RENEWABLE ENERGY ZONE (REZ) TRANSMISSION PLANNING PROCESS: A GUIDEBOOK FOR PRACTITIONERS

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LIST OF ACRONYMS

CREZ	Competitive Renewable Energy Zones
DAF	development adjustment factor
ERCOT	Electric Reliability Council of Texas
HVDC	high-voltage, direct-current
IA	interconnection agreement
PUCT	Public Utility Commission of Texas
REZ	renewable energy zone
TAC	technical advisory committee
Transmission WG	transmission and generation modeling working group
WG	working group
Zone WG	zone identification and technical analysis working group

RENEWABLE ENERGY ZONE (REZ) TRANSMISSION PLANNING PROCESS

Achieving clean energy goals may require new investments in transmission, especially if planners anticipate economic growth and increased demand for electricity. The renewable energy zone (REZ) transmission planning process can help policymakers ensure their infrastructure investments achieve national goals in the most economical manner.

What is a REZ?

A REZ is a geographic area that enables the development of profitable and cost-effective grid-connected renewable energy. A REZ has high-quality renewable energy resources, suitable topography and land use designations, and demonstrated interest from developers, all of which support cost-effective renewable energy development.

What is the REZ transmission planning process?

REZ transmission planning is a process to plan, approve, and build transmission infrastructure that connects REZs to the power system. The REZ process helps to increase the share of solar, wind, and other renewable energy resources in the power system while maintaining reliability and economics. The REZ process focuses on large-scale wind and solar resources that can be developed in sufficient quantities to warrant transmission system expansion and upgrades. These variable renewable energy resources are similar to large hydropower in that transmission systems must be brought to the location of the resource to connect them to the grid.

The REZ process focuses on large-scale wind and solar development because other renewable energy resources (e.g., geothermal or mini-hydropower) are seldom found in sufficient concentration to warrant consideration as a REZ. However, when located within a designated REZ, these supplemental renewable energy resources may provide additional value to a designated REZ, as described in step 2.

Why is the REZ transmission planning process necessary?

Traditional transmission planning may be ill-suited to the characteristics of renewable energy development because transmission planning decisions need to be made well in advance of renewable generation development decisions. Wind and solar power need to be located in windy and sunny areas that are sometimes far from large load centers. Transmission system access to these areas may require 5–10 years to plan and construct; however, wind and solar generation projects only require 1–3 years to construct. Financing for these remote generation projects is not available without transmission access, but transmission lines cannot be built without a demonstrated need for service. Siting for conventional generation such as coal is seldom as constrained. Renewable energy planning that does not consider transmission expansion may limit countries to less economical renewable energy development.

The REZ process presented here applies to renewable energy expansion that is constrained by the lack of existing transmission. The REZ process may not be applicable in situations in which other reasons limit renewable energy development, or if the existing transmission system already has capacity to accommodate new renewable energy development.[1]

Box 1. Defining Renewable Energy Zones (REZs) and the REZ Transmission Planning Process

A **REZ** is a geographic area that enables the development of profitable and cost-effective grid-connected renewable energy. A REZ has high-quality renewable energy resources, suitable topography and land-use designations, and demonstrated interest from developers, all of which support cost-effective renewable energy development.

The REZ transmission planning process is an approach to plan, approve, and build transmission infrastructure that connects REZs to the power system. The REZ process helps to increase the share of solar, wind, and other renewable energy resources in the power system while maintaining reliability and economics. The REZ process focuses on large-scale wind and solar resources that can be developed in sufficient quantities to warrant transmission system expansion and upgrades.

1. Other constraints, such as congestion on existing lines that leads to curtailment of renewable energy generation, can be addressed through traditional transmission planning activities and do not require the REZ process.

Who should use this guidebook, and how?

Policymakers, planners, and system operators around the world have used variations of the REZ process to chart the expansion of their transmission networks and overcome the barriers of traditional transmission planning. This guidebook seeks to help power system planners, developers, key decision makers, and stakeholders understand and use the REZ transmission planning process to integrate transmission expansion planning and renewable energy generation planning.

The first sections of this guidebook present the organizational structure of the REZ process and an outline of the steps involved in the process. The remaining sections describe each step of the REZ process in detail.

The broad outline presented here is based on the Competitive Renewable Energy Zones (CREZ) process used in Texas between 2005 and 2015 (see *REZ Process: Organizational Structure*) and may be modified based on unique circumstances.

Where can readers find additional information?

This overview is part of the United States Agency for International Development's REZ Technical Platform, which describes international best practices for transmission development. Additional information is available on the Greening the Grid website.[2]

2. Find additional information on the REZ process and related topics at the Greening the Grid website, greeningthegrid.org.

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THE REZ PROCESS: ORGANIZATIONAL STRUCTURE

The relationship between decision makers and stakeholders is important in the REZ process. While laws and institutional frameworks vary from one power system to another, a successful REZs effort depends on active stakeholder engagement and the flow of information between stakeholders and decision makers throughout the process. The authority to plan for and approve investment decisions rests with the decision makers. Examples of decision makers and stakeholders for the REZ Process are listed in Box 2. Stakeholder involvement is critical to the REZ process. Although stakeholders do not make legally binding decisions, they have important interests in the electricity system and will be affected by those decisions. In many cases, stakeholders also have technical information and expertise that can enhance the decision.

Figure 1 proposes an organizational structure for an effective, stakeholder-inclusive REZ process, as referenced throughout this document.[3] This begins with the Lead Entity—the decision maker that launches and oversees the planning activity and ensures its completion. A technical advisory committee (TAC) empowered by the Lead Entity guides and reviews the work of the REZ process. The working groups (WGs) conduct the technical and analytical work of the REZ process and generally include both:

- A zone identification and technical analysis WG (Zone WG)
- A transmission and generation modeling WG (Transmission WG).

