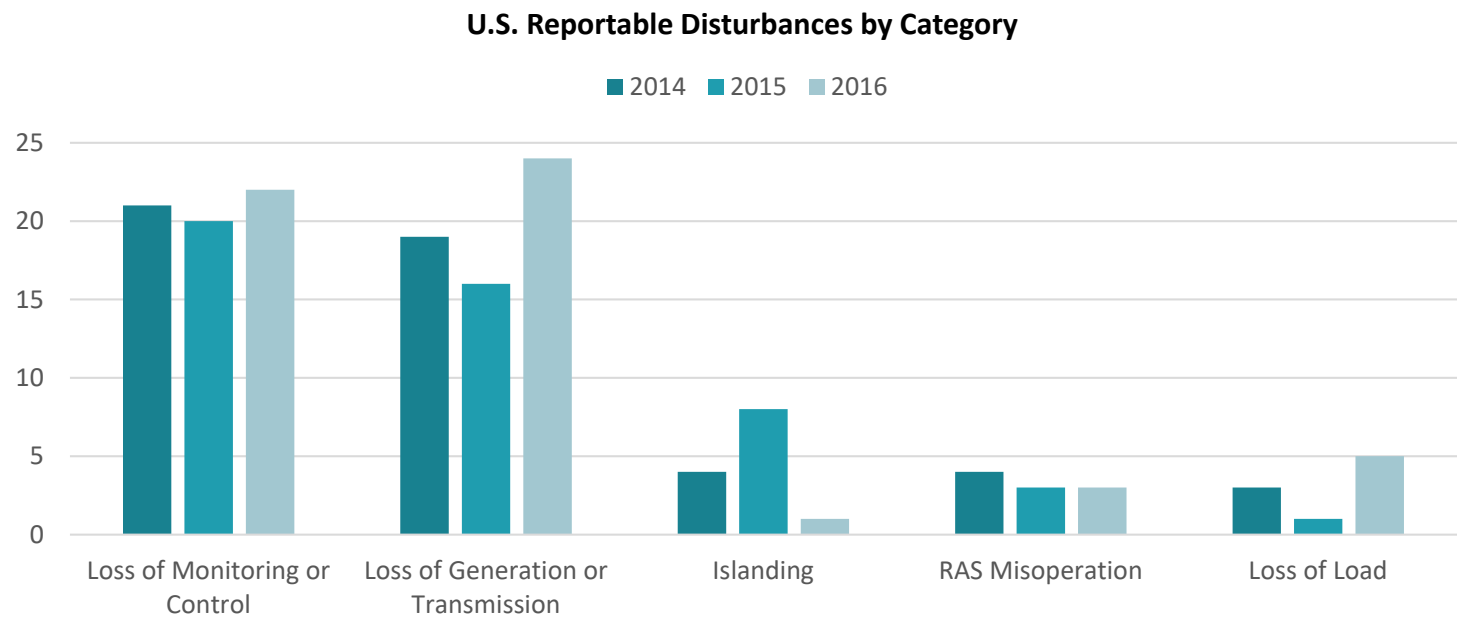
WINTER 2017-18

STATE OF THE INTERCONNECTION DIGEST

The State of the Interconnection is a snapshot of evolving trends in the Western Interconnection. Beginning in 2017, the Western Electricity Coordinating Council (WECC) published the report in an interactive, web-based platform. In an effort to maintain continuity with previous editions, this document contains information from the State of Interconnection that may be relevant for future reference.

The current State of the Interconnection is available at:

https://www.wecc.biz/epubs/StateOfTheInterconnection/



DISTURBANCES

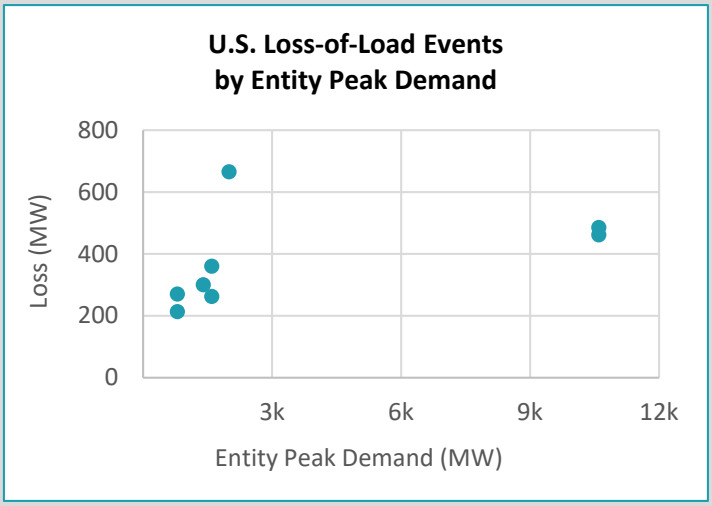
Entities report disturbances and other events that meet certain criteria through the Event Analysis Process, Reliability Standard EOP-004, and Department of Energy Form OE-417.

The State of the Interconnection includes five categories of disturbances:

- **Loss of monitoring or control:** Loss of monitoring or control capability for 30 minutes or more than affects an entity's ability to make operating decisions
- **Loss of generation or transmission:** Loss of three or more BES facilities from a common cause or loss of ≥ 2,000 MW of generation
- **Islanding:** Unintentional system separation resulting in an electrical island ≥ 100 MW
- **RAS misoperation:** Failed or unnecessary operation of a Remedial Action Scheme
- **Loss of load:** Loss of firm load for 15 minutes or more exceeding 300 MW for entities with previous year's demand ≥ 3,000 MW, or 200 MW for all other entities

LOSS-OF-LOAD EVENTS

Relatively few disturbances that result in the loss of load meet the reporting criteria for a loss-of-load event. There were only eight loss-of-load events in the West between 2014 and 2016.



The largest loss-of-load event occurred on August 7, 2016, with 665 MW lost. This represents only 0.5% of the day's peak system demand of 126,800 MW, a negligible impact from a system-wide perspective.

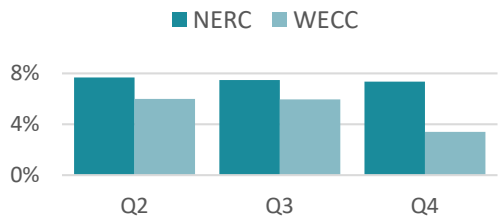
MISOPERATIONS

Protection systems help support overall system reliability by protecting sensitive equipment. When a protection system element—for example, a relay device—fails to operate as designed, or operates unintentionally or outside of its zone of protection, it is called a misoperation.

NERC measures the incidence of misoperations by the ratio of misoperations to correct operations, or "misoperation rate". WECC's current rate is 5 percent, based on the three quarters of data available.

NERC is undergoing efforts to effect a nationwide misoperation rate of 8 percent by 2020. To contribute in these efforts, WECC is working with stakeholders to develop misoperation reduction strategies and share recommended practices.

