Transmission in the West: Challenges and Proposals for Data Access

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WESTERN RESOURCE ADVOCATES

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Scope and Purpose

U.S. Energy Information Administration (EIA) Annual Energy Outlook[1] forecasts indicate a growth projection in electricity demand for the United States from 4,000 billion kilowatt hours (kWh) in 2021 to 5,100 billion kWh by 2050. To meet this projected increase in demand will require significant expansion to the infrastructure system over the next few decades. This need will be compounded as climate change affects grid reliability and as grid operation further regionalizes.

To successfully build and operate this next generation of our transmission system efficiently, transparent access to the current state of transmission operations and flows is necessary to inform the near- and long-term transmission expansion investments. Near-term and real-time transmission flow data is vital information; it is in the public interest to have access to it, but that access is currently lacking. Such data will be needed for transmission system operation, planning, and policy decisions by all transmission-owning or -operating stakeholders, regulators, and policymakers, transmission developers, and clean energy and ratepayer advocates. However, most of the information on actual real-time and recent historical transmission flow data is limited to the grid operators, merchant transmission owners, or utilities. Further, the publicly available data is often inconsistently reported and difficult to access. This primer is intended to provide a foundational understanding of the various dimensions to data as it pertains to transmission operations and availability. The report is split into three key sections:

- *A descriptive summary of how transmission flows are currently managed and reported in the Western Interconnection.*
- *Appreciation for the spectrum of metrics and information of transmission flow data.*
- *Identification of existing challenges and barriers to transparent access to transmission flow data and the data's impacts on transmission policy in the Western Interconnection.*

Bulk Transmission: Reliability Oversight

The bulk electric transmission system is regulated by federal, regional, and state entities to protect the interests of electricity users and companies. At the federal level, the **Federal Energy Regulatory Commission (FERC)** was established within the Department of Energy in 1977 to regulate the interstate movement of energy across all three of the nation's asynchronous interconnections – Eastern, Western, and ERCOT (Electric Reliability Council of Texas). FERC's specific role in bulk transmission is to regulate transmission and wholesale sales of interstate electricity commerce, review the siting for transmission projects, create mandatory high-voltage interstate transmission system reliability standards, monitor and investigate energy markets, and enforce regulatory requirements.[2] In short, FERC oversees bulk transmission at the interstate level, enforces compliance with interstate regulations of the electricity grid, and acts as the ultimate regulator of interstate power transactions.[3]

[1] https://www.eia.gov/outlooks/aeo/pdf/AEO2022_Narrative.pdf
[2] https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf
[3] https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/primer.pdf

Reliability oversight - Relevant federal regulations impacting transmission

FERC oversees interstate energy regulations and has four distinct orders that have impacted the bulk power transmission system. These orders and their effects are outlined in Table 1.

Table 1: Federal regulatory policies and their impacts to the transmission system[4]

Order	Year	Purpose	Impact on Transmission Policy or Planning or Operations
888	1996	To unbundle utility generation and transmission function to promote wholesale competition for electricity supply and non-discriminatory access to transmission services; requires transmission owners to provide open access to their transmission systems and submit services and rate plans to FERC via Open Access Transmission Tariffs (OATTs).	Made transmission pathways available to all and initiated a transmission market via an Open Access Same-time Information System (OASIS).
889	1996	To address the issues of access to transmission system information, including data on transfer capacity in near real time.	Made the OASIS data previously held only by vertically integrated utilities available to the public.
2000	1999	To establish requirements and encourage transmission-owning utilities to form or join a Regional Transmission Organization (RTO).	Transmission-owning utilities agreed to let the RTOs manage the power on the systems and perform long-term planning in exchange for compensation, leading to an increase in transmission planning for transmission pathway updates and additions. [5]
1000	2011	To require public utility transmission providers to coordinate a regional planning process to determine if there are more cost-effective solutions to mutual transmission needs.	Reduced transmission redundancies and increased transmission build-out efficiency. Broader industry acceptance of Non-Wires Alternatives (NWA), Demand Response (DR), and Distributed Energy Resources (DER).[6]

After the Energy Policy Act of 2005 called for an Electric Reliability Organization, FERC granted the role to the **North American Electric Reliability Corporation (NERC)** to develop and enforce compliance with reliability standards and ensure security of the U.S. grid.[7] Subject to FERC

[4] https://www.nrel.gov/docs/fy13osti/53696.pdf
[5] https://sustainableferc.org/rto-backgrounders2/#:~:text=The%20Electric%20Reliability%20Council%20of,not%20sales%20in%20interstate%20commerce.
[6] https://www.oati.com/Blog/transmission-reliability/ferc-order-1000
[7] https://www.nerc.com/AboutNERC/Pages/default.aspx

oversight, NERC is a not-for-profit international regulatory authority tasked with grid reliability creation and enforcement of standards. NERC is not involved in transmission planning or operation.[8]

Reliability oversight– Role of NERC and the Regional Entities

NERC has eight subsidiaries, or **Regional Entities (REs)**, charged with grid reliability assurance and who create, monitor, and enforce standards and promote activity that ensures reliability. The eight regional entities are the Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability First (RF), SERC Reliability Corporation (SERC), Texas Reliability Entity (Texas RE), Southwest Power Pool (SPP), Florida Reliability Coordinating Council (FRCC), and the **Western Electricity Coordinating Council (WECC)**. In the Western Interconnection, and relevant to this paper, there is only one regional entity: WECC. WECC is the largest of all the regional entities and is an independent, 501(c)(4) organization governed by voting members and an independent board. In regard to transmission, WECC's scope of oversight covers grid reliability and security of the infrastructure in the West, but WECC does not own transmission infrastructure or have authority over transmission siting, permitting, cost allocation, construction, or operation.[9]

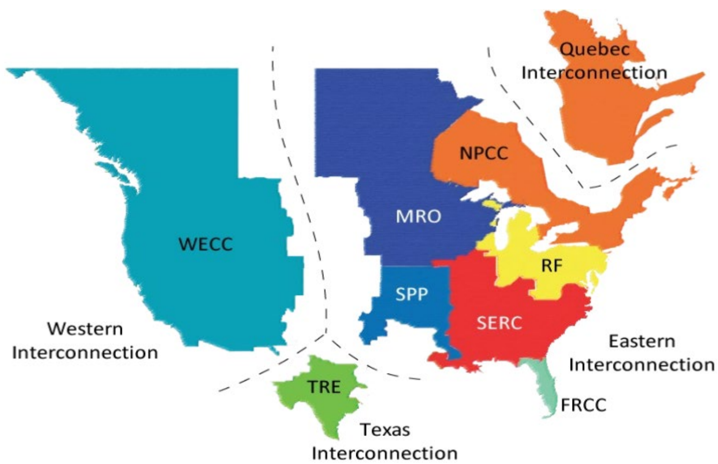

Figure 1: U.S. interconnections and regional entities.
WECC is the only regional entity for reliability assurance in the western U.S.

Within each Regional Entity boundary, there is one or more **Reliability Coordinators (RCs)**. These coordinators have the highest level of regional authority and are responsible for reliable operation of the bulk electric system. They coordinate system restorations, issue energy emergency alerts, and continuously monitor the reliability of the transmission system. They have authority to direct transmission operators and generators to take action to preserve reliable operation of the grid.[10] The Regional Coordinators oversee grid compliance with federal and regional grid standards and create strategies to prevent or mitigate system emergencies in both day-ahead and real-time operations.[11] In the Western interconnection, there are two coordinators: **Southwest Power Pool West (SPPW) and RC West** (a service of the California Independent System Operator), see Figure 2.

[8] https://www.nerc.com/AboutNERC/Resource%20Documents/NERCHistoryBook.pdf
[9] https://www.wecc.org/Pages/101.aspx
[10] https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf
[11] http://www.caiso.com/informed/Pages/RCWest/Default.aspx

Figure 2: A map of NERC Regional Coordinators as of 2022. There are 13 coordinators in the U.S., two of them in the West.[12]

The most granular level of grid reliability is carried out by Balancing Authorities (BAs). The operators of the 38 BAs in the Western interconnection (see Figure 3) are held to NERC's FERC-approved mandatory reliability standards and ensure sufficient electricity supply can meet electricity demand within each individual BA footprint.

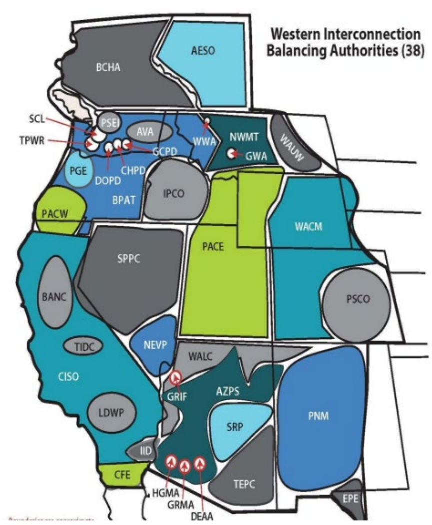

Figure 3: Illustrative picture of the balancing authorities within WECC.[13]

The balance is maintained by instructing generators to switch on or off, or by transferring electricity to or from neighboring BAs. Figure 4 is a graph of imports and exports of energy between WECC BAs in

[12] https://www.nerc.com/pa/rrm/TLR/Pages/Reliability-Coordinators.aspx
[13] https://www.wecc.org/Administrative/=INTRO_MOD_9-Grid%20Ops=rev2016.pdf

2018, revealing the strong interdependence between neighboring BAs. The graph essentially depicts that the energy transfer quantity and ratio of import vs. export vary for each BA, highlighting the dependency between BAs. This dependency reaffirms the need to better appreciate inter-BA energy transfers and the critical role of using existing transmission infrastructure and how congestion could manifest.

