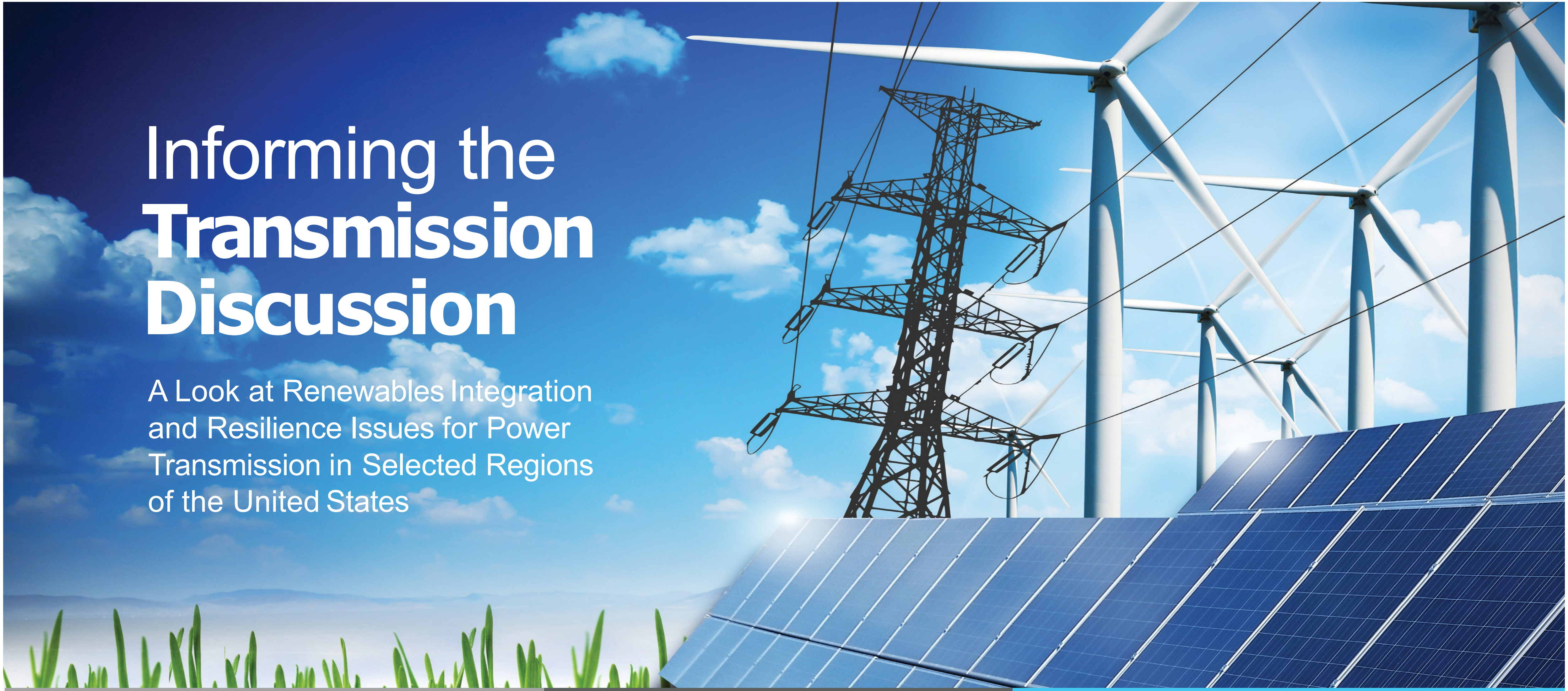
# Informing the **Transmission Discussion**

A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States



January 2020

scottmadden
MANAGEMENT CONSULTANTS

WIRES®

# Interregional Considerations

# Contents

# Filling Gaps: Considering Interregional Issues

**Need to Augment View with an Interregional Lens**

- **Regional legacy:** Regional characteristics help provide important context to what kinds of demand, resources, and resiliency risks are peculiar to a geography. However, those characteristics are driven by the historical growth of the bulk power systems in those areas—that is, the legacy transmission topography of a given area. Some of these legacy regional configurations are historical artifacts of grid and economic development, ownership (municipal, cooperative, or investor-owned utilities), and industry consolidation. In addition, a regional view does not fully acknowledge the potential for super-regional or interconnection-wide opportunities for grid support and renewable integration.
- **Pros and cons:** Of course, there are competing considerations with increasing linkages between regional grids. For resilience, the ability to island smaller grid components in the event of a major reliability event can be useful. Indeed, regional reliability coordination had its origins in a widespread power outage in 1965, and risks still existed in 2003 when the northeastern United States and southern Canada had a blackout that affected 50 million customers. Those risks—in part caused by system maintenance and lack of system understanding and situational awareness—are being mitigated through NERC standards.
- **Resilience and regionality:** However, interruptions due to resilience events can also be ameliorated by increasing access to power supply when local resources are inadequate or unavailable. Particularly as resource mixes in areas such as New England have grown more dependent upon gas-fired generation, increased access through transmission connectivity to other resources outside its control area, imported from adjacent regions, can enhance resilience against fuel-related risks.
- **Resource locations:** Another limitation of the regional view is that the regional location of resources for power production (fossil-fuel resources, solar irradiance, and productive wind speeds) may not be near major demand areas. For example, while Marcellus and Utica gas is plentiful in the Appalachian Basin areas of Pennsylvania, Ohio, New York, and West Virginia, some large demand areas lie west in the Great Lakes region and east along the Atlantic seaboard. While those resources can be piped to end-use demand locations, including power generation near load, pipeline development has become a protracted process. Further, solar and wind resources cannot be transferred between regions except through power transmission facilities.
- **Role of interregional linkages:** Consideration, then, needs to be given to how interregional approaches may enhance either renewable integration, specifically access to remote resources, and/or resilience through, for example, access to diverse resources.

# Filling Gaps: Considering Interregional Issues (Cont'd)

**Potential Benefits of an Enhanced Transmission Footprint**

- **Foundational principle:** In the wake of the Northeast blackout of 1965, which affected 30 million customers over an 80,000 square mile region, the Federal Power Commission (now FERC) concluded: "Isolated systems are not well adapted to modern needs either for purposes of economy or service" and recommended "…an acceleration of the present trend toward stronger transmission networks within each system and stronger interconnections between systems in order to achieve more reliable service at the lowest possible cost." This remains a foundational principle for interregional links. In particular, according to WIRES and The Brattle Group, "If an adverse event overwhelms the regional ability to absorb or manage the event, interregional transmission connections allow regional operators to 'lean' on neighbors for emergency support.... Recognition that stronger interregional transmission links could have prevented these outages led to the expansion of the transmission grid into the large regional networks we have today." (WIRES Grid Resilience Docket Comments, at Appendix p. 5)
- **Load diversity:** Even within large regions, enhanced access to resources across a wide geographic area can provide benefits that reduce the cost of serving customers. PJM recently studied the value of transmission within its footprint. It determined that with broader market integration, the system benefited from load diversity and generator diversity. Diversity of customer demand (or load diversity*) across the PJM region has increased from 1% to 3.5% since 2002, allowing resources to be reallocated and sent from a lower-demand zone to a higher-demand zone during peak periods. This increases reliability and captures larger economies of scale, including lowering required levels of capacity reserves (by about 2,500 MWs in PJM), thus reducing customer costs. (Benefits White Paper, at pp. 4, 19–20).
- **Generator diversity:** Benefits of generator diversity are manifested in several ways. There is a capacity benefit in that there is a wider pool of resources with diversity in fuel type, size, flexibility and duty cycle, and location that allows the next lowest cost resource to serve load. This wider pool also potentially provides less correlation of maintenance and forced outages, leading to greater overall availability. Those benefits are dependent upon fuel diversity, including pipeline, rail, solar irradiance, and wind availability.

