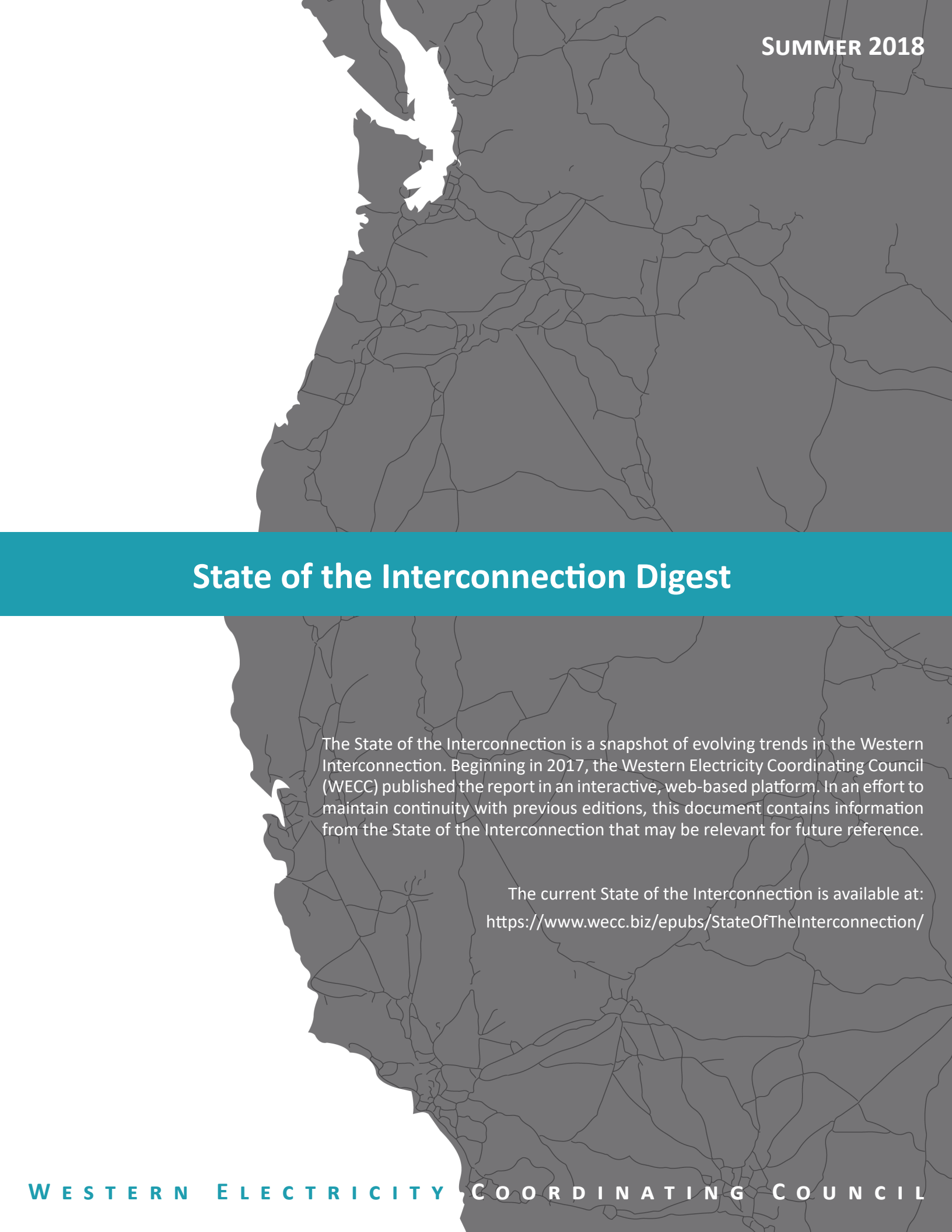


SUMMER 2018

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 the Interconnection that may be relevant for future reference.

The current State of the Interconnection is available at:
https://www.wecc.biz/epubs/StateOfTheInterconnection/

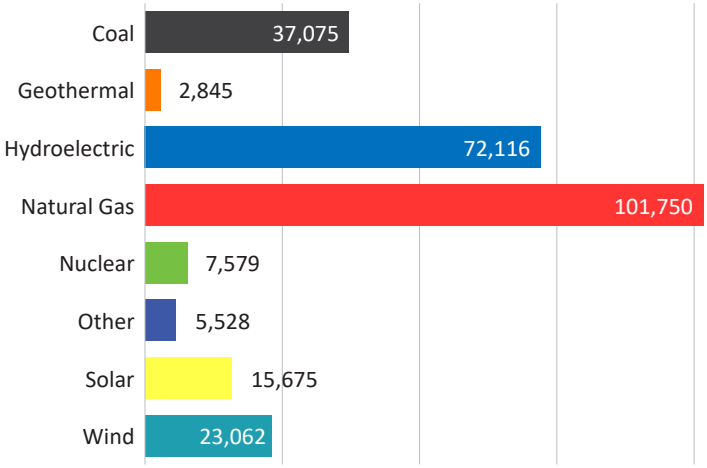
WESTERN ELECTRICITY COORDINATING COUNCIL

RESOURCE PORTFOLIO

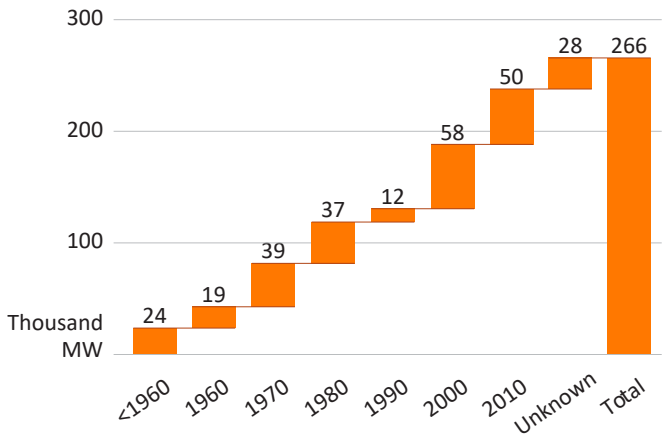
In 2017, the combined nameplate capacity of utility-scale resources in the Western Interconnection was 265,700 MW. Approximately 3,000 MW of wind and solar capacity were added during the year. Coal and natural gas capacity decreased by 2,300 MW.

The Western Interconnection has a diverse mix of resources, including large amounts of hydro and renewable resources. Compared the the Eastern Interconnection, a larger proportion of generation comes from hydroelectric and variable (wind and solar) resources.

