New Mexico Renewable Energy Transmission and Storage Study

SUPPLEMENT:

Glossary, Collector Plan Description, Case Studies

PREPARED FOR:
NM RETA
NM Renewable Energy Transmission Authority

Original author: ICF

Extracted content has been selected by NM RETA for release

This page left blank

IMPORTANT NOTICE:

Table of Contents

1 Features of this Report

This document provides supplemental information related to NM RETA's Update study report[1]; it includes summary descriptions of each Collector plan including line additions, substations and other key features; two transmission "robustness" cases are also discussed.

A complete Glossary listing technical terms, acronyms and units of measurement is contained in Section 2. ICF's findings addressing transmission system performance are contained in Section 3. Case studies addressing RTO formation and transmission impediments are also summarized in Section 4. URL references are numbered in various footnotes and are listed in Section 5.

Study content is extensively referenced by footnote page numbers, providing a link to source material if needed. ***All findings and observations are presented as-stated by ICF with no change in content.*** NM RETA has presented derivative content related to several ICF findings in this report; in these instances, each item has been footnoted as "ICF page (number)" to indicate attribution.

[1] See report titled "New Mexico Renewable Energy Transmission and Storage Study Update: Summary of Key Findings (February, 2022).

2 Glossary

Access	The contracted right to use an electrical system to transfer electrical energy.
AC Alternating Current	Electrical current in which the direction of the flow switches back and forth at regular intervals or cycles; flow in power lines is AC.
BLM	Bureau of Land Management, US Department of the Interior.
BAU	Business-as-Usual (scenario), the basis for ICF's analysis in this report.
Biomass	Organic waste from agricultural livestock and lumber industry products, dead trees, foliage, etc.; considered a renewable energy source.
Capacity	Load carrying ability expressed in megawatts (MW) of generation, trans-mission or other electrical equipment.
Capacity factor	Ratio of the electrical energy produced by a generating unit divided by the electrical energy that could have been produced at continuous full power during the same period.
Contingency	An outage of a transmission line generator or other piece of equipment which affects the flow of power on the transmission network and impacts other network elements.
Cooperative (utility)	Utility-owned entity operated by its members.
Demand	Rate at which electric energy is delivered expressed in kilowatts (kW), megawatts (MW), or gigawatts (GW) at a given instant or averaged over any designated interval of time. Demand should not be confused with Load or Energy.
Dispatching (generation)	Refers to operation of generating plants that can be used on demand and adjusted at the request of power grid operators, according to market needs.
DOE	US Department of Energy.
DoD	US Department of Defense.
EIA	DOE's Energy Information Administration.
EIM	Energy Imbalance Market; utilities pool their variable and conventional generation resources to improve operational efficiency over a wider area.
ESA	Endangered Species Act; a key federal law for both domestic and international conservation. The Act aims to provide a framework to conserve and protect endangered and threatened species and their habitats.
ETA	Energy Transition Act; Senate Bill 489 (2019), legislation that expanded statewide RPS requirements and establishes a pathway for a low-carbon energy transition in New Mexico.
EPE	El Paso Electric Company, an IOU serving New Mexico and Texas.
FERC	Federal Energy Regulatory Commission, regulator of interstate transmission service.
FTE	Full-time Equivalent employee; also referred to as Job-Years.

FWS	Critical Habitat for Threatened and Endangered Species Dataset.
Firming	Operating strategy to allow power output from a renewable power generation plant, such as wind or solar, to be maintained at a committed level for a period of time.
GHI	Total solar radiation incident on a horizontal surface.
GSP	Gross State Product, a measure of the economic output of a state; it is the sum of all value added by the combined industries within the state.
HVDC	High Voltage Direct Current (transmission).
JEDI	NREL's Jobs and Economic Development Impact model used in this study.
IMPLAN	Impact Analysis for Planning (IMPLAN) economic input-output model used in this study.
ICF	Technical author of this study; ICF International Inc., Fairfax, VA.
ISO	Independent System Operator; an organization with no financial interest in generating facilities that administers the operation and use of transmission systems; ISOs exercise final authority over the dispatch of electricity from generators to customers.
ITC	Investment Tax Credit; Federal ITC is a 30% tax credit for installing a solar system.
IOU	Investor-Owned Utility; common term for a privately owned (shareholder owned) gas or electric utility.
IPM	ICF's Integrated Planning Model (IPM®) simulates electricity market operation on a forward basis solving for capacity entry and exit over time.
Irradiance	The radiant flux (power) received by a surface per unit area.
kV Kilovolt	A kilovolt equals 1000 volts.
kWh	Kilowatt-hour; a measure of consumption; the amount of electricity that is used over some period of time, typically one hour.
Load	An end-use device or customer that receives power from an energy delivery system; Load should not be confused with Demand which is the measure of power that a load receives or requires; see Demand.
MW	Megawatt; a measure of demand for power which equals 1 million watts.
MWh	Megawatt-hour; the unit of energy equal to that expended in one hour at a rate of one million watts; one MWh equals 3,412,000 BTUs.
NERC	The North American Electric Reliability Corporation is certified by FERC to provide technical assessments of electric reliability for the United States; NERC administers six regional reliability councils (including WECC) to ensure compliance with national reliability standards.
NM RETA	New Mexico Renewable Energy Transmission Authority, sponsor of this study.
NREL	National Renewable Energy Laboratory, a DOE research facility.
O&M	Operations and Maintenance.

