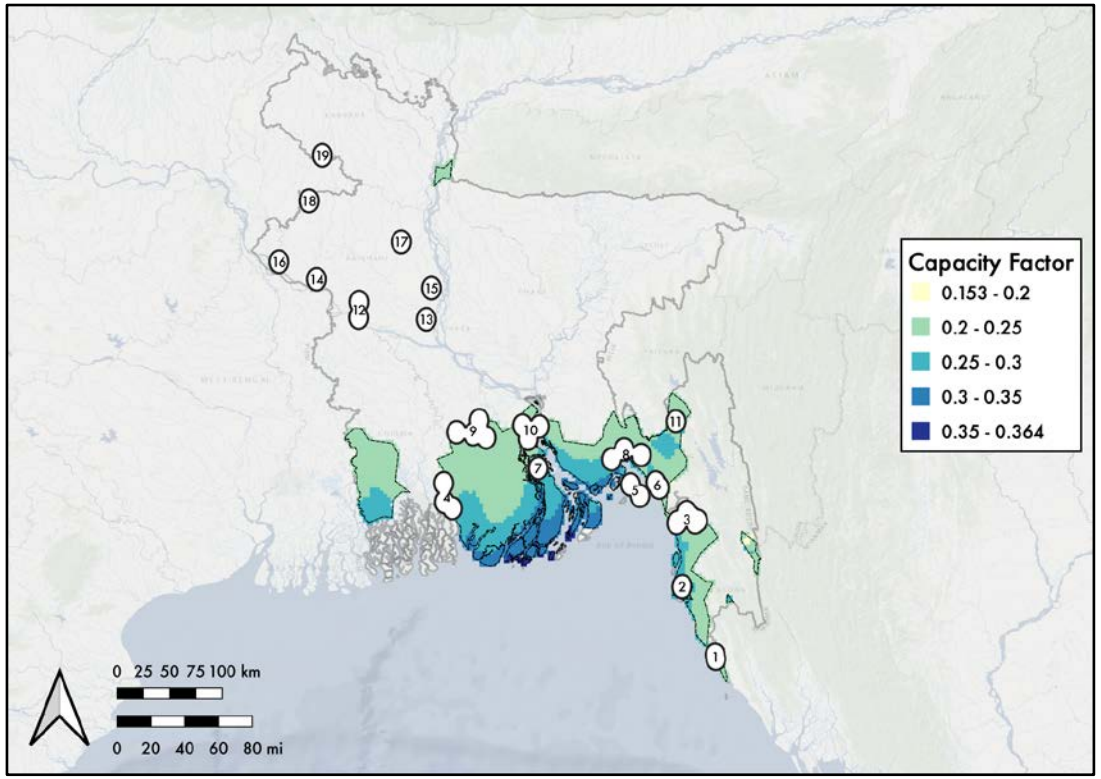
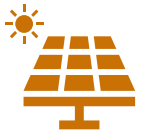


Figure 17. Potential candidates for REZs in Bangladesh compared to wind study areas

Key Results

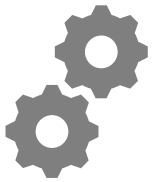


Solar resources are strongest in the west and southeast of the country, with a technical potential of ~3.0 TW in the moderate land exclusion scenario.

Wind resources are strongest in the south and southeast of the country, with a technical potential of ~0.2 TW in the moderate land exclusion scenario.

Zones 1, 2, 3, and 6 have both high-quality wind and solar resources, along with economic zones, and could be prioritized as REZs.

Insights and Next Steps



Pairing REZs with BEZA-designated economic zones can bolster economic development, serve the new electricity demand from zones, and take advantage of already planned infrastructure investments.

Conduct site-specific assessments for candidate REZ so that wind and solar resources can be incorporated into BEZA's economic zone planning and into other long-term energy sector planning efforts in Bangladesh.

Thank you

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NREL/PR-5R00-88268

References (1/2)

Australian Energy Market Operator (AEMO). “2022 Integrated System Plan for the National Electricity Market.” June 2022. https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

Bangladesh Economic Zones Authority (BEZA). “Economic Zones Site,” 2023. https://beza.gov.bd/economic-zones-site/.

Bangladesh Ministry of Power, Energy and Mineral Resources, Japan International Cooperation Agency (JICA), and The Institute of Energy Economics, Japan (IEEJ). “Integrated Energy and Power Master Plan (IEPMP) 2023.” Government of the People’s Republic of Bangladesh, July 2023. https://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/4f81bf4d_1180_4c53_b27c_8fa0eb11e2c1/IEPMP%202023.pdf.

Bracho, Riccardo, José Alvarez, Alexandra Aznar, Carlo Brancucci, Gregory Brinkman, Aubryn Cooperman, Francisco Flores-Espino, et al. “Mexico: North American Clean Energy Powerhouse.” Golden, CO: U.S. Department of Energy, U.S. Department of State, National Renewable Energy Laboratory (NREL), April 2022. https://www.nrel.gov/docs/fy22osti/82580.pdf.

Department of Forestry, Fisheries and the Environment (DFFE). “Renewable Energy Development Zones (REDZs) and Strategic Transmission Corridors.” Republic of South Africa, 2022. https://egis.environment.gov.za/redz.

Deshmukh, Ranjit, Grace Wu, and Amol Phadke. “Renewable Energy Zones for Balancing Siting Trade-Offs in India.” Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL), April 2017. https://www.osti.gov/servlets/purl/1366450.