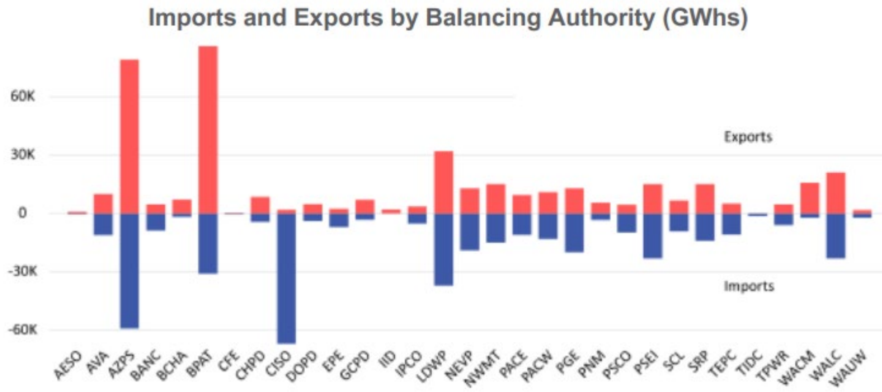

Figure 4: Exchanges of electrical energy between WECC BAs in 2018 (GWh).[14]

If an **Organized Wholesale Market (OWM)** operator such as a **Regional Transmission Organization (RTO)** or an **Independent System Operator (ISO)** is in place, most RTO/ISO operators take on the BA's responsibility to ensure that the electricity supply and demand are balanced and transmission capacity can move the electricity to where it is needed. The RTO/ISO manages the bulk power transmission system capacities, ensures customer and supplier access to the transmission grid, dispatches assets to keep a balance of supply and demand, and plans generation and transmission within its footprint.[15] For the purposes of this study, an RTO/ISO will be referred to as an Organized Wholesale Market.

Within the market footprint, the original transmission owners still own the lines, but relinquish operational control and are compensated for the use of their lines. The flow of electricity over the transmission system is then optimized over a larger geographic area, rather than by individual owners and transactions.

Two thirds of total United States' annual electricity demand is within an OWM. **California Independent System Operator (CAISO)** is the only ISO in the West and operates mostly within the borders of the state of California (see Figure 5). CAISO operates the flows along the transmission lines within its boundaries. For imports into or exports out of CAISO, transmission capacity reservations are made with external BAs using bilateral contracts. More details on the operation of CAISO can be found in the *CAISO as an ISO in the West* section on page 16.

[14] https://www.wecc.org/Reliability/State%20of%20the%20Interconnection%20Digest%20(Summer%202018).pdf
[15] https://www.publicpower.org/system/files/documents/January%202022%20-%20Wholesale%20Electricity%20Markets %20and%20Regional%20Transmission%20Organizations.pdf

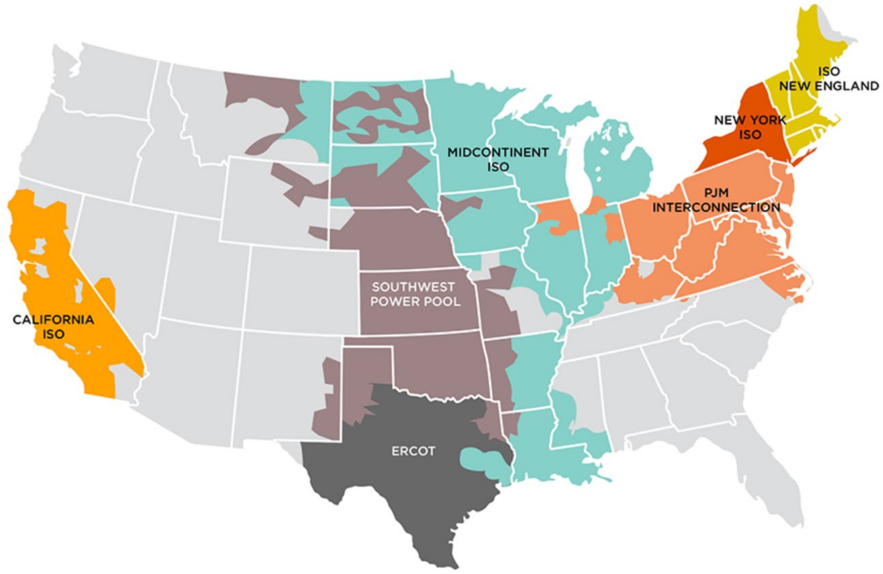

Figure 5: Illustrative map of the OWMs in the United States. Notice that CAISO is the only OWM in the West.[16]

Differences in the Western vs. Eastern Interconnections

Some contextual understanding of how the Western interconnection differs from the Eastern interconnection is critical to appreciating the transmission system and related information availability in the West. The U.S. electric grid serves nearly 157 million residential, commercial, and industrial customers[17] and operates at a steady 60 Hz, delivering alternating current. Approximately 7,300 power plants[18] and 700,000 miles of high-voltage transmission lines make this service possible.[19] Over time, three distinct grid systems have evolved in the United States: the Eastern interconnection, the Western interconnection, and ERCOT. Each interconnection is a network of wires that together span the continental United States and parts of Canada and Mexico (see Figure 1).

The Eastern and the Western interconnections are linked by six direct current ties, allowing 1,320 megawatts of electricity to flow between them; this is a relatively small amount compared to the hundreds of gigawatts flowing within each interconnection.[20] Benefits of increasing the ability for these two grids to share power are being researched by the Department of Energy.[21]

The ERCOT interconnection operates within Texas and therefore is not regulated by FERC, due to an intra-state (or not interstate) organized market for electricity. However, the Texas Reliability Entity serves as the Regional Entity for the ERCOT region and complies with NERC's reliability standards for operations and planning. The Eastern and Western interconnections have greater operational similarities than ERCOT and are compared in detail below. Table 2 offers a comparison of the major U.S. Eastern and Western interconnections characteristics.

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[16] https://sustainableferc.org/rto-backgrounders-2/
[17] https://www.eia.gov/electricity/annual/html/epa_01_02.html
[18] https://www.epa.gov/green-power-markets/us-electricity-grid-markets
[19] Transmission Planning: Introductory Overview. Slide deck. Clean Energy Buyers Institute, 2022.
[20] https://www.energy.gov/eere/wind/articles/uniting-us-power-system
[21] https://www.nrel.gov/analysis/seams.html

Table 2: Major characteristics of the U.S. portions of the Western and the Eastern Interconnections. The Western interconnection has greater distances between generators and load centers and a greater percentage of public lands, leading to increased challenges for transmission planning.

Characteristic	U.S. Western Interconnection	U.S. Eastern Interconnection
Footprint	1.8 million square miles	2.4 million square miles
Population Served	80 million[22]	240 million[23]
Transmission lines	136,000 miles[24]	459,000 miles[25]
Percent of public/protected land	87%	27%
Regional Entities for Reliability	1	6
Reliability Coordinators	2	11
Balancing Authorities	34	31
Organized Wholesale Markets	1	5
Electrical Generation Sources (2020)[26,27]	- Natural Gas (35%) - Hydroelectric (23%) - Coal (15%) - Wind (9%) - Nuclear (8%) - Solar (7%) - Biomass (1%) - Geothermal (2%)	- Natural Gas (41%) - Nuclear (24%) - Coal (21%) - Wind (7%) - Hydroelectric (4%) - Biomass (2%) - Solar (1%) - Geothermal (0%)

Uniqueness of the Western Interconnection Topology

Major electricity generators in the Western interconnection, such as the hydropower plants in the Northwest and the Palo Verde Nuclear Generation Station in Arizona, are generating electricity located far from the largest load centers. To transfer the electricity and connect remote generating resources to population load centers, long-distance high-voltage pathways were built along the West Coast and across the Southwest, with additional lines connecting to the states in the interior West.[28]

The location of Western electricity generators and loads creates a power system that is widely spread, with electricity demand served by long-distance transmission miles over very rugged Western terrain, from remotely located energy resources. In contrast, the Eastern interconnection has a more concentrated resource-to-load connection system that embodies a transmission spider web configuration.[29] See Figure 6 for a map of the bulk transmission system in the United States.

[22] https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/The-Western-Interconnection.aspx
[23] https://www.nrel.gov/docs/fy15osti/64795.pdf
[24] https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/The-Western-Interconnection.aspx
[25] https://www.nrel.gov/docs/fy15osti/64795.pdf
[26] https://www.epa.gov/egrid/data-explorer
[27] https://www.epa.gov/egrid/download-data
[28] https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/Interchange.aspx
[29] https://www.wecc.org/Reliability/State%20of%20the%20Interconnection%20Digest%20(Summer%202018).pdf

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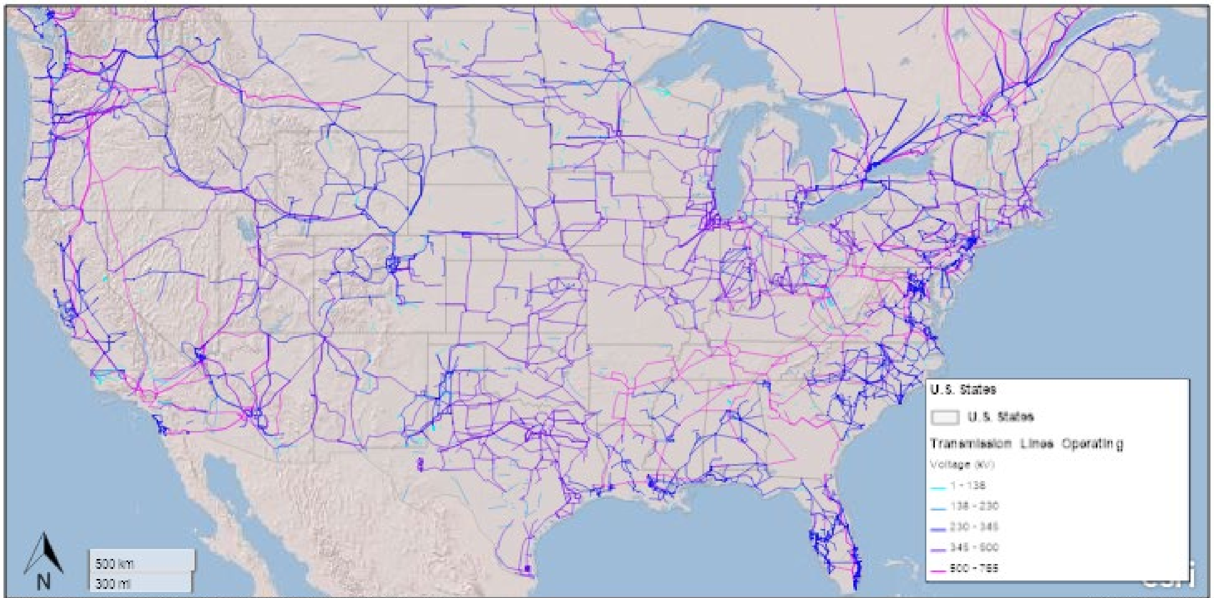

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Figure 6: High-voltage transmission pathways of the U.S.
In the West, electricity tends to flow to the south and to the west along a donut-shaped pattern.[30]

About 87% of the Western interconnection is on public or protected land, requiring transmission planning to consider wildlife and habitat conservation, rangeland preservation, and cultural elements, adding development challenges and costs that are not as prominent in the Eastern interconnection.[31]

Beyond topology, the Western interconnection has developed differently than the Eastern interconnection in how it operates. The Eastern interconnection has operated regionally organized electricity market entities since the 1990s, with PJM becoming the nation's first fully functioning ISO in 1996.[32] Except for one regionalized market in California, the western United States has preserved a balkanized system with less regional collaboration of transmission system operation and planning.