*Note: Load diversity is defined as the sum of all zonal non-coincident MW annual peaks minus RTO coincident MW annual peak.

# Filling Gaps: Considering Interregional Issues (Cont’d)

**Unique Characteristics of Renewable Resources**

- **Less predictable in real time:** Renewable energy resources are variable energy resources, uncertain both in output and timing versus conventional thermal resources, and inherently less predictable. These resources, however, have low or zero marginal cost, so their energy output is attractive from an economic standpoint. The environmental characteristics of this energy are attractive as well. Power systems have been designed to manage variable nature of loads, but only recently have supply resources included a significant amount of variable resources in some regions, posing challenges for system operators.
- **Solar variability and coincidence with load:** Despite its variability, renewable resource output is not completely unpredictable. And their variability differs both daily and seasonally. Solar energy output over the course of a day is predictable because solar movement is well-understood as is its seasonal variation (e.g., fewer daylight hours in winter, more daylight hours in summer). Less predictable is the presence of clouds that may pass over solar power plants and reduce output for periods of time, typically for shorter intervals (minutes versus hours). Cloud cover can rapidly reduce output in individual photovoltaic (PV) systems. Overall grid impacts are minimized, however, when solar projects are spread out geographically to account for both solar movement and weather systems. Solar output is greater during the middle of the day, sometimes coincident with peak load.
- **Wind variability and less coincidence with load:** By contrast, wind can be less predictable than solar, but still subject to daily and seasonal patterns. Wind energy is often more abundant during the nighttime hours and the wintertime. Changes in wind output from a particular facility, however, can occur quickly and last for hours as weather systems move through an area. The non-coincidence of load and wind—that is, relatively high-wind production during low-load nighttime hours—creates challenges for grid operators and other generators. In high-wind penetration areas, thermal-baseload generation may have to be “turned down” or run at minimum-operating levels.
- **Scale and potential ramping needs:** Another important differentiator between wind, solar, and other resources is scale. A typical wind farm (i.e., an incremental unit of independent capacity) in the United States ranges from 10 MWs to 300 MWs. Utility-scale solar capacity is typically in smaller increments, mostly in the 5 MWs to 100 MWs range. This affects the amount of ramping capability, up or down, required to meet demand and maintain system integrity should those resources become unavailable or provide unusually large amounts of output.

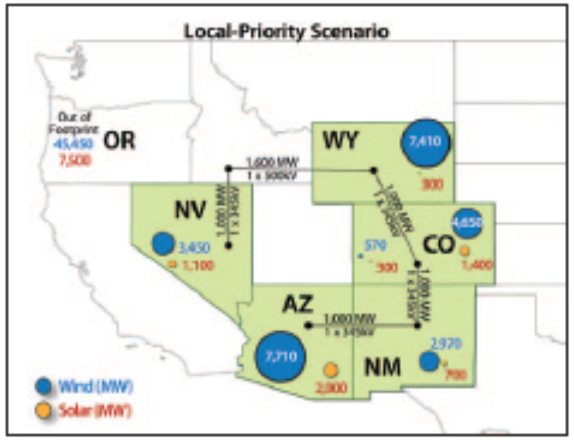
**Many have observed that a diversity of technologies and geography improves the ability of renewable resources to mitigate the risk of losing load. Transmission enhancements can provide the linkage to provide that diversity across a broader footprint and improve renewables’ load-serving capability (particularly in high-penetration scenarios), as well as providing access to needed ramping capability and reliable interconnection of new resources.**

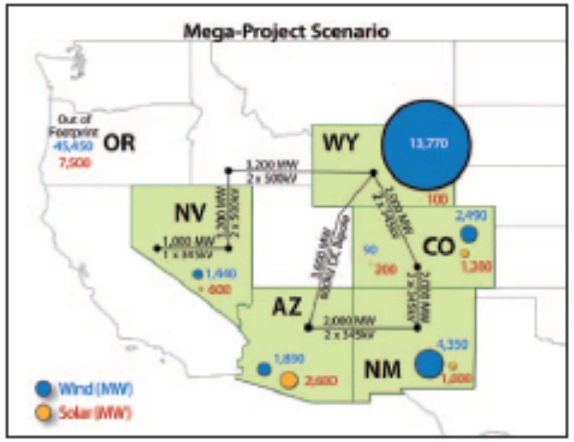
# Renewable Integration Studies

### Western Regional Analysis

- The electric industry has studied renewable integration for a number of years, in the wake of state policy changes incorporating renewable portfolio standards (RPS), declining installed costs for renewable resources, and industry and stakeholder interest in development of renewable resources, including replacing retiring thermal units. Those studies looked at renewable penetrations at various levels by interconnection.
- In a 2010 report, well before the current proliferation of variable energy resources, the National Renewable Energy Laboratory (NREL) looked at various scenarios of integrating up to 35% of wind and solar power in the Western grid, specifically in the WestConnect footprint. That study examined the potential for penetration of up to 30% wind and 5% solar energy for load and implications for particular technical and physical barriers for transmission system operations. Although it was not a transmission planning or reliability study, it proves instructive for understanding interregional needs. NREL found that integration of 35% wind and solar energy could be achieved if the following changes, among others, were made:
  - **Substantially increase balancing area cooperation or consolidation, either real or virtual.** Balancing area cooperation is essential since aggregating diverse renewable resources over larger geographic areas reduces the overall variability of the renewables, aggregating the load reduces the overall variability of the load, and aggregating the non-renewable balance of generation provides access to more balancing and more flexible resources. This is particularly true for smaller areas. Balancing area cooperation leads to cost savings because reserves can be shared.
  - **Build transmission as appropriate to accommodate renewable energy expansion.** The study did not find a need to build-out interstate transmission at lower penetrations or where more locally sourced renewables were preferred or prioritized. However, where targets were met using an area-wide evaluation of the best available solar and wind resources, additional transmission totaling 2,100 to 6,900 gigawatt-miles would be needed, mostly to bring Wyoming wind resources to load centers (see figure at right).

**Two Scenarios Show Need for More Transmission to Integrate Wind and Solar**




Source: NREL

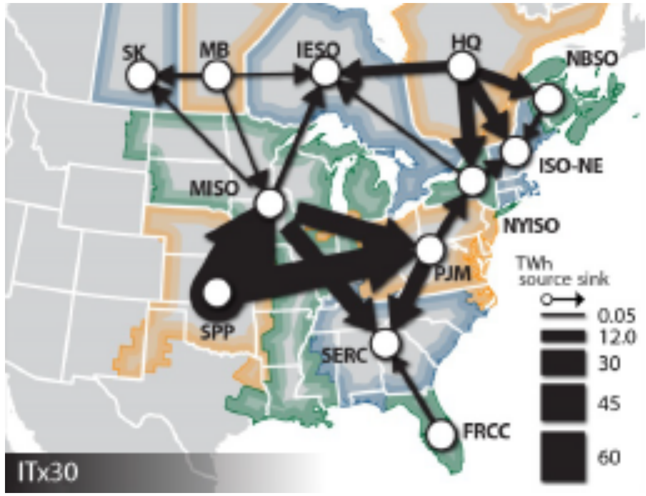
Sources: NREL, Western Wind and Solar Integration Study (May 2010)