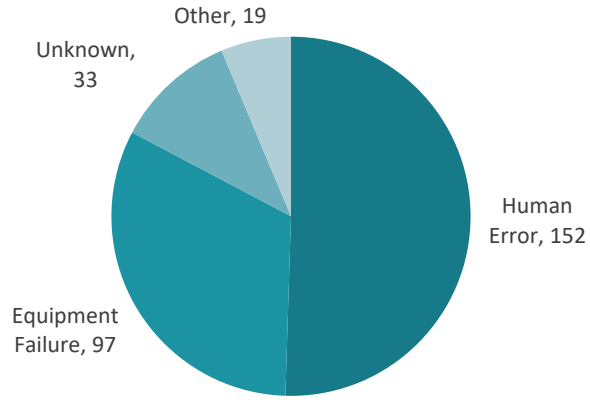
2016 Misoperation Rate



CAUSE CATEGORIES

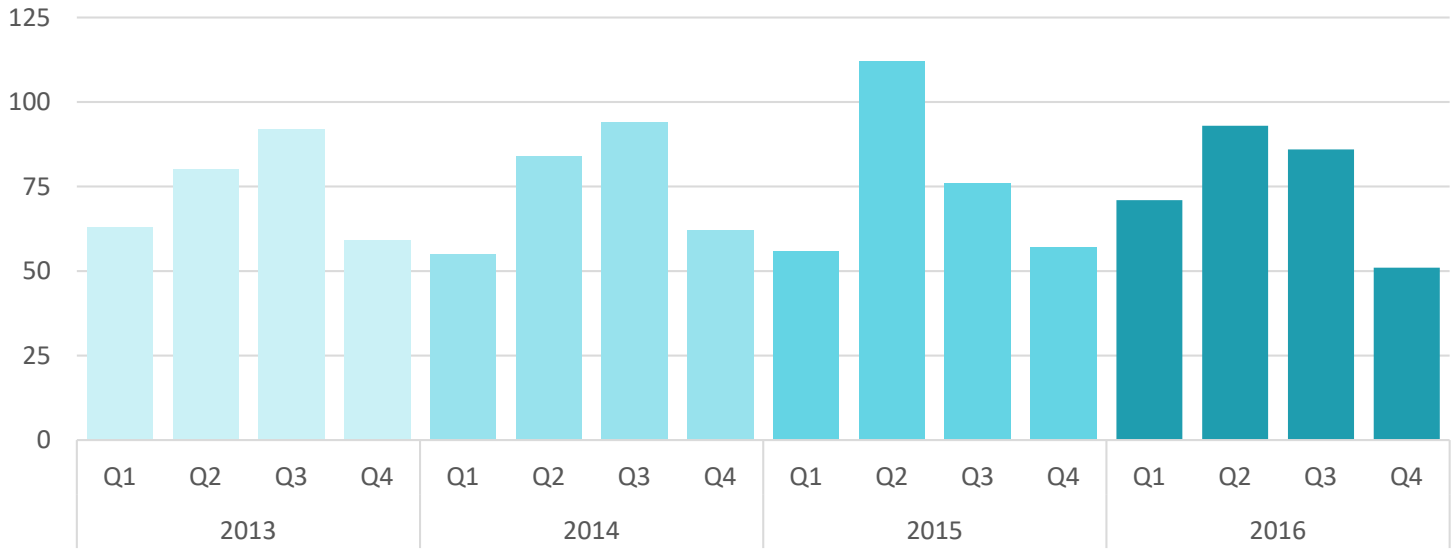
The three largest causes of misoperations in the Western Interconnection are human error, equipment failure, and unknown.

2016 Misoperations by Cause



The unknown category is of particular concern because it represents instances when the Interconnection operated in a less reliable state for unknown reasons, complicating the development and efficacy of corrective action plans.

WECC Misoperations

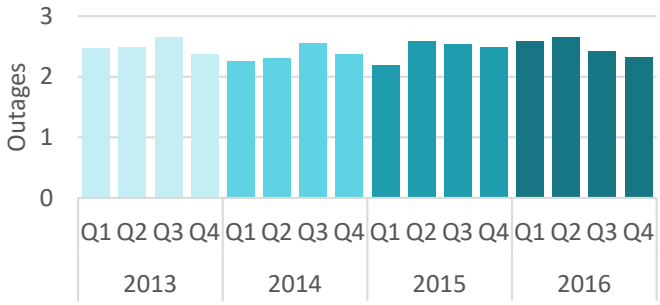


OUTAGES

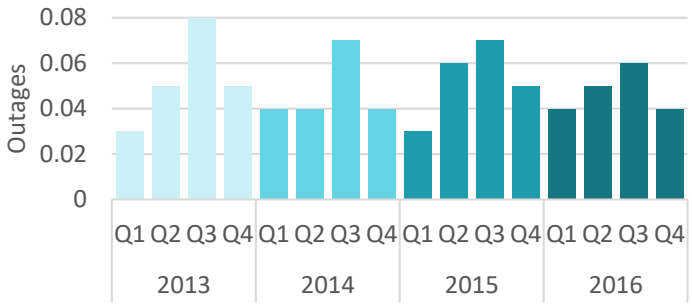
Unplanned outages represent times when the system is operating in a less reliable state. Incidence, cause and duration are important indicators of the potential impact of unplanned outages.

Generation outages can undermine reliability by reducing capacity available to meet demand, and introduce instability by reducing frequency and depriving the system of voltage support and ramping capability to match changes in load.

Unplanned Outages Per Generating Unit



Unplanned Outages Per Transmission Element



Transmission outages increase flow on transmission elements remaining in service, which can result in overload and/or trip.

UNKNOWN CAUSE CODE

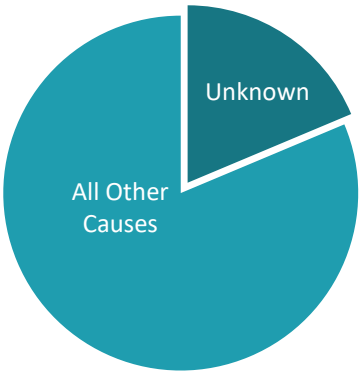
When the cause of the outage or misoperation is unknown, entities cannot effectively mitigate or avoid the issue in the future.

WECC's Evaluation of Unknown Outages and Misoperations recommends best practices for entities regarding unknown outages and misoperations, including: aligning organizational culture, strengthening processes, employing data analytics and involving management throughout the investigation process.

The report and associated webinars are available on WECC's website:

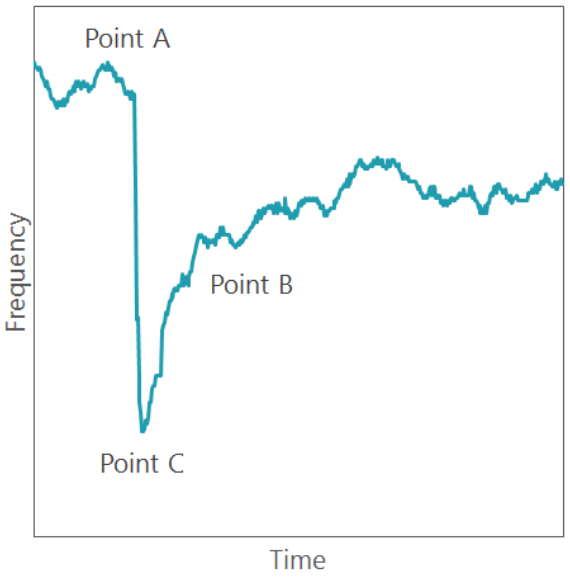
https://www.wecc.biz/PerformanceAnalysis/

Transmission Outages by Initiating Cause (2013-2016)

