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Transmission Planning with Renewable Energy Zones (REZ): Overview, Select Case Studies, and Key Enablers

Prateek Joshi and Jal Desai
National Renewable Energy Laboratory (NREL)

Clean Energy Ministerial (CEM) Senior Officials Meeting
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OUTLINE

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LESSONS LEARNED FOR RAPID DECARBONIZATION OF POWER SECTORS: KEY MESSAGES FOR ENERGY MINISTERS

Background

This report covers key lessons learned for the rapid decarbonization of power sectors, emphasizing best practices in **planning, building,** and **operating** electricity systems.

This report is the result of a collaborative effort among various Clean Energy Ministerial (CEM) workstreams and partner initiatives:

- 21st Century Power Partnership (21CPP)
- Carbon Capture, Utilization and Storage (CCUS)
- Global Power System Transformation Consortium (G-PST), a partner to CEM
- Industrial Deep Decarbonisation Initiative (IDDI)
- International Energy Agency Digital Demand-Driven Electricity Networks Initiative (IEA 3DEN), a partner to CEM
- International Smart Grid Action Network (ISGAN)
- Long Term Scenarios for the Energy Transition (LTES)
- Nuclear Innovation: Clean Energy Future (NICE Future)
- Super-Efficient Equipment and Appliance Deployment (SEAD)

The contents are not intended to be comprehensive of all power sector topics, and there may be overlap between content in each section due to the nature of this first-of-its-kind collaborative effort to deliver unified messaging on power sector decarbonization to energy ministers. **This work is intended to complement other work at the Clean Energy Ministerial and offers options for consideration, not specific policy recommendations.**

Overarching Themes

Overarching themes for energy ministers, within the categories of **planning, building,** and **operating** are highlighted in Figure 1 from the compilation of detailed lessons learned for rapid power sector decarbonization.

Collaborating Workstreams

21st CENTURY POWER PARTNERSHIP
CARBON CAPTURE, UTILIZATION & STORAGE
GLOBAL PST CONSORTIUM
INDUSTRIAL DEEP DECARBONISATION
ISGAN INTERNATIONAL SMART GRID ACTION NETWORK
LTES LONG-TERM SCENARIOS FOR THE ENERGY TRANSITION
NICE Future NUCLEAR INNOVATION: CLEAN ENERGY
SEAD SUPER-EFFICIENT EQUIPMENT & APPLIANCE DEPLOYMENT

To view the full version of this report please visit: https://www.nrel.gov/docs/fy22osti/83951.pdf

Section 1. Planning

Coordinate Renewable Energy and Transmission Planning

I. Overview

II. Case Studies

III. Key Enablers

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Brazil (co-lead) | **China** | **India** (co-lead) | **Denmark** | **Finland** | **Mexico** | **South Africa** | **Spain** | **United States** (co-lead)

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PART I—RENEWABLE ENERGY ZONES (REZ): OVERVIEW

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What are Renewable Energy Zones?

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

1. High-quality renewable energy (RE) resources

+

2. Suitable topography exclusions

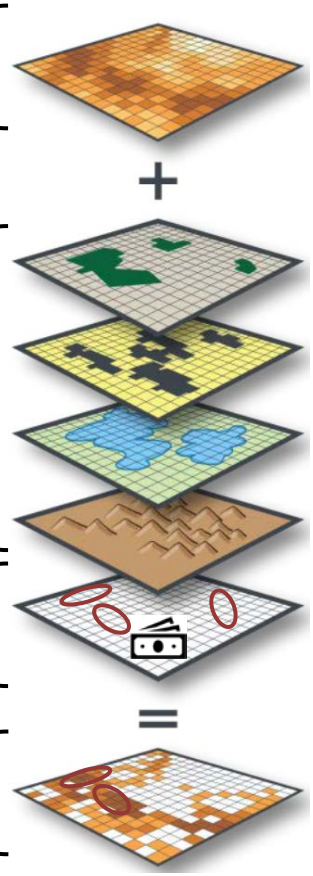
+

3. Strong commercial interest

=

Candidates for REZs

Figure 1. Components of Candidate Renewable Energy Zones



e.g., solar irradiance, wind speed, etc.

e.g., exclusions for protected environmental areas, urban areas, waterbodies, terrain features, etc.

e.g., economic development areas, demonstrated developer interest etc.

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

Source: Hurlbut et al. (2016)
Figure by Billy Roberts, NREL, adapted from: Lopez (2016)

What is a REZ Transmission Planning Process?

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A **REZ transmission planning process** is a proactive method to plan, approve, and build transmission infrastructure that connects high-quality and **large-scale** renewable resources (e.g., REZs) to the power system.