# Renewable Integration Studies (Cont'd)

**Eastern Regional Analysis**

- In 2016, NREL performed a similar analysis of high-renewables penetration in the Eastern Interconnection (EI): the Eastern Renewable Generation Integration Study (ERGIS). ERGIS was an operational impacts study; it was not designed to identify the most optimal mix of generation and transmission or analyze dynamic power system characteristics. It used a scenario-based approach to understand system-wide operational impacts of high amounts of variable generation on the EI under different transmission grid configurations.
  - ERGIS used different levels of renewable target penetration levels and assumed transmission capacity at different levels from minimal to substantial, based upon scenarios for needed transmission identified by the Eastern Interconnection Planning Collaborative. Those transmission scenarios were (i) business as usual (limited renewable or carbon policy requirements), (ii) a national RPS of 30%, and (iii) a national carbon constraint. While current national policy does not embrace (ii) and (iii), selected state policy action provides some momentum toward scenario (ii), which can be instructive.
  - The NREL analysis found the following in high-penetration scenarios:
    - As coal and gas combined cycle units are displaced by increased wind and solar, daily operational patterns change, with increased ramping before and after peak solar generation. These operational impacts are greater where there is more solar and less interregional transmission.
    - Daily transmission flows between regions change more as more renewables are added to the system, in part due to assumed increased transmission build-out, but also seen at high-renewable penetration levels.
    - One caveat to the study's analysis was that it assumed that all areas in the EI possessed characteristics of a structured market. However, the EI is comprised of both organized and vertically integrated markets, which may have different incentives for power exchanges.

**Potential Net Energy Interchange in 30% Renewables, HVDC-Enabled Scenario**




Scenario above:
- About 30% utility-scale variable generation (25% wind, 5% solar)
- Emphasis on the best wind and PV resources in the U.S. EI
- Assumed interregional transmission expansion with large high-voltage direct current (HVDC) lines (2 lines x 3.5 GWs each) between
  - SPP and PJM
  - MISO and PJM
  - Western MISO and Eastern MISO

Source: NREL

Sources: NREL, Eastern Renewable Generation Integration Study (Aug. 2016)

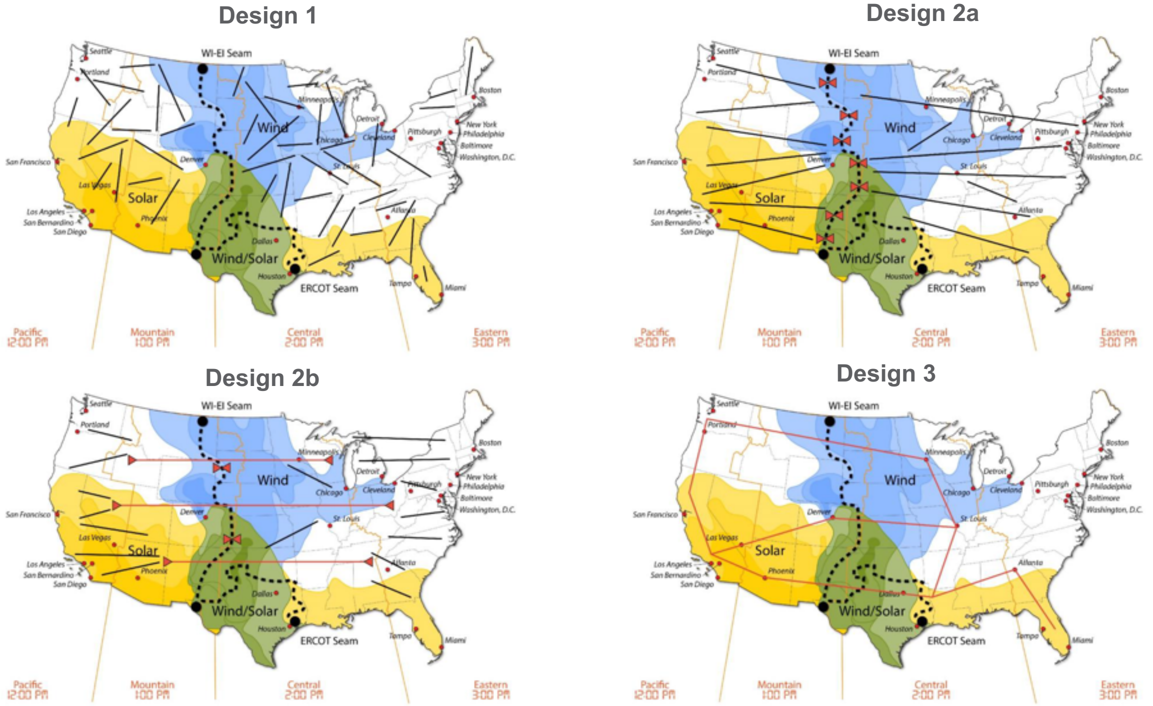
# Renewable Integration Studies (Cont'd)

## Interconnection Seams Study

- In 2018, NREL presented analysis of several scenarios for U.S. grid design, with consideration given to moving locationally concentrated variable energy resources (specifically wind and solar) to demand centers. The analysis considered potential movement of resources across interconnections (East, West, and Texas). Scenarios ranged from replacement of existing AC facilities at current capacity levels with new transmission and generation optimized to minimize system-wide costs to a national scale high-voltage DC network (see maps at right). Note that only 1,300 MWs of capacity exists joining Eastern and Western Interconnections.
- NREL's preliminary results found that increased capacity, including capacity across the interconnection seams, has a positive benefit-to-cost ratio and provides production cost savings from $800 million to $2.5 billion under current policy (i.e., no national carbon tax and RPS as of 2017). Substantial AC transmission capacity is added in all cases.
- The analysis also found that the system is reliable from a resource adequacy perspective, and all load was met under N-1 constraints. Additional analysis for reliability and resilience is required.
- The study, however, made certain assumptions, including a centralized dispatch approach to modeling (versus real-world regional dispatch decisions) and that economic transmission is able to be constructed. It also modeled a single year and did not perform a probabilistic analysis.

**While only a modeling exercise, the seams study highlights the potential for increased transmission capacity to provide cost savings opportunities through better delivery of renewable resources to market.**

## Design Alternatives for NREL Interconnection Seams Study*




| 1 | 2a | 2b | 3 |
|---|---|---|---|
| Existing B2B facilities are replaced at their current (2017) capacity level and new AC transmission and generation are co-optimized to minimize system-wide costs. | Existing B2B facilities are replaced at a capacity rating that is co-optimized along with other investments in AC transmission and generation. | Three HVDC transmission segments are built between the Eastern and Western Interconnections, and existing B2B facilities are co-optimized with other investments in AC transmission and generation. | A national scale HVDC transmission network, Macro Grid, is built and other investments in AC transmission and generation. |

Source: NREL

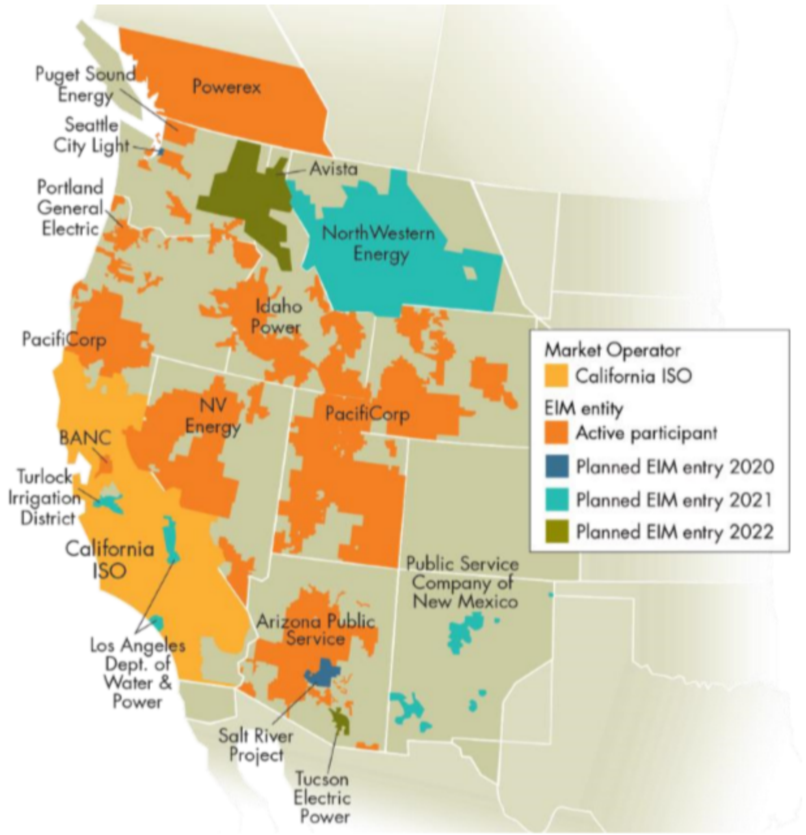
Notes: *Maps show high-solar and wind resource regions; cities shown are Top 25 U.S. population centers.
Sources: NREL Interconnection Seams Study, Presentation by A. Bloom, TransGrid-X Symposium (July 26, 2018)