Overloads	Off-normal events which occur when power flow is greater than rated equipment capacity.
Peak Load, Peak Demand	Electric load that corresponds to a maximum level of electric demand within a specified time period usually a year.
PPA	Purchase Power Agreement; a contract between a seller generating electricity and a purchaser or buyer. The PPA defines all of the commercial terms for the sale of electricity between the two parties.
PTC	Production Tax Credit; Federal PTC is a per-kilowatt-hour tax credit for generating electricity, for a certain period of the solar system's operation.
PNM	Public Service Company of New Mexico, an IOU serving New Mexico
PSLF	GE Consulting's Positive Sequence Load Flow model used in this study.
PV	Photovoltaic solar.
REC	Renewable energy certificate; issued when one MWh of electricity is generated and delivered to the grid from a renewable energy plant.
ROW	Right-of-Way for transmission corridors.
RPS	Renewable Portfolio Standard; a regulation requiring increased production of energy from renewable sources, such as wind, solar, biomass, and geothermal; Chapter 62, Article 16 NMSA 1978 established New Mexico's RPS.
RTO	A regional transmission organization designed to operate the grid and its wholesale power market over a broad region and with independence from commercial interests; an RTO would also coordinate with other RTOs.
SPP	Southwest Power Pool; oversees the bulk electric grid and wholesale power market on behalf of utilities and transmission companies in 14 states.
SPS	Southwestern Public Service Company, a subsidiary of Xcel Energy, a utility holding company based in Minneapolis, Minnesota.
Tariff	A document listing the terms and conditions including a schedule of prices under which utility services will be provided.
Thermal Rating	Maximum amount of electrical current that a transmission line or electrical facility can conduct over a specified time period.
Transformer	An electrical device for changing the voltage of alternating current.
TSGT	Tri-State Generation & Transmission Association, Inc., a cooperative utility serving New Mexico and Colorado.
USDA	US Department of Agriculture.
Voltage	A type of "pressure" that drives electrical charges through a circuit; higher voltage lines generally carry power over longer distances.
RE	Variable renewable energy; solar- or wind-generated energy.
WECC	Western Electricity Coordinating Council, primary planning organization for the 14-state western US.
Wheeling	The transportation of electric energy from within an electrical grid to an electrical load outside the grid boundaries.

WPC Wind Power	Wind Power Class; a site’s WPC is related to its typical wind speed; ranges from 1 to 7, with WPC 1 offering the least wind power and WPC 7 the most.

3 Description of Transmission Collector Plans

This section describes key features of Collector Plans 1,2,3 which are presented as stand-alone configurations for New Mexico's grid development. ICF analysis also addressed important concerns related to 1) Phased-in implementation and 2) Collector Design Robustness; these topics are discussed first.

Phased-in implementation

Phasing of renewable development would ideally be gradual, consistent with growth of other factors such as electric demand. This process would begin in the early- to mid-2020s and continue over time. Each transmission Collector plan was required to satisfy the condition of supporting 11,500 MW of renewable capacity by 2030 and was designed with this system capability in mind. In phasing analysis, the reliability impact of each transmission line in the proposed Collector plan was analyzed through power flow analysis and ranked in the order of importance. Higher ranked lines were expected to produce more reliability benefits to the system and hence should be considered as prime builds ahead of others[2]. ICF estimated the total count of thermal violations arising from the absence of each proposed line. The total count of violations at 115 kV and above is used to rank lines in the order of reliability benefits.

3.1 Collector Plan 1- Centralized Renewable Generation

Collector Plan 1 has been designed to support centralized renewable capacity additions. All identified upgrades, except the new 345-kV Luna to Greenlee line, were designed to come in service in the 2020 to 2025 timeframe[3].The key features of Collector Plan 1 are:

- Create interconnection between existing 345-kV infrastructure in central New Mexico to reinforce local delivery reliability.
- Add a new high-capacity transmission corridor to interconnect New Mexico's key renewable zones to the Springerville substation in Arizona.
- Add a new circuit adjacent to the existing transmission corridor from southern New Mexico to the Greenlee substation in Arizona.
- Add two new 345-kV substations near the New Mexico border to enable additional transmission corridors to Springerville and Greenlee Substations in Arizona.

This transmission plan is characterized by two separate 345-kV single-circuit builds[4]. A 345-kV single-circuit build of 643 new line miles, with one new substation and the upgrade of one existing substation, is scheduled for construction from 2023 through 2028. Additionally, a 345-kV single-circuit build of 110 new line miles, with one new substation, is scheduled for construction from 2028 through 2030.

Two substations near the state border were designed to be connected to the adjacent Springerville and Greenlee substations in Arizona. A new line connecting Luna to Greenlee is aimed to accommodate the incremental solar buildout in the 2026 to 2030 period and, hence, was expected to come online in this timeframe. Reactive shunts (15 MVAr rating at 115 kV Phelps Dodge and 115 kV Apollo) are required additions not listed in the study Update report.

[2] ICF Page 81
[3] ICF Page 75
[4] ICF Page 104.

3.2 Collector Plan 2- Centralized Renewable Generation (Sun Zia)

The centralized renewable siting scenario has been further modified by modelling Sun Zia[5] to be in-service in 2022. All identified upgrades except the new 345-kV Luna to Sun Zia South line were designed to come in service in the 2025 timeframe. The proposal of a new line connecting Luna to Sun Zia South will accommodate incremental solar buildout and, hence, was expected to come online in the 2026–2030 timeframe. The key features of Plan 2 are:

- Create interconnection between existing 345-kV infrastructure to reinforce the delivery reliability within New Mexico.
- Connect high-capacity transmission paths in the key renewable development zones to the Sun Zia project for deliverability to the western states.
- Local reliability reinforcement driven by the overloading issues along the 115 kV system in central New Mexico and the 345-kV system from Guadalupe to Sandoval.

This transmission plan is characterized by varying voltage levels, constructed in different years. Construction of 383.4 new line miles and the upgrade of one existing substation of a 345-kV single-circuit transmission line are scheduled for 2023 through 2025. There are 9 new line miles (345-kV single-circuit) scheduled in 2028 through 2030. Construction of 23 new line miles and the upgrade of two existing substations for 345kV kV double-circuit transmission lines are scheduled for construction in 2023 through 2025. A total of 628 new line miles, two new substations, and an upgrade of one existing substation of 500 kV single-circuit transmission lines are further scheduled for 2023 through 2025.

Sun Zia was included as a firm project and served as an incremental interstate transmission path to the existing network in Collector Plan 2. The project provides up to 3,000 MW of transfer capacity. Consequently, the enhancement of local reliability reinforcement solely has been identified as needed in Collector Plan 2 for the centralized renewable siting scenario.

Reactive shunts (15 MVAr rating at 115 kV Phelps Dodge and 115 kV Apollo) are required additions not listed in the study Update report.

3.3 Collector Plan 3- Distributed Renewable Generation

Collector Plan 3 has been designed to support decentralized renewable capacity additions. All identified upgrades, except the new 345-kV Luna to Greenlee and 230 kV PEGS[6] to Ambrosia lines, were designed to come in service in the 2020 to 2025 timeframe[7].
The key features of Plan 3 are:

- Create an incremental series of upgrades to 345-, 230- and 115-kV circuits within New Mexico with low to moderate reserve-capacity levels for future renewable development.
- Allow existing 345-kV radial transmission lines to remain radial, with minimal impacts on in-state power delivery reliability.