How is access to transmission in the West currently structured and made available?

Exploring how transmission pathways are organized and made available for electricity transfer first requires an understanding of capacity and congestion on transmission pathways.

Characterizing the Transfer Capability of Transmission Pathways

The transfer *capability* of a transmission pathway is different than its design *capacity* (thermal limit or rating) because the *capability* is dependent on generation, customer demand, and transmission system conditions. Expressed in megawatts (MW), electricity can flow in only one direction at a time, but the

[30] https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/Western-Interconnection.aspx
[31] https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/The-Western-Interconnection.aspx
[32] https://www.ferc.gov/electric-power-markets

transfer capability of a line is bidirectional and not necessarily the same from Area A to B as from Area B to A.

Two important metrics of transmission pathways are the Total Transfer Capability (TTC) and the Available Transfer Capability (ATC).

Total Transfer Capability

The total transfer capability is the amount of power that reliably can be reliably transferred over a transmission pathway within a given time.[33] This value is measured in megawatts and depends on the pathway's load patterns, generation commitments, thermal limits, and assumptions at the source and endpoint. Assumptions the power system modelers incorporate into TTC calculations include demand, loss specifications, generator commitments, power system model and operation (DC/AC, automatic controls, interchange, economic dispatch), and network topology (outages).[34]

The calculated TTC is then allocated to meet various grid needs, as shown in Figure 7.

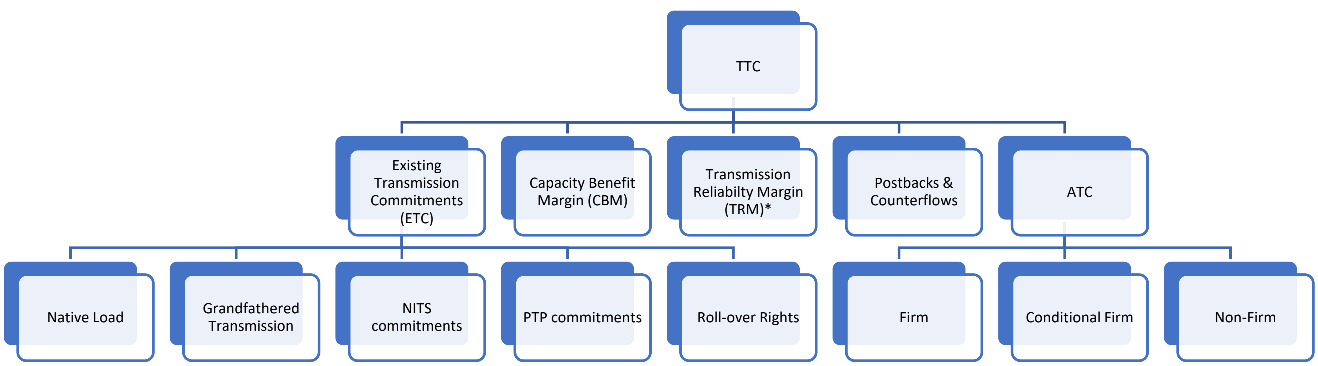

Figure 7: Breakdown of how Total Transfer Capability is divided. This is for firm transmission capacity. The breakdown for non-firm capacity is similar but does not have a Native Load or Roll-over Rights component.
**If Transmission Reliability Margin is not needed, it is released as additional non-firm transmission capacity.*

Available Transfer Capability

After subtracting all other capacity that the TTC is committed to meet, including existing commitments, capacity benefit margin, and reliability margin, and adding other adjustments such as *postbacks* (release of capacity in the hour ahead) and *counterflows* (occurring when a load offsets transmission congestion in a particular direction), the ATC is what transmission capability is left over on the pathway. The amount of ATC varies temporally and by pathway. In the West, there are three main types for a transmission customer to reserve: **Firm ATC, Conditional Firm ATC, and Non-Firm ATC**.

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33 https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/primer.pdf
34 https://www.pserc.cornell.edu/tcc/tutorial/TCC_Tutorial.pdf

Table 3 characterizes the three types of ATC and their curtailment priorities. More detailed information on reserving ATC is provided on page 13 in the section Transmission Availability: The Open Access Transmission Tariff Environment.

Firm ATC	Conditional Firm ATC	Non-Firm ATC
• Long-term or short-term reservation (d,w,m,y) • Given a higher priority, less likely to be curtailed	• Pending firm transmission service after necessary transmission upgrades are met • Lower priority in a defined number of hours/year, or predefined system conditions	• Short-term reservation only (h,d,w,m) • Given a lower priority, more likely to be curtailed

Table 3: Breakdown of ATC into its three types of reservation options.[35]

TTC, and therefore ATC, is limited by the thermal, voltage, and stability limits that ensure reliability. When there isn't sufficient ATC available on a pathway, transmission congestion becomes an issue in localized areas. **Congestion creates an inability to deliver lower-cost (typically renewable) generation resources to consumers and requires the use of higher-cost generation resources located nearer to the load. This also increases the price of electricity in congested areas, as reflected in higher locational marginal prices and higher electricity prices for consumers.[36]**

Characterizing the Congestion of Transmission Pathways

A proxy for measuring congestion is the Locational Marginal Pricing (LMP) at various points along the transmission system. The LMP is defined in the California Independent System Operator Corporation 5th Replacement Tariff as "the marginal cost ($/MWh) of serving the next increment of Demand at that [pricing node] consistent with existing Transmission Constraints and the performance characteristics of resources."[37] LMP is measured within any organized wholesale market along the transmission system at thousands of points called pricing nodes (PNodes), and the weighted average price of the loads in the service territory informs the price the electricity buyer pays. The LMP is the summation of the cost of energy, energy lost in transmission, and cost of transmission congestion.[38] The congestion component of the price increases when there is a lack of transmission capacity of the transmission system around the PNode and electricity can't flow along the least-cost pathways, increasing the marginal price to move the electricity. Changes in the congestion component can be used as a proxy for congestion of the transmission system at the PNode.

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[35] http://www.oatioasis.com/SWTC/SWTCdocs/Westconnect_Conditional_Firm_09-11-07.pdf

[36] https://gridstrategiesllc.com/2019/09/17/transmission-congestion-costs-in-the-u-s-rtos/#:~:text=58%20from%20the%20above%20approximates,and%20%246.1%20billion%20in%202019.

[37] http://www.caiso.com/Documents/Conformed-Tariff-as-of-Dec1-2020.pdf

[38] http://www.caiso.com/Documents/Presentation-Existing-Day-Ahead-Market-Overview.pdf

Having sufficient transmission capacity is a way to mitigate increases in congestion and pricing. To help increase the efficient use of transmission pathways across the nation and increase capacity available to transmission customers, FERC created the Open Access Transmission Tariff.

Transmission Availability: The Open Access Transmission Tariff Environment

FERC Orders 888 and 889 were regulatory changes that had a large effect on how the West organizes transmission. The orders opened and ensured access to transmission for interstate commerce by requiring **Investor Owned Utilities (IOUs)** to unbundle wholesale generation from transmission services, adopt a nationwide electronic transmission system information network to report transmission data (OATI OASIS), and file an **Open Access Transmission Tariff (OATT)** with FERC. The transmission service and rates outlined in the OATT must then be approved by FERC. Orders 888 and 889 initiated a first step in coordination among the balkanized transmission owners.

OATTs in the Western Interconnection

The use of OATTs varies according to whether or not the IOU is within an organized wholesale market. FERC requires all organized wholesale markets to have an OATT that sets rates and conditions for use of transmission. This OATT applies to all IOUs within the boundaries of the market and individual utilities are not required to file separate OATTs. Outside an organized wholesale market, the utilities must file an OATT with FERC that outlines the terms and conditions for transmission service.