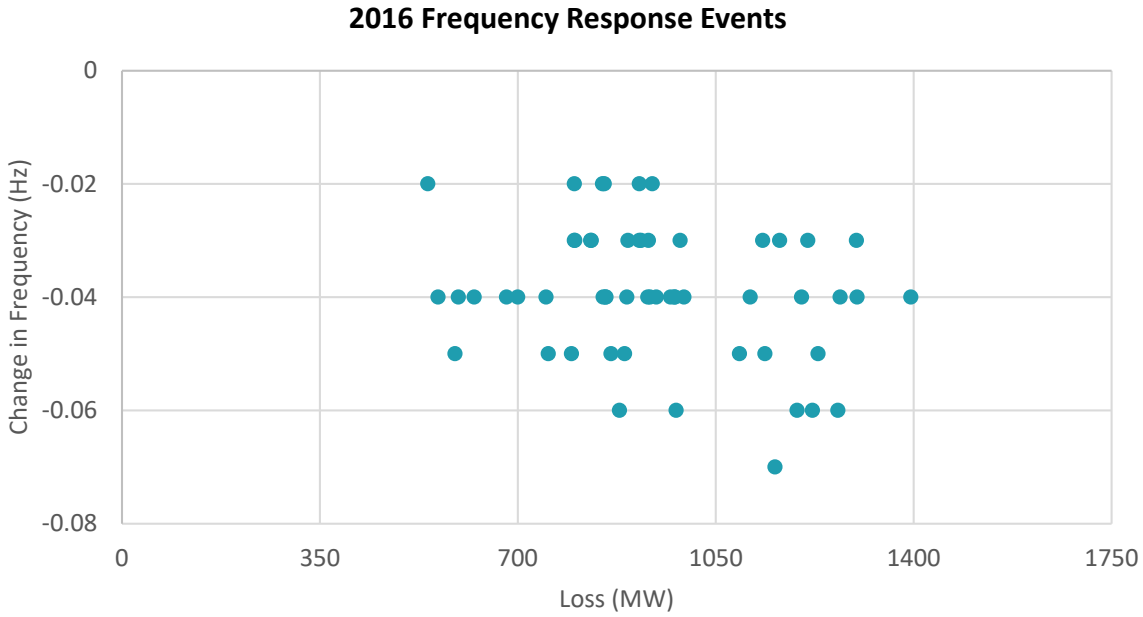


FREQUENCY RESPONSE

Frequency response measures the stability of a system. When an event—such as the sudden loss of a large amount of generation—causes a significant drop in system frequency from a steady state (Point A), various actors work to arrest the decline (Point C) and restabilize frequency (Point B). In a system with strong frequency response, Point A and Point B will be close together, so that a major event will result in a minor change in frequency.



The strength of frequency response can be measured by comparing it to the current Interconnection Frequency Response Obligation, a target set by NERC.

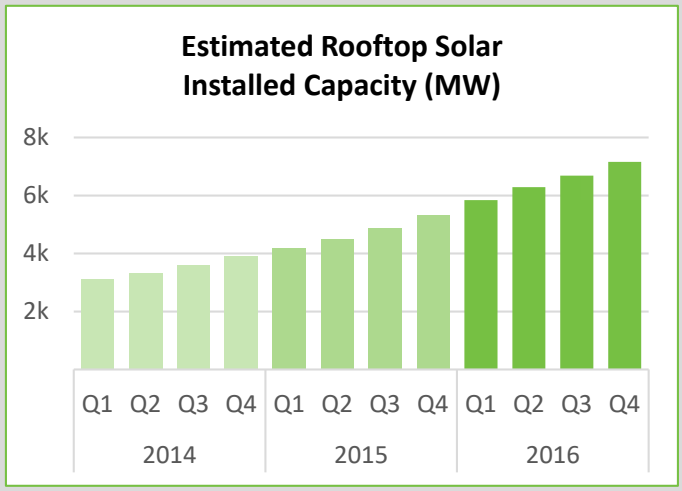


Between 2013 and 2016, the Western Interconnection's frequency response consistently exceeded the Interconnection Frequency Response Obligation. With a median response of 1,350 MW/0.1 Hz, it would take the loss of around 6,750 MW to lower system frequency enough to activate Underfrequency Load Shedding (UFLS). This indicates the system can arrest and stabilize frequency during extreme frequency events, while avoiding load shedding.

DEMAND

The Western Interconnection has a diverse load composition. The majority is concentrated along the West Coast, with pockets in the Southwest and Rocky Mountains. Overall, the Interconnection is summer-peaking, though the Northwest is winter-peaking. Over the last several years, annual energy consumption has changed in response to various factors driving demand, including fluctuations in weather patterns and economic conditions.

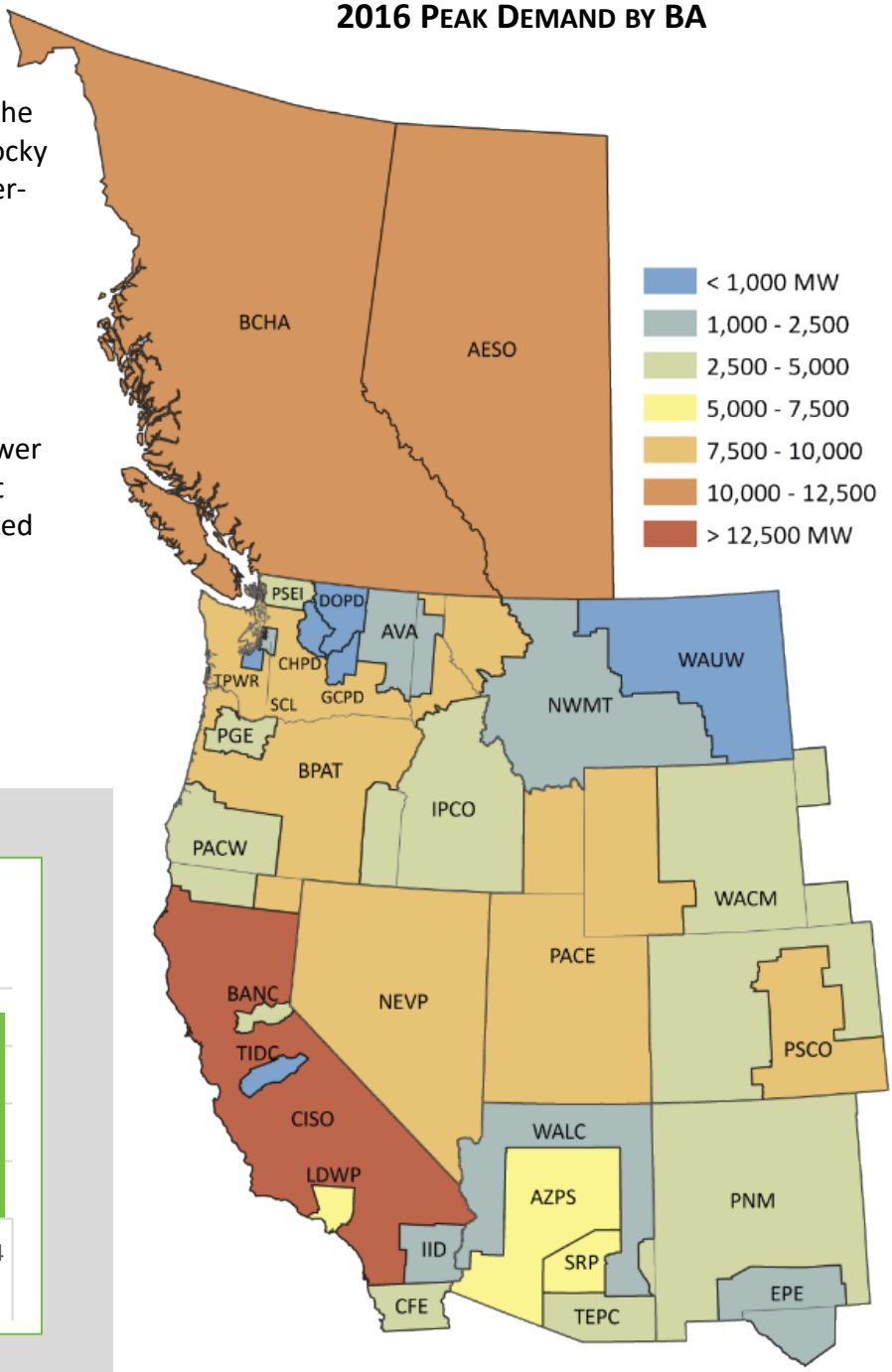
Although energy consumption was 0.6 percent lower in 2016 than in 2015, peak demand was 4 percent higher. The decrease in consumption may be related to the increasing prevalence of rooftop solar in California.