---

[5]SunZia began planning, permitting and development activities in late 2008. It consists of two 500 kV transmission lines and related facilities; it will originate near Corona, NM at a new substation SunZia East, and span up to 520 miles to its western terminus at the existing 500 kV station Pinal Central near Coolidge, Arizona

[6] Prewitt Escalante Generating Station.

[7] ICF Page 81.

- Distribute transmission capacity across all renewable development zones.
- Upgrade existing line capacity from Rio Puerco and Ojo substations to support higher power inflow to Four Corners Hub.

This transmission plan is characterized by two 345-kV single-circuit builds and a 230 kV single- circuit build[8]. The development of 957 new line miles, one new substation, and an upgrade of six existing substations of 345-kV single-circuit is scheduled for construction in 2023 through 2025. Next, 110 new line miles and one new substation of 345-kV single-circuit is scheduled for construction in 2028 through 2030. The construction of 15 new line miles of 230 kV single- circuit line was scheduled for 2028 through 2030.

Reactive shunts (15 MVAr rating at 115 kV Phelps Dodge and 115 kV Apollo; 35 MVAr rating at 345-kV Gladstone) are required additions not listed in the study Update report.

[8] ICF Page 106.

3.4 Collector Design Robustness

ICF conducted a series of analyses to ensure the proposed Collector designs will operate within normal range under a range of expected future conditions; this can be accomplished by configuring robust power flow solutions. Two cases are discussed in this section: (1) Assessment of a new export Hub in southwest New Mexico with interconnection to an Arizona substation and (2) Transmission needs and associated impacts for ETA renewables diversion to New Mexico's in-state load centers. Each case analysis is described separately below.

3.4.1 Case 1: New Export Hub Springerville, NM

ICF's 2020 analysis proposed a new high capacity 345-kV transmission line connecting a third export Hub to allow power exchange with Arizona. There are currently two major export Hubs at New Mexico connecting the state to the neighboring markets: 345-kV San Juan/Four Corners Hub connecting Northern and Central New Mexico to Arizona, Utah, and Colorado, and 345-kV Greenlee Hub connecting southern New Mexico to Southern Arizona.

Operation of Springerville coal plant is expected to have a direct impact on the proposed Rio Puerco – Springerville 345-kV circuit. Generally, a ramp-down of the plant dispatch will promote New Mexico's renewable power to flow towards Arizona to serve the load customers as "displacement power". In the Update study, ICF simulated 2030 power flow cases with Units 2, 3 and 4[9] dispatched at 50% of their nameplate capacity. As a result, a 40-45% line loading was observed on the Rio Puerco – Springerville circuit.

Flow Control (PAR)

The proposed interstate 345-kV Rio Puerco – Springerville circuit will connect New Mexico's grid to the TEP transmission system in Arizona. ***ICF recommends installation of a 780 MVA Phase Angle Regulating transformer (PAR) to control inter-state power exchange.*** PARs are often used in power systems to control the active power flow (MW) in branches in meshed networks or to control the active power flow at the interface between large independent grids. By changing the effective phase displacement between the input voltage and the output voltage of a transmission line as needed, phase shifters enforce, block and revert power flows as well as reduce or eliminate loop flows. Phase shifters can rebalance line loading between parallel lines or network sections.

Retirement of Four Corners

In this study, RETA assumed retirement of Four Corners power plant. As a result, ***Collector Plans 1, 3 could be modified to replace the proposed Rio Puerco – Springerville 345-kV circuit with an upgrade of the existing 230-kV Rio Puerco – Ambrosia – Pillar – Four Corners corridor***. This 345-kV upgrade may be able to utilize the existing right of way along the 230-kV Rio Puerco – Four Corners corridor to avoid land acquisition and permitting challenges. It represents a feasible alternate solution to avoid construction of the Rio Puerco – Springerville 345-kV circuit in 2030 when Four Corners is assumed to be retired and frees up transmission capacity at the Four Corners hub[10]. Unless Four Corners is retired prior to 2030 or can be economically dispatched at low output level, ICF recommends future consideration of this alternative design.

Hub Utilization

To quantify the utilization of the export Hubs, export power flowing through those Hubs was analyzed, including power splits among the export Hubs in percentage of the total export flow. The following paths were included:

[9] Springerville Unit 1 is assumed to be retired by 2027.
[10] However, this upgrade will be dependent on the operational status of the Four Corners plant. If retirement is accelerated to mid-2020, ICF recommends future consideration of this alternative transmission design.

- Springerville Hub connecting New Mexico to Arizona
- 345-kV Springerville – Rio Puerco Circuit 1
- 345-kV Macho Spring – Springerville Circuit 1
- 345-kV McKinley – Springerville Circuit 1 & 2

- Four Corners/San Juan Hub connecting New Mexico to Arizona, Colorado and Utah
- 345-kV Four Corners – Cholla Circuit 1 & 2
- 500-kV Four Corners – Moenkopi Circuit 1
- 345-kV Four Corners – Pinto Circuit 1
- 345-kV San Juan – Hesperus Circuit 1

- Greenlee Hub connecting New Mexico to Arizona
- 345-kV Hidalgo – Greenlee Circuit 1
- 345-kV Luna – Greenlee Circuit 1

The proposed 500-kV Sun Zia transmission project included in the Collector Plan 2 directly connects New Mexico to southern Arizona and adds a fourth export path to send New Mexico's renewable energy to Arizona. Table 1 summarizes key results obtained from this analysis[11]. Total export (MW) is tabulated in last row, with percentage contributions listed under each export interconnection.

Table 1. Summary of New Mexico's 2030 Export Flows

Export Hub	Collector Plan 1	Collector Plan 2	Collector Plan 3
Springerville	25%	12%	21%
Four Corners/San Juan	45%	37%	50%
Greenlee	30%	22%	29%
Sun Zia	-	28%	-
Total Export MW	2,828	2,910	2,695

Note that 345-kV Springerville Hub substation is connected to New Mexico through three paths[12]: 345-kV Springerville – Rio Puerco (proposed,), 345-kV Springerville – Macho Springs and 345-kV Springerville – McKinley circuits. Power flows from New Mexico towards Arizona along all three paths and is included in the total export flow through Springerville. Four Corners/San Juan Hub is connected to the neighboring systems through multiple paths and the export share in the table above was calculated based on an aggregated export power flow along all paths.