# Case Studies

### Western Energy Imbalance Market

- Ambitious California clean energy goals: California was an early actor on renewable energy goals and has increased its already ambitious renewable energy goals to target 60% of its energy needs from renewables by 2030 and 100% carbon emissions-free energy by 2045. In pursuit of those goals, significant amounts of utility-scale and distributed energy resources (DERs), largely solar, have been installed on the system, administered by the California ISO (CAISO).
- Ramping and curtailment: As these resources have increased, net load (load less utility-scale wind and solar output) has seen dramatic drops coinciding with the solar cycle, dropping in early morning and rising significantly in late afternoon, with significant solar energy surplus during the middle of the day, particularly in low-load seasons of spring and fall (known as the “duck curve”). CAISO has had to curtail solar output for system stability in those overages. In addition, as thermal generation has been retiring, the steep ramps in late afternoon/early evening have created increased demand for ramping capability. Steadily decreasing net load (see next page) exacerbates these challenges.
- Imbalance market formed: CAISO formed the Western Energy Imbalance Market (WEIM) with northern neighbor PacifiCorp in late 2014. The WEIM is a real-time, five-minute market that uses “as available” transmission to move energy across a larger geographic area—and different time zones—allowing for more flexibility in scheduling and dispatching. The WEIM covers eight western states and more than half of the real-time energy in the region. As of August 2019, there are nine active participants, with eight more pending. There is some discussion of potentially expanding the market to include day-ahead transactions.

### WEIM Market Participants (Current and Pending)




Source: California ISO

Sources: Western Energy Imbalance Market website, at www.westerneim.com

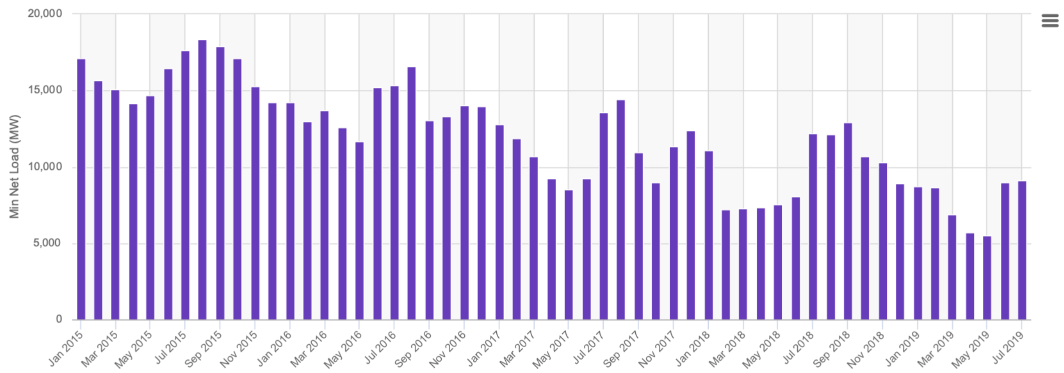
# Case Studies (Cont'd)

## Western Energy Imbalance Market (Cont'd)

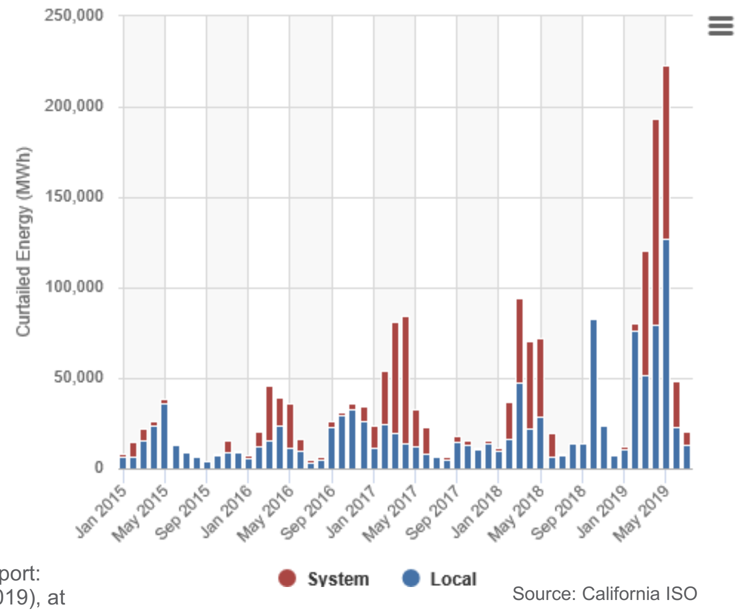
- **Savings and benefits:** The reach of resources across a wider area has generated benefits and savings related to uncurtailed renewable energy, including hydro and wind power from the Northwest. Savings from the WEIM since its inception total more than $700 million through Q2 2019, growing as participation in the WEIM as expanded. In Q2 2019, nearly 57,000 metric tons of $CO_2$ emissions were avoided through avoided curtailment and an estimated 45% reduction in flexibility reserves across the WEIM footprint.
- **Continued needs:** Despite this growth, California has seen a growth in economic curtailment of resources (solar, mostly), attributable to a mix of local and system conditions. This could signal opportunity for transmission expansion as well as increasing membership in WEIM.
- **Alternative approaches:** California system operators and state energy agencies are also considering other approaches to managing variability of increasing energy storage, energy efficiency, and demand response systems so that energy users can reduce use when the grid is low on supply; offering time-of-use rates that better match energy production times and are an incentive to reduce energy use; integrating electric vehicles and encouraging owners to charge when supply is high; and improving flexibility of power plants.