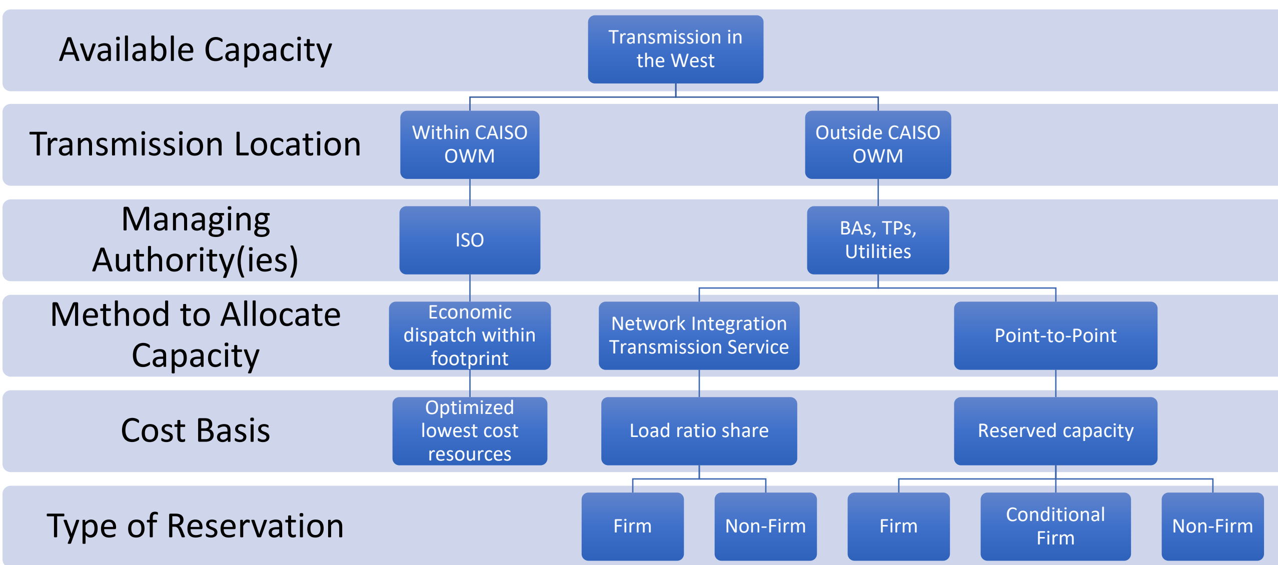

Figure 8: High-level topology of how transmission is allocated in the West.

Transmission capacity reservations outside an Organized Wholesale Market

The OATT for investor-owned utilities that are not in an OWM must describe and offer both **Network Integration Transmission Service (NITS)** and **Point to Point (PTP)** transmission service. The Network Integration Transmission Service is a transmission contract that allows for transmission to be used by a Designated Network Resource (DNR) owned by a Network Customer. A Network Customer must designate generators as their DNRs, and the DNR has the highest transmission service priority. NITS also allows for non-firm utilization by non-DNR entities. This non-firm non-DNR has capacity priority over other non-firm service, such as PTP non-firm.[39,40] The NITS transmission cost rate is based on the resource's Load Share Ratio, which is calculated as the transmission customer's share of the transmission provider's total load.[41]

After NITS customers are served, the remaining transmission capacity can be reserved using PTP Transmission Service between specific Points of Receipt (PORs) and Points of Delivery (PODs) on a transmission provider's pathway. This capacity is made available on a first-come, first-served basis[42] and is not used to serve native or network load.[43] PTP transactions can be either a firm or a non-firm reservation of the available capacity on the pathway, the details of which are outlined in Figure 9. The majority of transmission transactions in the West outside of CAISO are made through PTP reservations.

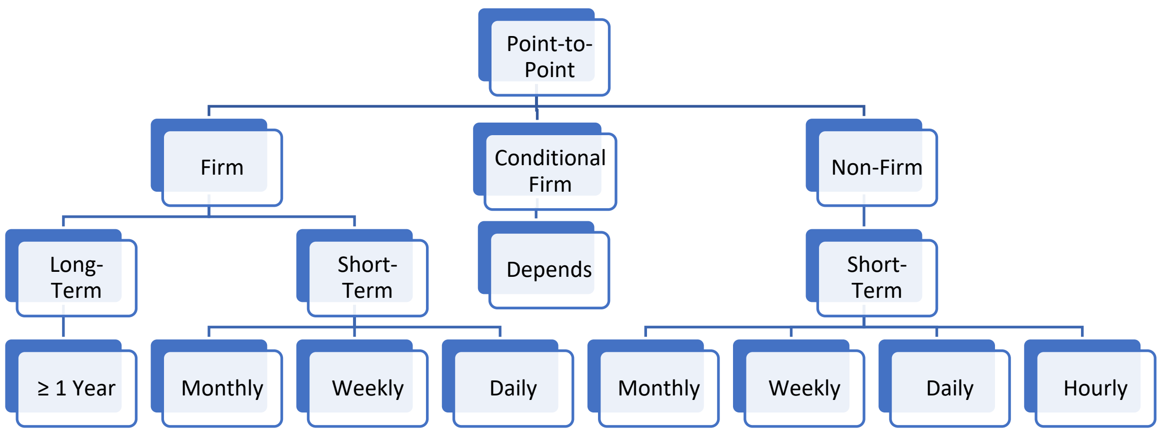

Figure 9: A visual of the types and terms of Point-to-Point transmission reservations options. [44]

The NITS and PTP transmission capacity reservations are a purchase of space and not a reflection of utilization of the line. The reserving entity pays for the space on the line, regardless of whether electricity flows on the line during the specified contractual timeframe.

Pathway curtailments

Note that electricity will flow along the transmission pathways based on the laws of physics, not according to contracts. Therefore, system operators must ensure actual transmission capability is adequate to meet demand along the pathways, even when changes in environmental or grid conditions affect the flow of electricity. When the capacity of a line is lower than forecasted, reservations are curtailed for safety. The order of reserved transmission capacity curtailment is shown in Figure 10.

[39] http://www.caiso.com/InitiativeDocuments/Presentation-ExtendedDay-AheadMarket-TransmissionProvision-EIMEntities.pdf

[40] https://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/5-19-2021_Xcel%20Energy%20OATT_Current%20Tariff_ER22-201.pdf

[41] https://www.lawinsider.com/dictionary/load-ratio-share#:~:text=Load%20Ratio%20Share%20means%20the,Transmission%20Provider's%20total%20load.

[42] https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf

[43] https://www.nrel.gov/docs/fy17osti/67462.pdf

[44] https://www.pjm.com/~/media/documents/manuals/m02.ashx

Figure 10: The order of transmission curtailment from low priority (curtailed first) to high priority (curtailed last). PTP Conditional Firm's priority depends on the curtailment condition agreement, but is always before Firm curtailment.[45,46]

Transmission providers and operation

NITS and PTP reservation contracts are made between transmission customers and transmission providers. Transmission providers are any entity that transports electricity on behalf of a seller or buyer. Often, they are also the local utility.[47] The reservation and operation of transmission is different depending on whether the transmission provider is within or outside an organized wholesale market.

A transmission provider within an organized wholesale market (OWM) is called a **Participating Transmission Owner (PTO)** and has transferred operational control of their transmission lines and facilities to an OWM.[48] The PTO maintains its lines and is paid for the use of its assets. An **Independent Transmission Operator (ITO)** is a vertically integrated utility that owns and operates its transmission lines but cannot participate in an OWM because operational control must be given to the market operator. ITOs can participate in imbalance markets, where participation is voluntary. [49] Table 4 outlines these differences for Western transmission providers within the CAISO organized wholesale market versus those outside the market. The next section will take a closer look at how CAISO operates in the West.

Table 4: Transmission reservation and operation in the Western Interconnection outside of and within CAISO.[50]

Provision	ITO (outside of CAISO)	PTO (within CAISO)
Products	Network Integration Transmission Service & Point-to-Point	Scheduled delivery
Rate Structure	Single provider – charges based on posted OATT rates, vary by services procured by the customer, and offered in hourly, daily, monthly, and annual increments, as well as firmness	High voltage (≥200 kV) = combined revenue requirements of all transmission owners Low voltage zonal rates based on utility-specific costs Volumetric rate ($/MWh)

[45] http://www.oatioasis.com/SWTC/SWTCdocs/Westconnect_Conditional_Firm_09-11-07.pdf
[46] https://www.bpa.gov/-/media/Aep/transmission/transmission-availability/110221-curtailment-priority.pdf
[47] https://www.lawinsider.com/dictionary/transmission-provider#:~:text=Transmission%20Provider%20means%20any%20entity,or%20from%20the%20Delivery%20Point.
[48] https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Operations. Version 82
[49] https://renewablesgrid.eu/fileadmin/user_upload/Files_RGI/RGI_Publications/Factsheets/RGI_Factsheet_TSO.pdf
[50] Table from: http://www.caiso.com/InitiativeDocuments/Presentation-ExtendedDay-AheadMarket-TransmissionProvision-EIMEntities.pdf

Firm Transmission Rights	Service is firm when network load is supplied from a registered Designated Network Resource Firm PTP can be reserved if there is Available Transfer Capability available	Firm PTP right only for "grandfathered" pre-existing transmission contracts
Congestion Management Policy	Expectation is that absent an outage or de-rate, there will be sufficient transmission capacity to accommodate NITS and firm PTP Non-Firm PTP may be subject to curtailment	Costs due to congestion are collected through Locational Marginal Price (LMP)
Valuation of Transmission Losses	Average system losses based on stated rate	Marginal losses charged through LMP
Curtailment Priority	Based on "firmness" of rights used by transmission customer	Based on economic bids; self-schedules based on priority assigned in tariff
Wheeling Charges	If PTP moves through multiple balancing authorities/ transmission service providers, OATT rates for each service are additive ("pancaked")	Transmission customers operating with providers outside the CAISO boundary will have additional pancaked charges

CAISO as an Independent System Operator in the West

The California Independent System Operator (CAISO) was created in 1998 in response to the Energy Policy Act of 1992, which removed the barriers to competition of wholesale generation of electricity. The only RTO in the Western Interconnection, CAISO is geographically limited to California and a small part of Nevada, but is one of the largest ISOs in the world, managing 80% of California's electricity flow. As an ISO, CAISO operates day-ahead and real-time wholesale electricity markets, operates the transmission lines within its balancing authority area, and oversees planning and reliability coordination. Note that CAISO operates, but does not own, the transmission lines. Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, and other smaller CAISO members own and maintain the transmission lines.