Table 1 indicates comparable export share between Springerville[13] and Greenlee Hubs while the Four Corners/San Juan Hub still serves as the highest-utilized path to deliver renewable energy to neighboring markets. ***Retirement of the Four Corners coal plant releases transmission capacity through Four Corners Hub and allows more power to flow from New Mexico towards the 500-kV Moenkopi substation in northern Arizona***; this path provides direct 500-kV highway access to southern Arizona, Utah, and Nevada. The 500-kV system promotes higher levels of flow compared to the other export paths.

[11] The 230/115-kV Gladstone substation in northeastern New Mexico is connected to southern Colorado through the 230-kV Gladstone – Walsenburg circuit owned by TSGT. This circuit is not included due to relatively lower capacity compared to the other export paths.
[12] Collector Plan 2 does not include the Springerville Hub, instead it substitutes Sun Zia as the functional equivalent of an exporting Hub.
[13] Utilization of the Springerville Hub is lower than observed in ICF's 2020 study, mainly driven by the retirement of Four Corners power plant. Four Corners is a major electricity Hub in the Southwest connecting New Mexico with Arizona, California, Colorado, and Nevada through a 500-kV high voltage transmission path.

Flow Congestion

A transmission line that is operating at or above its rated capacity may exceed thermal, voltage and stability limits and is said to be congested. With New Mexico renewable sales into the neighboring markets, loading of the Arizona system will increase or approach significant congestion. ICF performed a qualitative analysis by comparing the line loadings of major transmission paths and each of three Collector Plans. This qualitative review indicates an increase in line loading along the following paths:

- 500-kV Moenkopi – Eldorado Circuit
- 230-kV Eagle Eye – Buckeye Circuit
- 500/345-kV Coronado Transformer
- 345-kV Springerville – Coronado Circuit
- 500-kV Navajo – Moenkopi Circuit
- 500-kV Westwing - Morgan Circuit

Most of the lines listed are key components in the 500-kV backbone transmission system connecting Arizona to neighboring states. No additional severe congestion issues were noted in Arizona. ***However, ICF recommends further analysis of line utilization to investigate the transmission performance in Arizona, Nevada and Colorado resulting from the additions of New Mexico renewable resources.***

3.4.2 Case 2: ETA Renewables Diversion to Load Centers

This case analyzes the performance of ICF's Collector designs by assuming 5,900 MW[14] of renewable is partially absorbed in-state; the 2020 study previously identified potential localized issues[15] resulting from the consumption of renewable energy at higher levels required by the ETA. To achieve that goal, renewable power totaling up to 40.1% [16]of the total renewable generation was forced to circulate within the state by replacing the local thermal generation from the retirement units. This change reduces thermal plant dispatch within New Mexico by 963 MW, a 50% reduction in generator output.

This analysis provides a high-level overview of potential renewable plant development and the grid's ability to deliver power to end-users. A utility-standard analytic method[17] was used to assess the power delivery performance of a subset of lines and renewable generators. Ten transmission lines and ten renewable plants were selected for this analysis; Table 2 summarizes the sample set.

[14] ICF's 2030 study case models summer peak conditions with solar operating at 100% rating and wind operating at 50% of the rating. Injected generation equals 4,550 MW.

[15] The observed overloads occur in the 115-kV transmission system with maximum overloads less than 120%; they can be mitigated by thermal plant re-dispatch and generation curtailment.

[16] After thermal redispatch, 2,727 MW of renewable generation is exported to out-of-state markets representing 60% of renewable generation; 1,823 MW is retained in-state.

[17] The method is called "shift factors"; it does not address congestion or other dynamics of how the grid will respond to large amounts of power injected.

Table 2. Sample Set (Renewable Plants, Transmission Lines

Sample set	Function/location
345-kV lines	Export/import: Four Corners, Springerville NM, Hildago
115-kV lines	Distribution: Santa Fe, Albuquerque, Las Cruces, Taos, Clayton (Rosebud), Alamagordo
Wind plants; rated 900 MW	345-kV source: Springer, Western Spirit, Blackwater
Solar plants; rated 1,850 MW	345-kV source: San Juan, Taiban Mesa, Macho Springs, McKinley, West Mesa, Arroyo, Blackwater

Note that all plants listed in Table 2 are connected to the 345-kV transmission grid while lines serve one of two functions, either to transmit power for 345-kV export/import or to transmit power on the 115-kV distribution grid serving load centers.

An increment of 10 MW was applied as the "shift" factor at each plant. The shift factor approach described above utilizes a simplification[18] of flow impact on the sample lines. ICF observed both positive and negative flows[19]. Additionally, selection of the sample set exhibited a major influence on reported results in this analysis. ***More analysis is required to confirm the selection of samples to properly capture New Mexico's grid dynamics.***

Flow from Renewable Plants

The total flow contribution to load centers and export paths were estimated from each of the renewable sources, and shortlisted the top five sources (ranked high to low flow) as summarized in Table 3[20].

Table 3. Power Flow from Renewable Plants

Plant Sample	Plants (Flow MW)	Source Quadrants
Highest Flow for Export	Taiban Mesa (20.9), Blackwater (18.8), Western Spirit (16.4), West Mesa (15.2), Springer (-4.8).	NE, SE, SW, NW, NE
Highest Flow to Load Centers	Arroyo (32.4), Springer (8.7), Blackwater (5.7), San Juan (5.3), Taiban Mesa (4.2).	SW, NE, SE, NW, NE

The total MW contribution was estimated by multiplying shift factor values by the total generation at each plant respectively. Table 3 indicates highest flow for both plant samples is ***primarily located in the Northeast and Southwest quadrants***. Also, the ranked list of plants indicates a large difference in power flows between the two plant samples. Generally, plants located in Central and Northern New Mexico are expected to contribute more power to the export lines as the typical flow direction observed is from plants towards load centers and export Hubs on the state border; the remaining plants are located downstream of the general direction of power flow. An observed disparity in these quantities suggests a mismatch in the

[18] Values derived by injecting 1 MW could be very different from the flow change by injecting 10 MW.

[19] Positive values indicate injection at the load center will contribute to customer load or power export, while negative values indicate a reduction of the same amount in line flow.

[20] To aggregate results from this analysis, New Mexico's grid is subdivided into four quadrants: Northwest; Northeast; Southeast; Southwest.

sampling set[21] occurred which could account for some differences in reported shift factor values[22]..

Flow to Load Centers

Similarly, plants that are closer to load centers and located upstream of flow are expected to contribute more renewable power to the load centers. Table 4 summarizes line flows summed to each load center.