ROOFTOP SOLAR

Installed capacity of rooftop solar in the Western Interconnection increased by 130 percent between January 1, 2014 and December 31, 2016.

2016 PEAK DEMAND BY BA

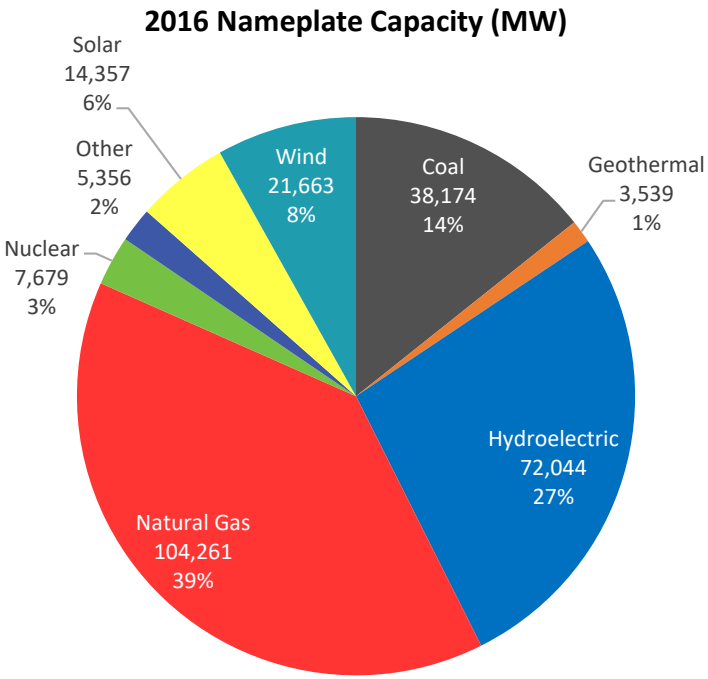


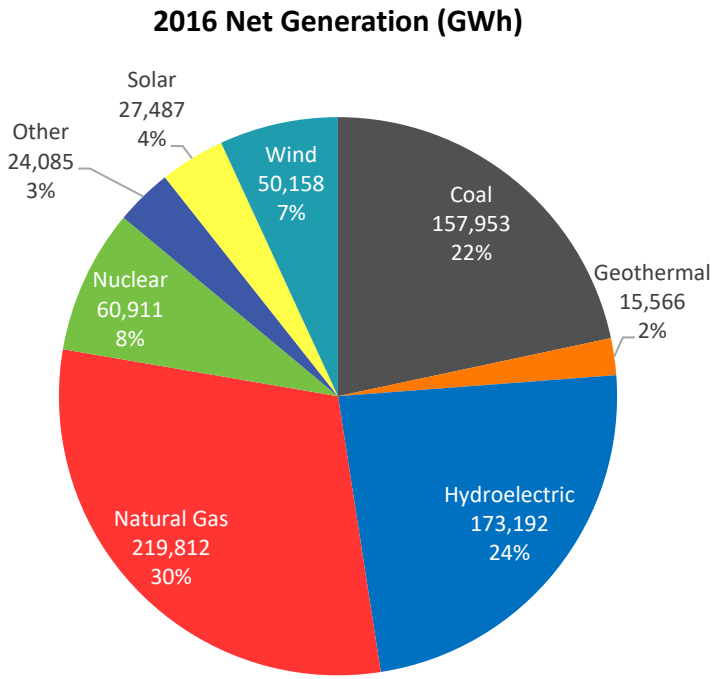
The same trend occurred at the BA level. Generally, although energy consumption was reduced compared to 2015, peak demand was not similarly affected.

RESOURCE PORTFOLIO

The Western Interconnection has a diverse mix of resources, including large amounts of hydro and renewable resources. Although the generation capacity of the Western Interconnection represents approximately 20 percent of total capacity in the United States and Canada, it encompasses over 70 percent of all solar capacity and one-third of all hydro capacity.

In 2016, the combined nameplate capacity of all utility-scale resources in the Western Interconnection was 267,000 MW. This is a 1 percent increase from 2015. Retirement of coal and steam-turbine gas units lead to slight decreases in capacity from these fuel types, while the installed capacity of utility-scale solar increased by over 6,000 MW.





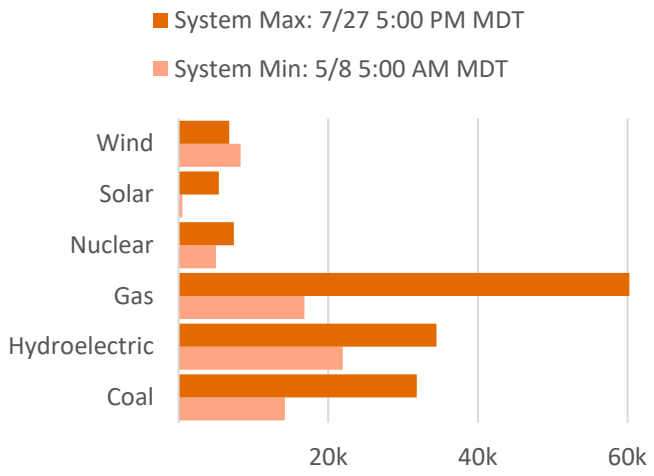
ESSENTIAL RELIABILITY SERVICES

The West's changing resource portfolio presents several operational challenges, including ensuring sufficient voltage and frequency support, and ramping capability to balance generation and load. Without these Essential Reliability Services (ERS), the grid cannot be operated reliably. With continued growth of variable energy resources, flexible resources like natural gas are critical for following fluctuations in generation caused by variable resources.