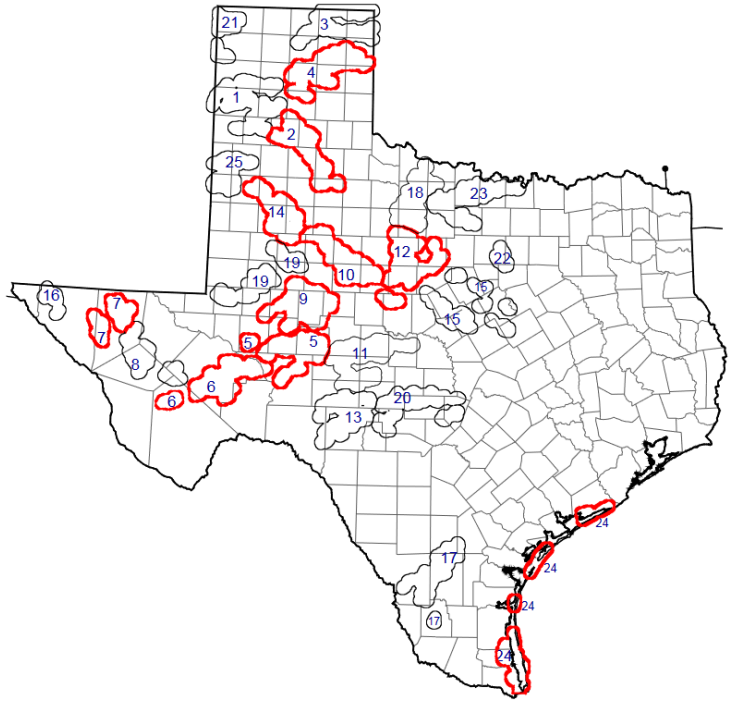


Figure 2. Candidate REZs in Texas (Red) from Study Areas

Source: Lee et al. (2017)
Figures: Lee et al. (2017), Lee and Barrows (2018)

Step 1. Process Design & Vision Statement

Step 2. Renewable Energy Resource Assessment

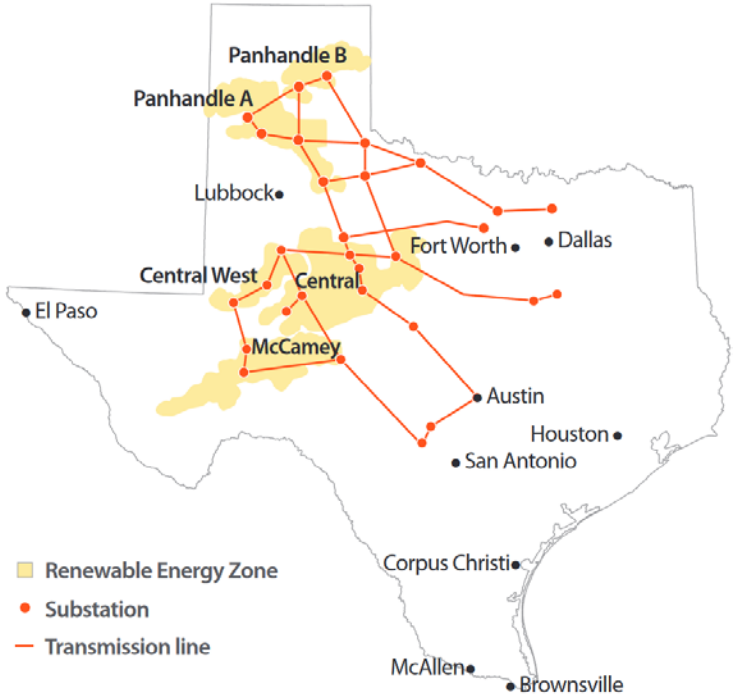
Step 3. Candidate Zones Selection

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



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 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)

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Part II—Renewable Energy Zones (REZ): Select Case Studies

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Australia Energy Market Operator (AEMO) 2022 Integrated System Plan (ISP)

Categorizes the development of REZs and supporting transmission network investments as:

COMMITTED & ANTICIPATED
Development in progress

ACTIONABLE
Regulatory approval is in progress or should start now

FUTURE ISP PROJECTS
Some investigations required to refine these long-term projects

ISP identifies different scenarios for REZ development (e.g., slow change, progressive change, step change, hydrogen superpower).

REZs include 6 offshore wind zones and account for battery storage needs and pumped storage hydropower (PSH) resources.