**WEIM demonstrates that access to and high utilization of transmission resources across a large footprint with variable energy resources increase its market reach. Organized Eastern power markets have had real-time markets for some time, and congestion costs signal the opportunity to invest in transmission upgrades to access more diverse resources.**

**CAISO Monthly Minimum Net Load (Jan. 2015 – July 2019)**




**Monthly Economic Curtailment in the WEIM 5-minute Market (RTD) by System Condition**




Source: California ISO

Sources: Western Energy Imbalance Market website, at www.westerneim.com; CAISO, Western EIM Benefits Report: Second Quarter 2019 (July 31, 2019); California ISO, Monthly Renewables Performance Report (July 2019), at http://www.caiso.com/Documents/MonthlyRenewablesPerformanceReport-Jul2019.html

# Case Studies (Cont'd)

**European Grid Expansion**

- **Ambitious renewables goals:** In Europe, countries have begun a process of aggressively shifting to a generation mix that incorporates significantly more renewables. For example, Germany's energy transition has reduced nuclear-generating capacity and seeks to reduce its coal-fired generation, supplanting both with wind, solar, and imported hydro.
- **Resource location:** Renewable resources, however, are not evenly distributed through the continent. Large amounts of offshore wind and hydro are in the north and northwest with solar potential in the south.
- **Planning for uncertain grid characteristics**: In addition, grid planners have to deal with planning uncertainty for new demand sources (electric heat pumps and electric vehicles) and distributed resources. Planners also have to deal with declining levels of system inertia in areas like Ireland, which are small, weakly interconnected, and have abundant variable energy resources.
- **EU interconnection target:** One approach to grid integration has been the European Union's (EU) target of 10% interconnection by 2020, moving to 15% by 2030. Under this target, each EU member state should have in place "electricity cables" that allow at least 10% of the electricity that is produced by their power plants to be transported across its borders to its neighboring countries. Expected interconnection levels for 2020 range from 12% to 59%. This integration is being accomplished through "projects of common interest" to increase grid reinforcement.
- **Grid scenario planning:** ENTSO-E, the European electric system operator, uses scenario-based planning to develop 10-year network development plans. Key metrics it uses in evaluating options include unserved energy (load), curtailed energy, $CO_2$ emissions, cost differentials between regions (average hourly cost and marginal cost yearly average), and cross-border and country-internal bottlenecks. In its most recent plan, ENTSO-E looked out to 2030 and 2040, evaluating market evolutions options, such as steady renewables growth (but short of 2050 climate targets), large-scale renewables growth, and increasing distributed generation (e.g., small-scale decentralized generation, batteries, and fuel switching). Scenarios considered moving from about 15% wind and solar continent-wide in 2020 to around 30% by 2030 and 37% to 50% by 2040 (ENTSO-E TYNDP 2018 System Needs Analysis, at p. 36). **Its analysis showed that internal reinforcements and interregional capacity increases would save customers €43 billion per year versus less integration.**

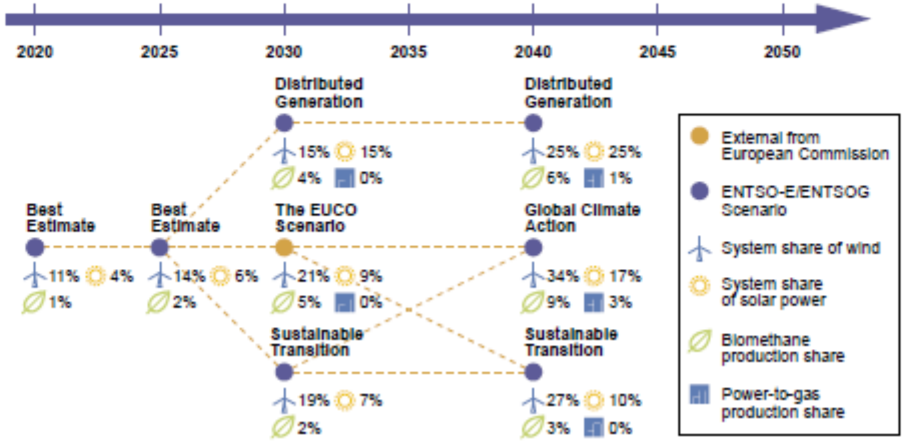
Sources: ENTSO-E, European Power System 2040: Completing the Map, Ten-Year Network Development Plan, 2018 System Needs Analysis (Feb. 2018); ENTSO-E, TYNDP 2018 Executive Report: Connecting Europe: Electricity 2025-2030-2040 (Dec. 2018); European Commission, Communication on Strengthening Europe's Energy Networks, COM (2017) 718 (Nov. 23, 2017)

# Case Studies (Cont'd)

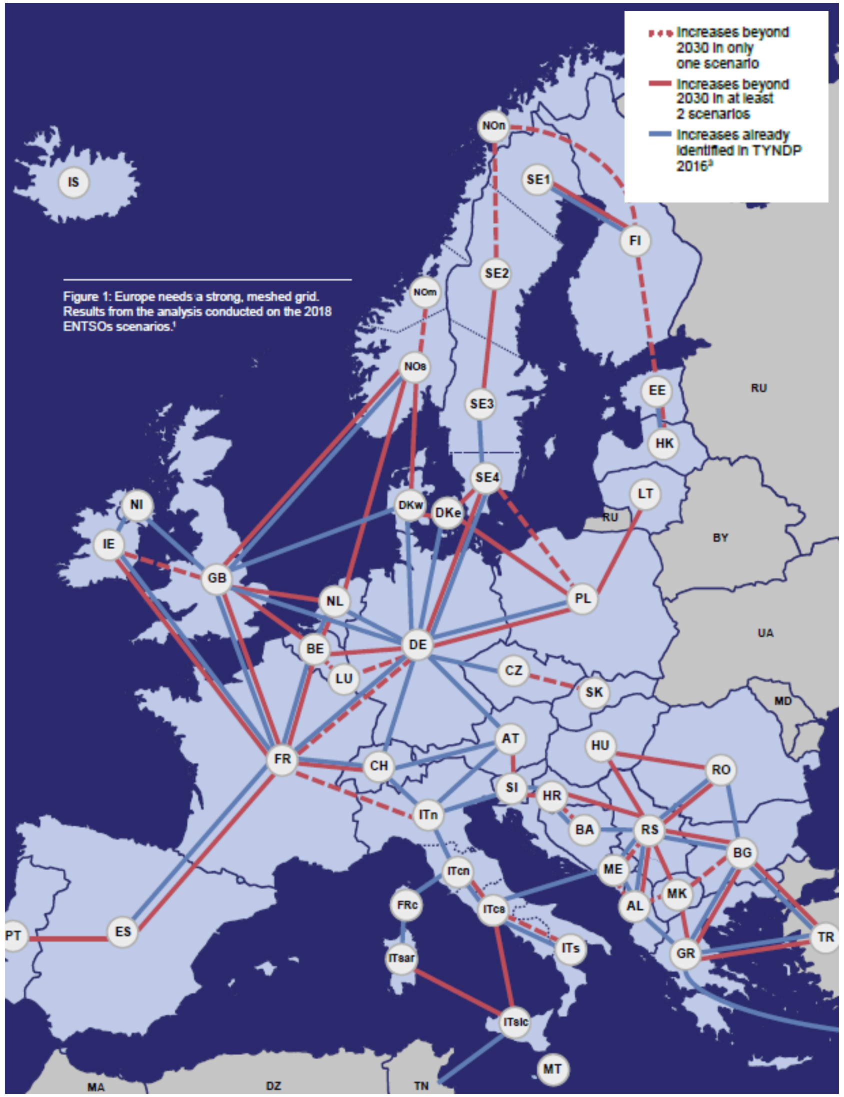
**European Grid Expansion (Cont'd)**

- **First step in planning:** The European 10-year development plan is not prescriptive, but it provides a framework for evaluation of projects, including more detailed regional and member state planning incorporating local considerations; system needs (stability, voltage, and other technical issues); and technology options.
- **Possible lessons:** Of course, one difference between the European and North American industry environments is the alignment of policy objectives around EU's commitments on climate and other relevant policy objectives. **However, European grid development, in response to greater development of renewable resources, may be a view into the future in North America, and it may provide some useful lessons for higher-interregional linkages.**