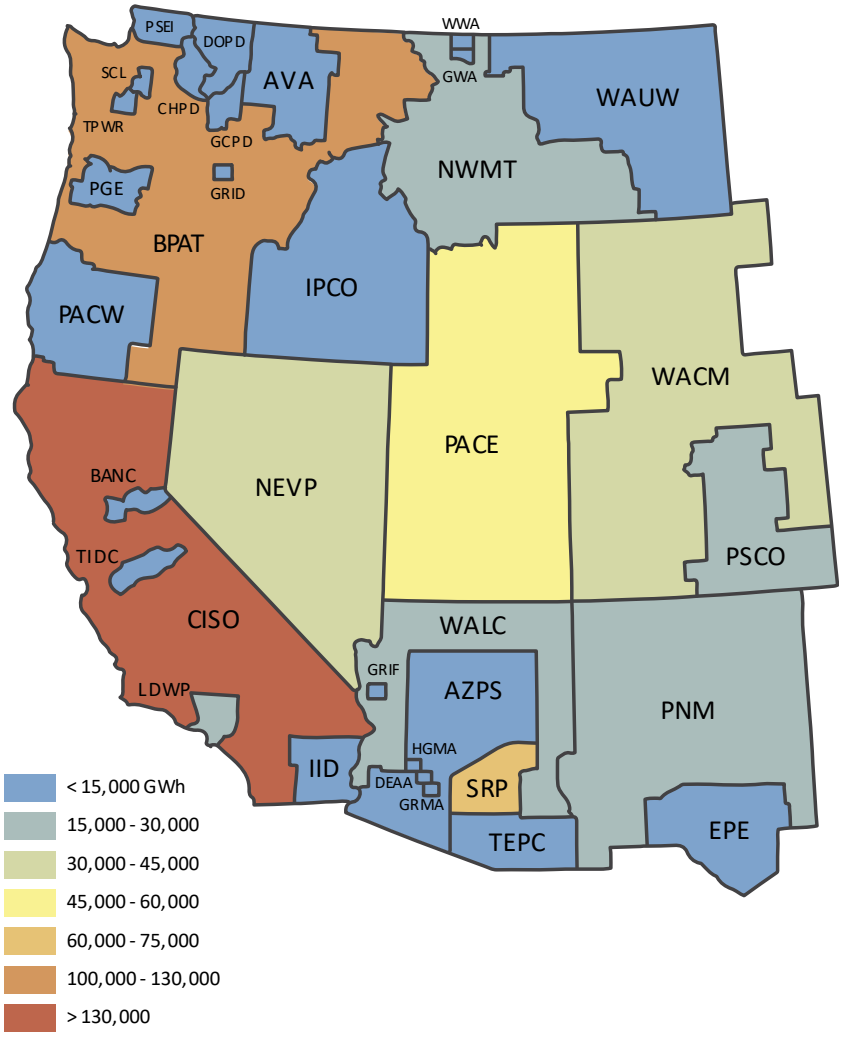
NET GENERATION

The vast majority of generation on the system comes from coal, natural gas and hydroelectric resources. This is the case at both system maximum and minimum generation. Flexible resources, like natural gas and hydroelectric units, have the greatest fluctuation in generation during different periods of the day and season. Base-load resources, like coal and nuclear units, are operated differently and experience far less fluctuation.

2016 Net Generation at System Extremes (MW)



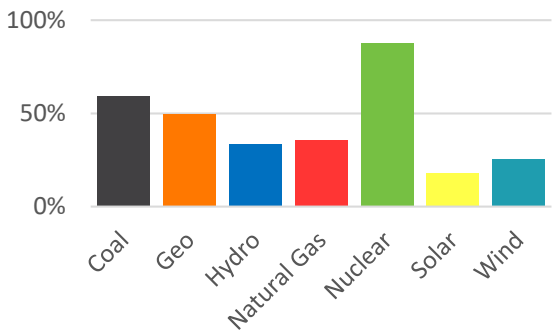
2016 NET GENERATION BY BA



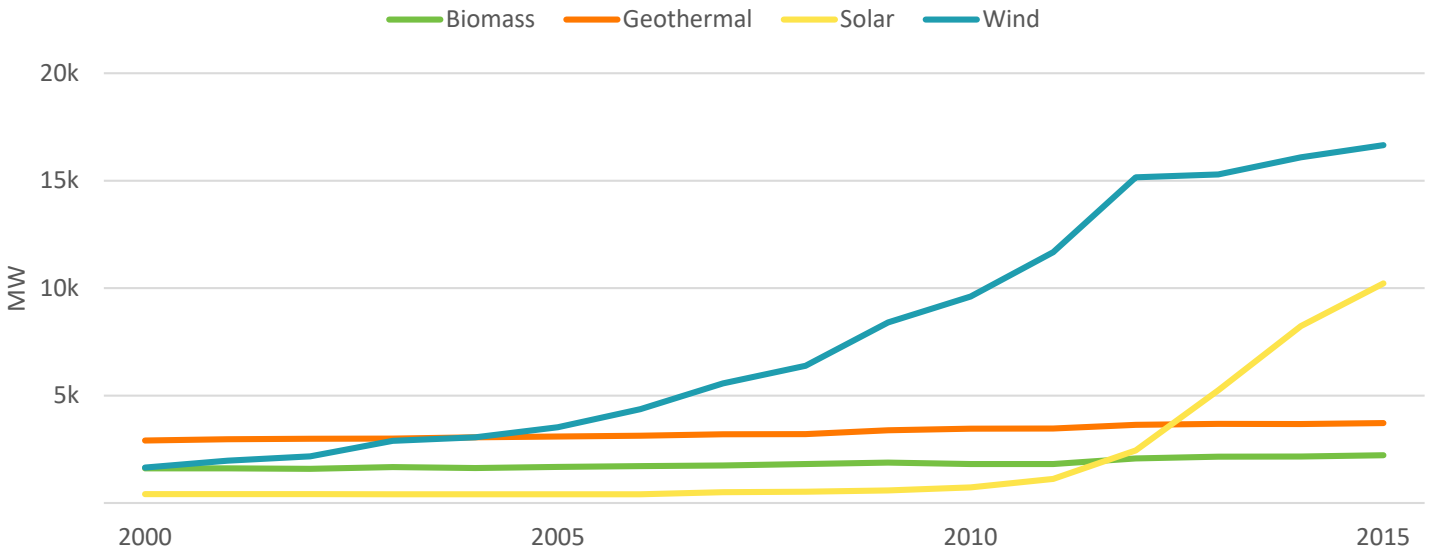
CAPACITY FACTOR

Depending on the resource type, there can be a significant difference between nameplate capacity and the capacity available at any given time. This difference can be measured with a unit's capacity factor, the ratio of what the unit actually generated during a period to what it would have generated if it had operated constantly at its nameplate capacity.

2016 Estimated Capacity Factor by Fuel Type



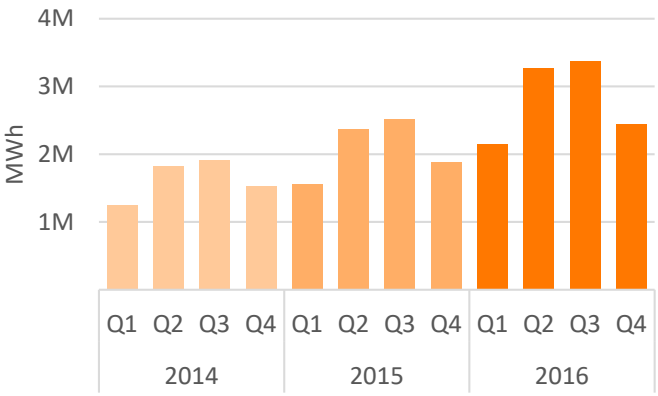
Western U.S. Renewable Capacity

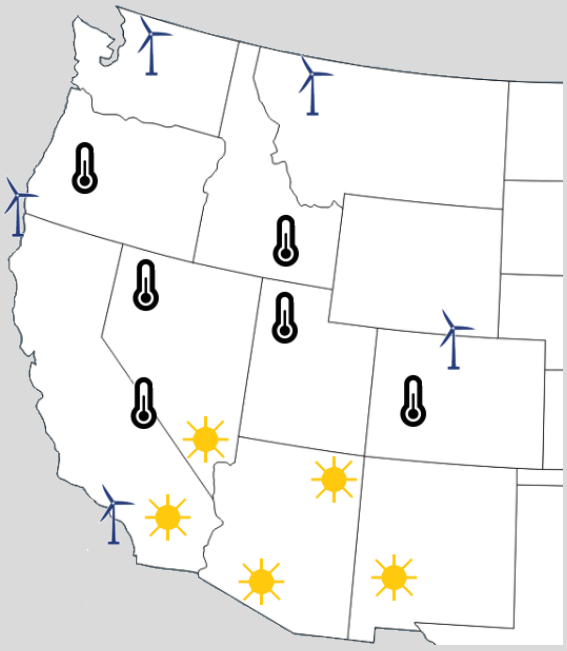


RENEWABLES

The growth of wind and solar resources is driven by political, economic and social factors. Increased installation of wind and solar units is associated with the availability of tax credits and other financial and political incentives. Technological improvements also increase penetration of these units, especially photovoltaic solar. Other types of renewable resources have not experienced the same changes.