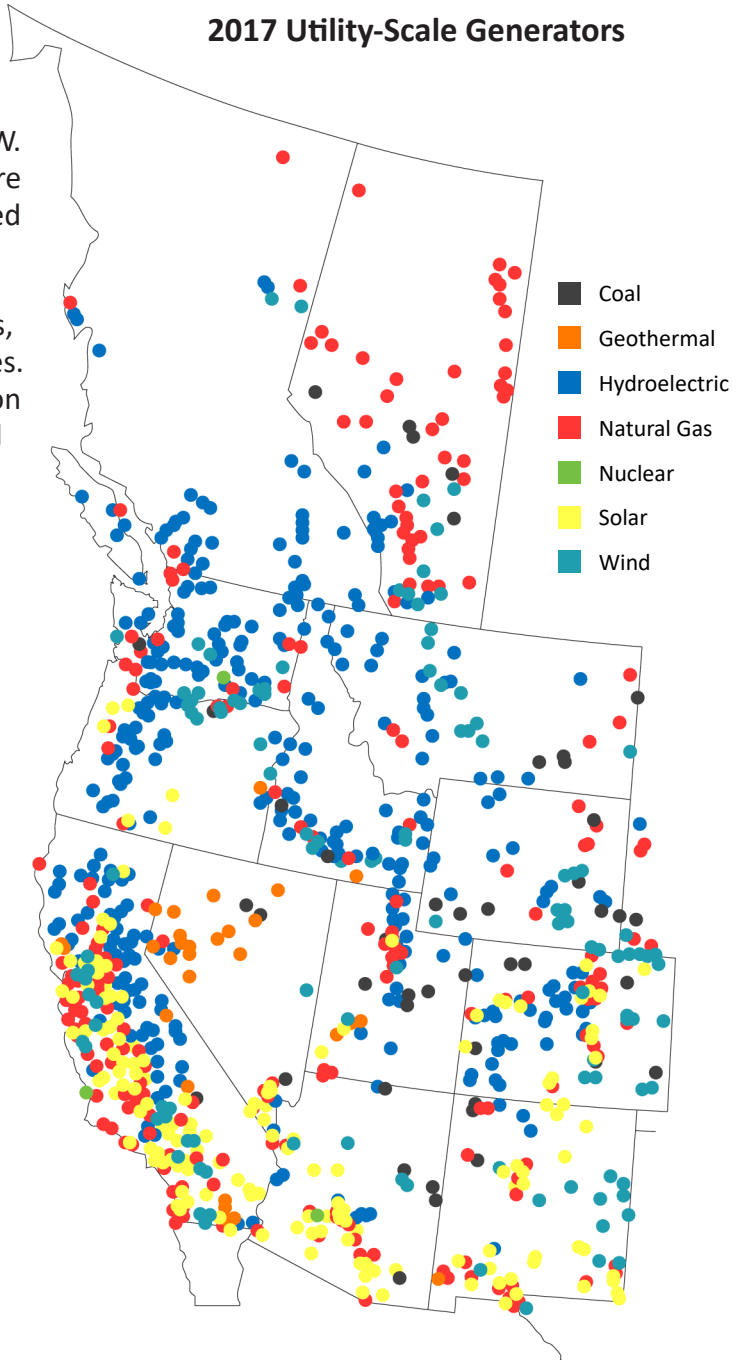
Net Capacity by Fuel Type (MW)



Net Capacity Growth by Decade



2017 Utility-Scale Generators



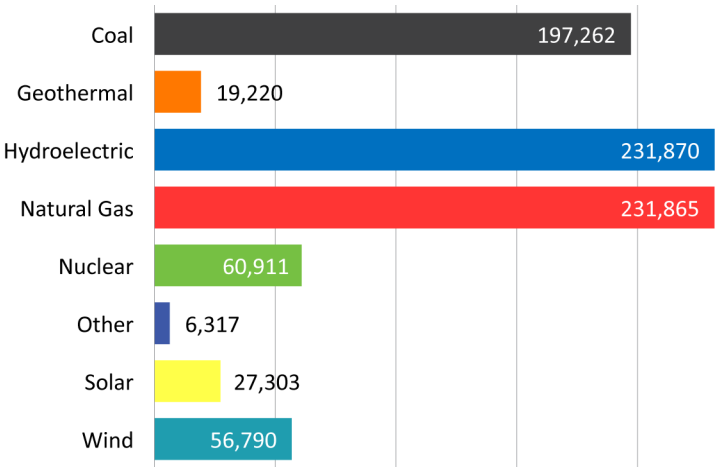
Different subregions of the West have widely different resource portfolios. Hydro units are dominant in the Northwest, while California and the Southwest rely heavily on natural gas. Solar units have become increasingly prevalent, especially in California, as wind capacity has grown in the Rocky Mountains and along the Columbia River.

NET GENERATION

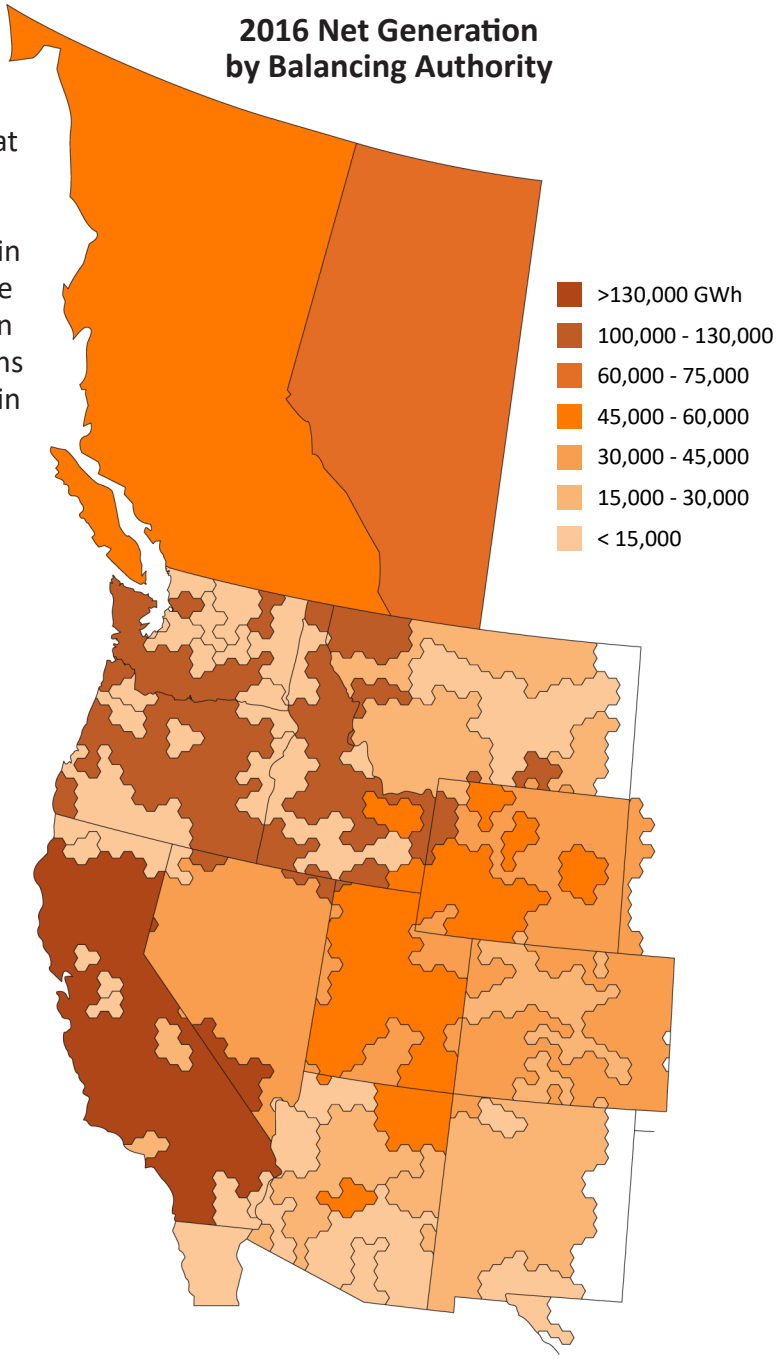
Most generation on the system comes from coal, hydroelectric, and natural gas resources. This is the case at both system maximum and minimum generation.