**ENTSO-E Scenarios for 2018 System Needs Analysis**




Source: ENTSO-E




Source: ENTSO-E

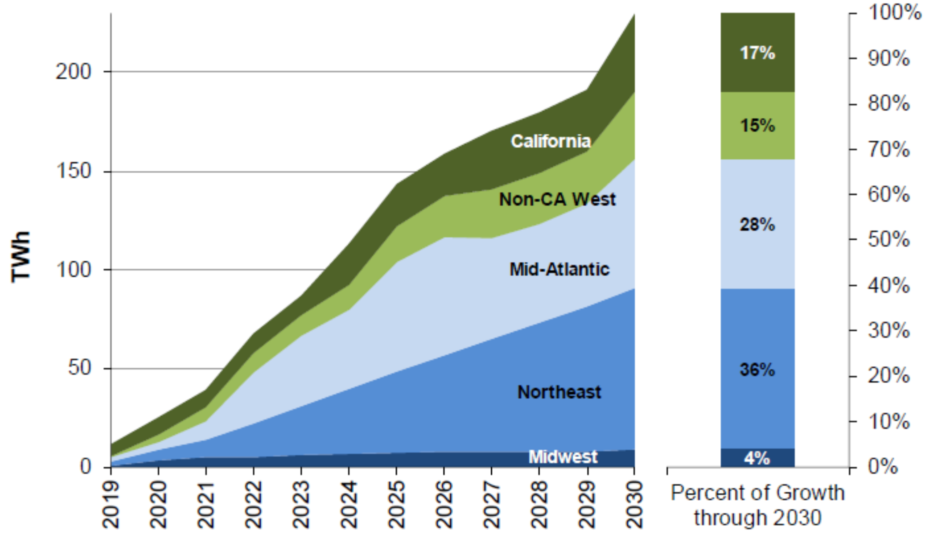
**ENTSO-E 2018 System Needs Analysis: Summary of Identified Border Increases in 2040**

# Clean/Renewable Energy Supply-Demand Balance

### Clean Energy Goals Continue to Advance

- **Interregional benefits:** Both renewables and transmission advocates have long made the case that interregional transmission can yield benefits by moving large, utility-scale, zero-marginal cost solar and wind power from the best resource areas to load centers.
- **Large project queues:** As installed costs for both wind and solar installations have declined, more renewable energy projects have been proposed in the United States, as evidenced by interconnection queues nationwide. As noted by AWEA, 89 GWs of proposed wind capacity was added to interconnection queues nationwide in 2018, the largest volume of new additions since 2008. About 137 GWs of solar capacity was added to interconnection queues in 2018. At the end of 2018, wind and solar capacity in interconnection queues totaled 225 GWs and 282 GWs, respectively, followed by 86 GWs of gas-fired capacity (see chart on next page). Of course, only a small share of projects are built, in part, because of (historically) low-queue entry and exit requirements (AWEA 2018 Market Report, at p. 125).
- **Intraregional efforts:** Intraregional development has been taking place, helping integrate new resources, alleviate congestion, and reduce curtailment. Project portfolios, such as MISO's Multi-Value Projects and CapX2020 and SPP's Priority Projects, have been critical in providing market access to higher-quality renewable resources.
- **Analyzing renewable supply and demand:** To help inform the potential needs for interregional transmission to meet clean energy and RPS demands, we took a long-term look at projected utility-scale wind and solar generation potential and compared that with estimated regional demand for clean energy. **While this analysis is indicative and not prescriptive, it may point to additional "trail signs" of opportunities for enhanced interregional transfer capabilities.**

**Required Increase in Renewable Portfolio Standard Compliance Generation Through 2030 by Region (TWh) (LBNL Est.)**




Source: LBNL

Lawrence Berkeley National Laboratory estimates a required 270 TWh (about 50%) increase in renewable generation by 2030.

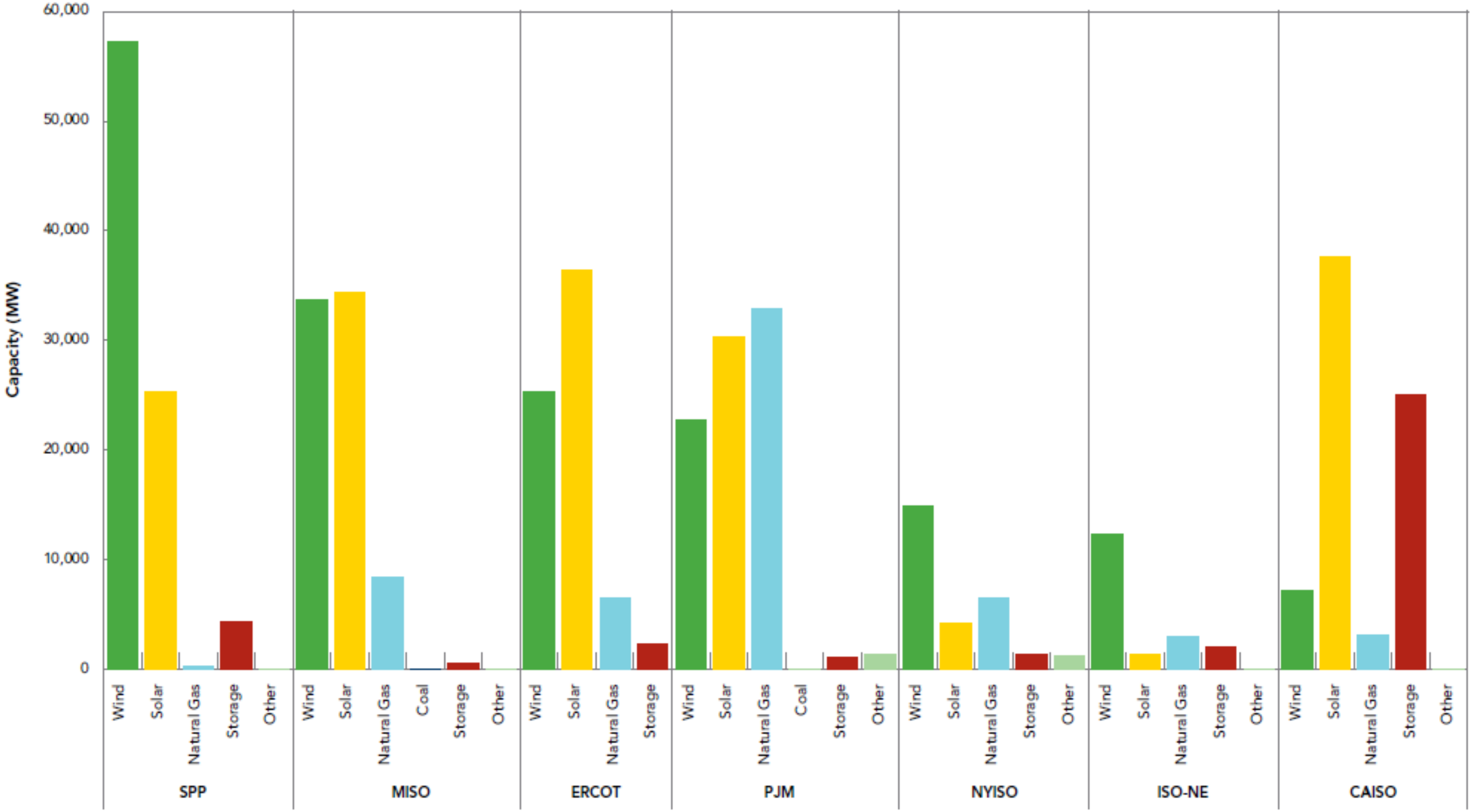
**Clean energy standards introduce a new dynamic: As development continues in resource-rich regions, what has changed in recent years is that more states and utilities—including areas that may be less renewable resource-rich—are proposing clean energy and more ambitious RPS and targets. These new and updated standards will likely drive resource development and additional transmission needs to ensure deliverability to jurisdictions and utilities that have prioritized clean energy.**

Sources: AWEA; SPP, MISO transmission planning materials; LBNL

# Clean/Renewable Energy Supply-Demand Balance (Cont'd)

## Clean Energy Goals Continue to Advance (Cont'd)

### Interconnection Queue Activity Across RTOs by Technology Type (Year-End 2018)




While renewable resources, particularly wind and solar, are being developed nationwide, the regions in which they are being developed do not necessarily coincide with areas requiring RPS-driven energy (per the previous page).