Table 4. Power Flow to Load Centers

Load Center	Quadrant	Network features noted	Sum Flow MW	Base Flow MW
Albuquerque	NW	345-kV B-A, West Mesa, Sandia, Rio Puerco	37.7	75.2
Santa Fe		345-kV Norton, 115- to 46-kV only	3.3	23.5
Gladstone	NE	Springer 345-kV and Walsenburg in Colorado	10.6	-69.1
Taos		345-,115-kV Ojo and 115 kV Blacklake	-24.2	69.2
Alamogordo	SE	115-kV Carrizo radial line, 115-kV DonaAna and 345-kV Amrad	-2.2	59.5
Las Cruces	SW	115-Kv Arroyo, 115-kV Dona Ana and 115-kV Salopek	35	28.1
State-wide			60.3	186.4

The column "Sum Flow" tabulates power flow observed from shift factors, the column "Base Flow" tabulates power flow at each load center prior to application of shift factors. These results suggest the following observations: ***The northwest and southwest quadrants may exhibit higher efficiency in receiving renewable plant power while remaining areas are relatively inefficient.*** Both quadrants also exhibit network features which promote flow towards load centers, such as connectivity to the 345-kV system.

The main load centers and export hubs drive a general east-to-west power flow trend across the state. As a result, higher total flow was observed towards the western quadrants. General flow direction on lines located in the northeast and southeast quadrants exhibit the same trend[23]. ICF also observed examples in which monitored lines closer to the load center exhibit less responsive line flow changes in response to plant power injection. A trial-and-error approach was therefore applied to select plant-line pairings which exhibit higher response.

---

[21] As a result, ICF's findings in this analysis are only applicable to the reported pairings.
[22] The total power consumption of sampled load centers is approximately 908 MW; for the set of sampled plants, power injection into the grid equals 2,750 MW.
[23] For example, flows towards the Northwest quadrant on Clines Corner - Diamond Tails (Circuit 1) and Diamond Tails – Norton. Flows were observed leaving Northeast quadrant on Gladstone – Springer (Circuit 1) and Springer – RAINVL_T (Circuit 1).

4 Assessments and Case Studies

4.1 Southwest Power Pool SPP

In November 2020, SPP announced that several utilities would evaluate the benefits of placing western facilities under the terms and conditions of SPP's Open Access Transmission Tariff[24].

- Prospective western participants include Basin Electric Power Cooperative, Colorado Springs Utilities (CSU), Deseret Power Electric Cooperative, the Municipal Energy Agency of Nebraska, Tri-State Generation and Transmission Association, Wyoming Municipal Power Agency and the Western Area Power Administration (WAPA). WAPA's evaluation of full RTO participation in the Western Interconnection includes its Upper Great Plains-West region, Colorado River Storage Project and Rocky Mountain region.

- All these organizations except CSU joined SPP's Western Energy Imbalance Service (WEIS) Market on its Feb. 1, 2021, launch before announcing their intent to explore full western RTO participation. CSU anticipates joining the WEIS Market in 2022 and is also exploring RTO membership as part of this group of entities.

Prospective participants plan to execute a financial commitment agreement in April 2022 to initiate the western RTO expansion. SPP then plans to file tariff modifications with FERC in October 2022 with approval expected sometime in early 2023. Once approved, SPP will extend its RTO into the west March 1, 2024.

4.2 California ISO CAISO

CAISO has announced intentions to expand its ISO network to neighboring states to form a Western Interconnection RTO. In the past, CAISO has struggled to garner enough support in the California Legislature to pass a measure that would open its governance to representatives from other western states. However, CAISO continues to successfully expand its Western Energy Imbalance Market (WEIM) to include new members and is attempting to expand its market offerings through WEIM[25].

- In September 2021, the Bonneville Power Administration announced it would join the WEIM in March 2022.

- The Western Area Power Administration's Desert Southwest Region signed its own implementation agreement with the WEIM, putting the agency on track to join in 2023. By that time, the WEIM will consist of 22 members representing 84% of the West's load, CAISO estimates.

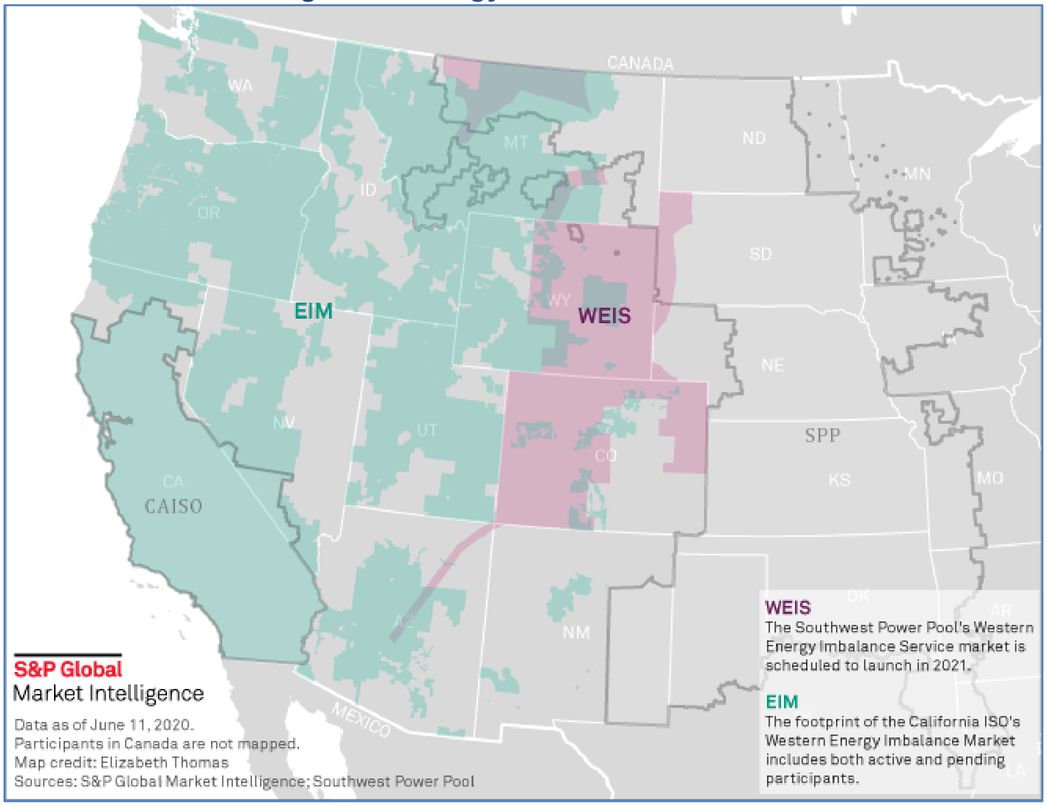
- CAISO's Board of Governors and the WEIM's Governing Body recently approved a plan that would delegate more authority to the Governing Body over issues affecting the WEIM, a move widely popular among Northwest utilities and power producers.