The Lead Entity has authority to approve new transmission and to convene stakeholders and other decision makers. The Lead Entity would also arbitrate any disagreements that cannot be settled within the TAC. The Lead Entity may be an energy ministry, an environment ministry, the regulatory authority, or other relevant authority. As an example, the Texas Legislature directed the Public Utility Commission of Texas (PUCT) to take action in 2005 that paved the way for the Texas CREZ initiative (Hurlbut 2013).

The TAC guides and reviews specific REZ tasks and outputs. The committee may include representatives of the Lead Entity, the technical WGs, other government agencies, stakeholders, and organizations that can support the process such as transmission system operators. The Zone and Transmission WGs deliver their work products to the TAC for review and discussion. The TAC mediates any differing views within the WGs throughout the process.

The Zone WG conducts the step-by-step screening that results in a list of candidate REZs. The Zone WG's membership includes organizations that can help assess the productive potential of renewable energy resources, and any significant constraints to renewable energy project development, at specific locations. Members can include renewable energy technology experts, meteorological experts, power system planners, land use planners, wildlife experts, civil society groups, and other stakeholders. The work might begin by defining initial study areas (see step 2), which the group then screens more rigorously into smaller candidate zones (see step 3). In the Texas CREZ initiative, the Electric Reliability Council of Texas (ERCOT)—the system operator—conducted a wind resource potential study and identified areas with significant potential for generation (Lasher 2008).

Box 2. Example REZ Process Decision Makers and Stakeholders

Decision Makers	Stakeholders
Energy ministry or agency officials	Renewable energy project developers
Environment ministry and other relevant ministry officials	Electric utilities
Regulators	Environment, natural resource, and land use authorities
Power system planners	Economic and social development authorities
Transmission system operators	Environment, wildlife, social, and other interest groups
	Non-governmental organizations

3. This general institutional structure may require modifications when applied to specific country or other contexts.

The Transmission WG models options for connecting the candidate zones to the existing transmission network to deliver energy generated in candidate zones to demand. The Transmission WG performs the requisite transmission planning studies (e.g., operational and reliability analyses) and develops transmission expansion options (including cost estimates for the necessary transmission facilities). The group analyzes and compares the results of each option based on the amount of new renewable energy delivered, changes in the cost of production, total cost of transmission upgrades, and any other metrics of interest. The Transmission WG may consist of transmission system operators, energy research institutes, government agencies, and other stakeholders. Transmission WG discussions also include representatives of existing and planned generation to share generator characteristics and support modeling activities.

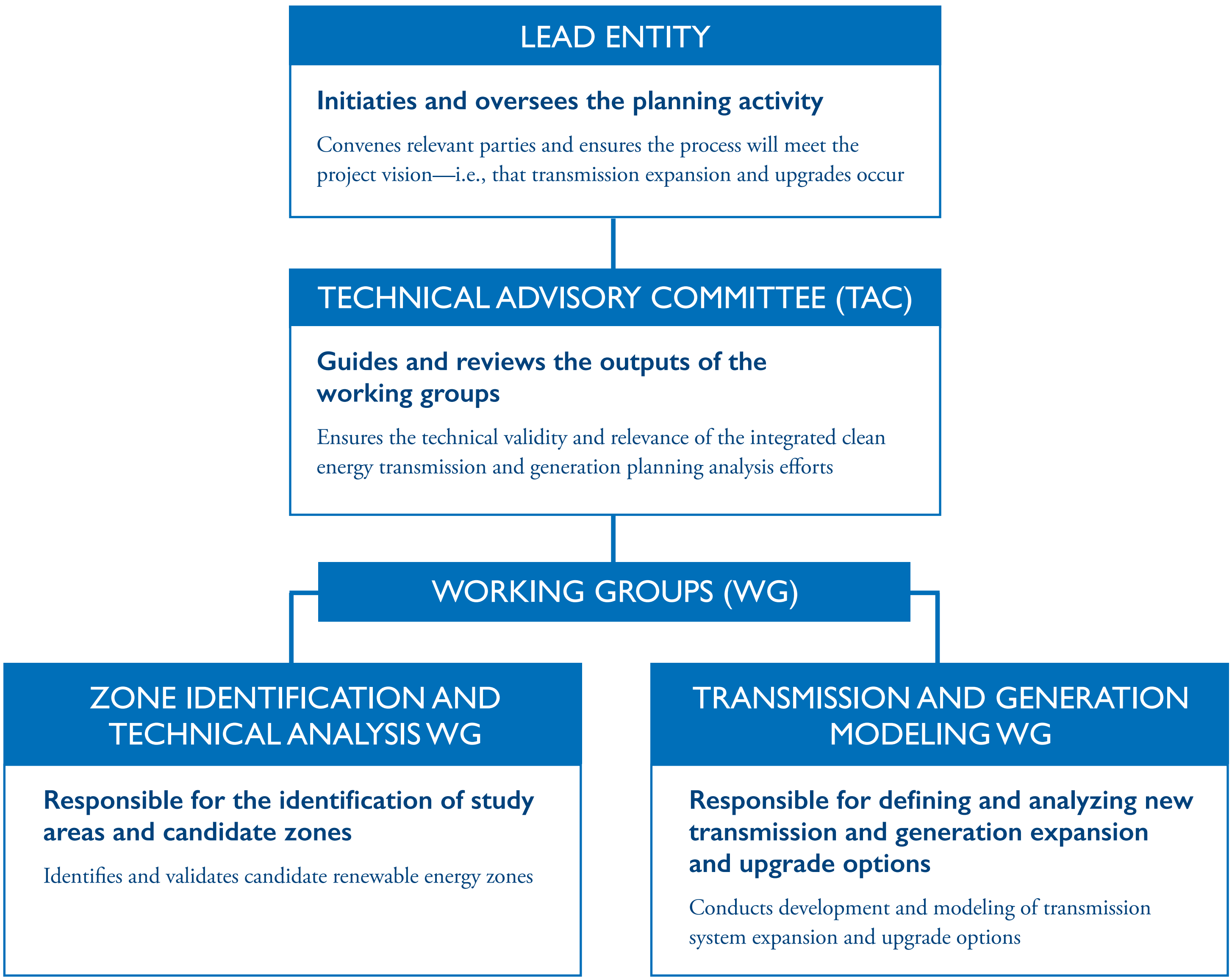


Figure 1. General REZ transmission planning organizational structure

THE REZ PROCESS: OVERVIEW

Figure 2 outlines the six steps of the REZ process. These steps are individually described in the sections that follow, providing detailed description of their purpose, outputs, and the key decision makers and stakeholders involved.