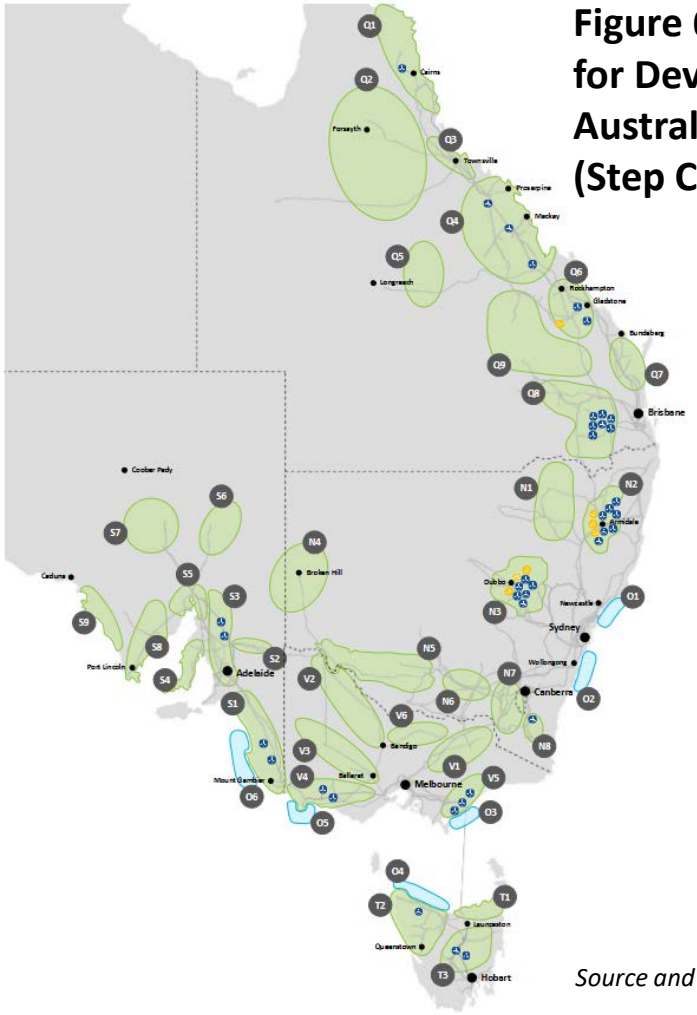
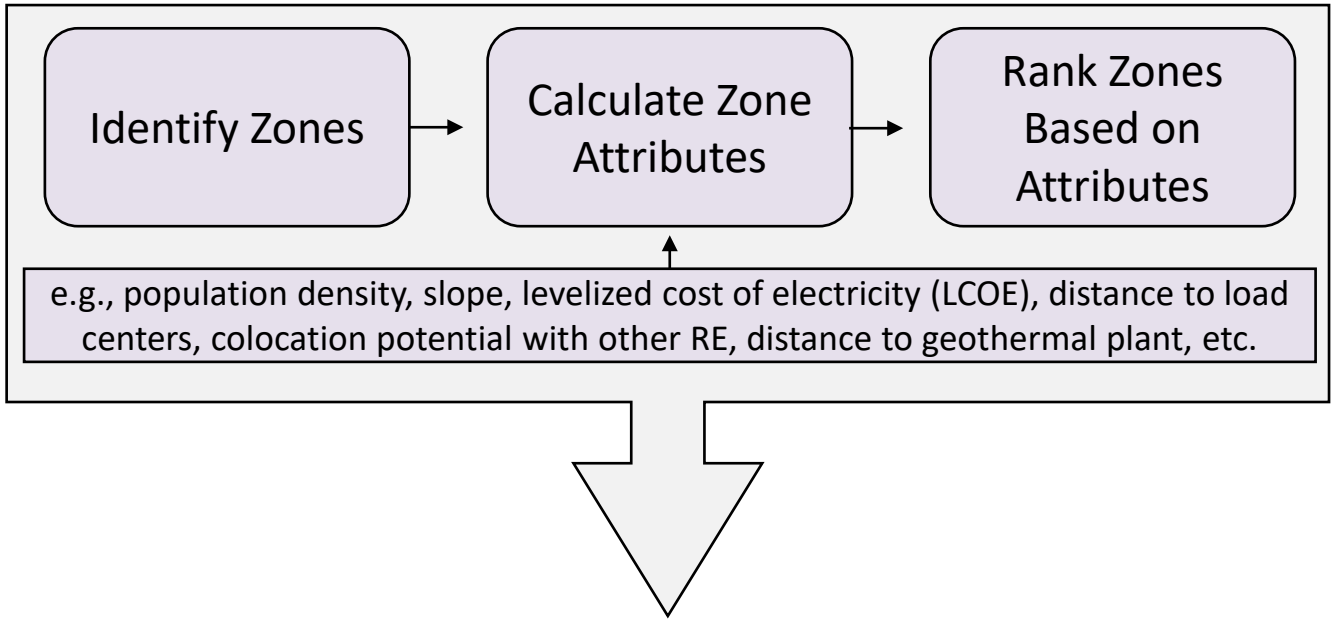


Figure 6. REZs Identified for Development in Australia by 2029-2030 (Step Change Scenario)

Source and Figures: AEMO (2022)