- CAISO has been working with WEIM participants on a proposal to introduce a day-ahead imbalance reserve product.

Figure 1 displays the extent of two competing energy imbalance markets planned for the western region.

[24] See Ref. 1.
[25] See Ref 2.

Figure 1. Energy Imbalance Markets



4.3 Regional Power Market Assessments

Western Markets Exploratory Group (WMEG)

Members of the informal Western Markets Exploratory Group (WMEG) are exploring the potential for a staged approach to new market services, including day-ahead energy sales, transmission system expansion, and other power supply and grid solutions consistent with existing state regulations[26]. The group hopes to identify market solutions that can help achieve carbon reduction goals while supporting reliable, affordable service for customers.

- The group, which began discussions this summer, includes Xcel Energy-Colorado (PSCo), Arizona Public Service, Black Hills Energy, Idaho Power, NV Energy, Inc., PacifiCorp, Platte River Power Authority, Portland General Electric, Puget Sound Energy, Salt River Project, Seattle City Light, and Tucson Electric Power. The participating utilities control "about 60 GW load," which alone could be a viable RTO.
- Many of the companies in the group are currently participating in or preparing to join the California Independent System Operator's Western Energy Imbalance Market or have announced plans to evaluate energy imbalance services.
- WMEG's discussions will not impact participation in or evaluation of those markets in the short-term, as the group is focused on long-term market solutions.

[26] See Ref. 3.

Western Flexibility Assessment

The purpose of this assessment was to investigate the flexibility of a future grid in which renewable resources are deployed at levels consistent with enacted and foreseeable public policy requirements of Western states. Findings suggest that near-term policy targets are achievable even if coordinated wholesale markets in the West do not materialize. However, the West will operate with a less flexible system with higher operational costs and emissions should coordinated markets not materialize in the next several years. In the long-term, results indicate that it will be very difficult, or at least extremely costly, to achieve Western policy targets without broad coordination of wholesale markets.

Colorado Markets Study

In a 2021 study conducted by Siemens on behalf of the Colorado PUC[27], it was reported that Colorado could reduce statewide system costs by 7%-9% by fully integrating its utilities with SPP, a hypothetical WECC RTO, or both.

- Across the three scenarios DA and RT variable costs decreased by 7%-15%. Fixed and capital recovery costs decreased by 6%-8%

- All three RTO structures, WECC, SPP, and Split, showed a more significant opportunity for cost savings for Colorado utilities than just imbalance market participation.

- The primary source of cost savings consistently came from the reduction in the requirement for local energy storage capacity.

- Colorado also experienced increased energy market sales through participation in day-ahead markets in the RTO scenarios.

Given the proximity of Colorado to New Mexico, the similarity between the state's clean energy targets and their existing wholesale market structures, the findings of this study may be of value to New Mexico regulators when considering RTO integration.

4.4 Texas CREZ

After first wave of wind development in the early 2000s, West Texas began to experience issues of congestion and curtailment on its power grid. Further investment in wind projects in the resource-rich region stopped given the lack of transmission to accommodate new projects. In order to recover the costs of new lines, transmission utilities had demonstrated that the line would be used and useful. By precedent, a financial commitment from the generator that would connect to the new line was required. In 2005 the state legislature gave PUCT statutory authority to designate Competitive Renewable Energy Zones (CREZ) in resource-rich parts of the state, and to approve transmission projects serving those zones even if they do not serve the utility's needs. By settling the question of need and guaranteeing cost-recovery, CREZ's unlocked a regulatory path for approving high voltage transmission for the purpose of integrating renewables[28].

Parties nominated CREZs and demonstrated financial commitment and the first hearing was held in June 2007. In Oct. 2007, the PUCT issued an Interim Order which designated five areas as CREZ and requested that ERCOT and stakeholders develop transmission plans for four scenarios ranging from 12,000 to 24,000 MW of wind capacity. PUCT staff developed a schedule to consider the routing applications for 72 new circuits. Transmission Service Providers studied potential routes, developed testimony, and worked with property owners. Figures 2,3 display key features of the CREZ project.

---

[27] See Ref. 4.
[28] See Ref. 5.

Figure 2. Texas CREZ and Line Routes

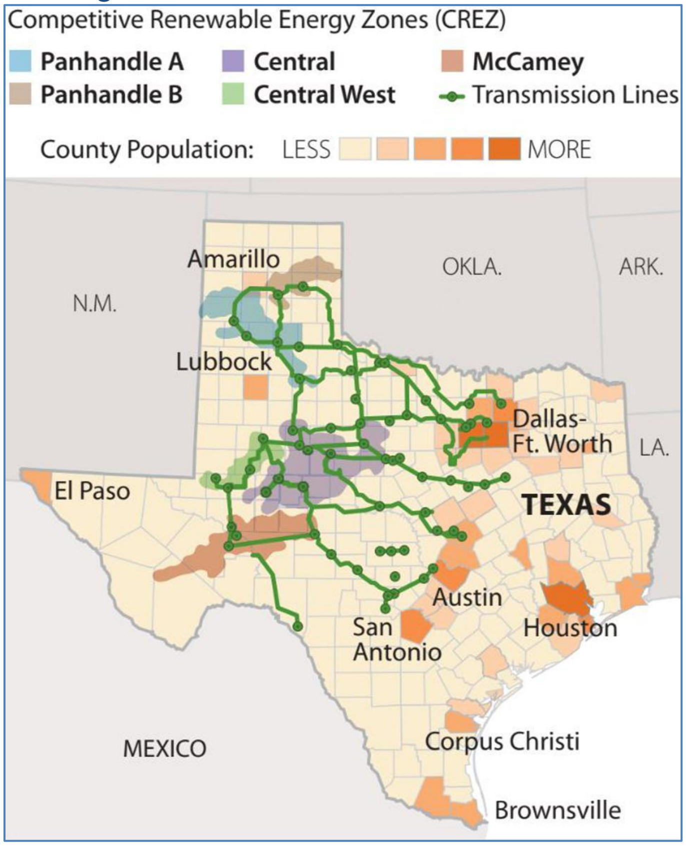
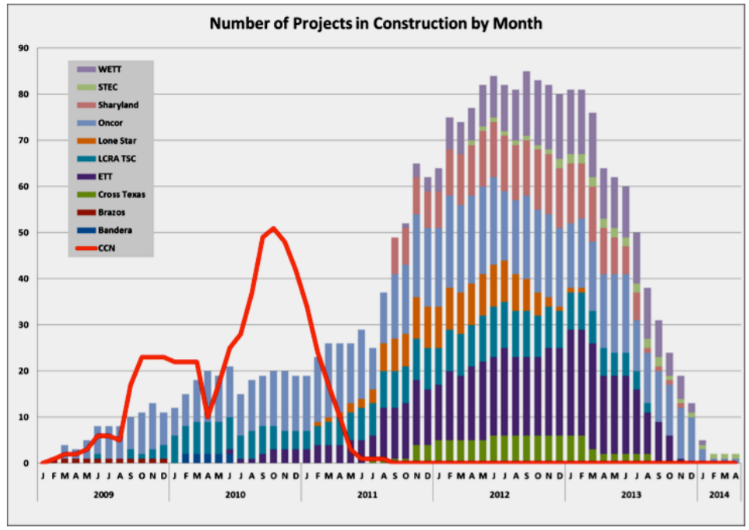