STEP 1. PROCESS DESIGN & VISION STATEMENT

STEP 2. RENEWABLE ENERGY RESOURCE ASSESSMENT

Summary: Select areas with highest potential

Output: Study areas map and supply curves

- Assess resource
- Screen exclusion areas
- Identify the areas with the highest quality, developable resource

STEP 3. CANDIDATE ZONES SELECTION

Summary: Identify zones with highest probability of development

Output: Candidate zone map and supply curves (one per area)

- Gauge commercial interest
- Identify areas where high quality resources intersect with commercial interest

STEP 4. TRANSMISSION OPTIONS DEVELOPMENT

Summary: Bundle candidate zones and conduct analyses of the options

Output: Cost, benefit, and reliability impacts for each transmission alternative

- Select scenario creation (bundling) methodology
- Conduct cost-benefit analysis of options
- Steady-state, dynamic stability, production cost, and reliability analysis

STEP 5. FINAL TRANSMISSION PLAN DESIGNATION

Summary: Select transmission option according to pre-set criteria

Output: Final transmission order

- Select transmission option that best complies with predetermined criteria, including reliability standards, economic benefits, and environmental goals

STEP 6. TRANSMISSION SYSTEM UPGRADE

Figure 2. Renewable energy zones transmission planning process outline

STEP 1. PROCESS DESIGN AND VISION STATEMENT

Summary: Design a specific process and develop a vision statement

Final outputs: Vision statement and program design document

Estimated time: 3 months

Central decision makers and stakeholders: Lead Entity

An effective REZ process is firmly rooted in applicable laws and regulations. This ensures that decision makers have the authority to approve and direct transmission investment and guarantees that the designation of REZ has relevant legal ramifications.

1.1 Identify the scope of the REZ process

The scope defines the geographic boundaries and the renewable energy resources included in the REZ process. The geographic area being considered in the REZ process defines the boundary of application. A clear boundary of application is important because it focuses the scope of the REZ process. The Lead Entity sets the geographic boundary based on the existing layout, operation, and regulation of the transmission infrastructure. This boundary may include a local, regional, national, or multinational area.

The scope of the REZ process also establishes the renewable energy resources included in the REZ process. The criteria for this decision may include government priorities and/or availability of spatially linked resource data. This step does not consider the production cost of electricity for different renewable energy resources because this is evaluated in step 2. For example, wind and solar are the most often defined resources for the REZ process.

1.2 Develop a vision statement

After establishing the scope of the REZ process, the Lead Entity reviews relevant laws and regulations to create a vision statement for the REZ process. While decision makers and stakeholders may provide comments, the vision statement comes from the Lead Entity. The vision statement has two practical purposes:

1. To establish the goal of the REZ process—for example, to build new transmission infrastructure and make improvements that cost-effectively and fully use the best renewable resources in the region.
2. To clearly state the scope of the REZ process. A clear scope sharpens the focus of the process and manages stakeholder requests and expectations. This may include the boundary of application and the renewable energy resources considered.

1.3 Establish a detailed process design

The Lead Entity may also publish a REZ process design document describing the process in more detail, including steps, responsibilities, deliverables, timelines, and goals. The design document adds transparency and creates a process baseline that bounds subsequent changes as the different decision makers and stakeholders provide input on the scope and adjust the process to accommodate unforeseen circumstances. Prior to publication, the Lead Entity may share the process design document for review and input from decision makers and stakeholders.

Box 3. Example Vision Statement from the Texas CREZ Initiative

The Texas CREZ vision statement was included in the Texas Utility Code (Texas Public Utility Regulatory Act 1999):

The commission, after consultation with each appropriate independent organization, electric reliability council, or regional transmission organization: (1) shall designate competitive renewable energy zones throughout this state in areas in which renewable energy resources and suitable land areas are sufficient to develop generating capacity from renewable energy technologies; (2) shall develop a plan to construct transmission capacity necessary to deliver to electric customers, in a manner that is most beneficial and cost-effective to the customers, the electric output from renewable energy technologies in the competitive renewable energy zones; and (3) shall consider the level of financial commitment by generators for each competitive renewable energy zone in determining whether to designate an area as a competitive renewable energy zone and whether to grant a certificate of convenience and necessity.

STEP 2. RENEWABLE ENERGY RESOURCE ASSESSMENT

Summary: Identify areas with the highest potential for low-cost development; allow governments to identify priority or avoidance areas

Final output: Study areas map and supply curves (one per area)

Estimated time: 8 months

Central decision makers and stakeholders: TAC and Zone WG

The REZ process identifies regions through a systematic and transparent procedure based on resource quality, topography, land use, and developer interest. The theoretical renewable energy resource potential (unconstrained by cost or land use issues) is the base layer for this process.

The goal of step 2 is to estimate the renewable energy resource potential and identify a set of study areas (and associated supply curves) capable of supporting high levels of clean energy development.

2.1 Conduct technical potential analysis

The technical renewable energy potential estimates the achievable installed capacity and generation of a specific technology based on the topographic limitations, land use constraints, and system performance. This step identifies areas with abundant renewable energy resources that are technically developable.

The Zone WG screens the theoretical renewable energy potential (data often presented in the form of a renewable energy resource map) with the areas not available for project development. This process can also highlight known priority renewable energy development areas (e.g., "eco-towns" or economic development areas) to identify the set of study areas—the output of the technical resource analysis. Figure 3 depicts this process of screening the resource potential for excluded and priority development areas to calculate the technical potential for renewable energy generation in each of the study areas. The steps of this process are detailed below.