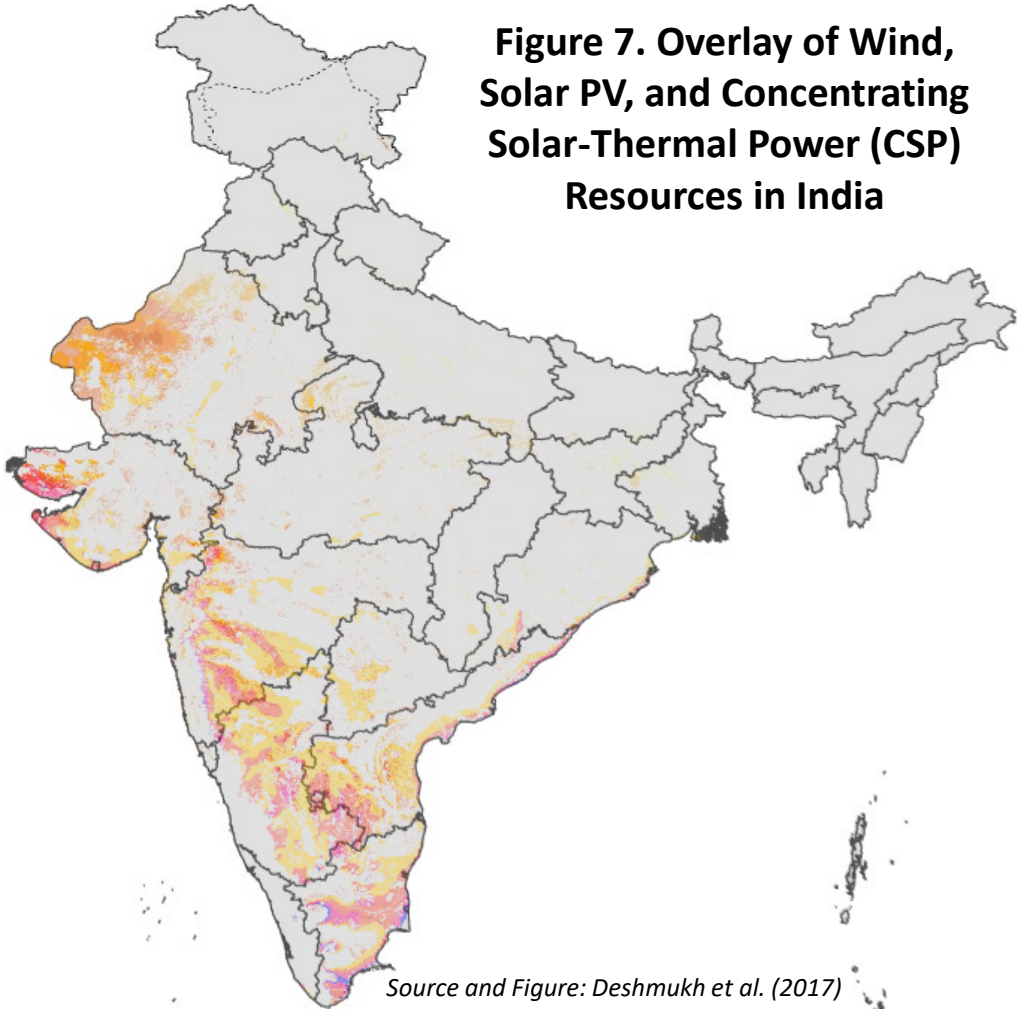
INDIA

2017: Study utilized the Multi-criteria Analysis for Planning Renewable Energy (MapRE) Methodology:



2022: India announced transmission plans to connect **66.5 GW of Renewable Energy Zones**.

Figure 7. Overlay of Wind, Solar PV, and Concentrating Solar-Thermal Power (CSP) Resources in India



Source and Figure: Deshmukh et al. (2017)

Mexico

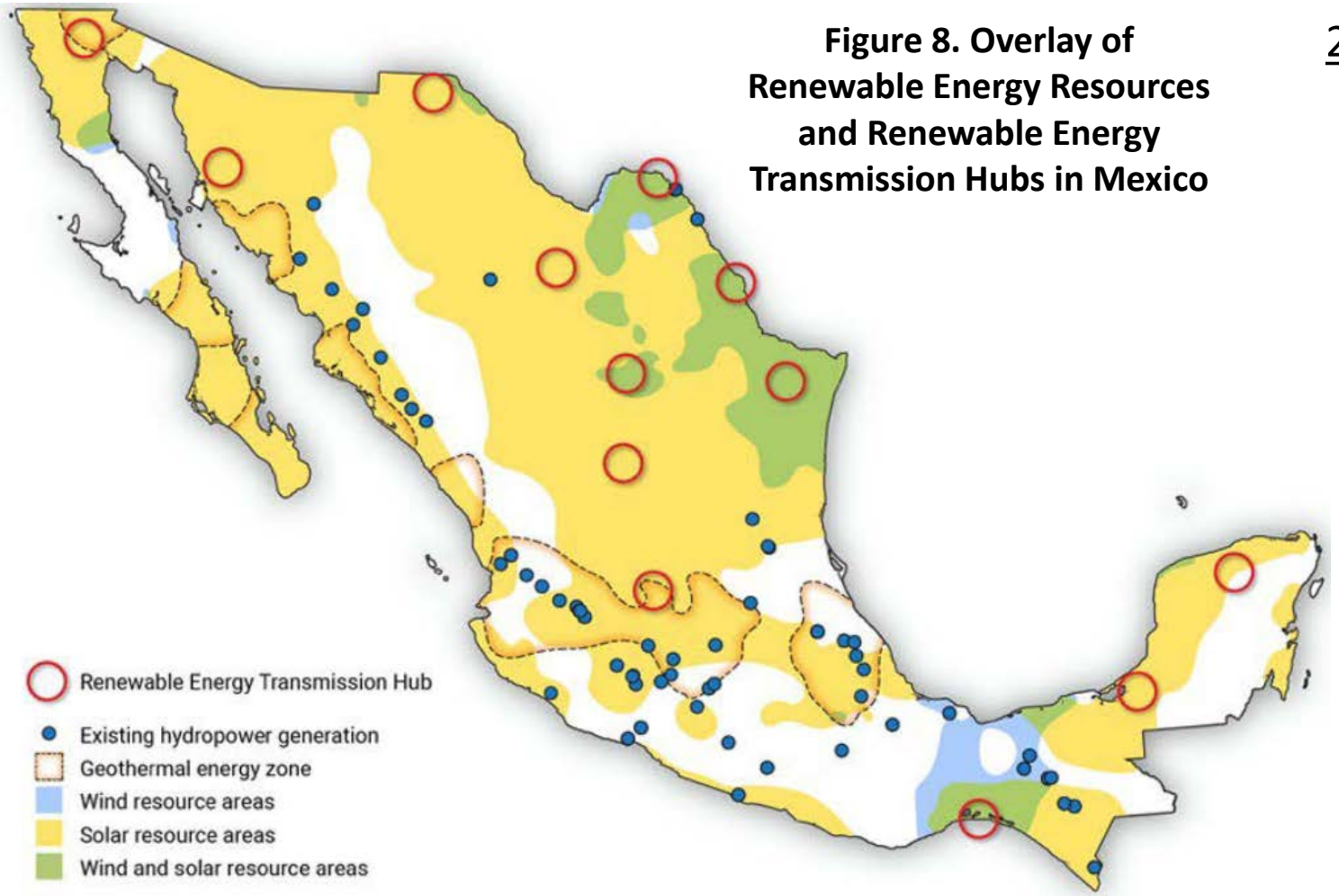


Figure 8. Overlay of Renewable Energy Resources and Renewable Energy Transmission Hubs in Mexico