Base-load generators, like coal and nuclear units, maintain relatively steady daily and seasonal outputs. Flexible generators, like natural gas and hydroelectric units, can have varying output because they respond to fluctuations in output from Variable-Energy Resources (VER), changes in consumer demand, and other conditions.

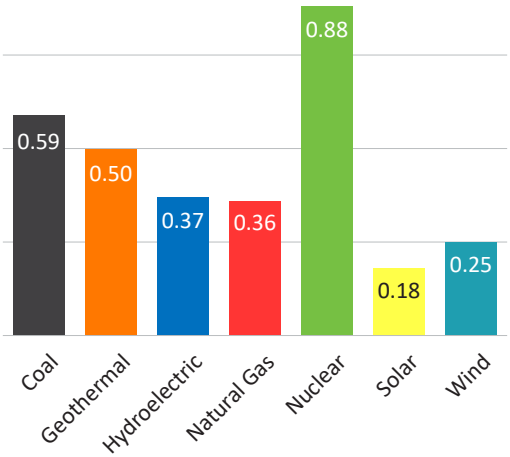
2016 Net Generation by Fuel Type (GWh)



2016 Net Generation by Balancing Authority



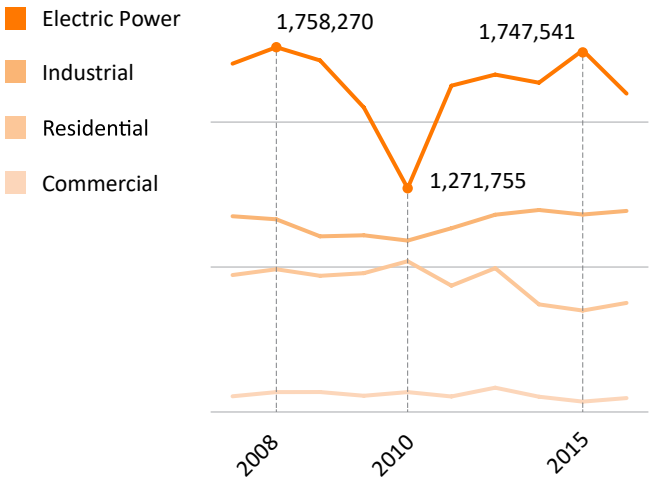
2016 Capacity Factors by Fuel Type



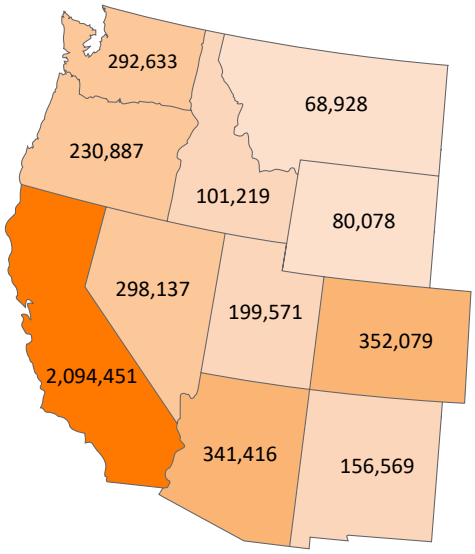
CAPACITY FACTOR

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.

Natural Gas Consumption by Sector (MMcf)



2016 Consumption by State (MMcf)

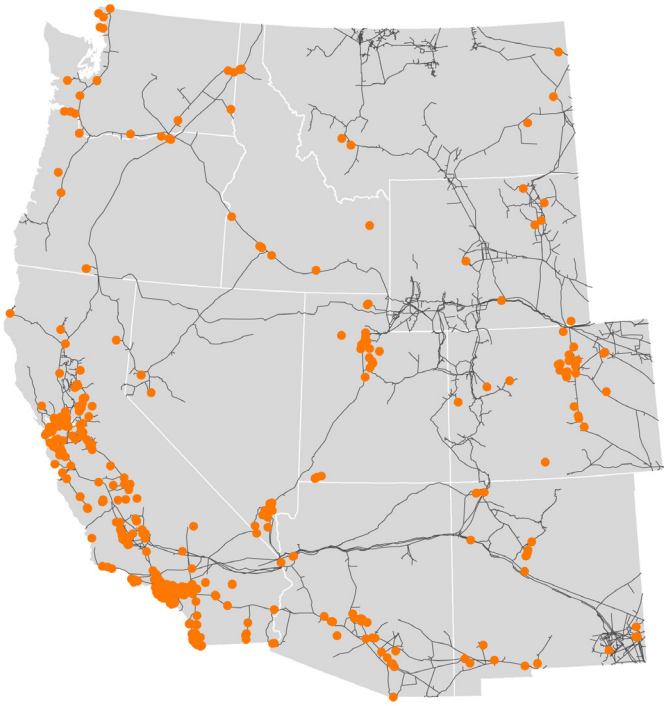


Natural Gas

The Bulk-Power System is becoming increasingly reliant on natural gas for generation. Natural gas is the largest fuel source by capacity and the second largest by actual generation in the Western Interconnection. The electric power sector is the largest consumer of natural gas in the Western United States. As VER capacity increases and coal and nuclear plants retire, gas will become more important than ever.

Gas offers economic, environmental, and reliability advantages as a fuel for power generation. It is an increasingly critical resource because the flexibility and quick-start capability of some gas technologies enable the system to adapt to fluctuating output from VER and other changes in demand. The use of gas also poses several challenges.

Pipelines and Power Plants



There are over 40,000 miles of natural gas pipeline in the Western United States. These pipelines carry gas long distances from production sites to consumers, including power plants.

About half of gas-fired power plants in the Western Interconnection receive their fuel supply directly from these pipelines. In states like California and Nevada, where natural gas is the primary fuel source for electric power generation, these pipelines are vital to reliability.