Hurlbut, David, Dylan Harrison-Atlas, and Jianyu Gu. “Interregional Renewable Energy Zones in National Transmission Analysis.” Technical Report. Golden, CO: National Renewable Energy Laboratory (NREL), September 2022. https://www.nrel.gov/docs/fy22osti/83924.pdf.

Hurlbut, David, Ilya Chernyakhovskiy, and Jaquelin Cochran. “Renewable Energy Zones: Delivering Clean Power to Meet Demand.” Greening the Grid. Golden, CO: National Renewable Energy Laboratory (NREL), United States Agency for International Development (USAID), May 2016. https://www.nrel.gov/docs/fy16osti/65988.pdf.

Joshi, Prateek, and Jal Desai. “Transmission Planning with Renewable Energy Zones (REZ): Overview, Select Case Studies, and Key Enablers.” National Renewable Energy Laboratory (NREL) presented at the Clean Energy Ministerial (CEM) Senior Officials Meeting, Rio de Janeiro, Brazil, March 2023. https://www.nrel.gov/docs/fy23osti/85346.pdf.

Lee, Nathan, Ana Dyreson, David Hurlbut, Isabel McCan, Edward V. Neri, Noriel Christopher R. Reyes, Mylene C. Capongcol, et al. “Ready for Renewables: Grid Planning and Competitive Renewable Energy Zones (CREZ) in the Philippines.” National Renewable Energy Laboratory, Department of Energy of the Philippines, National Grid Corporation of the Philippines, United States Agency for International Development, September 2020. https://www.nrel.gov/docs/fy20osti/76235.pdf.

Lee, Nathan, and Clayton Barrows. “Transmission Planning Studies for the Renewable Energy Zone (REZ) Process.” Renewable Energy Zones (REZ) Toolkit. Greening the Grid. United States Agency for International Development (USAID) and National Renewable Energy Laboratory (NREL), August 2018. https://www.nrel.gov/docs/fy18osti/71005.pdf.

References (2/2)

Lee, Nathan, Francisco Flores-Espino, and David Hurlbut. “Renewable Energy Zone (REZ) Transmission Planning Process: A Guidebook for Practitioners.” Golden, CO: National Renewable Energy Laboratory (NREL), United States Agency for International Development (USAID), September 2017. https://www.nrel.gov/docs/fy17osti/69043.pdf.

Lee, Nathan, Francisco Flores-Espino, Ricardo Oliveira, Billy Roberts, Thomas Bowen, and Jessica Katz. “Exploring Renewable Energy Opportunities in Select Southeast Asian Countries: A Geospatial Analysis of the Levelized Cost of Energy of Utility-Scale Wind and Solar Photovoltaics.” Technical Report. USAID-NREL Partnership. Golden, CO: National Renewable Energy Laboratory (NREL), June 2020. https://www.nrel.gov/docs/fy19osti/71814.pdf.

Lopez, Anthony. “High-Level Overview of Data Needs for RE Analysis.” Presentation NREL/PR-6A20-67835. Golden, CO: National Renewable Energy Laboratory (NREL), 2016. http://www.nrel.gov/docs/fy17osti/67835.pdf.

Maclaurin, Galen, Nick Grue, Anthony Lopez, Donna Heimiller, Michael Rossol, Grant Buster, and Travis Williams. “The Renewable Energy Potential (ReV) Model: A Geospatial Platform for Technical Potential and Supply Curve Modeling.” Technical Report. Golden, CO: National Renewable Energy Laboratory (NREL), June 2021. https://www.nrel.gov/docs/fy19osti/73067.pdf.

Maclaurin, Galen, Manajit Sengupta, Aron Habte, Grant Buster, Evan Rosenlieb, Mike Bannister, Michael Rossol, et al. “Development and Validation of Southeast Asia Solar Resource Data.” Presented at the USAID-NREL Advanced Energy Partnership for Asia, National Renewable Energy Laboratory (NREL), January 2022. https://www.nrel.gov/docs/fy22osti/81799.pdf.

National Renewable Energy Laboratory (NREL). “High-Resolution Southeast Asia Wind Resource Data Set.” National Renewable Energy Laboratory (NREL) and United States Agency for International Development, March 2023. https://www.nrel.gov/docs/fy23osti/85089.pdf.

“Renewable Energy Zones National Consultation.” Transpower New Zealand Limited, 2022. https://tpow-corp-production.s3.ap-southeast-2.amazonaws.com/public/uncontrolled_docs/REZ_National_2022_FINAL.pdf?VersionId=g2BiS6k1hPcffW.Yrg21drx6Ompyt7.H.

Rose, Amy, Ilya Chernyakhovskiy, David Palchak, Samuel Koebrich, and Mohit Joshi. “Least-Cost Pathways for India’s Electric Power Sector.” Golden, CO: National Renewable Energy Laboratory (NREL), May 2020. https://doi.org/10.2172/1659816.

Rose, Amy, and Prateek Joshi. “Policy and Regulatory Environment for Utility-Scale Energy Storage: Bangladesh.” Strategic Partnership Project Report. Golden, CO: National Renewable Energy Laboratory (NREL), August 2021. https://www.nrel.gov/docs/fy21osti/80569.pdf.

Tetra Tech ES, Inc. “Challenges in the Development of Variable Renewable Energy in Bangladesh.” Scaling Up Renewable Energy (SURE). Washington, DC: U.S. Agency for International Development, June 2020. https://pdf.usaid.gov/pdf_docs/PA00WPXQ.pdf.

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