2022: Mexico Clean Energy Report REZ Findings

- Geographic diversity of renewable energy zones could reduce RE integration costs.
- Several possible transmission hubs identified to connect to high quality wind, solar, geothermal, and hydropower.
- REZs near the border with the U.S. and Central America can provide opportunities for interconnections to export clean energy.

Source and Figure: Bracho et al. (2022)

New Zealand

Renewable Energy Zones National Consultation (2022)

New Zealand has also identified "industrial clusters", where large electricity users can be co-located with renewable energy generation and can take advantage of lower cost electricity.

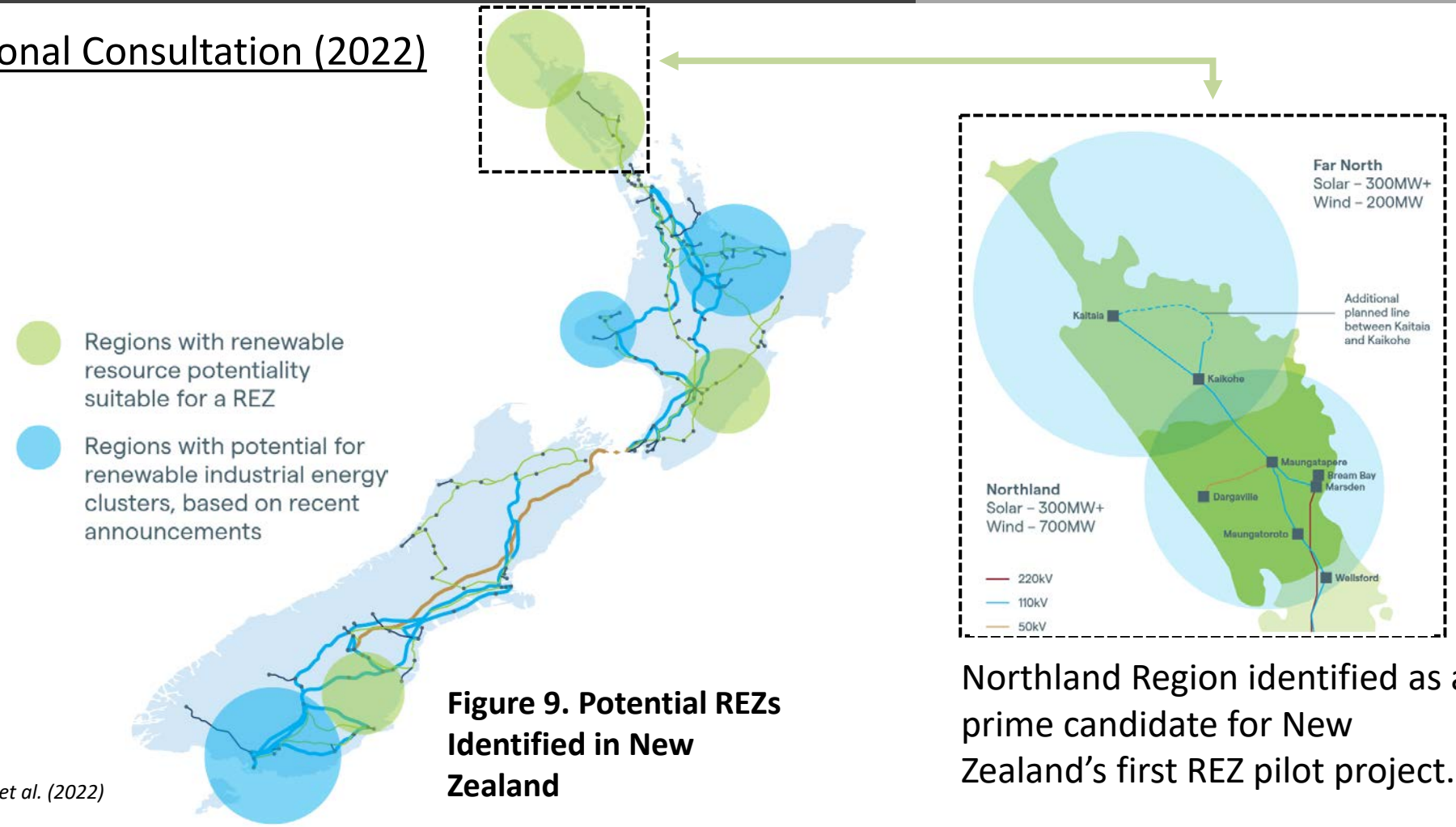


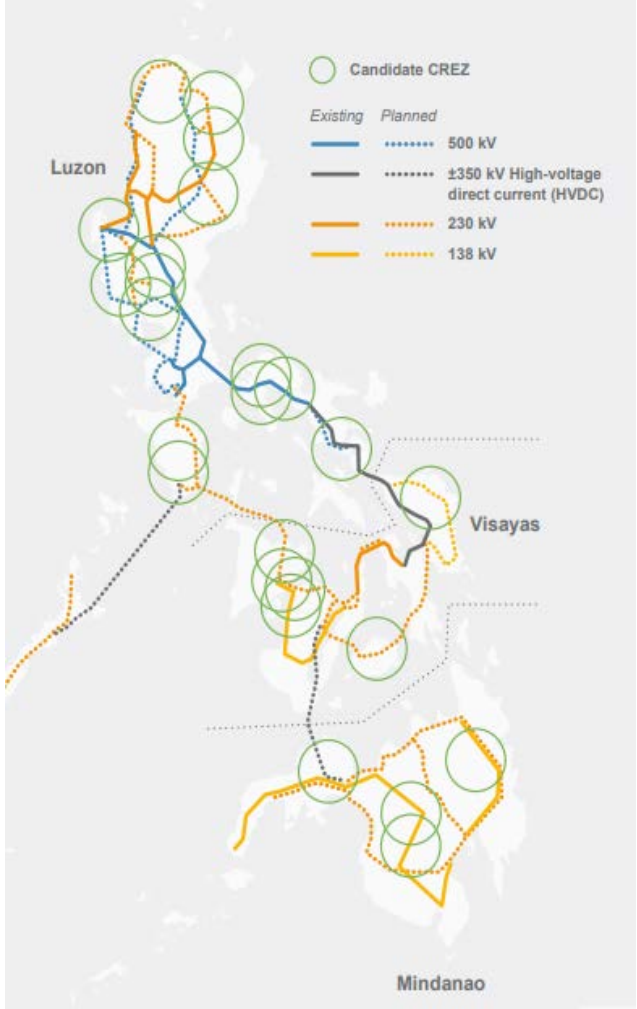
Figure 9. Potential REZs Identified in New Zealand

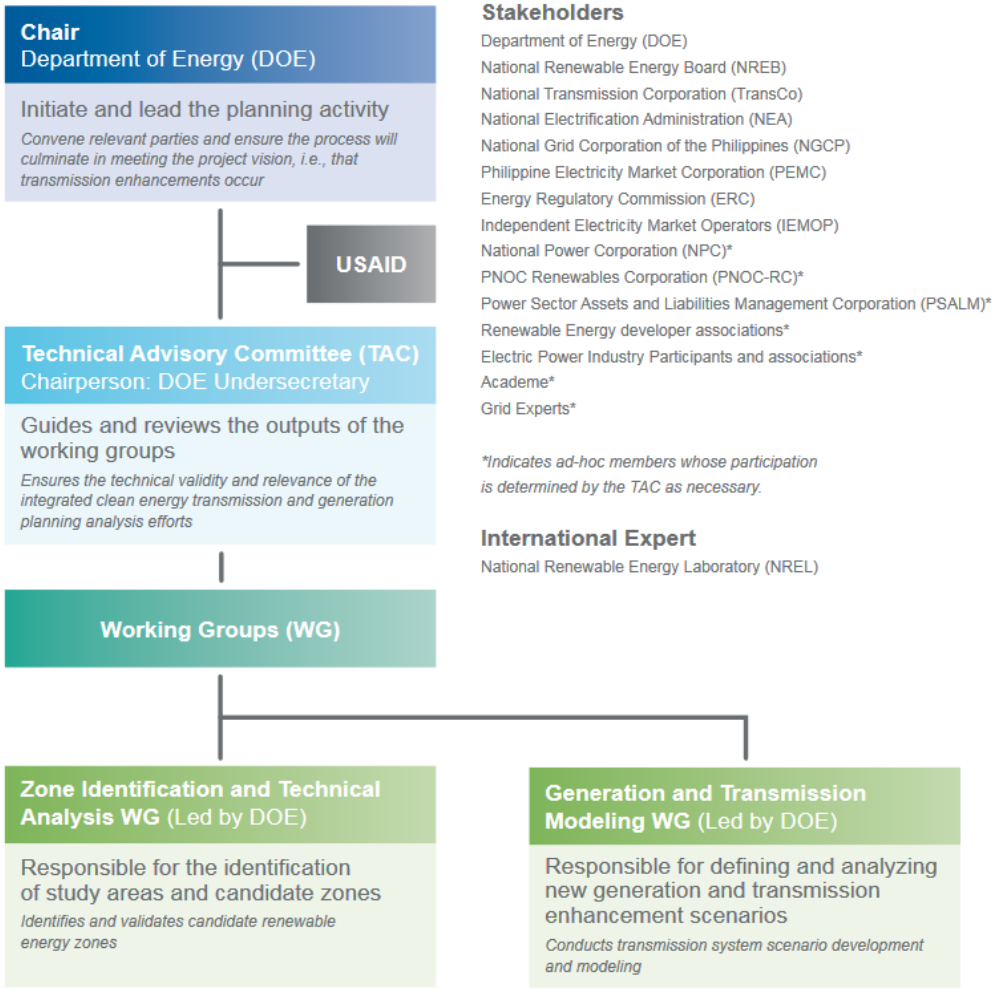
Northland Region identified as a prime candidate for New Zealand's first REZ pilot project.