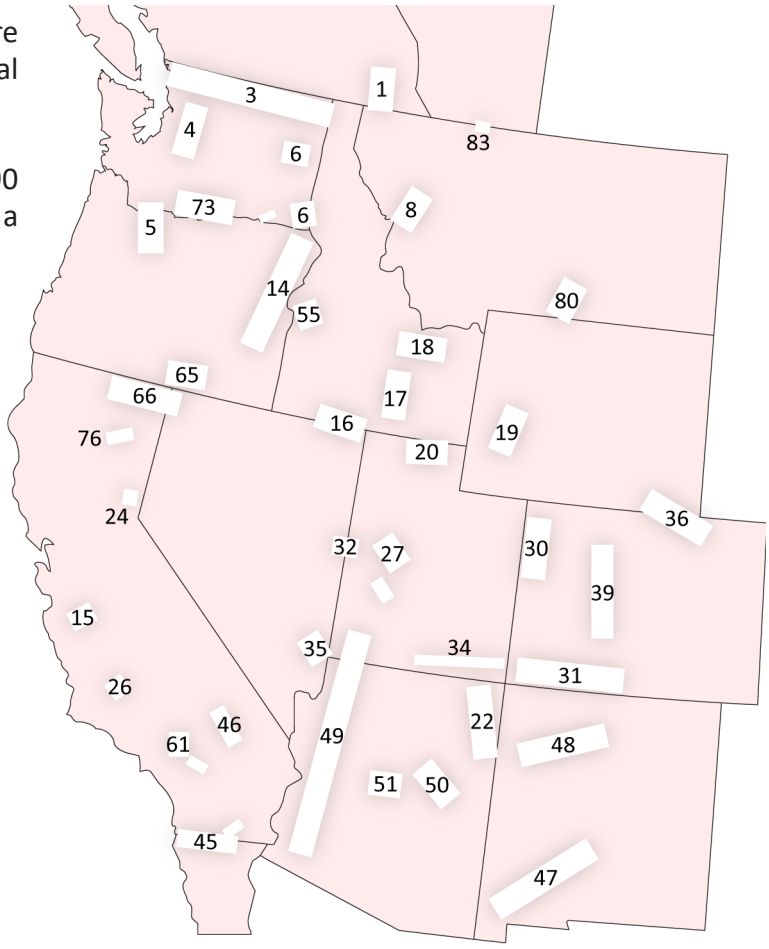
WECC PATHS

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

Two measures of path congestion are the U75 and U90 metrics. These measure the percent of time that flow on a path is above 75 or 90 percent of its operating limit.

Many factors determine operating limits. A low U75 or U90 does not necessarily indicate a path is underutilized, nor does a high values necessarily indicate congestion. For example, some paths were built to carry electricity from large plants—high flow is not unusual for these paths.

Major WECC Paths



2017 Path Flow

Path	U75 (%)	U90 (%)	Path	U75 (%)	U90 (%)
Path 1	10.0	3.5	Path 35	11.6	2.3
Path 3	8.2	1.3	Path 36	31.5	2.6
Path 4	1.4	0.0	Path 39	0.0	0.0
Path 5	0.2	0.0	Path 45	0.1	0.1
Path 8	4.6	0.0	Path 46	0.6	0.0
Path 14	2.2	0.5	Path 47	3.5	0.1
Path 15	21.4	12.5	Path 48	4.5	0.5
Path 16	0.8	0.0	Path 49	0.4	0.0
Path 17	0.1	0.0	Path 50	0.0	0.0
Path 18	7.9	0.0	Path 51	0.0	0.0
Path 19	20.7	2.1	Path 55	2.6	0.1
Path 20	12.8	4.0	Path 61	6.7	0.1
Path 22	2.2	0.0	Path 65	42.4	21.1
Path 24	3.2	0.1	Path 66	42.3	12.6
Path 26	2.9	0.4	Path 73	3.9	0.2
Path 27	17.9	2.0	Path 76	1.2	0.1
Path 30	11.1	2.2	Path 80	0.2	0.0
Path 31	11.9	5.7	Path 83	2.8	0.2
Path 32	2.4	0.7			

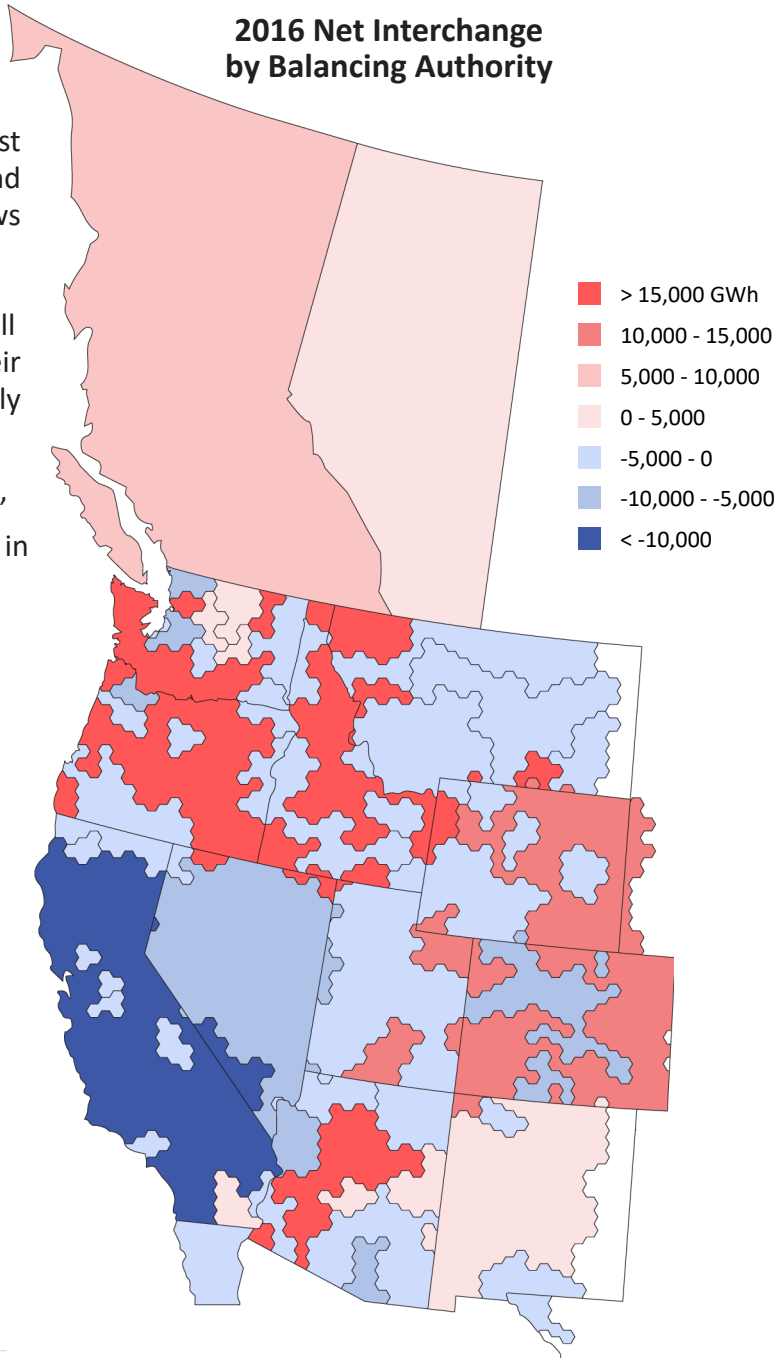
NET INTERCHANGE

There is a strong interdependence among Balancing Authorities in the Western Interconnection. BAs must balance generation and load within their own footprint and throughout the Interconnection. As a result, electricity flows from generation-rich BAs to load centers.