Estimated Rooftop Solar Net Generation





POTENTIAL BY SUBREGION

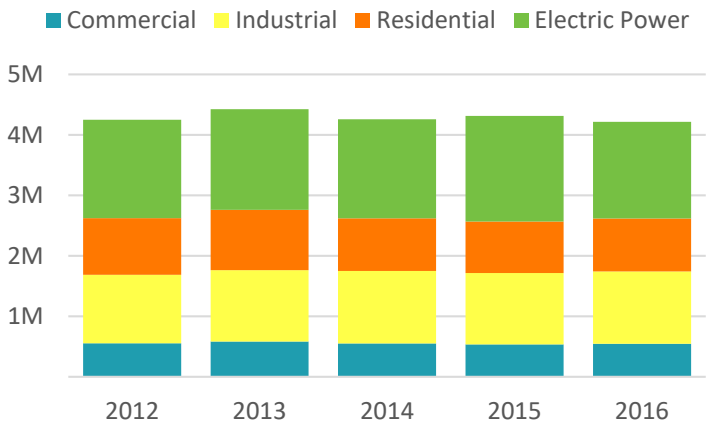
The West is characterized by a high degree of renewable potential. The Southwest has the highest solar potential in the nation, and is the only region in the US with areas of significant geothermal potential. There are also areas of significant wind potential, including along the eastern edge of the Rocky Mountains and along the Columbia River.

NATURAL GAS

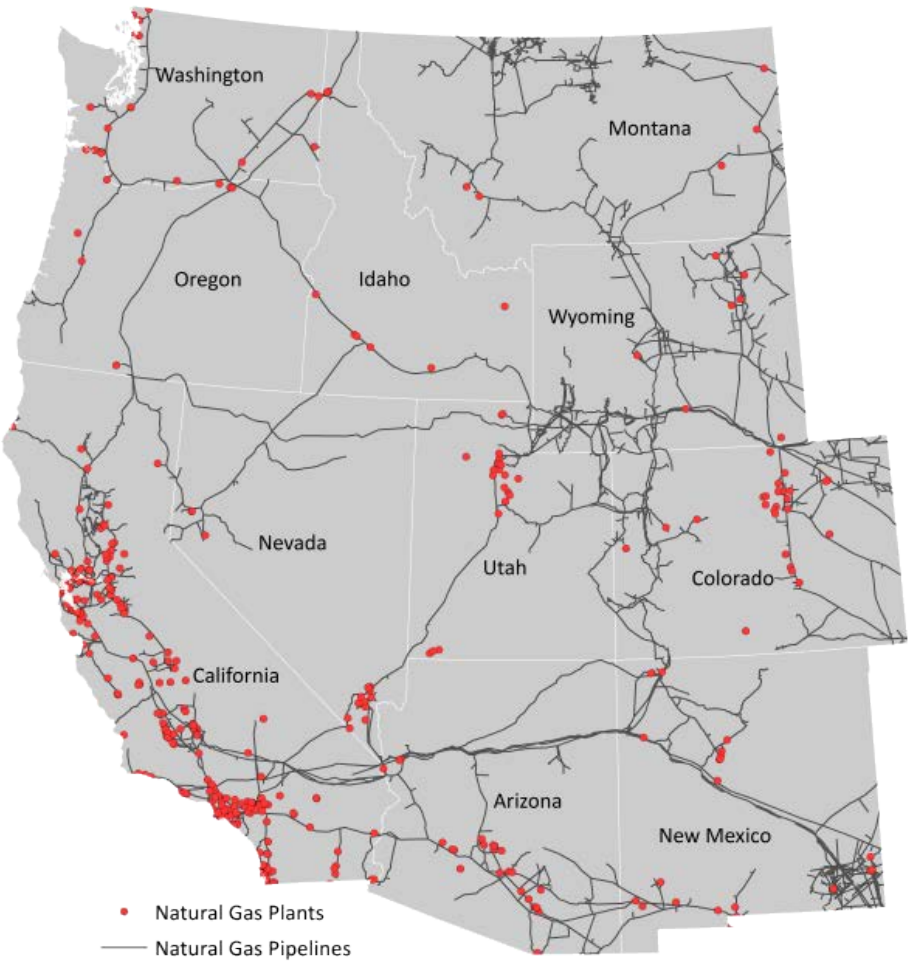
There is significant fluctuation from year to year in the consumption of natural gas for electric power generation. Consumption in other sectors is relatively steady.

Natural gas consumption for electric power generation is driven by the availability of other resources, especially hydroelectric and variable energy resources, and demand for electricity overall. As penetration of variable energy resources increases, the system relies more on natural gas resources for ramping, load-following and changes in generation associated with these variable resources.

Natural Gas Consumption by Sector (MMcf)



PIPELINES AND POWER PLANTS



There are over 54,000 miles of natural gas pipeline in the Western United States. These pipelines carry gas long distances from production sites to consumers, including power plants.

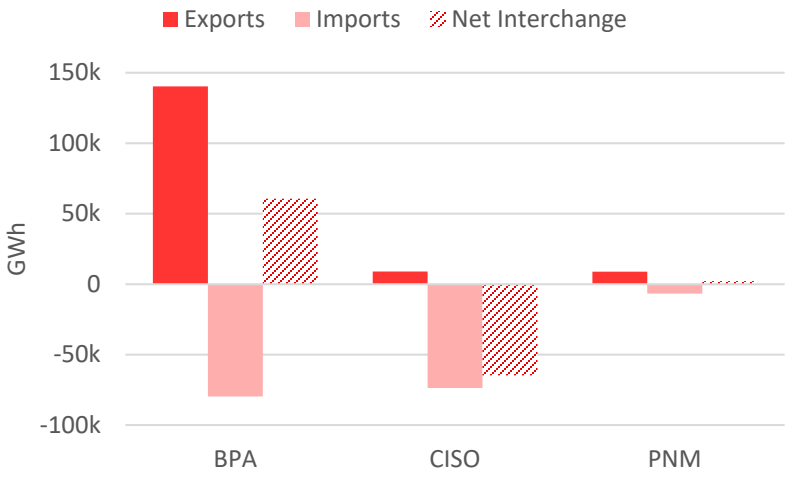
California consumes more natural gas than any other state in the West. It is the primary fuel source for electric power generation in the state, as well as in Nevada. The amount of natural gas consumed for generation in California is expected to be steady or decrease in future years as the penetration of variable energy resources increases. However, natural gas and other conventional technologies that provide Essential Reliability Services remain critical for the reliability of the Western Interconnection.