The main differences in transmission operation between CAISO versus the rest of the West is that CAISO operates the transmission system based on flow, not contracted capacity. CAISO operators optimize for least-cost resources and transmission availability. Transmission prices are calculated at each PNode as Locational Marginal Prices, based on the marginal cost of energy, cost of congestion, and cost of losses.[51] In the rest of the West, transmission capacity is allocated based on bilateral contracts, except for transmission from utility-owned generation on utility-owned transmission lines. Transmission providers

[51] http://www.caiso.com/Documents/AppendixC-LocationalMarginalPrice-asof-Mar1-2019.pdf

offer NITS and PTP transmission capacity on *OATI OASIS*, and then individual contracts are agreed to between providers and customers. When multiple transmission lines are needed to move generated electricity to a load center, each transmission line owner can charge a fee, and those fees are added together as “pancaked” rates. These rates vary by transmission provider and are set by the utilities and regulated by FERC using Open Access Transmission Tariffs. Within CAISO, there are no additional fees added when moving the electricity between various CAISO transmission pathways.

CAISO portfolio of market services and transmission availability

Day-ahead and real-time markets

The primary markets in CAISO’s market services portfolio are the day-ahead (DAM) and real-time wholesale markets. The majority of electricity transfers in the CAISO footprint are executed through either day-ahead or real-time transactions. The day-ahead market opens for bids and schedules seven days before the trade date and closes the day prior to the trade date. The results are published at 1 p.m. Pacific Time the day before the trade day. Then, the real-time market opens at 1 p.m. Pacific Time the day before the trade date, and utilities can buy power to meet last-minute needs and accommodate for last-minute changes to the system. The market closes 75 minutes before the trading hour, and then CAISO operators dispatch power on 15-minute or 5-minute increments, or even a single 1-minute interval under certain grid conditions.[52] To ensure transmission availability in these markets, power system models continuously calculate the status of the transmission system.

Western Energy Imbalance Market

In addition to the day-ahead and real-time markets within California, CAISO operates the Western Energy Imbalance Market (WEIM) to take advantage of the economic, operational, and environmental benefits of having a more expansive real-time market. WEIM is an imbalance market that allows its 17 participants to trade electricity supply and demand across a larger geographic area in real time (5-minute intervals). This more optimized market reduces congestion on transmission lines and automatically finds the lowest-cost energy across the WEIM footprint. The imbalance market also provides resilience to grid operations while reducing curtailments and energy that may otherwise be wasted. The WEIM is the only imbalance market in the West, and since its inception in 2014, the WEIM has grossed $2 billion in benefits and reduced regional greenhouse gas emissions by 712,270 metric tons since 2014, the equivalent of removing 149,752 cars from the road for one year.[53]

A major difference between a full ISO/RTO, such as CAISO, and an energy imbalance market (EIM) such as WEIM is the voluntary nature of the EIM. The Western utilities involved in the EIM maintain control of their assets and compliance responsibilities to NERC and WECC, while gaining the benefit of diversity of resources through a larger geographic footprint. Within an EIM, the amount of power traveling on the transmission lines is very low relative to the rest of the day-ahead or retail systems. Since this power flow is relatively low, the transmission providers currently don’t charge additional costs or fees for use of their lines. A transmission provider within an EIM informs the EIM that it is making its transmission available for EIM use, on a voluntary basis.[54] Transmission line capacity, generation, and supply are then balanced in real time by the EIM operators, which, in the case of WEIM, is CAISO.

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[52] http://www.caiso.com/market/Pages/MarketProcesses.aspx
[53] https://www.caiso.com/Documents/western-energy-imbalance-market-fact-sheet.pdf
[54] https://www.oasis.oati.com/PGE/PGEdocs/CAISO_EIM_Overview_-_PGE_Meeting_1.pdf

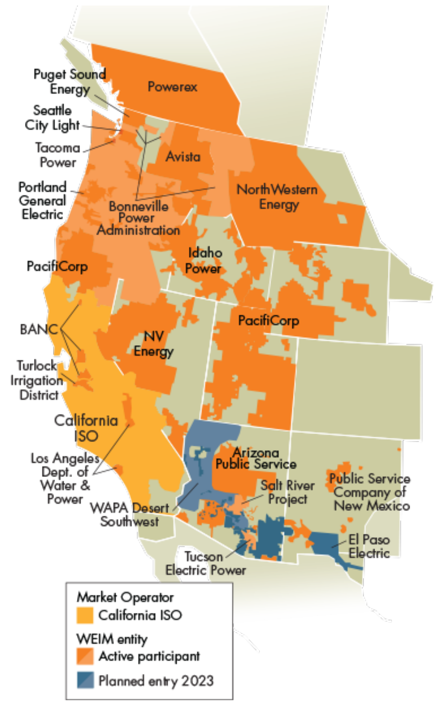

Figure 11: Map of WEIM geographic area as of 2022. Shading delineates participant footprints.[55]

The CAISO markets and the Western region's bilateral market entities make various types and formats of transmission flow data publicly available. Some of this data is publicly available and some is not; the distinctions between the data are discussed below.

Available sources of transmission flow data

Publicly available datasets

To operate the bulk power system, transmission flow data is needed to make sure the system has sufficient and reliable transmission capability. While grid operators must have full access to this data for reliability of the grid, there are business and security reasons for not publicizing this data. However, NERC Mod-001-1 requires some data to be reported publicly. The following sections will discuss both the publicly available and private data, and each dataset's limitations.

The main publicly available and free transmission flow data sources applicable to the West are CAISO OASIS EIM data and EIA Balancing Area transfers data. The two private and subscription-based transmission flow datasets are OATI OASIS and third-party data sources.

[55] https://www.westerneim.com/Pages/About/default.aspx

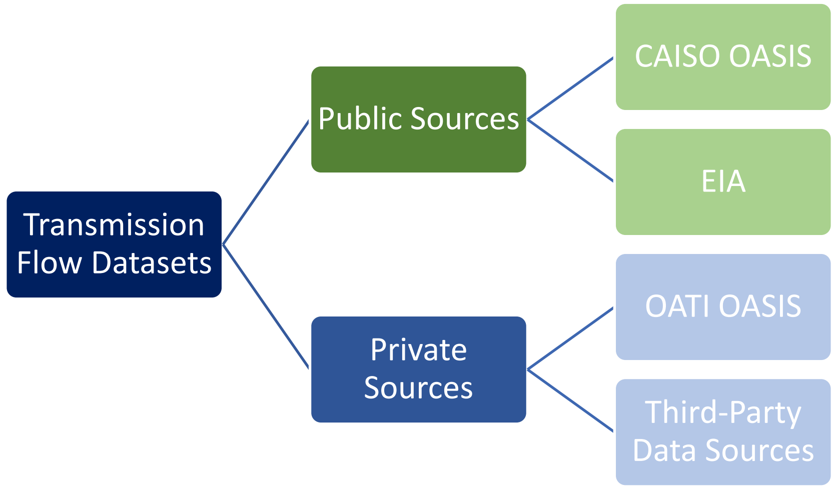

Figure 12: Transmission flow datasets used within the Western Interconnection.

CAISO OASIS EIM

California Independent System Operator Open Access Same-time Information System (CAISO OASIS) is a publicly available dataset maintained by CAISO. The data can be found on the CAISO website, and it includes demand forecasts, transmission outages, capacity status, market prices, and market results. For transmission, the website includes historical, real-time (hour-ahead, real-time unit commitment, short-term unit commitment, 15-minute market, 5-minute market, and real-time dispatch) information, and modeled future projections of data such as current transmission usage, transmission outages, transmission interface usage, market ATC and LMP. CAISO inputs data into the system in real time.

EIA

The **U.S. Energy Information Administration (EIA)** has a publicly available dashboard of hourly electricity use in the lower 48 states.[56] The dashboard includes an interactive map with electricity demand broken into regions, organized wholesale markets, and balancing areas. There is also data showing daily generation mix for the nation and regionally, on a megawatt-hour basis. The data is collected by the EIA directly from 79 balancing areas in the U.S., Canada, and Mexico that use Form EIA-930, the "Hourly and Daily Balancing Authority Operation Report." The form collects electric system operating data including system demand, net generation, and interchange that is submitted on an hourly (for demand) and daily (for all other data types) basis.[57] Historical data (dating back to 2015 in six-month intervals) from the EIA-930 form and hourly interchange data by balancing area (in MWhs) are available, as well.

Both of these publicly accessible datasets can be downloaded into CSV files or through an Application Programming Interface (API), making the data easier to work with and allowing custom data analysis.

Datasets with restricted public access

OATI OASIS

In 2005, NERC enacted Reliability Standard MOD-001-1 as part of a group of standards established in response to FERC Orders 890 and 693. This Model and Data Standard (MOD) requires transmission operators to calculate and report, among other metrics, their ATC on an hourly, daily, and monthly

[56] https://www.eia.gov/electricity/gridmonitor/dashboard/electric_overview/US48/US48
[57] https://www.eia.gov/survey/#eia-930

basis, in a consistent and transparent manner. For use in forward-looking projections, the ATC is required to be calculated hourly for at least the next 168 hours, daily for at least the next 31 days, and monthly for at least the current month plus the next 12 months.[58]

Each timestep of ATC for every transmission line is calculated by the transmission provider using one of three methodologies: Area Interchange methodology,[59] Rated System Path methodology,[60] or Flowgate methodology.[61] In the West, the most common methodology transmission providers use is the **Rated System Path**. The transmission provider explains their ATC calculation methodology in an Available Transfer Capability Implementation Document (ATCID) in enough detail that the results can be validated by NERC.

This data and the implementation document are collected on the **Open Access Technology International webSmartOASIS (OATI)**, where NITS and PTP transmission capacity is actively reserved on a yearly, monthly, daily, and hourly basis. This auction area creates a repository of information on how transmission capacity has been reserved and provides projected transmission capabilities. While NERC MOD-001-1 helped standardize some of the data being collected, there is still variety and flexibility in how the data is reported. The OATI data is only accessible through a paid subscription and is typically accessed by transmission providers, grid operators, and energy consultants.