2.1.1 Produce renewable energy resource maps

Renewable energy resource maps show the theoretical resource potential for the technologies considered within each region of interest. Spatially referenced renewable energy resource data form the base layer that is filtered in order to identify the study areas and are particularly important for site-constrained resources such as wind and solar. These resource potential layers consist of modeled or measured geospatial data. Ideally, ground measurements validate the modeled data. These data layers allow for calculation of power density (W/m^2) or potential electricity generation per unit

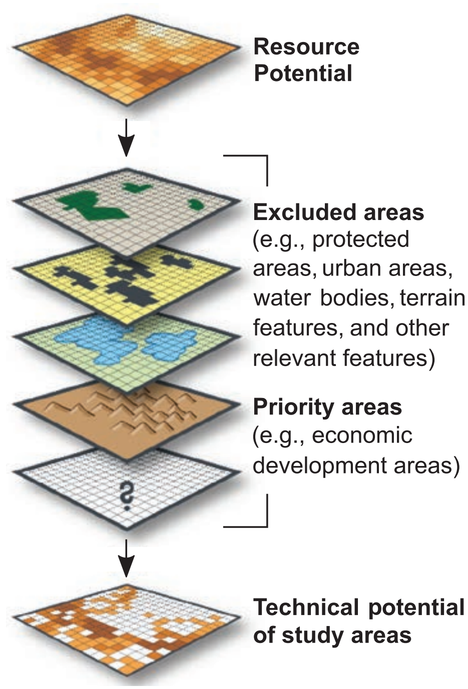


Figure 3. Process of screening resource potential to calculate the technical potential of study areas.

Adapted from Lopez (2016)

of area over a given period of time (kWh/m[2]/day) for renewable energy resources under consideration. At a minimum, annual average resource data are needed to identify study areas; however, higher temporal resolution data provide additional insight for decision makers. Solar resource layers ideally consist of direct normal irradiance, diffuse horizontal irradiance, air temperature, and wind speed. Wind resource layers ideally consist of wind speed, wind direction, air pressure, and air temperature. Local sources for these data may include energy ministries, environment ministries, or research institutes. Where local data is not available, high-quality, global data sets are publicly available.[4] Additionally, commercial firms can create these data with a high degree of accuracy.

2.1.2 Exclude areas not available for development

Many areas may be undevelopable despite having high-quality renewable energy resources. This step identifies and excludes areas within the boundary of application where development is prohibited or not possible for technical or other reasons. Constraints to project development may include:

- Land use: water features, urban areas, roads, other transportation infrastructure
- Topographic: slope, minimum contiguous area
- Protected lands: government-protected, critical environmental areas (e.g., bird migratory pathways), radar footprints, areas important for social or cultural reasons
- Other state or local issues that prohibit or severely restrict development.

Study areas do not have to be located close to load centers, existing transmission, or planned transmission, and proximity to these is not a criterion used for exclusion. This step aims to capture all of the study areas that represent high-quality, developable resources—ensuring that these areas are considered in subsequent steps. Constraining study areas to the vicinities of existing transmission or load centers may result in targeting less productive (and therefore less cost-effective) resources. In many power systems, areas that are far from existing transmission and load centers often host the most cost-effective and viable renewable energy resources. In later steps (steps 4 and 5), decision makers evaluate the associated trade-offs of the transmission enhancements necessary to connect these potentially remote, high-quality resources.

2.1.3 Identify priority development areas

Economic development or other priority areas may exist that offer benefits like expedited permitting or special incentives for (renewable) energy projects. These areas might intersect high-quality, renewable energy resources, and early identification in the REZ process could be an important step in achieving multiple policy objectives.

4. High-resolution, modeled annual average solar and wind resource data are available on the Global Solar Atlas from the World Bank and the Global Wind Atlas from the Danish Technical University, respectively. More information is available at globalsolaratlas.info and globalwindatlas.com. Also, the Renewable Energy Data Explorer is a no-cost, web-based application that provides spatial data and analysis capabilities for renewable energy resources in select regions. Additional information is available at re-explorer.org.

2.2 Conduct economic analysis

The technical potential analysis identifies areas where development is technically feasible (i.e., study areas) but does not include considerations of economic feasibility. An economic analysis further filters the study areas based on economic considerations such as the cost of generation.

2.2.1 Determine development adjustment factor

In practice, only a few technically feasible sites within a zone may actually be developed even if transmission were available. Project developers have limited capital and will seek out the sites where cost is minimized and returns maximized.

To account for this, the Zone WG estimates how much new capacity may actually be developed in each study area through the use of a development adjustment factor (DAF). The DAF is typically technology-specific and represents an estimated percentage of total potential capacity likely to be developed after accounting for the potential reasons that investment might not occur on a specific site (e.g., limited capital) despite technical feasibility. The DAF mathematically reduces the estimated capacity potential of a study area without having to specify exactly where each reduction would occur. The considerations captured by the DAF require stakeholder engagement and consensus as these potential reasons that investment might not occur are often subjective. The Zone WG determines the DAFs based on the characteristics of the specific market and context of the REZ process.

The adjusted developable capacity informs later transmission modeling steps in the REZ process.

2.2.2 Develop a supply curve for each study area

A supply curve for each study area helps project developers and the regulatory authority quantify the resource that can be developed for a particular cost in that area and compare these prices across the set of study areas. On its vertical axis, the supply curve shows the levelized cost of each unit of energy produced by potential generators sited in each area. On its horizontal axis, the supply curve shows the total amount of energy that such generators would produce annually at or below a given levelized cost.

Figure 4 shows electricity generation technologies by type along the horizontal axis from lowest cost per unit of energy produced annually to highest. The curve shows that the zone could provide up to 10,363 GWh/year at a levelized cost of no greater than $102/MWh, for example. Supply curves enable comparison of potential zones based on the cost of energy that can be obtained.

Large-scale wind and solar are the focus of the REZ process because other renewable energy resources (e.g., geothermal, mini-hydropower) are seldom sufficiently concentrated in a location to warrant development as a REZ. However, when co-located within a designated REZ, these supplementary renewable energy resources may provide additional value such as controllability from geothermal resources and reliability attributes.