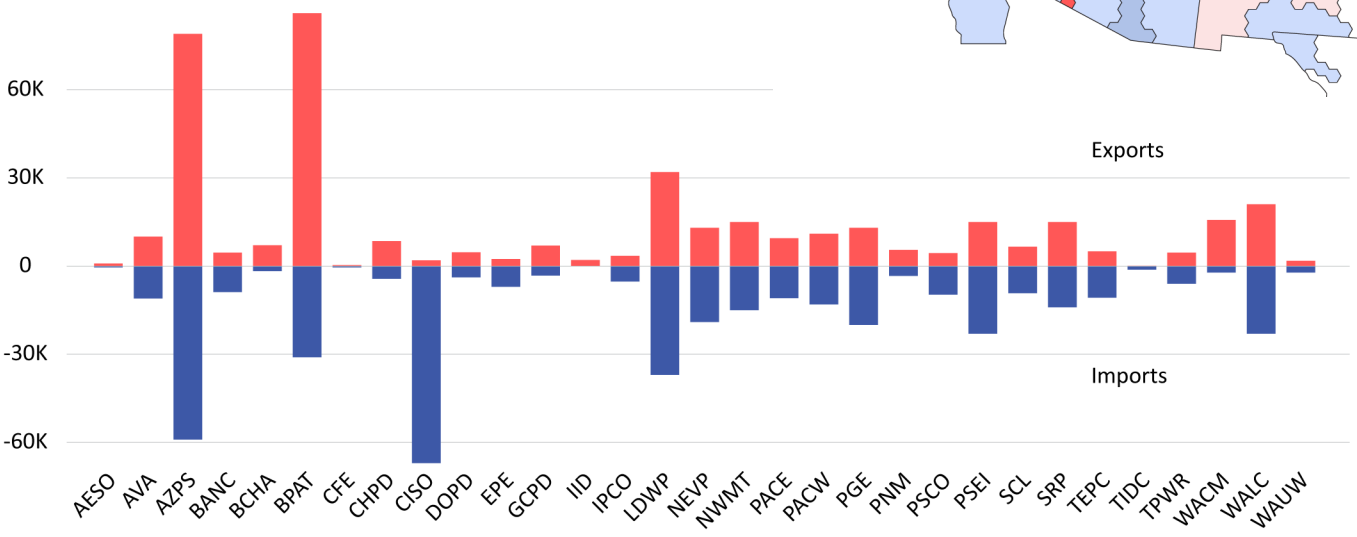
BAs with a small amount of total net interchange may still have large amount of electricity flowing into and out of their footprints daily, with imports and exports that are roughly equal.

Electricity generally flows south and west in a "doughnut" pattern, in contrast to spiderweb-shaped configurations in other North American Interconnections.

2016 Net Interchange by Balancing Authority



Imports and Exports by Balancing Authority (GWh)

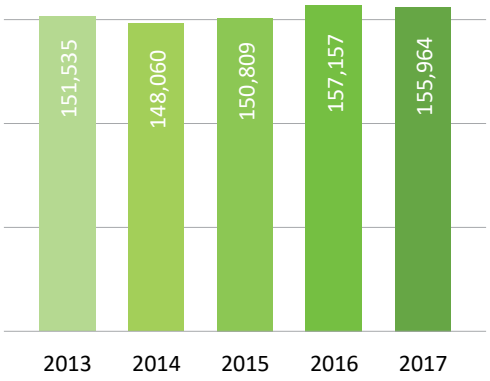


DEMAND

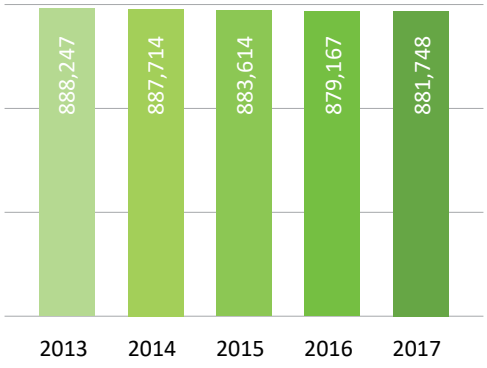
The Western Interconnection has a diverse load composition. The majority is concentrated along the West Coast, with pockets in the Southwest and Rocky Mountains. Overall, the Interconnection is summer-peaking, though the Northwest is winter-peaking.

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.

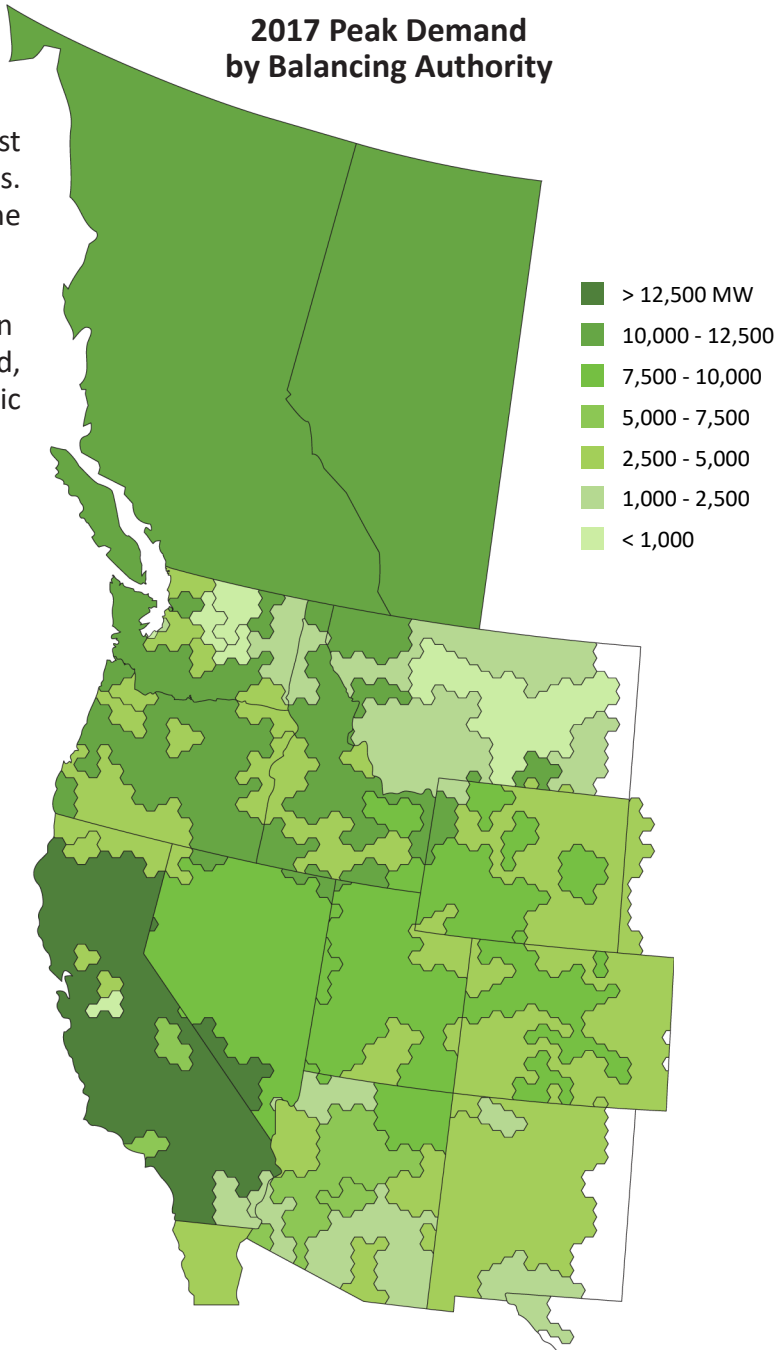
Peak Demand by Year (MW)