Third-party data sources

Third-party companies pull data from primary sources and present the data, often with a subscription access model. The value these companies add is that the data is typically verified and can be more accessible, and personalized data retrieval requests can be made to the third-party host. For example, S&P Global is a data source for many industries and has transmission-specific datasets that are pulled from CAISO OASIS. The data includes Annual Transmission Transactions and LMP broken into its components (energy, loss, congestion), and the information is granular, up to date, and can be downloaded into a CSV file for easy analysis. A major downside to third-party data sources is the subscription firewalls, typically with tiers of costs depending on the desired data.

Appendix B provides a comparative view of the different data sources.

[58] https://www.nerc.com/pa/Stand/Project%20200607%20MODV0Revision%20DL/MOD-001-1_clean_25Oct07.pdf
[59] https://www.nerc.com/files/MOD-028-2.pdf
[60] https://www.nerc.com/files/MOD-029-2a.pdf
[61] https://www.nerc.com/files/MOD-030-1.pdf

Challenges and recommendations for transparency and validation of transmission data

Challenges

Despite being the backbone of the grid, the world's largest "machine," and the greatest engineering achievement of the 20th century,[62] the transmission system has insufficient data access, standardization practices, and transparency systems. While operators must have access to flow and reservation data in order to maintain reliability of the grid, the data may not be accessible to the public for security or strategic business reasons. This limits what policymakers, industry, and the public can learn about how the grid functions.

In the Western Interconnection, there is a growing interest among states and electric utilities to join or create an organized wholesale market.[63] The added efficiency, reliability, and sustainability of regionalizing grid operations cannot be attained without improvements to the transmission system. Transmission flow data of the current system can help inform and shape the necessary improvements. However, there are challenges to understanding and using the currently available data, and data gaps need to be filled.

➢ Need for access

Contractual transmission flow data is reported on OATI OASIS systems, but actual physical flow data is not. Physical flows are used internally by grid operators within organized wholesale markets, regional entities, balancing areas, and utilities for successful operation of the grid; however, for commercially strategic and security reasons, this physical flow data is not publicly available. Physical flow data, and therefore utilization and true congestion levels of pathways, would be useful to have in order to inform transmission development and increase efficient transmission use in the future.

CAISO OASIS and the EIA are the only web-based data repositories that hold transmission flow data that is publicly accessible without cost or login.

- The CAISO OASIS data includes transmission data for both the California ISO (day-ahead and real-time markets) and the CAISO-operated WEIM. The ISO is mostly within California's border, while the WEIM participants are in all Western states except Colorado. A very small portion of the total power in the Western grid is coordinated by the WIEM market, and therefore its data isn't a representation of the power flows of the West.
- The EIA data reports hourly contractual transmission flows between BAs.

Combined, the CAISO OASIS and EIA publicly available datasets give contractual transmission flow information on CAISO, WEIM, and U.S. balancing areas, but no data on physical transmission flows.

➢ Need for consistency in metrics

Transmission flow metrics from different markets and timeframes must be considered when trying to understand the transmission system. Transmission capabilities are available for day-ahead markets, 15-minute markets, and 5-minute markets. This data availability varies across the West, depending on if the

[62] NAE (National Academy of Engineering). 2003. Greatest Engineering Achievements of the 20th Century. Available online at http://www.greatachievements.org/.
[63] https://energy.utah.gov/energy-information/state-led_market_options_study/

transmission pathway participates in each level of market (energy imbalance market, day-ahead market, full organized wholesale market).

For LMP data, CAISO reports PNode and aggregate PNode data for California and some parts of the West, but not all. No other public LMP data is available.

- ### Need for consistency of reporting templates

Transmission providers model and report various data to data repositories; however, there is not a standard system to report the transmission flow metrics. Use of the data that is publicly reported is hampered by issues that stem from having a variety of reporting methods.

> *For example, transmission providers are required by [NERC MOD-001-1] to post their Available Transmission Capability (ATC) to an Open Access Same-time Information System (OASIS). However, they can choose between three different methods to report their ATC. Rated System Path methodology is the most commonly used in the West, but Area Interchange methodology or Flowgate methodology can also be used, leading to three different possible ATC values for each system.*

Reports submitted for NERC MOD-001-1 must state the method used and calculation assumptions sufficient for NERC or any other validator to re-create the results. However, Figure 13 shows the discrepancy in data reporting strategies for five randomly selected transmission pathways on OATI OASIS. Modeling into the future, path 1 on the graph appears to have variance that signifies changing inputs into the model, which would be expected as conditions change. Then in 2026, the variance on this line stops and the value flatlines at a ratio of about .62. Paths 2 and 3 stop reporting data in 2028 and 2030, respectively, and the potential blue path 5 didn't report any data for this timeframe. Also, path 3 had a surprising jump in 2029 that would need analysis and path 4 stayed with one value for the whole timeframe, which is likely not considering typical and expected changes that happen over time. The causes of these data variances would need to be analyzed before the data could be used to draw dependable conclusions.

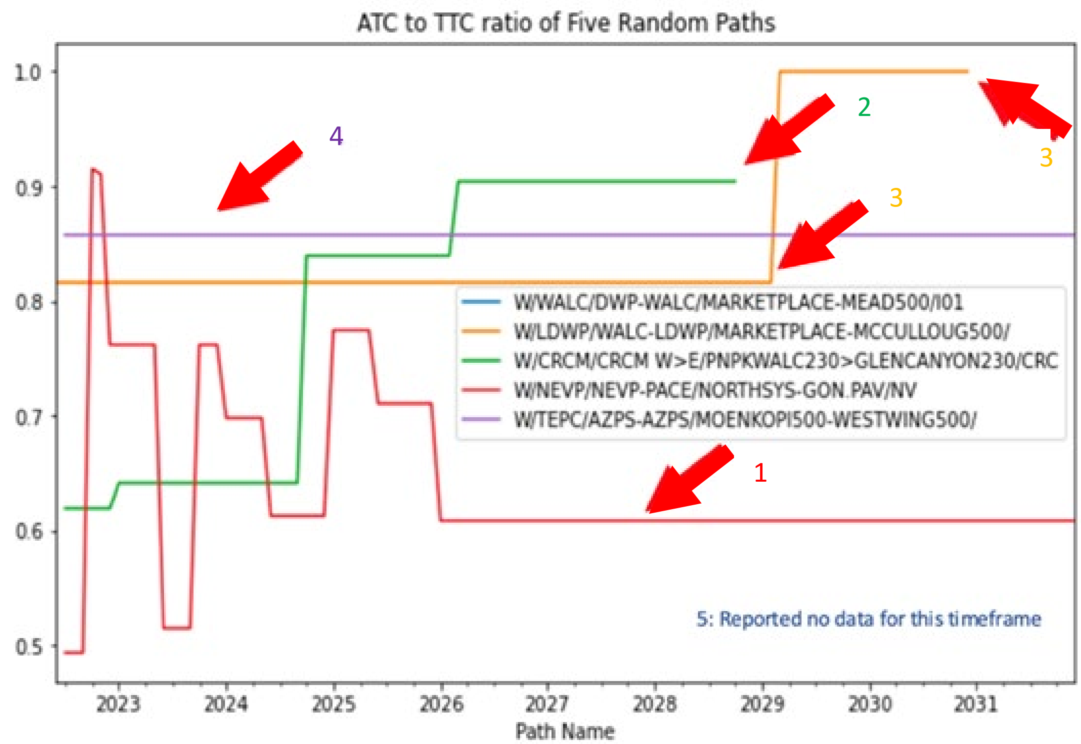

Figure 13: ATC to TTC ratio for five transmission pathways. The red arrows mark the varying data characteristics that result from each transmission provider having different data reporting strategies.

Beyond NERC ATC reporting requirements, there are no standardized metric definitions, so values with the same name, but reported by different entities, may be representing different transmission concepts. Different reporting practices and methods for each metric and time period of interest can affect data, and a user needs to be aware of these differences.

> *For example, a TTC value may or may not include postbacks and counterflows, depending on the reporting entity and how close to real-time dispatch the value was reported.*

These discrepancies in data reporting make data analysis difficult, and having too many various built-in assumptions makes insights unreliable and data-driven transmission decisions challenging.

Among the datasets, there are various levels of granularity.

> *For example, Firm ATC data is reported to OATI OASIS in daily, weekly, monthly, and yearly increments, while the Non-Firm ATC is reported in hourly, daily, weekly, and monthly.*

These timeframes are how the ATC is reserved, but a user must be aware of differences in reporting methods for each timeframe before gaining reliable and accurate insights.

Complexity of data reporting and storage

While data is limited to a few repositories, the data on these repositories is vast. There is ATC and TTC (MW) data going back to 2010 on OATI OASIS, and projections forward up to 10 years. On CAISO OASIS, there is transmission usage (MW) data going back to 2010 and forward six days, historical Market ATC

(MW) and LMP ($/MWh) data going back three years and up to the present hour, and EIA has data going back to 2015 and updated to the present time. Transmission flow data can be reported on 5-minute, 15-minute, hourly, daily, monthly, and/or yearly increments for each transmission pathway and metric. The quantity and unfriendly user interface of the data hides trends. To glean accurate insights, acute familiarity with transmission data, reporting metrics, built-in assumptions, and data management are needed, but currently, these are well understood only by the reporting entities.

Recommendations

Currently, the majority of transmission system data is hidden, and increased transparency is needed for informed transmission development, customer advocacy, and policy creation. Transparency enables accountability and helps increase system efficiency, reliability, and cost savings for customers. Recommendations for the previously listed challenges are listed below.

➢ Need for access

WECC allows historical physical ATC and TTC data to be reported three years after it is generated, but after the three years, there is no reporting requirement for the data. Required reporting after three years, or even more recent years, would improve public transparency and effective use of the data.

➢ Need for consistency in metrics

Various definitions and assumptions that go into metrics need to be standardized. Agreed-upon metrics would make data comparisons across entities more accurate and dependable. Also, having a unifying location for transmission flow data would provide the standardization and accountability needed to have valid and trusted data.

➢ Need for consistency of reporting formats

Similar to consistency in metrics, having an agreement on data calculation methods would increase potential insights from the transmission data.