Source and Figures: Transpower NZ (2022), Transpower NZ et al. (2022)

PHILIPPINES

Figure 10. Candidate Renewable Energy Zones in the Philippines with Existing and Planned Transmission





The REZ process involved extensive and collaborative **stakeholder engagement** with a clearly defined **institutional structure**.

The analysis focused on utility-scale wind and solar PV, but also characterized the biomass, geothermal, and hydropower resources within the candidate zones.

Source and Figures: Lee et al. (2017)

South Africa

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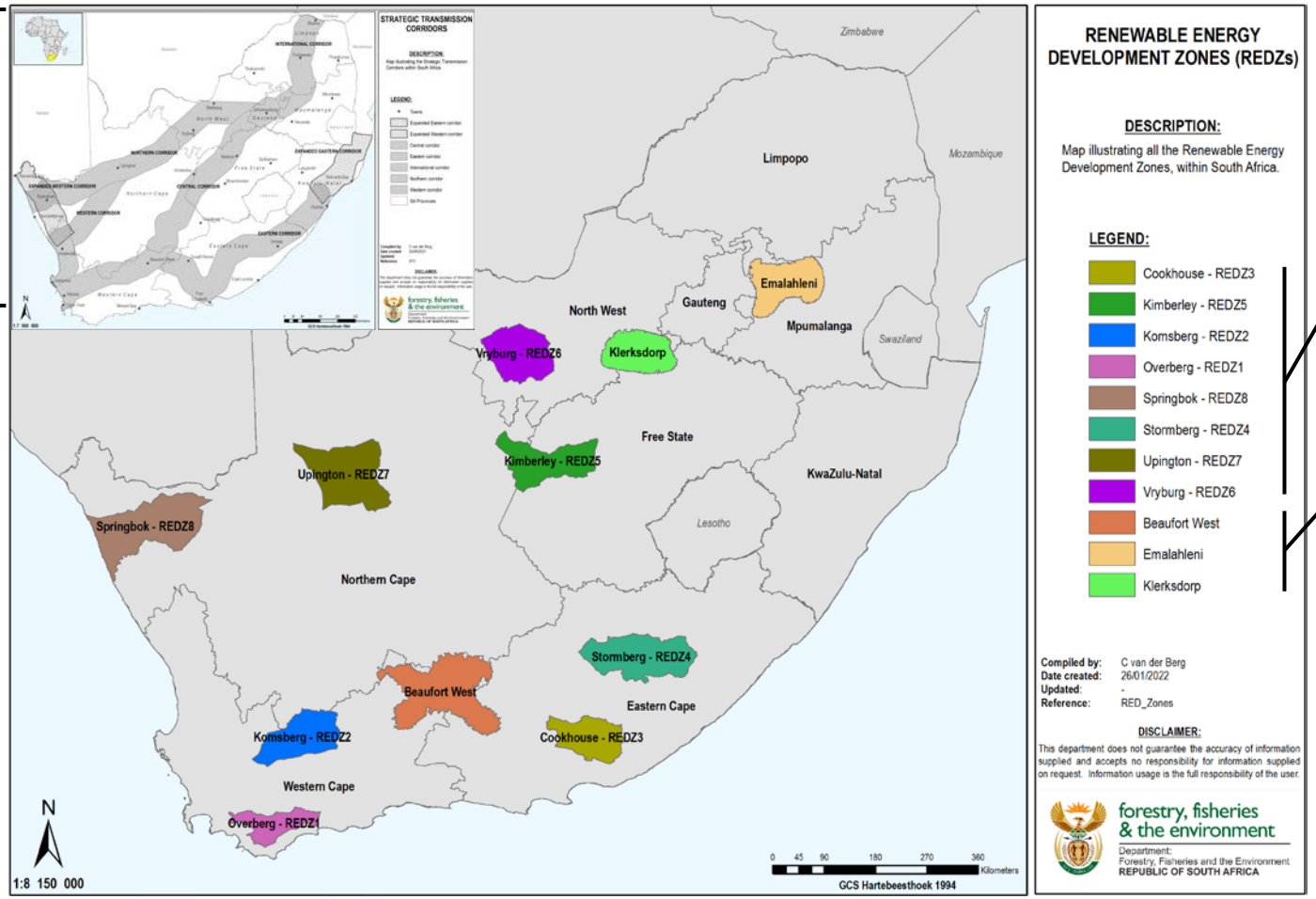
Figure 11. Renewable Energy Development Zones (REDZs) in South Africa

Strategic transmission corridors identified in South Africa



2018: Government Gazette No. 41445 identified 8 REDZs for large-scale wind and solar PV