2.3 Continue updating resources database

The initial resource database for identifying study areas is generic across a wide area and relies on simplified assumptions that discount project-specific variations. Later, private developers use more detailed resource data to examine projects and focus on areas within an identified zone. These resource data updates are not required before the selection of the final REZs.

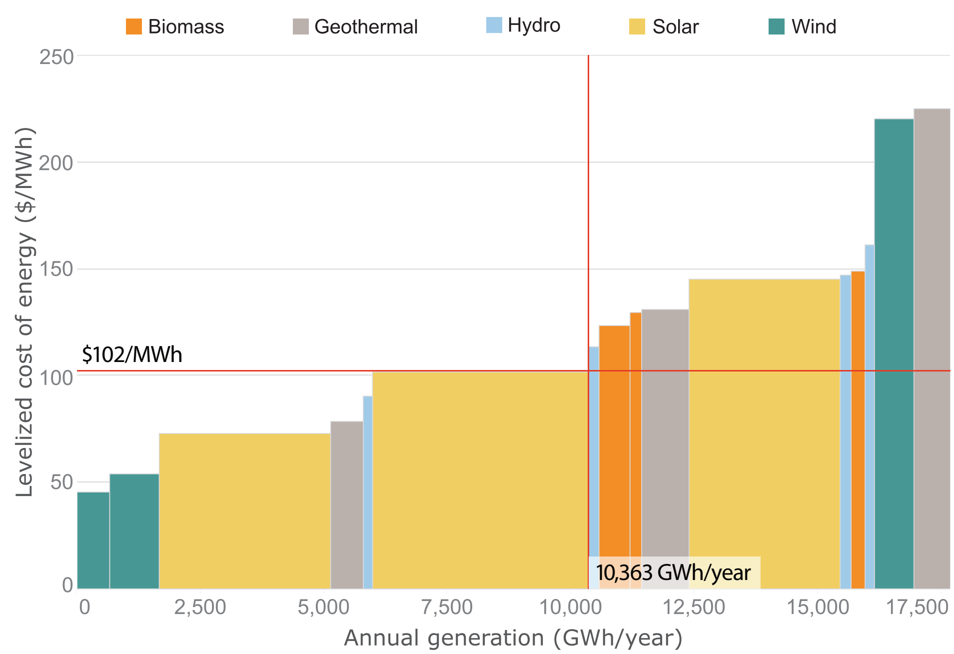


Figure 4. Hypothetical supply curve for renewable energy generation technologies.

Technology cost and performance data based on NREL (2016)

STEP 3. CANDIDATE ZONES SELECTION

Summary: Select areas with the highest probability of commercial development

Final output: Candidate zones map

Estimated time: 2–6 months

Central decision makers and stakeholders: TAC and Zone WG

Certain areas with excellent renewable energy resources may not be attractive to private developers for reasons the previous assessment step (step 2) fails to capture. In the candidate zone selection step, the Zone WG invites developers to demonstrate their interest in the screened areas to ensure that the chosen REZs are commercially attractive for development. This step provides a level of certainty that development will occur in the chosen REZs and that any investment in transmission lines would be used and these costs could be recovered.

3.1 Gauge commercial interest

To gauge the likelihood of development occurring in the previously identified study areas, the Zone WG and the regulatory authority request indications of commercial interest from private renewable energy project developers. The regulatory authorities determine the threshold that constitutes enough commercial interest or financial commitment by developers for a zone to be considered a candidate zone.

Private developers can demonstrate financial commitment or commercial interest in different ways. The acceptable forms of commitment can be specified during step 1–Program Design and Vision Statement of REZ. Examples of commercial interest and financial commitment may include:

- Pending or signed interconnection agreements
- Leasing agreements
- Letters of credit
- Interconnection studies by a transmission owner or grid operator[5]
- Any other indication deemed appropriate by the regulatory authority.

5. Interconnection studies require financial commitments from developers in the form of fees and deposits. Using a 10 MW generator as an example, a developer in ERCOT could pay $15 per MW for a full interconnection study and a $5,000 security screening study deposit (ERCOT 2017). For the same size generator, the Midcontinent Independent System Operator could pay a $5,000 application fee as well as a total of $224,000 (deposits and fees) for a definitive planning study (MISO 2017). In the California Independent System Operator area, a similar generator could incur an interconnection study deposit of $60,000 as well as a generator site exclusivity deposit of an additional $100,000 (CAISO 2017).

3.2 Produce candidate zone map

Once the period to provide information has ended, the Zone WG and the regulatory authority evaluate the submitted evidence and decide which study areas have generated sufficient developer interest. This finding leads to a selection of candidate zones, which have high-quality resources and high probabilities of being developed.

The Zone WG and the regulatory authority may at this point decide to modify candidate zones, combine some adjacent zones into a single zone, or eliminate a candidate zone for reasons that may only become obvious at this stage of the process as new information is available, such as supply curves and developer interest.

Figure 5 (left) shows three types of metrics used in the Texas CREZ initiative to compare levels of developer commitment for study areas: the amount of existing development in the study area; signed interconnection agreements (IAs) with ERCOT; and pending IAs for projects under study by ERCOT.

Figure 5 (right) also presents an example candidate zone map from the Texas CREZ process, in which 10 candidate zones were selected out of 25 study areas based on demonstrable commercial interest of developers. Study areas that did not receive enough interest, such as zones 8, 13, and 20, were not included in the final selection of candidate zones.