> *For example, having one method to calculate ATC and one power systems model to know a pathway's TTC would promote consistency, accountability, and the ability to compare data between reporting entities.*

More consistent data gathered and reported outside of the current repositories would also expand potential data insights.

> *For example, if CAISO tracked and reported LMPs throughout the WEIM at the same high concentration of PNodes that it tracks within California, regional transmission congestion insights would be increased.*

➢ Complexity of data reporting and storage

To improve the pace of insights, more graphs (such as how data is presented in EIA's dashboard) and maps to see geographic trends could inform a basic understanding of transmission flows.

> *For example, to increase understanding of data, transmission providers could be required to create visual dashboards of transmission flow data on a Western map that updates in real time.*

Data presented in dashboards that are easier to update and have granular and verifiable data would ease data analysis, enable additional insights, and better inform how transmission policy is developed.

Policy Considerations

Questions the data can help address

Transparent transmission flow data would enable evidence-based policymaking and help promote cost-effective and efficient transmission system modernization. The data can currently shed light on proxies for congestion and contracted available transfer capabilities, but the policy questions the data can address are limited. This section discusses how more transparent data would help inform policy creation and the potential benefits of those policies.

Required reporting of physical flow data

Policy questions that need more transparent data include *what is the overall degree of utilization on select transmission pathways?* With only contractual transmission flows accessible to the public, there is no way to know if the lines are actively in use or being held through reservation and paid for, but not utilized regularly. This difference between contract reservations and actual utilization may especially be true for long-term firm transmission reservations, where the incentive to have secured capacity into the future outweighs the incentive to efficiently utilize the lines in real time.

Recognizing this utilization gap, a report by NREL found that changing how the transmission line capacity is managed can help improve the use of the lines that are already built. It suggests implementing Conditional Firm Transmission reservations (like those used in the Pacific Northwest) in addition to the Firm and Non-Firm reservation options. This operational change bridges the gap between what was contractually reserved and what is physically used, and "allows increased use of the transmission system when conventional firm transmission is not available, but when the system is not actually constrained."[64] However, for systemic operation change, data on physical flows would need to be available to all transmission providers and users.

[64] https://www.nrel.gov/docs/fy13osti/53696.pdf

Even without operation change, having access to physical flow data would help clarify whether pathways that are currently "congested" have additional capability to increase system efficiency, or if pathways are truly utilized and additional transmission infrastructure is needed. This could verify or dispute interchange congestion claims by balancing areas and hold them accountable for the transmission in each balancing area footprint. Knowing the answers to these types of utilization issues could help policymakers and advocates (for clean energy and ratepayer costs) focus efforts on where transmission investments will have the most beneficial impact on the system as a whole.

Reduce curtailment

When a transmission pathway reaches capacity, the lines are curtailed for public safety and power efficiency reasons. Since the amount of power that can be transmitted is decreased, electricity generation is lost, decreasing system efficiency and reliability. Easily accessible data on physical transmission capacity and its degree of electricity curtailment due to transmission congestion would help inform development of transmission in the long term and affect renewable energy resource development in the short term. If the curtailment frequency and resource type data were readily available, it would hold transmission providers accountable to energy generators, publicly incentivize transmission developers to build where capacity demand exists, and inform renewable energy developers where projects could most effectively be interconnected to the transmission system.

Curtailment solutions include increasing storage participation, expanding imbalance markets, increasing demand response options, creating a regional market, implementing time-of-use rates, incorporating responsive electric vehicles, reducing the minimum operating levels for electricity generators, and investing in modern quick-response resources.[65]

From the policy perspective, a question to be answered is *which solution would be most effective to reduce curtailment, and how should the policy be designed to address this?* Data transparency would enable informed decisions about which solution will be most effective for select systems and would guide policy design to make the solutions a reality.

The negotiating power and insights gained by having transparent and easily accessible transmission flows data is currently untapped. Policy action is needed to upgrade the grid and improve efficiency, and data-informed policy will make these policy outcomes as successful as possible. As the Smart Electric Power Alliance mentioned in the 2022 report on Coordinating for Transmission Development, "Following the tradition of evidence-based policy-making, the advancement of data analytics promotes data-driven administration to solve social problems and innovate government operations."[66] **A first step would be transparency on transmission pathway utilization and curtailment frequency and resource types.**

Policy and market mechanisms to address these challenges

Confidentially issue vs. public interest

Among the hurdles to increased transparency of real-time transmission use data are the proprietary use and security issues raised by transmission providers and operators.[67] As representatives of public

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[65] http://www.caiso.com/informed/Pages/ManagingOversupply.aspx

[66] Sungsoo Hwang, Taewoo Nam & Hyunsang Ha (2021) From evidence-based policy making to data-driven administration: proposing the data vs. value framework, International Review of Public Administration, 26:3, 291-307, DOI: 10.1080/12294659.2021.1974176

[67] https://arpa-e.energy.gov/sites/default/files/documents/files/GRIDDATA_ProgramOverview.pdf

interest, policymakers will be a part of the discussion of confidentially vs. public benefits of having accessible transmission flow data. Then regulators will have to require and initiate the data standardization, sharing, and common reporting systems. There is precedent by NERC regulators to change data reporting requirements, such as enacting the MOD-001-1, which required transmission providers to report ATCs, and by FERC order 888 to report OATTs. New regulations that require transmission data to be publicly reported will be needed to make any progress in data transparency, as transmission entities have little incentive to publicly report data on their own.

Transparency compromise

WECC data-sharing policies allow for historical transmission flow data to be made available for data that was generated three or more years prior to the current year. With frequent changes to the grid, the three-year-old data is a useful, but not updated, snapshot of the status of the transmission system. Also, few utilities report the data after the three years have passed. There are opportunities to improve this reporting strategy: first, requiring utilities to report the historic data, and second, creating a transparency compromise to decrease the arbitrary three-year waiting period to one year. The more recent data would be useful for analysis, and the year-long delay would still alleviate the business and security concerns. Policy or regulatory changes would need to be in place, as utilities have little incentive to publicize their data without outside requirements.

Join or form a Western organized wholesale market

Transmission data flow challenges are reduced when the system has an organized wholesale market operator. According to the DOE-funded 2021 *State-Led Market Study*, "an RTO is anticipated to provide the most transparent and timely access to information." This is because organized wholesale markets are required by FERC to report on pricing transparency, uplift payments, resource commitment decisions, resource operations, and transmission congestion.[68]

Conclusion

Current transmission flow data in the West is difficult or expensive to access, uses a variety of metrics, is inconsistently reported, and is difficult to draw conclusions from. This paper highlights these challenges as a first step to increasing data transparency in the West. The next step is to require and standardize reporting for contractual and physical transmission flow data by transmission providers and utilities, or for the West to form or join an organized wholesale market, where a level of data transparency is already required.

With thoughtfully designed regulations and policies, transmission flow data could be publicly shared without sacrificing the service, economics, or security of the grid, while adding accountability for grid entities. More easily accessible transmission flow data would support efficient grid development for a reliably decarbonized electric grid, while fostering increased stakeholder engagement for all concerned decision makers. The transparency will enable the cost-effective and technologically advanced upgrades needed by the transmission system in the West.

[68] Clean Energy Buyer's Association. Slide deck. *Western Market Expansion*. December, 2021.

Appendix A

Glossary

The definitions in the below glossary are sourced from CAISO's Business Practice Manual "Definitions and Acronyms" document, FERC Market Assessments glossary, or the Department of Energy U.S. Electricity Primer. The below glossary's terms are alphabetized.

ATC – Available Transfer Capability: The available capacity of a given transmission path, in megawatts, after subtraction from that path's total transfer capability of capacity associated with existing contracts and transmission ownership rights and any transmission reliability margin, as established consistent with CAISO and WECC transmission capacity rating guidelines, further described in Appendix L to the CAISO tariff.

ATCID – Available Transfer Capability Implementation Document: A document required to be submitted to the North American Electric Reliability Corporation by transmission providers that describes the implementation of an available transfer capability methodology. The potential methodologies are area Interchange methodology, Rated System Path methodology, or Flowgate methodology. In the West, the most common methodology transmission providers use is the Rated System Path.

BA – Balancing Authority: The responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a balancing authority area, and supports interconnection frequency in real time.

BAA – Balancing Authority Area: The collection of generation, transmission, and loads within the metered boundaries of the balancing authority. The balancing authority maintains load-resource balance within this area.

CAISO – California Independent System Operator: The California Independent System Operator Corporation, a state-chartered, California non-profit public benefit corporation that operates the transmission facilities of all participating transmission owners and dispatches certain generating units and loads.

CAISO OASIS – California Independent System Operator Open Access Same-time Information System: Provides energy market and power grid information to the public and market participants, through reports with real-time updates. This information includes the following: system load requirements, market price information, transmission availability, and system demand conditions.

CBM – Capacity Benefit Margin: That amount of transmission transfer capability reserved for load- serving entities (LSEs) to ensure access to generation from interconnected systems to meet generation reliability requirements.

Conditional Firm ATC: Conditional firm service (CFS) is a form of long-term firm (LTF) point-to-point (PTP) transmission service that allows the transmission provider to curtail the reservation subject to one of two types of conditional curtailment options: number of hours per year during which conditional curtailment may occur; or system condition(s) (e.g., system operating limit impacting certain path(s) under which conditional curtailment may occur).

Counterflows: When a load offsets transmission congestion in a particular direction.

DAM – Day Ahead Market: Forward markets for electricity to be supplied the following day. Processes conducted include the market power mitigation, the integrated forward market and the residual unit commitment. This market closes with acceptance by the independent system operator, power exchange, or scheduling coordinator of the final day-ahead schedule.

DER – Distributed Energy Resource: Any resource with a first point of interconnection of a utility distribution company or metered subsystem.

DR – Demand Response: A program to provide a reduction in demand in response to specified conditions or circumstances, typically implemented by a load-serving entity.

Eastern Interconnection: A network of transmission lines that reach from Central Canada eastward to the Atlantic coast (excluding Québec), south to Florida and west to the foot of the Rockies (excluding most of Texas). All of the electric utilities in the Eastern interconnection are electrically tied together during normal system conditions and operate at a synchronized frequency operating at an average of 60Hz.