Energy Consumption (GWh)

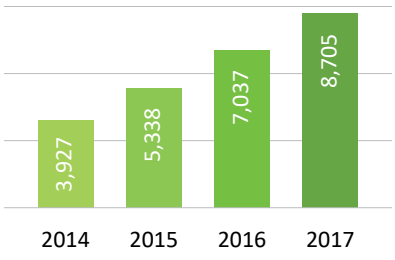


2017 Peak Demand by Balancing Authority



One factor affecting demand is the increasing prevalence of rooftop solar. The estimated capacity of rooftop solar in the Western Interconnection increased by roughly 120 percent between 2014 and 2017.

Estimated Rooftop Solar Capacity (MW)



EVENTS

Through the Event Analysis Process (EAP), entities voluntarily collaborate with NERC and their Regional Entities to review events on the BPS. The EAP provides a consistent approach to event analysis and a platform for lessons learned to be shared with industry. All lessons learned through the EAP are posted on the NERC website.

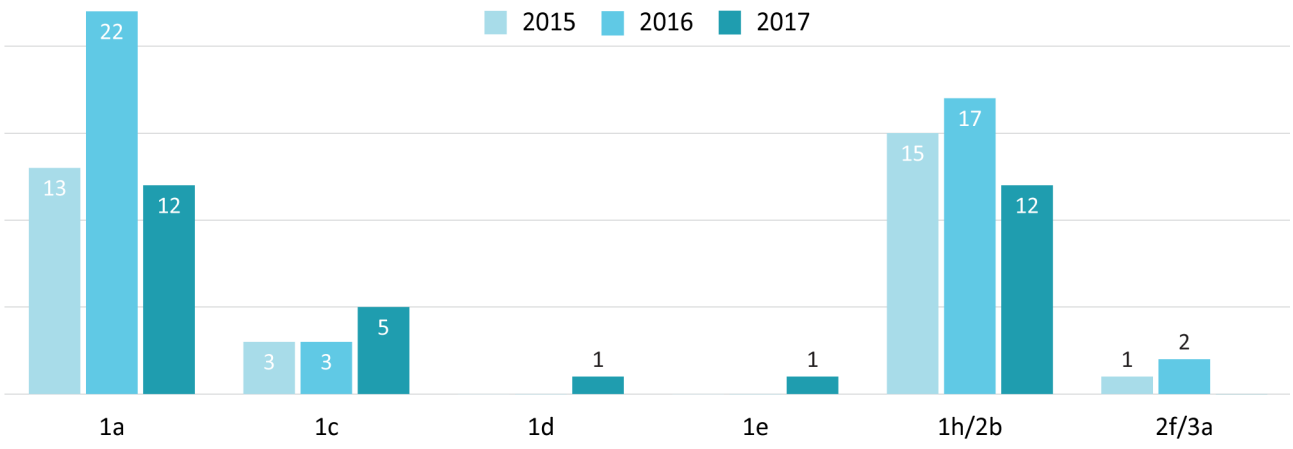
In order for an event to be reported through the EAP, it must meet predetermined criteria. Events reported in the Western Interconnection over the last several years fall into the following categories:

Reportable Events by Year

Category	*2013*	*2014*	*2015*	*2016*	*2017*
1a	17	13	13	22	12
1c	3	5	3	3	5
1d	0	0	0	0	1
1e	0	0	0	0	1
1h/2b	20	19	15	17	12
2f/3a	2	0	1	2	0

- **Category 1a: Loss of Bulk-Electric System Facilities**
  Unintended loss of three or more facilities from a common cause
- **Category 1c: Remedial Action Scheme Misoperation**
  Failure or misoperation of a RAS
- **Category 1d: System Voltage Reduction**
  System-wide voltage reduction of ≥ 3 percent for 15 minutes or more due to a BES emergency
- **Category 1e: Islanding**
  Unintentional BES separation resulting in an electrical island ≥ 100 MW
- **Category 1h and 2b: Loss of Monitoring or Control**
  Loss of monitoring or control capability for 30 minutes or more that affects an entity's ability to make operating decisions
- **2f and 3a: 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; or the unintended loss of ≥ 2,000 MW of generation

Reportable Events by Category



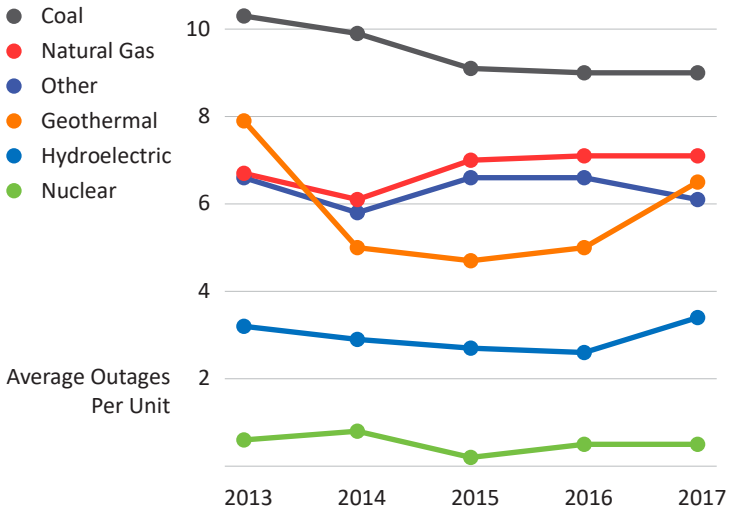
UNPLANNED OUTAGES

Unplanned outages can undermine the reliability of system operations. Incidence, cause and duration are important indicators of the potential impact of unplanned outages across the Interconnection.