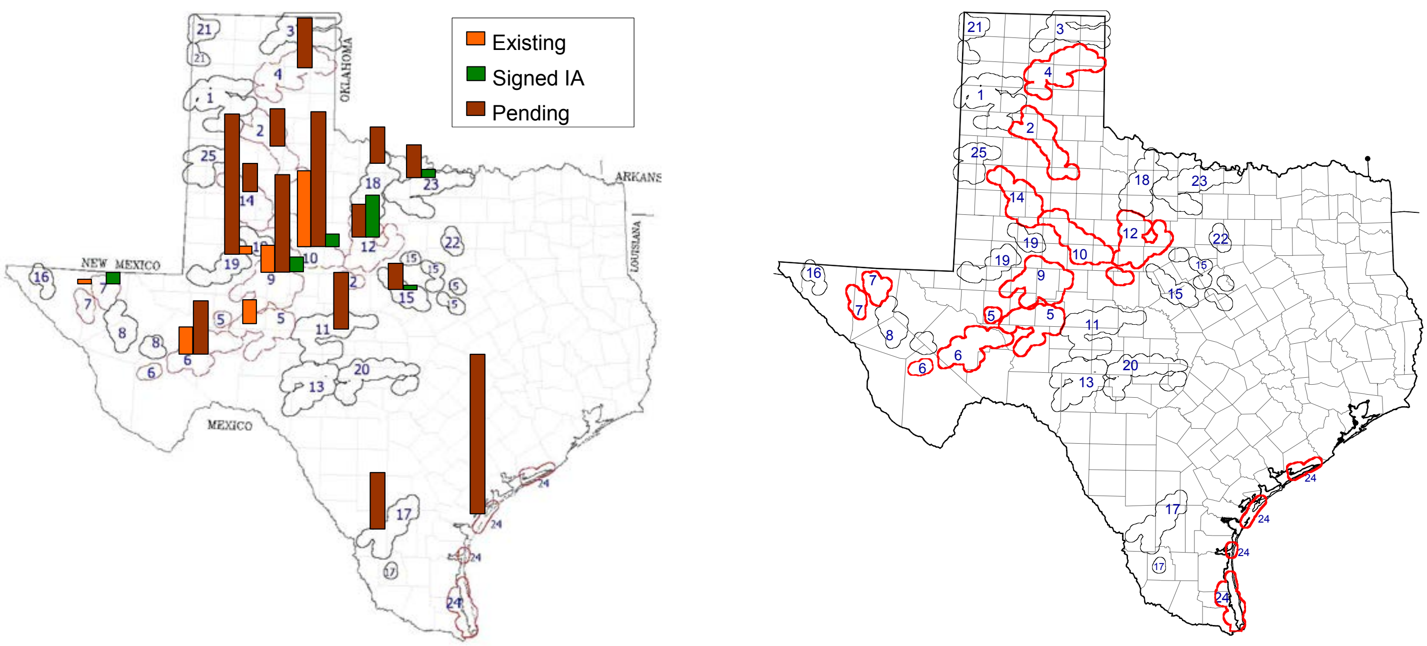


Figure 5. Candidate zone selection example from Texas CREZ. Left – Existing wind development, signed IAs, and pending IAs in each study area. Right – Candidate zone map: 10 candidate wind zones selected from 25 initially identified study areas, outlined in red.

Source: Adapted from ERCOT (2006).

STEP 4. TRANSMISSION OPTIONS DEVELOPMENT

Summary: Bundle candidate zones and develop transmission enhancement options

Final output: Transmission planning studies and cost-benefit results for each option

Estimated time: 9–18 months

Central decision makers and stakeholders: TAC and Transmission WG

Delivery of the electricity generated in the candidate zones to load requires upgrades and/or extension of the existing transmission system. After selecting the candidate zones, the analysis focuses on developing a set of transmission enhancement options to cost-efficiently connect candidate zones to load and yield the most benefits. A set of feasible options allows the TAC and Transmission WG to select the most attractive option based on pre-set criteria.

4.1 Produce transmission enhancement options

Knowing the location and target installed RE capacity of candidate zones enables the Transmission WG and system operator to formulate transmission expansion options for a REZ transmission optimization study. There are often a large number of potentially feasible approaches to connecting candidate zones to load. To reduce this complexity, the transmission optimization study includes a reasonable set of transmission development options (e.g., three to five options) that cover the diverse range of feasible solutions, including the addition of new lines and other transmission improvements such as equipment upgrades, new substations, or transformers.

Each option includes a list of specific transmission upgrades, transfer capability, and associated costs. Some of the options developed might not contain the entire set of candidate zones. Additionally, the voltage level of new transmission and other upgrades may differ due to alternate assumptions about the carrying capacity needed to bring new renewable energy to the rest of the grid. Table 1 depicts example REZ transmission optimization study options and corresponding additional zone and total transfer capacities from the Texas CREZ process. This total transfer capability also includes existing wind capacity in the state. This table shows the potential diversity of the considered options. For example, Option 4 does not connect Zone 4 and as a result does not have transfer capability (MW) from this zone. Also, the CREZ transfer capability of each of the options differs and the transmission levels range from 5,150 MW to 17,956 MW for Options 1 and 3, respectively.

Table 1. Transmission System Transfer Capabilities in Various Texas CREZ Transmission Optimization Study Options

	Option 1 (MW)	Option 2 (MW)	Option 3 (MW)	Option 4 (MW)
Zone 2A	1,422	3,191	4,960	6,660
Zone 4	1,067	2,393	3,720	-
Zones 5/6	829	1,859	2,890	3,190
Zone 9A	1,358	3,047	4,735	5,615
Zone 19	474	1,063	1,651	2,051
CREZ transfer capability	**5,150**	**11,553**	**17,956**	**17,516**
Total transfer capability	**12,053**	**18,456**	**24,859**	**24,419**

Sources: ERCOT (2008); Lasher (2008)