EIA – Energy Information Administration: An independent agency within the U.S. Department of Energy that develops surveys, collects energy data, and analyzes and models energy issues.

Electrical Transmission: Transmission pathways facilitate the bulk transfer of electricity from a generating station to a local distribution network. These networks are designed to transport energy over long distances with minimal power losses which is made possible by boosting voltages at specific points along the electricity supply chain. The components of transmission lines consist of structural frames, conductor lines, cables, transformers, circuit breakers, switches, and substations. High voltage are typically >230kV.

ERCOT – Electric Reliability Council of Texas: ERCOT covers most of the state of Texas. All of the electric utilities in the Texas Interconnection are electrically tied together during normal system conditions and operate at a synchronized frequency operating at an average of 60Hz.

ETC – Existing Transmission Commitments: Committed uses of a transmission service provider's transmission system considered when determining available transfer capability.

FERC – Federal Energy Regulatory Commission: An independent agency within the U.S. Department of Energy that regulates the interstate transmission of electricity (as well as natural gas and oil) within the United States.

Firm ATC: The highest quality (priority) service offered to customers under a filed rate schedule that anticipates no planned interruption.

FRCC – Florida Reliability Coordinating Council: A regional entity headquartered in Tampa, Florida and responsible for reliability and security of the bulk power system in part of Florida.

IOU – Investor Owned Utility: a for-profit power company owned by its shareholders that generates, transmits, and/or distributes electricity for sale to customers.

ISO – Independent System Operator: Entity that controls and administers nondiscriminatory access to electric transmission in a region across several systems, independent from the owners of the facilities.

ITO – Independent Transmission Operator: is a vertically integrated utility that owns and operates its transmission lines, but cannot participate in an organized wholesale market (OWM) because operational control must be given to the OWM operator. ITOs can participate in imbalance markets, where participation is voluntary.[69]

MOD – Model and Data Standard: Standards set forth by the North American Electric Reliability Corporation.

MRO – Midwest Reliability Organization: A regional entity headquartered in Saint Paul, Minnesota, and responsible for reliability and security of the bulk power system in all or parts of the states of Arkansas, Illinois, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wisconsin.

Native Load: Load required to be served by a utility within its service area pursuant to applicable law, franchise, or statute.

NERC – North American Electric Reliability Corporation: a not-for-profit international regulatory authority whose mission is to ensure the effective and efficient reduction of risks to the reliability and security of the grid. NERC is the electric reliability organization (ERO) for North America, subject to oversight by the Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada.

NITS – Network Integration Transmission Service: Service that allows an electric transmission customer to integrate, plan, economically dispatch and regulate its network reserves in a manner comparable to that in which the Transmission Owner serves Native Load customers.

Non-Firm ATC: Transmission service that is reserved on an as-available basis and is subject to curtailment or interruption.

NPCC – Northeast Power Coordinating Council: A regional entity headquartered in New York and responsible for the reliability and security of the bulk power system in Northeastern North America.

OASIS – Open Access Same-time Information System: The electronic posting system for transmission access data that the CAISO maintains on the CAISO website that allows all market participants to view the data simultaneously.

OATI OASIS – Open Access Technology International webSmartOASIS: a web-based reservation and information repository used by multiple transmission providers and is accessed by hundreds of merchants to obtain transmission reservations.

OATT – Open Access Transmission Tariff: Documents filed to FERC by all public utilities that own, control or operate transmission facilities in interstate commerce that outline the minimum terms and conditions of non-discriminatory access to transmission.

OWM – Organized Wholesale Market: Electricity-generating entities sell the electricity they generate through competitive power markets knowns as ISOs and RTOs.

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69 https://renewablesgrid.eu/fileadmin/user_upload/Files_RGI/RGI_Publications/Factsheets/RGI_Factsheet_TSO.pdf

PNode – Pricing Node: A single network node or subset of network nodes where a physical injection or withdrawal is modeled and for which a locational marginal price is calculated and used for financial settlements.

POD – Point of Delivery: Point(s) within the CAISO Balancing Authority Area or, for purposes of scheduling and operating the real-time market only, the energy imbalance market (EIM) where energy and ancillary services are made available to a receiving party under the CAISO Tariff.

POR – Point of Receipt: Point(s) within the CAISO Balancing Authority Area or, for purposes of scheduling and operating the real-time market only, the EIM Area where energy and ancillary services are made available by a delivering party under the CAISO Tariff.

Postbacks: Released transmission capacity in the hour ahead.

PTO – Participating Transmission Owner: A party to the transmission control agreement whose application under Section 2.2 of the transmission control agreement has been accepted and who has placed its transmission assets and entitlements under CAISO's operational control in accordance with the Transmission Control Agreement. A participating transmission owner may be an original participating transmission owner or a new participating transmission owner.

PTP – Point to Point: The reservation and transmission of capacity and energy on either a firm or non-firm basis from the point(s) of receipt to the point(s) of delivery.

RC – Reliability Coordinator: The entity designated by the regional entity as responsible for reliability coordination in real time for the area defined by the regional entity.

RC West: The reliability coordinator services provided by CAISO for 42 balancing authorities and transmission operators in the Western United States.

RE – Regional Entity: An entity to whom the North American Electric Reliability Corporation has delegated certain of its electric reliability organization functions for a particular geographic region.

RF – Reliability First: A regional entity headquartered in Cleveland, Ohio, and responsible for the reliability and security of the bulk power system in the Great Lakes and Mid-Atlantic areas of the United States, which includes all or portions of Delaware, New Jersey, Pennsylvania, Maryland, Virginia, Illinois, Wisconsin, Indiana, Ohio, Michigan, Kentucky, West Virginia, Tennessee, and the District of Columbia.

RTO – Regional Transmission Organization: An independent regional transmission operator and service provider that meets certain criteria, including those related to independence and market size, established by FERC Order 2000.

SERC Reliability Corporation: A regional entity headquartered in Charlotte, North Carolina, and responsible for reliability and security of the bulk power system in all or parts of the states of Florida, Georgia, Alabama, Mississippi, Louisiana, Texas, Oklahoma, Arkansas, Missouri, Iowa, Illinois, Kentucky, Tennessee, Virginia, North Carolina, and South Carolina.

SPPW – Southwest Power Pool West: The reliability coordinator services provided by the Southwest Power Pool for 10 balancing authorities and transmission operators in the Western United States.

Texas RE – Texas Reliability Entity: A regional entity headquartered in Austin, Texas, and responsible for reliability and security of the bulk power system within the ERCOT interconnection.

TO – Transmission Owner: An entity owning transmission facilities or having firm contractual rights to use transmission facilities.

TRM – Transmission Reliability Margin: An amount of transmission transfer capability reserved necessary to provide reasonable assurance that the interconnected transmission network will be secure. The margin accounts for the inherent uncertainty in system conditions and the need for operating flexibility to ensure reliable system operation as system conditions change.

TTC – Total Transfer Capability: The amount of electric power that can be moved or transferred reliably from one area to another area of the interconnected transmission systems by way of all transmission lines (or paths) between those areas under specified system conditions.

WECC – Western Electricity Coordinating Council: A regional entity headquartered in Salt Lake City, Utah, and responsible for reliability and security of the bulk power system within the Western Interconnection. WECC extends from Canada to Mexico and includes the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 Western states between.

WEIM – Western Energy Imbalance Market: A wholesale energy market that automatically dispatches low-cost electricity resources over a large geographical area. By participating in the WEIM, balancing authorities can utilize the CAISO's real-time market while maintaining control of their transmission system.

Western Interconnection: The network of transmission lines embodied within the WECC region. The network stretches from Western Canada south to Baja California in Mexico, reaching eastward over the Rockies to the Great Plains. All the electric utilities in the Western interconnection are electrically tied together during normal system conditions and operate at a synchronized frequency operating at an average of 60Hz.

Appendix B

Summary table of available transmission data sources

Table 5: A table of the different transmission flow original data sources showing the different qualities of each data source. There is no central data repository.

	CAISO OASIS	EIA	OATI OASIS
Primary Documentation	CAISO Business Practice Manuals (Market Operations & EIM)	EIA: About the EIA 930 Data	OATI Academy/Tutorial Videos
Supporting Documentation	Energy Transfer Scheduling in EIM	EIA 930 Instructions	WesTTrans Map
Ease of access	Web interface and public API	Web interface and public API	Credentials required; No formal API
Region	CAISO EIM Entities	All U.S. Balancing Authorities	US transmission Providers
Dataset Entities	EIM Balancing Authorities	All U.S. Balancing Authorities	Contract Paths (POR-PODs)
Type of Flow	EIM Transfers (& Limits) by CAISO tie	Net Metered Tie Line Flow on each "BA-to-BA Interface"	Contractual: TTC and both Firm and Non-Firm ATC
Granularity	RTPD (15-min) and RTD (5-min)	Hourly Measured Values	Yearly (Long-Term) to Hourly (Short Term)
Update Frequency	Real-Time	Real-Time	Differs by Transmission Provider
Timeline	Historical (2-3 Years)	Historical (5+ years)	Historical, Present, and Future

What the data can tell us

While there are challenges and gaps to this publicly available data, insights can still be gleaned from these datasets. For example:

- Historical trends of available transmission can be used to see which pathways are increasing or decreasing in capability. This knowledge is important for understanding the current reliability status of the lines, as well as inform long-term investment in the transmission system, the placement of new electricity generating sources, or shed light on interconnection difficulties.
- The locational marginal pricing (LMP) data can help regulators and stakeholders see cost trends relative to other areas and learn where changes are needed to reduce electricity rates for the customers that are affected. This data could also help regulators share and inform best practices across regulatory footprints.
- The data can show advocacy groups and decision makers which balancing areas are the "big players" as far as transmission importing and exporting, to understand who will have incentives or larger voices at the table for policy change, such as regional market efforts.
- The data can validate or dispute congestion claims that are brought forward by utilities, transmission providers, or operators.