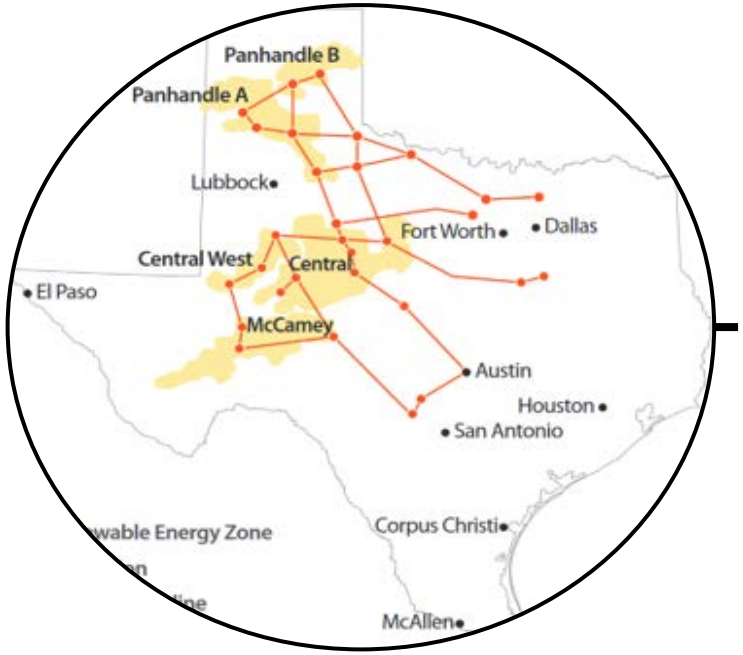
2021: Government Gazette No. 44191 identified 3 additional REDZs

All REDZ notices included a procedure for environmental permit applications.

Source and Figures: Department of Forestry, Fisheries and the Environment (2022)

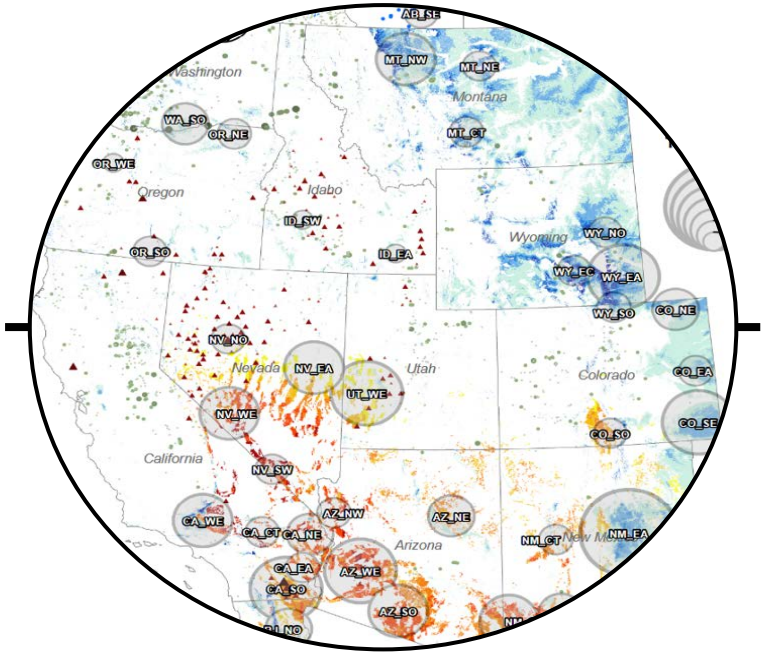
United States

Figure 12. Timeline of REZ Projects and Studies in the United States



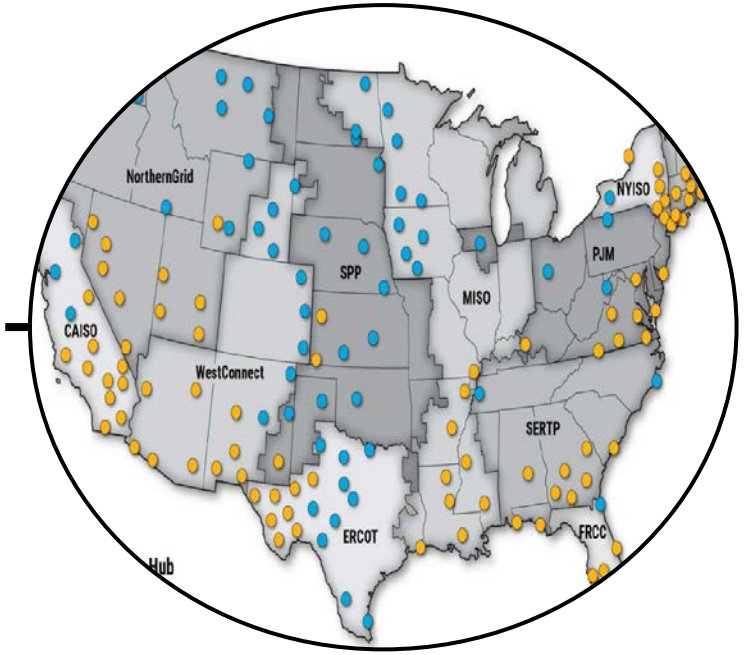
Texas Competitive Renewable Energy Zones

Timeframe for planning: ~2005-2009
Resources considered: wind



Western Interconnect Renewable Energy Zones

Timeframe for planning: ~2008-2013
Resources considered: wind, solar PV, hydropower, and geothermal



Interregional Renewable Energy Zones

Timeframe for planning: ~2021-2023
Resources considered: wind and solar PV

Source and Figures: Lee et al. (2017), Lasher (2008), Pletka and Finn (2009), Hurlbut et al. (2022)

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PART III—RENEWABLE ENERGY ZONES (REZ): KEY ENABLERS

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Key Enablers of REZ Transmission Planning

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Process Clarity

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

Strong Stakeholder Engagement

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

High-Quality Data

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

Regulatory Weight

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

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THANK YOU!

Prateek Joshi (prateek.joshi@nrel.gov)
Jal Desai (jal.desai@nrel.gov)

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