NET INTERCHANGE

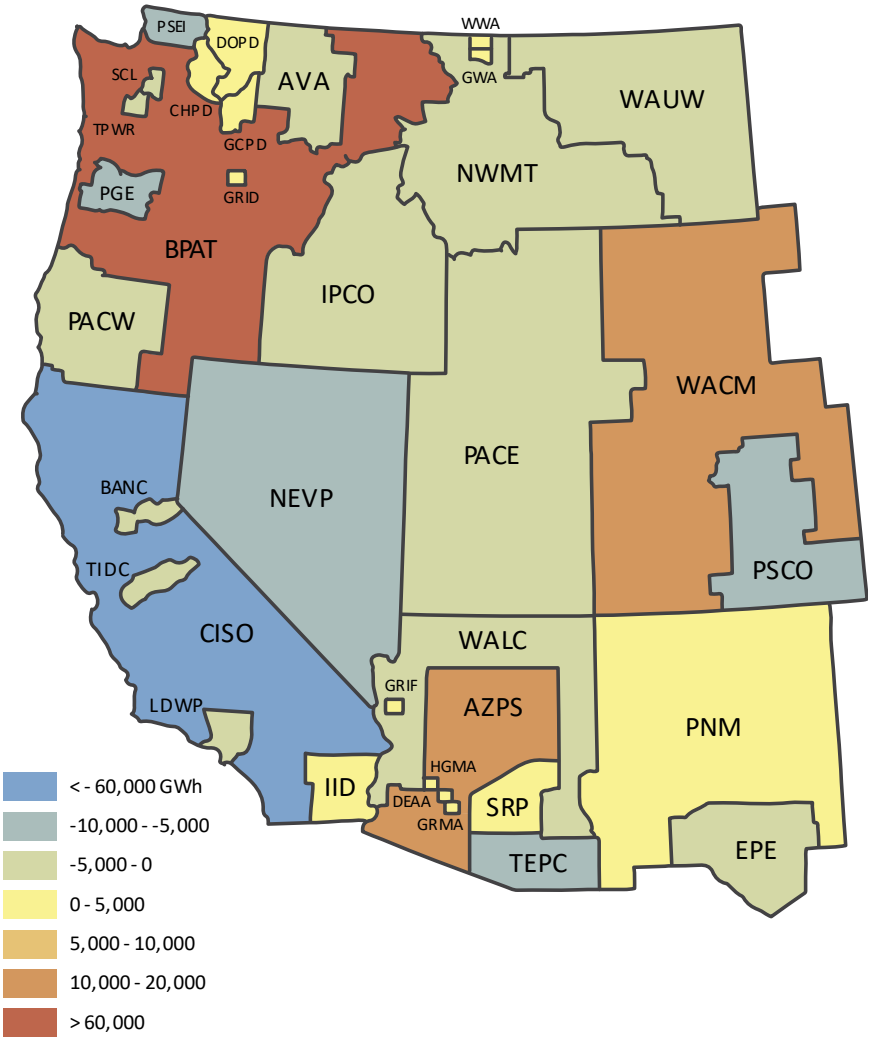
There is a strong interdependence between BAs in the Western Interconnection. Electricity flows from generation-rich BAs to load centers.

BAs with a small amount of total net interchange may still have large amount of electricity flowing into and out of their footprints daily, with imports and exports that are roughly equal.

2016 Interchange Summary



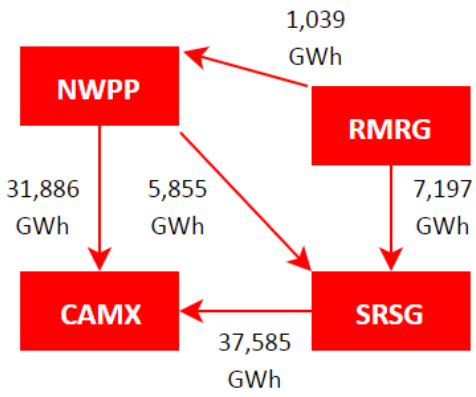
2016 NET INTERCHANGE BY BA



The Western Interconnection is made up of approximately 136,000 circuit-miles of transmission lines, which traverse long distances between remote and population-dense areas.

Electricity generally flows south and west in a "doughnut" pattern, contrasting with a spiderweb configuration in the Eastern Interconnection.

2016 Reserve Sharing Group Net Interchange



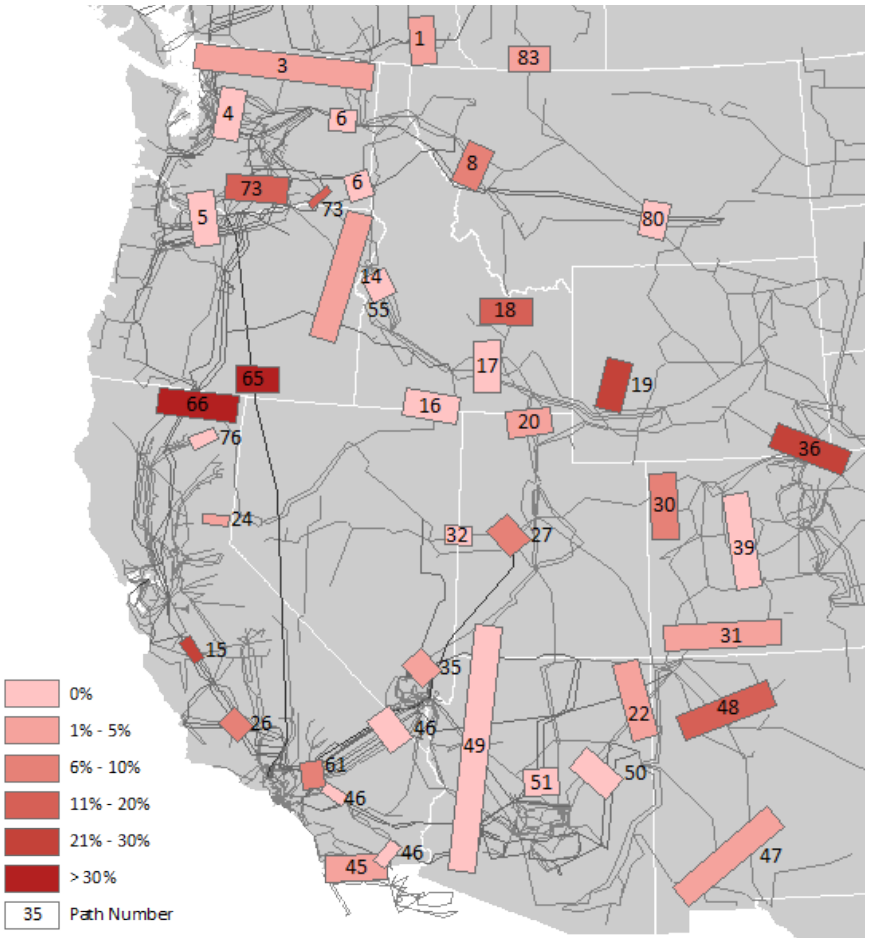
WECC PATHS

Key transmission lines in the Western Interconnection are grouped into numbered paths for planning and operational purposes.

One measure of congestion on WECC paths is the U75 metric, which measures the percent of time that flow on a path is above 75 percent of its operating limit.

A low U75 does not necessarily indicate a path is underutilized, nor does a high U75 necessarily indicate congestion. Many factors determine operating limits. For example, some paths were built to carry electricity from large plants—high flow is not unusual for these paths.