Figure 3. Texas CREZ Buildout



Source: ERCOT, August 11, 2014.

The success of CREZ can be attributed to several factors:

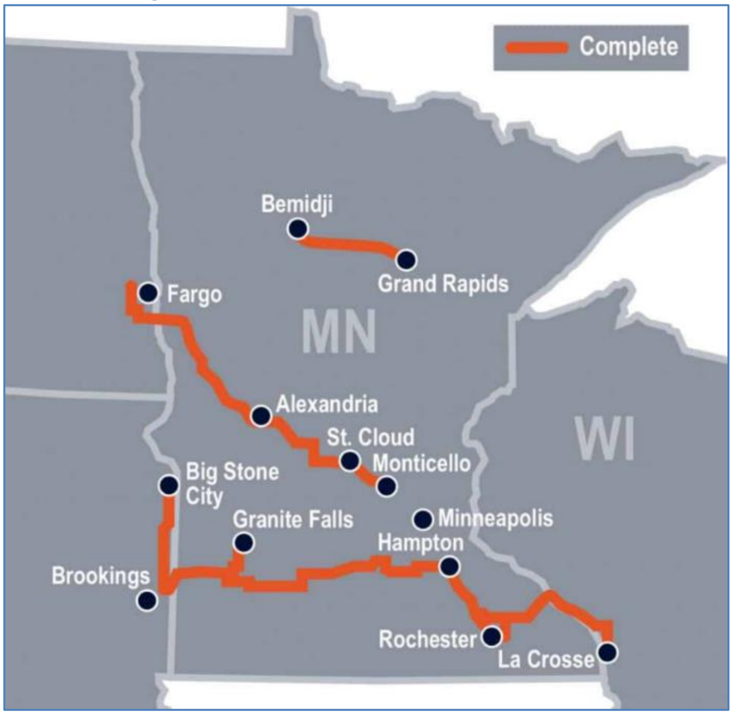
- The CREZ project combined economic development, development of in-state energy resources, and development of green energy
- There were few barriers to land development in west Texas; the geographic scope of the ERCOT system lends itself well to regional planning
- The regulatory processes and technical planning analyses moved forward in tandem; Cost allocation formulas were settled early
- Wind integration was facilitated in ERCOT by a large fleet of flexible natural gas, combined-cycle generation, and by system-wide dispatch at 5-minute intervals
- The overall risk of the project was controlled by taking small steps, and by maintaining the ability to change course if needed

Construction of the CREZ facilities was complete by January 31, 2014. CREZ projects were designed to serve approximately 18,500 MW of renewable capacity including approximately 3,600 right-of-way miles of 345-kV with a $6.9 billion project cost.

4.5 CAPX2020

A group of 11 transmission-owning utilities in Minnesota, the Dakotas, and Wisconsin formed the CapX2020 initiative to upgrade and expand the electric transmission grid to ensure continued reliable and affordable service[29]. Figure 4 displays key features of the CAPX2020 project.

Figure 4. CAPX2020 Transmission Lines



The 800-mile, $2 billion investment includes four 345-kilovolt transmission lines and a 230-kilovolt line. The CapX2020 transmission projects were completed in 2017 and are delivering 3,600 MW of wind energy.

The projects benefited from a new law adopted by the Minnesota Legislature in 2005 that encouraged investment in strengthening power delivery systems by, among other things, allowing investor-owned utilities to recover costs as lines are being built.

4.6 MISO Multi Value Projects (MVP)

MISO MVPs refer to network upgrade projects that satisfy multiple transmission criteria. The projects are regional in nature and enable compliance with public policy requirements, and/or provide economic value. The costs of these projects are entirely socialized across load.

In 2011, MISO approved its first MVP portfolio: 17 high-voltage transmission lines spanning nine states. Developed in collaboration with stakeholders over more than eight years and in anticipation of increasing demand for wind energy. Goals established for the project include:

- Provide cost savings to ratepayers by relieving congestion and reducing the cost to

[29] See Ref. 6.

deliver electricity to end use customers.

- Improve system reliability and help states cost-effectively achieve state public policy requirements

- Capable of delivering 25-29 GW of renewable energy to Midwestern states.

In its 2017 Triennial Multi-Value Project Review, MISO reported that its MVP Portfolio provides benefits in excess of its costs, with its benefit-to-cost ratio ranging from 2.2 to 3.4; an increase from the 1.8 to 3.0 range calculated in MTEP1, it creates $12.1 to $52.6 billion in net benefits over the next 20 to 40 years. This project enables 52.8 million MWh of wind energy to meet renewable energy mandates and goals through year 2031. Sixteen of the seventeen proposed projects have been completed between 2013 and 2019.

The final transmission project is delayed due to multiple lawsuits challenging it at the state and federal level by the Driftless Area Land Conservancy, the Wisconsin Wildlife Federation and several counties and municipalities. The groups have challenged the permit issued by the Public Service Commission of Wisconsin, claiming that two members of the commission should have recused themselves from the decision due to perceived conflicts of interest on the project.