Source: AWEA

# Clean/Renewable Energy Supply-Demand Balance (Cont'd)

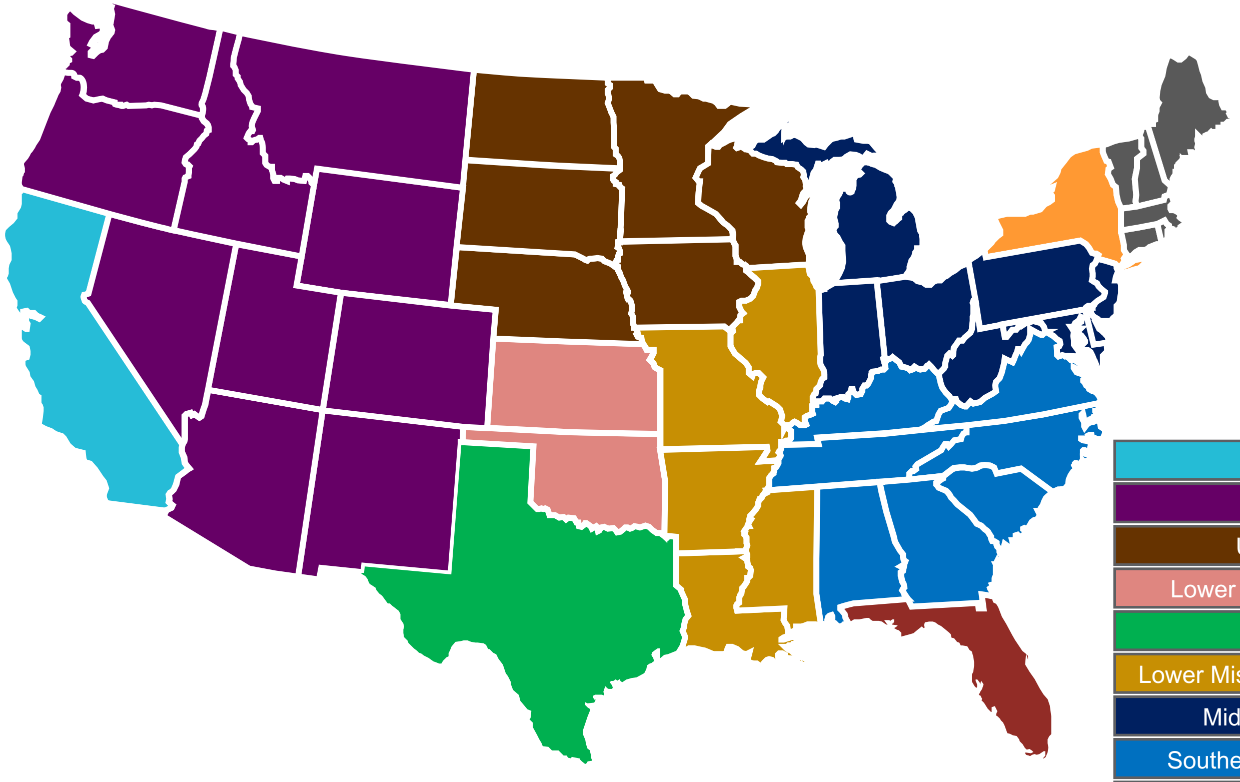
### Supply/Demand Analysis Overview

- To complement our regional analysis, we looked at each region's expected supply of wind and solar resources (typically the primary resources intended to fulfil renewables policy mandates) and expected renewables demand, driven by retail sales growth and renewable or clean energy standards targets.
- Renewable power supply was based upon Energy Information Administration's (EIA) annual energy outlook, which projects multi-decadal electricity resources by technology. For near-term analysis, we triangulated against AWEA and SEIA/Wood Mackenzie forecasts of installed utility-scale wind and solar.*
- Renewable demand was based upon state's RPS/clean energy goals as of August 2019, existing state-level retail sales**, and forecast load growth (at the state level or the most granular level available).
- This analysis indicates potential imbalances between state renewable and clean energy targets and forecast solar and wind resources in the respective regions.

### Analysis Regions

- Regions were grouped as closely as possible to the regional breakdown elsewhere in this report (RTOs plus Southeast and West regions) (shown at right).

**Regional Groupings for Clean Energy Supply/Demand Comparison Analysis**




Notes:
This analysis is limited by mismatch between state boundaries, reliability regions, RTOs, and census regions, particularly the data sources for projected supply. Some judgment was exercised in placing a state in a particular region and grouping subregions together. In some cases, separating cleanly into RTO regions was not possible. For example:

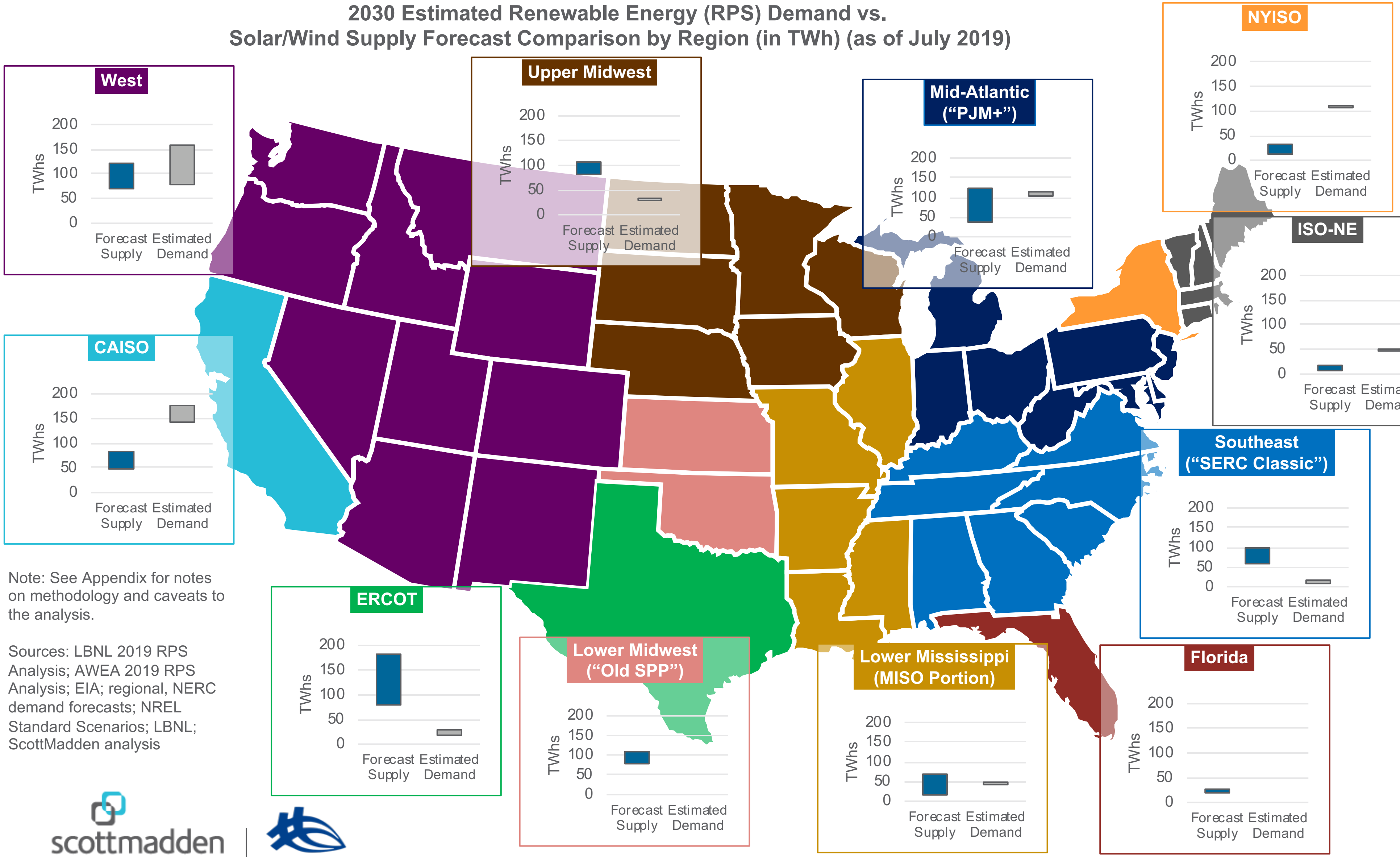
- Virginia, while part of PJM, is aligned with the Southeast.
- The Upper Midwest could not be cleanly divided between SPP and MISO.
- SPP's old footprint (KS, OK) is shown as a standalone region, although it is managed electrically with states to the north.