2016 U75 FOR WECC MAJOR PATHS

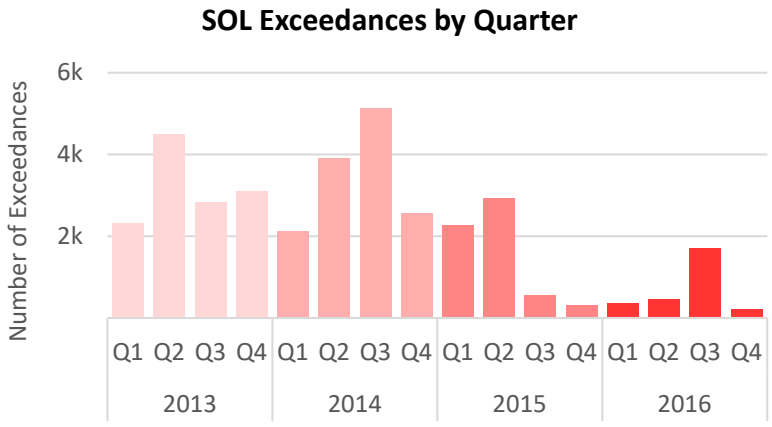


SYSTEM OPERATING LIMITS (SOL)

The System Operating Limit is the maximum designated flow allowed on a path to ensure reliable operations. Thermal, voltage or stability criteria performance may be impacted if flow exceeds the SOL.

The number of SOL exceedances continued to decline in 2016, with a decrease of 55 percent from 2015. The decrease in exceedances over the last two years has been primarily driven by infrastructure improvements and load composition changes in the Pacific Northwest and Canada.

Most exceedances are short in duration and low in magnitude. Eighty-three percent in 2016 lasted less than one minute and were less than 50 MW above SOL.

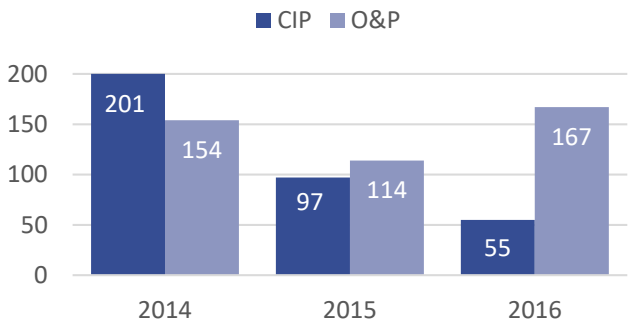


COMPLIANCE MONITORING

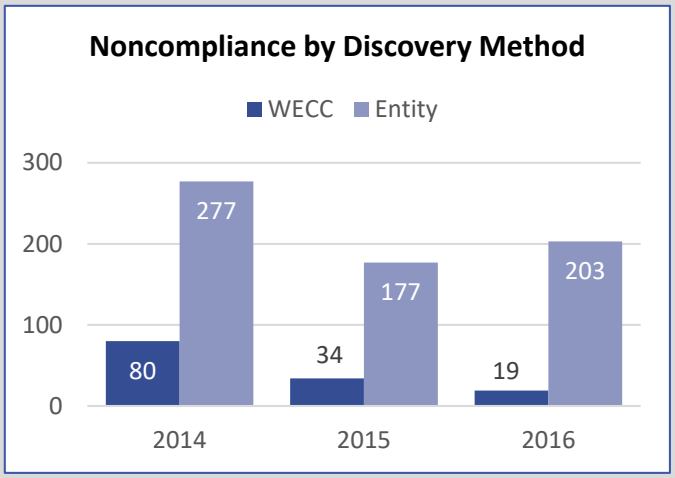
WECC reviews potential noncompliance with Reliability Standards reported by entities or identified during compliance audits.

In 2016, WECC performed compliance audits of 44 entities, including 31 audits of Critical Infrastructure Protection (CIP) Standards and 39 audits of Operations and Planning (O&P) Standards.

Noncompliance by Year Reported or Discovered



Noncompliance by Discovery Method



RISK-BASED OVERSIGHT

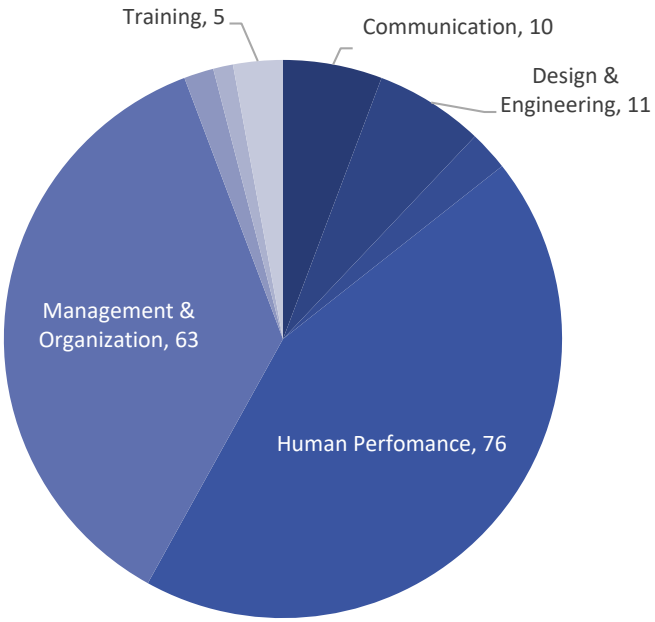
In 2014 WECC implemented a risk-based framework and approach to entity oversight. Since adoption of risk-based methodology, the percentage of noncompliance identified internally by entities increased. This is a positive indicator of the industry's reliability culture.

TARGETED MITIGATION

WECC analyzes noncompliance using NERC's Cause Code Assignment Process to investigate possible trends and identify areas for potential improvement.

In 2016, the majority of noncompliance was attributed to the Individual Human Performance and Management & Organization cause codes. In addition to targeting issue-specific causes, WECC encouraged entities to focus mitigation efforts in these areas to help reduce recurrence.

2016 Noncompliance by Root Cause



Source	Publisher
The Event Analysis Management System (TEAMS) Generation Availability Data System (GADS) Misoperations Information Data Analysis System (MIDAS) Transmission Availability Data System (TADS)	North American Electric Reliability Corporation
Various	Peak Reliability
Canadian Socioeconomic Database (CANSIM)	Statistics Canada
Forms FERC-714 and OE-417	US Department of Energy
Electric Power Monthly Forms EIA-826, EIA-860, EIA-861 and EIA-923 Natural Gas Monthly	US Energy Information Administration
Loads and Resources Data Request	Western Electricity Coordinating Council
GIS and Map Data	National Oceanic & Atmospheric Administration (NOAA); National Centers for Environmental Information (NCEI); National Renewable Energy Laboratory (NREL); National Atlas of the United States (NAUS); United States Geological Survey (USGS); USGS Geospatial Multi-Agency Coordination (GeoMAC); US Census Bureau (USCB); US Department of Commerce (USDC); US Department of Agriculture (USDA); USDA Farm Service Agency (USDA FSA); US Forest Service (USFS); Natural Earth Vector; Esri; Esri Canada; DigitalGlobe; Earthstar Geographics; CNES/Airbus DS; GeoEye; Getmapping; Aerogrid; Institut Géographique National (IGN)

The State of the Interconnection presents the most accurate historical data available at the time of publication. All data are subject to revision in future updates to the report and in other WECC documents without notice.