Generation outages can limit available capacity, and may introduce instability by reducing frequency, inertia, voltage support, and ramping capability. In some cases, the loss of a large unit in one part of the Interconnection can cause generators in other parts of the system to trip, further impacting reliability.

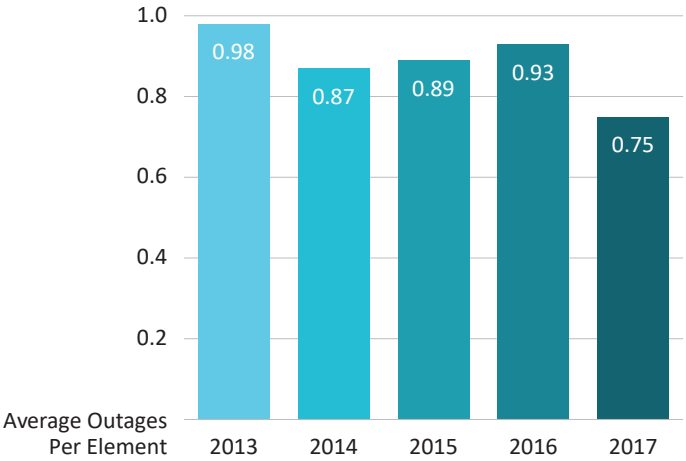
Measuring the frequency (per unit), duration (weighted by capacity), and causes of of unplanned outages allows WECC to identify and monitor vulnerabilities in the power system.

Unplanned Generator Outages by Fuel Type

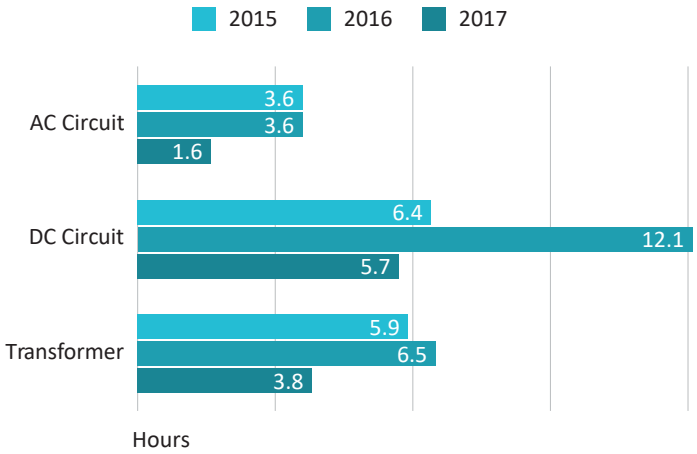


Transmission outages increase flow on transmission elements remaining in service, potentially causing them to overload or trip. The loss of transmission elements can also limit available generation and lead to reduced system stability.

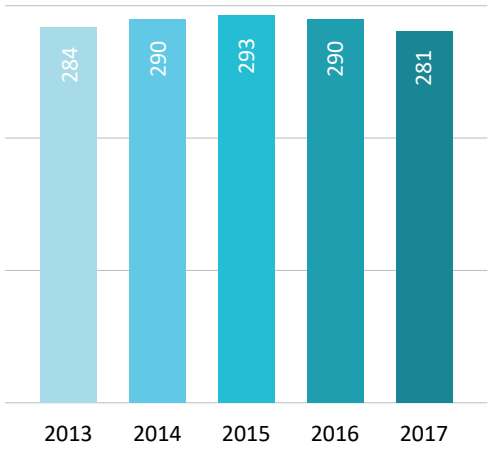
Unplanned Transmission Outages (>200kV)



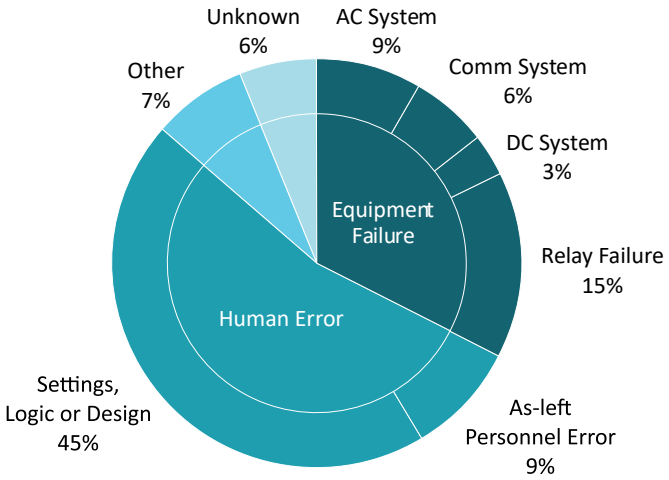
Median Outage Duration by Element (>200kV)



Misoperations by Year



Misoperations by Cause (2013-2017)



MISOPERATIONS

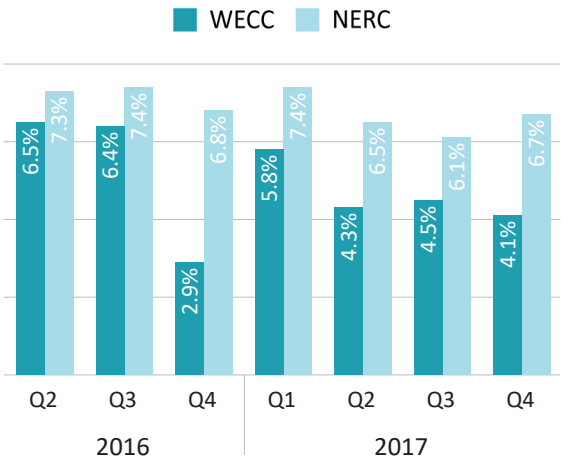
Protection systems help support overall system reliability by protecting sensitive equipment. When a protection system element—for example, a relay device—fails to operate as designed, or operates unintentionally or outside of its zone of protection, it is called a misoperation. Misoperations contribute to outages of generation and transmission facilities, and place the system in a less reliable state.

The three largest causes of misoperations in the Western Interconnection are human error, equipment failure, and unknown. Misoperations with unknown causes are of particular concern because they represent instances that may not be completely remediated by a corrective action plan.

NERC measures the incidence of misoperations by the ratio of misoperations to correct operations, or "misoperation rate".

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

Misoperation Rate



REGISTRATION

In accordance with the Compliance Monitoring and Enforcement Program (CMEP), NERC and WECC assure reliability by holding entities in the Western Interconnection accountable for compliance with Reliability Standards.