*American Wind Energy Association; Solar Energy Industries Association

**Lawrence Berkeley National Lab analysis was used to apply the renewable demand analysis only to sales that would be subject to RPS goals, where they were limited to certain utility types (e.g., investor-owned utilities).

# Clean/Renewable Energy Supply-Demand Balance (Cont'd)

**2030 Estimated Renewable Energy (RPS) Demand vs. Solar/Wind Supply Forecast Comparison by Region (in TWh) (as of July 2019)**




Note: See Appendix for notes on methodology and caveats to the analysis.

Sources: LBNL 2019 RPS Analysis; AWEA 2019 RPS Analysis; EIA; regional, NERC demand forecasts; NREL Standard Scenarios; LBNL; ScottMadden analysis

**2030 estimates**
Clean energy demand (standards): 600 TWh (per LBNL) to 714 TWh (latter is ~17% of estimated 2030 U.S. retail sales)

## Key Takeaways

- As shown here, by 2030, many regions are projected to have adequate or excess renewable supply compared with “headline” clean energy demand.
- The West (including California), New England, and New York appear to have opportunities for additional supply, perhaps through imports from other regions.
- This analysis does not include corporate, utility, or state clean energy “goals” that do not have regulatory or legislative force; thus, additional potential regional demand may be higher.

scottmadden MANAGEMENT CONSULTANTS | WIRES

# Sources


- AWEA, Grid Vision: The Electric Highway to a 21st Century Economy (May 2019) (Grid Vision)
- AWEA, 2019 State RPS Market Assessment (Mar. 2019) (AWEA 2019 RPS Analysis)
- AWEA, U.S. Wind Industry Annual Market Report Year Ending 2018 (Mar. 2019) (2018 Market Report)
- AWEA, WindIQ, at https://www.awea.org/resources/wind-iq
- CAISO, Western EIM Benefits Report: Second Quarter 2019 (July 31, 2019)
- California ISO, Monthly Renewables Performance Report (July 2019), at http://www.caiso.com/Documents/MonthlyRenewablesPerformanceReport-Jul2019.html
- Energy Information Administration (EIA), Annual Energy Outlook 2019 (Jan. 2019)
- EIA state energy data, at https://www.eia.gov/electricity/data/state/
- ENTSO-E, European Power System 2040: Completing the Map, Ten-Year Network Development Plan, 2018 System Needs Analysis (Feb. 2018)
- ENTSO-E, TYNDP 2018 Executive Report: Connecting Europe: Electricity 2025-2030-2040 (Dec. 2018)
- ENTSO-E, TYNDP 2018: Technologies for Transmission System (Aug. 2018)
- European Commission, Communication on Strengthening Europe's Energy Networks, COM(2017) 718 (Nov. 23, 2017)
- Lawrence Berkeley National Laboratory, U.S. Renewables Portfolio Standards: 2019 Annual Status Update (July 2019) (LBNL 2019 RPS Analysis)
- National Renewable Energy Laboratory (NREL) Standard Scenarios, at https://openei.org/apps/reeds/#
- NREL, Western Wind and Solar Integration Study (May 2010)
- NREL, Eastern Renewable Generation Integration Study (Aug. 2016)
- NREL Interconnection Seams Study, Presentation by A. Bloom, TransGrid-X Symposium (July 26, 2018), available at https://energyexemplar.com/wp-content/uploads/seams-transgridx-2018.pdf
- PJM Interconnection, The Benefits of the PJM Transmission System (Apr. 16, 2019) (Benefits White Paper)
- Solar Energy Industries Association and Wood Mackenzie, Q2 2019 U.S. Solar Market Insight

# Sources (Cont'd)

- Western Energy Imbalance Market website, at www.westerneim.com
- S&P Global Market Intelligence
- Industry news

# Appendix: Clean Energy Supply/Demand Balance Analysis Notes

**Some Caveats and Notes on Methodology**

- **Simplified assumptions:** This analysis is a view of order of magnitude differences between renewable or clean energy needs and supply and not a precise supply-demand forecast for meeting RPS obligations. This analysis does not account for carve-outs for local renewables development nor technology (including, e.g., distributed solar, hydro, or nuclear) or the role of energy efficiency or demand-side management resources to meet RPS demand was not factored even where states allow. Further, it does not factor in credit multipliers that some jurisdictions include for certain preferred technologies. Nor does it make distinctions between classes of resources or limits on certain types of technologies (e.g., wind or solar eligibility limits). It assumes that utility scale wind and solar will be the principal technologies to meet renewable portfolio standards demand.
- **Banked RECs not considered:** A few states have already reached their targets. This analysis does not analyze the impact of banked renewable energy credits (RECs) on future year compliance (and hence potential demand reduction or supply met by RECs).
- **Forecast capacity and generation:** Potential solar and wind capacity development was estimated using renewable industry forecasts in the near term. Further out (beyond five years), installed capacity and generation was taken from forecasts using the EIA’s latest Annual Energy Outlook and the NREL’s Standard Scenarios (Mid-Case Scenario), which is reflected in the range of renewable supply by region. Note that NREL’s Mid-Case Scenario includes some assumptions about transmission expansion that informs projections of resource development. That forecast capacity was converted to estimated MWhs generation using assumed, typical capacity factors. Note that this comparison assumes that U.S. utility-scale solar and wind (onshore and offshore) generation will be the supply resources to meet RPS demand.
- **Forecast demand and RPS demand:** Clean energy demand was based upon 2018 retail sales (escalated annually by a growth rate) as most clean and renewable energy standards are based upon retail sales. Usage growth rates (in some cases negative) were applied to project future retail electricity sales. Those assumptions came from the most specific sources possible. For those without state-specific growth rates, regional growth rates from NERC were applied. RPS and clean energy targets were weighted (using DOE Berkeley National Laboratory analysis) based upon utility type, as many states impose different requirements on investor-owned utilities versus others. RPS demand was based upon state RPS targets as of July 2019. Clean energy goals were not included unless they included a correlative RPS; for Washington state, based upon the clean energy goal legislation’s language, we assumed the clean energy standard effectively created an 80% renewable target in 2030.

**Differences in Demand Assumptions Driving Range of RPS Demand**

- The range of demand assumptions is bounded by ScottMadden analysis and LBNL analysis of projected RPS demand. Small differences arise from use of the simplifying assumptions above (carve-outs, exclusions, banked RECs, etc.). The larger ranges are principally in the West, reflecting the following differences:
  - Assumptions for California retail sales growth
  - Change in clean energy (and assumed RPS) target for Washington from recent legislation