4.7 New England – Quebec Transmission Expansion

Northern Pass

A highly controversial proposal to run a new 190-mile power line from Canada, through New Hampshire. The project would support 1,092 MW of clean hydroelectric generation from Quebec through New Hampshire to Massachusetts.
Eversource, the project developer, proposed 80 percent of the line to be sited in existing right of ways or buried underground to avoid disruption.

The project faced years of opposition from New Hampshire residents who believed the project would harm property values and tourism in the White Mountains. Conservation groups also opposed the project. The project was awarded a contract through Massachusetts but failed to meet milestone requirements due to delays.
In July 2019, the NH supreme court upheld the project's rejection by the state's Site Evaluation Committee.

Figure 5 displays key features of the Northern Pass project.

New England Clean Energy Connect

This transmission project in Maine designed to import Canadian hydropower from Quebec dams. The project would be constructed by Central Maine Power. The project was awarded the Massachusetts contract after Northern Pass failed to meet milestone schedule requirements and was viewed as more likely to be permitted. Hydroelectric generation on the project would be enough to meet 17% of the Massachusetts's yearly demand with a low-carbon, baseload resource[30].

The project faced opposition from owners of existing power plants in New England, private residents, conservationists, and state lawmakers in Maine. Maine voters elected to block the construction of high-impact transmission lines in the state in a November, 2021 ballot initiative. Central Maine Power is likely to challenge the ballot outcome in court.

Figure 6 displays key features of the NE-Quebec transmission project.

[30] See Ref. 7.

Figure 5. Northern Pass Project

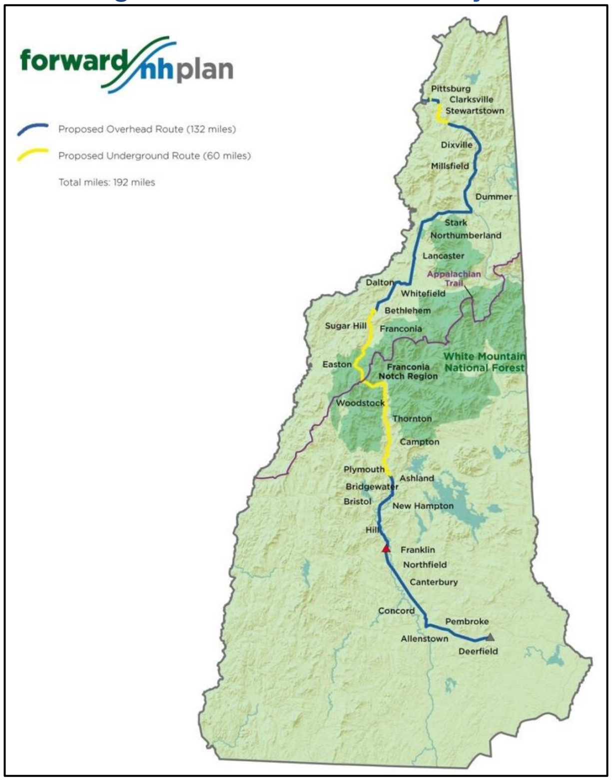
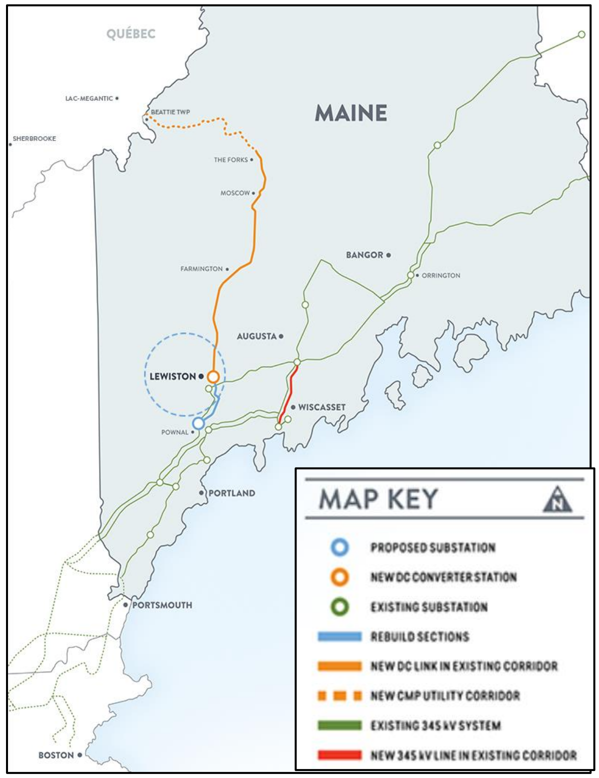


Figure 6. NE-Quebec Project



Multiple proposed transmission projects have been fueled by Massachusetts's strategy for clean energy goals which includes importing increasing amounts of hydropower from Canada[31]. Massachusetts developed this Strategy as part of the 2008 Green Communities Act. The strategy incented many private developers to consider projects which would support the round-the-clock power supply. While the Northern Pass and NECEC received contracts from Massachusetts, neither have been successful for several reasons:

- While the primary motivation for the transmission lines has been supporting Massachusetts, the lines would run through states to its north including New Hampshire, Vermont, and Maine. Running through highly forested areas.
- Difficulty in permitting and local opposition has been a stumbling block for all proposals to date.
- In addition to concerns for the disruption of land and wildlife, local opponents are concerned that the benefit of the lines would only materialize out of state.
- Local opponents have also voiced concerns regarding whether importing from Canada would result in greater fossil emissions elsewhere in Canada through increased demand.
- While the ISO New England has an active transmission planning process for reliability and efficiency which engages multiple stakeholders, projects such as these fall outside of the ISO-NE's processes.

[31] See Ref. 8.

5 URL References

1. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/across-the-divide-spp-faces-a-challenger-in-bid-to-form-western-rto-56967190

2. https://www.westerneim.com/Pages/About/default.aspx

3. https://static1.squarespace.com/static/59b97b188fd4d2645224448b/t/6148a03ea5c43d63b2873506/1632149569046/Final+Roadmap+-+Market+and+Regulatory+Review+Report+210730.pdf

4. https://www.ourenergypolicy.org/wp-content/uploads/2021/12/C21-0755A_19M-0495E1.pdf

5. https://www.energy.gov/sites/prod/files/2014/08/f18/c_lasher_qer_santafe_presentation.pdf

6. https://gridnorthpartners.com/projects/

7. https://www.nhpr.org/northern-pass

8. https://www.necleanenergyconnect.org/map

\