Approximately 25 percent of the Registered Entities in the NERC Compliance Registry are under WECC's jurisdiction. WECC also provides certain oversight services for international entities, which are designated for reliability functions by their respective governmental authorities.

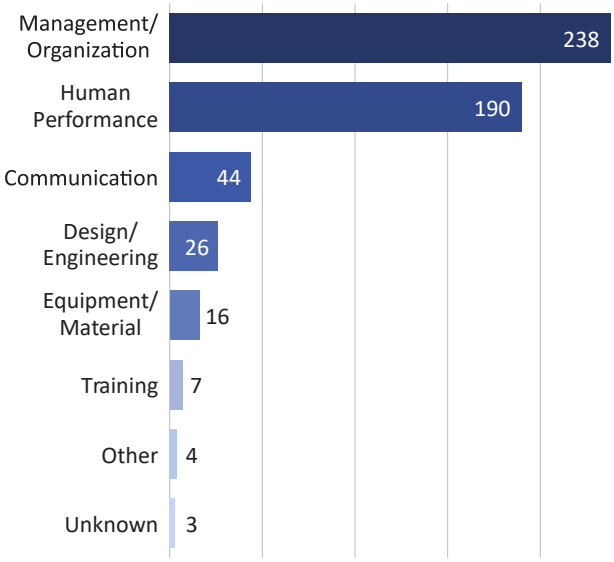
In some cases, multiple operational entities share a single registration, while other entities are split across multiple registrations. For example, from an operational perspective there are 38 BAs, but there are only 34 BAs registered with NERC in the WECC footprint.

Registered Entities by Function

*Function**	*WECC*	*NERC*	*AB*	*BC*	*MX*
Balancing Authority	34	111		1	1
Distribution Provider	75	355		13	2
Distribution Provider (UFLS)	7	55		3	
Frequency Response Sharing Group	1	1			
Generator Operator	247	918		16	2
Generator Owner	254	962		16	2
Planning Authority/Coordinator	32	78		1	
Reliability Coordinator	1	21		1	
Reserve Sharing Group	3	19			
Resource Planner	52	174		2	
Transmission Operator	49	187		3	1
Transmission Owner	78	343		4	1
Transmission Planner	49	199		2	
Transmission Service Provider	35	88		2	1
Unique Entities	372	1526	1	29	4

*This table does not include all reliability functions.

Noncompliance by Cause (2015-2017)

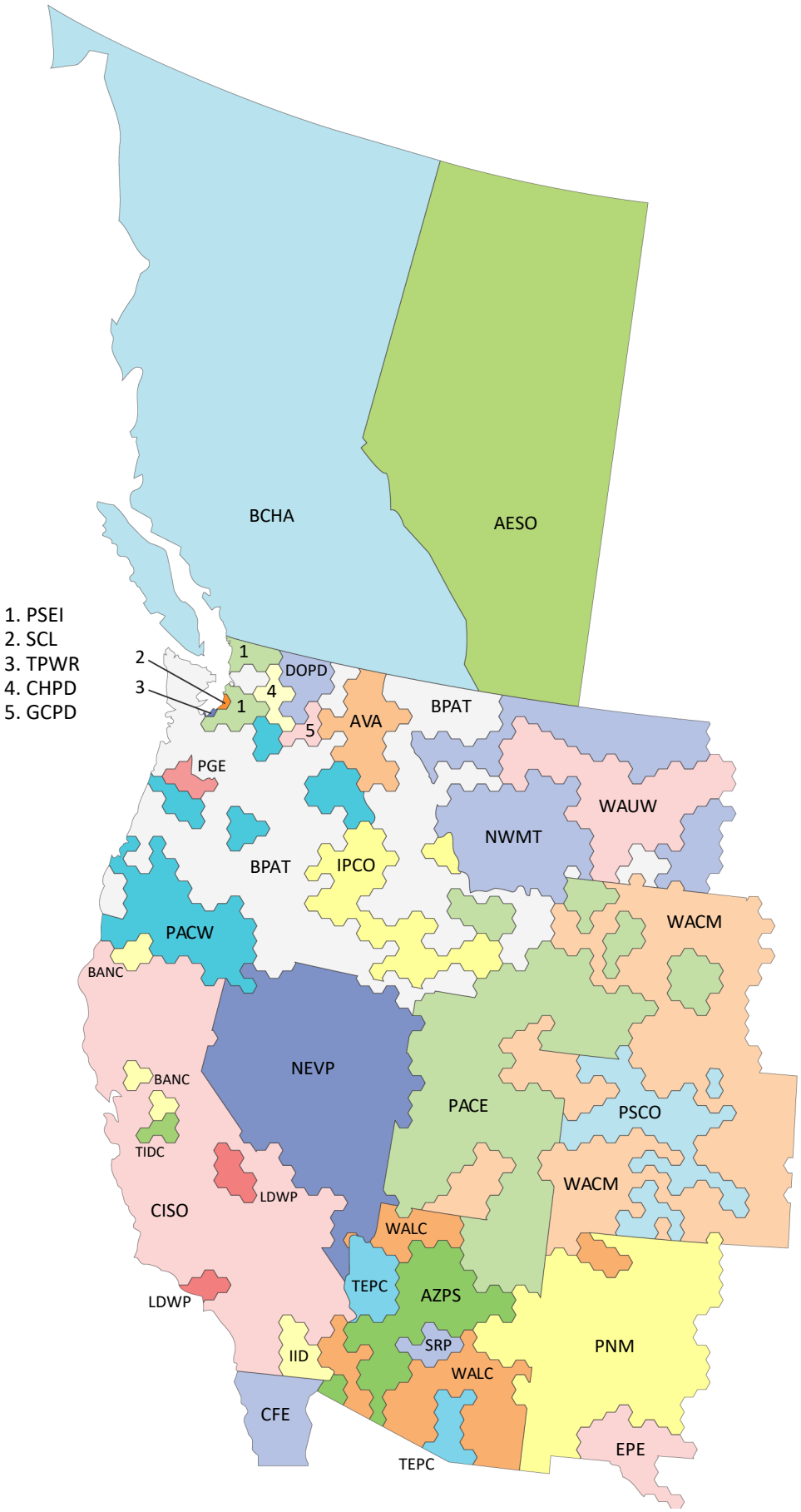


COMPLIANCE MONITORING

WECC reviews potential noncompliance reported by entities or identified during compliance audits. In 2017, WECC performed compliance audits of 25 entities, including 22 audits of Critical Infrastructure Protection Standards and 25 audits of Operations and Planning Standards.

WECC analyzes noncompliance to investigate possible trends and identify areas for potential improvement. To date, the majority of noncompliance has been attributed to the Individual Human Performance and Management/Organization cause codes. In response, WECC has encouraged entities to focus mitigation efforts in these areas to help reduce recurrence.

Balancing Authority Reference Map



Sources

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	Commission for Environmental Cooperation; 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.