4.2 Perform transmission planning studies

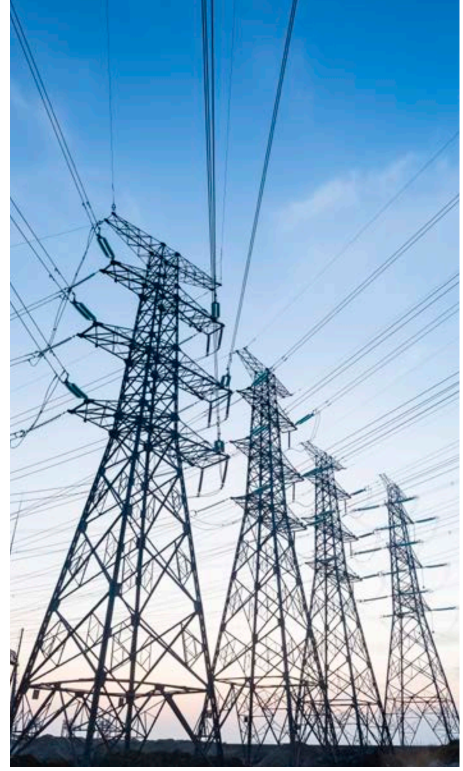
The Transmission WG performs three types of transmission planning studies for each of the options in an iterative fashion: steady-state analysis, dynamic stability analysis, and production cost analysis. The steady-state and dynamic stability analyses help the Transmission WG understand the reliability limitations and needs of the transmission network. Production cost analysis helps the Transmission WG understand the performance of the transmission network and expansion options. Outcomes include transmission system limitations, potential transmission improvements, total production costs over a test year, projected constraints, congestion costs, and local marginal cost of electricity. The Transmission WG can use the production cost analysis to determine the costs and benefits of each set of transmission system improvements for a given option.

It is not typically economically efficient to build the transmission network such that there is no curtailment of renewable resources because of transmission reliability constraints. For example, in the Texas CREZ process, an assumed system-wide wind generation curtailment of approximately 2% of annual energy potential was economically efficient (ERCOT 2008).

4.3 Conduct a cost-benefit analysis

Cost-benefit analyses allow for comparison of the production cost savings to the cost of new transmission. The Transmission WG and system operator analyze a sufficient number (e.g., three to five) of transmission options to understand the costs and benefits of each option. A cost-benefit analysis of the transmission enhancement options may include additional factors such as reliability benefits, legislative intent (i.e., the legal intent to develop clean energy), environmental benefits, future expansion capability, and other factors (e.g., social criteria). The TAC and the system operator can recommend the inputs used for the cost-benefit analysis as well as the individual criteria employed to evaluate the options.

At any point, the Transmission WG and regulatory authority may choose to drop a candidate zone with less commercial interest if the cost-benefit analysis suggests resources are better spent connecting other zones. The commercial interest shown by developers in step 3 can be quantified and included with factors from the cost-benefit analysis to rank the REZs.



Box 4. The Texas CREZ Approach to Producing Transmission Enhancement Options

Because there are many feasible approaches to connecting candidate zones to load, the Texas CREZ initiative reduced this complexity by studying a set of diverse transmission enhancement options that covered the range of feasible solutions.

In the Texas CREZ the Public Utility Commission of Texas (PUCT) bundled a set of selected candidate zones into a reasonable number of scenarios (e.g., three to five). These scenarios represented different levels of transfer capability for the transmission system based on the assumed installed capacity (MW) in each zone as well as the number of zones included. The PUCT asked the Electric Reliability Council of Texas (ERCOT) to develop transmission enhancement options to connect candidate zones to load and conduct a transmission optimization study to identify attractive, feasible options for each of these scenarios.

ERCOT then explored a diverse range of options for connecting candidate zones to load under each of the scenarios shared by the PUCT. These options included lower-voltage 345 kV networks, higher-voltage 765 kV networks, high-voltage, direct-current (HVDC) lines, hub-and-spoke circuits, and loop circuits around zones. Each option consisted of a list of specific transmission upgrades, transfer capability, and associated costs. An analysis of these transmission enhancement options and hybrid options—including the addition of new lines and other transmission improvements such as equipment upgrades, new substations, or transformers—identified the lowest cost, preferred option within each scenario.

Detailed studies of the final, preferred transmission enhancement option under each scenario were then possible. The studies conducted included steady-state analyses, dynamic stability analyses, production cost analyses, and a cost-benefit analysis (ERCOT 2008).

STEP 5. FINAL TRANSMISSION PLAN DESIGNATION

Summary: The appropriate authority issues transmission plan

Final output: Final transmission plan

Estimated time: 3–9 months

Central decision makers and stakeholders: TAC and Transmission WG

The appropriate authorities (e.g., regulatory authority) may need to ensure specific reliability and other requirements before selecting the final transmission plan from the set of previously considered transmission development options from step 4. To select the most appropriate option, the Transmission WG and TAC make an interim selection of a transmission option—with the information provided by the system operator from step 4—pending full reliability modeling results. Finally, in step 5 the regulatory authority designates the final transmission plan to be implemented.

5.1 Perform a full reliability analysis

The Transmission WG and TAC perform reliability and ancillary cost impact analyses on the selected transmission option and disclose any major problems. The appropriate authorities use these reliability analysis and modeling results together to determine whether the selected transmission plan meets all requirements to issue a final transmission order.

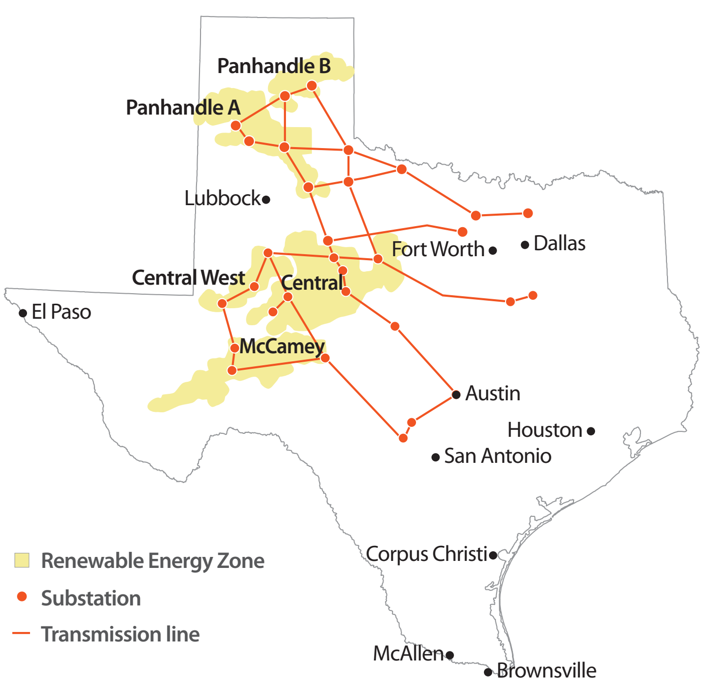


Figure 6. REZs and new transmission infrastructure necessary to access these zones identified in the Texas CREZ process. *Source: Hurlbut, Chernyakhovskiy, and Cochran (2016)*

5.2 Issue final transmission order

The regulatory authority's final order memorializes and authorizes the body of decisions made throughout the REZ process. This means including the selected transmission enhancements in official transmission planning documents. The designation includes a geographic description of the selected REZs; identifies major transmission improvements needed to cost-effectively deliver the electricity; identifies who will pay for the transmission improvements; and updates the estimate of the maximum generating capacity in the REZs based on capacity upgrades.

Figure 6 shows a map of the REZs and new transmission infrastructure necessary to access these zones as identified through the Texas CREZ process.

STEP 6. TRANSMISSION SYSTEM UPGRADE

Summary: Execution of the transmission development plan through the implementation of system upgrades

Final output: Transmission upgrades

Estimated time: 1–10 years

Central decision makers and stakeholders: Lead Entity, utilities, and private developers

The ultimate goal of the REZ process—part of the vision statement of the Lead Entity (step 1)—is the construction and upgrade of transmission infrastructure. The Lead Entity designs and conducts the REZ process with this goal in mind. The sixth and final step of the REZ process is the coordinated implementation of the transmission enhancements and the development of the REZs.

Building transmission lines is capital-intensive and understanding financial constraints can help to optimize investments in transmission system upgrades. When financing constraints limit the feasibility of a single transmission system infrastructure overhaul, the REZ process can consist of a staged investment and development approach. The outputs and the time horizon for each REZ process may differ, and they may range from larger, complete transmission system expansions to smaller or staged upgrades.

OUTCOMES OF THE REZ TRANSMISSION PLANNING PROCESS

Successful implementation of the REZ process enables integrated transmission expansion and renewable energy generation development—helping to cost-effectively increase the share of solar, wind, and other renewable energy resources in the power system.

Following implementation of expansion and upgrades, the transmission system can harness the best and most developable renewable energy resources and deliver the lowest possible cost renewable energy. This improved transmission infrastructure can reduce potential curtailment resulting from congestion, connect high capacity factor locations for development, and help to more efficiently load transmission lines.

Ultimately, the REZ process is a proactive transmission planning approach that can assist policymakers and planners in meeting clean energy goals, meeting increased demand, and providing economic power generation through the successful integration of REZs and the significant scale-up of renewable energy deployment.

GLOSSARY

Boundary of application. The geographic area being considered in the REZ process, which may consist of a local, regional, national, or multinational region—principally determined by the existing layout, operation, and regulation of the transmission infrastructure.

Candidate zone map. Map showing the location of the candidate zones.

Candidate zones. Subset of study areas that have high-quality resources and high probabilities of being developed, as demonstrated by sufficient commercial interest.

Decision makers. Entities with the authority to launch planning and approve investment decisions (e.g., ministry officials, regulators, and others with power granted to them by the government).

Development adjustment factor (DAF). An estimated percentage of total potential capacity likely to be developed after accounting for the potential reasons that investment might not occur on a specific site (e.g., limited capital) despite technical feasibility—typically technology-specific.

Lead Entity. The decision maker that initiates and oversees the planning activity and ensures its completion.

Transmission and generation modeling working group (Transmission WG). Responsible for modeling options for connecting candidate zones to the rest of the grid. It develops transmission enhancement options and models how each option might change, among other things, the total cost of generating electricity—may consist of transmission system operators, energy research institutes, government agencies, and other stakeholders.

Priority development areas. Economic development areas identified by the government that offer benefits like expedited permitting or special incentives that may intersect with high-quality renewable energy resources.

Resource maps. Show the theoretical resource potential for technologies considered within each region of interest and form the base layer that is gradually filtered down to identify study areas.

Renewable energy zone (REZ). Geographic area characterized by high-quality renewable energy resources, suitable topography, and a strong interest in commercial development that supports cost-effective renewable energy development.

REZ process design document. Describes the REZ process in more detail, including steps, deliverables, timeline, responsibilities, and goals in addition to adding transparency and creating a process baseline that bounds subsequent changes as decision makers and stakeholders discuss and adjust the scope.

REZ transmission optimization study. Series of studies (steady-state analysis, dynamic stability analysis, and production cost analysis) for a set of feasible transmission development options (three to five), including both new lines and/or other transmission improvements such as equipment upgrades, new stations, or transformers.

REZ transmission planning. Process that enables planning and construction of transmission infrastructure that cost-effectively transports renewable electricity from a REZ to load.

Stakeholders. Group that does not make legally binding decisions but has interests and/or rights in the electricity system and will be affected by decisions. They often have technical information and expertise that can enhance a decision.

Study areas. Regions within the boundary of application capable of supporting large levels of high-quality clean energy development.

Technical advisory committee (TAC). Group that oversees and guides the work of the REZ process. It may include representatives of the Lead Entity, the technical WGs, government agencies, stakeholders, and possibly other organizations that can support the process such as transmission system operators.

Transmission development option. Feasible transmission expansion plan to connect candidate zones to load—includes transmission system limitations, potential transmission improvements, total production costs over a test year, projected constraints, congestion costs, and local marginal cost of electricity

Vision statement. Establishes the goal of the REZ process—a process to enhance transmission infrastructure that cost-effectively and fully uses the best renewable resources in the region—in addition to clarifying the scope of the REZ process.

Zone identification and technical analysis working group (Zone WG). Conducts the step-by-step screening that results in a list of candidate zones—may include renewable energy technology experts, meteorological experts, power system planners, land use planners, wildlife experts, and other stakeholders.

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