Transmission Backbone for Western Renewables

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1. Introduction

Renewables, mainly wind and solar, are expanding rapidly in my home state (California) and the rest of the Western Grid. Many of these are "Grid-Scale" generation projects – hundreds of MW. Also, many of these projects tend to be concentrated a particular area because of concentration of the renewable resource (mostly wind) or financial consideration (like low-cost long-term land-lease arrangements from the federal government or other land-owners).

The primary source for the information in this paper is Reference 1 below.

The Western Interconnection Baseline Study (baseline study) provides an assessment for how potential investments in transmission and renewable generation projects could contribute to achieving future decarbonization goals across the Western Interconnection. By modeling a high renewable generation scenario for the year 2030, the baseline study provides an initial assessment of how transmission lines in advanced permitting stages, combined with anticipated new renewable resources, align with national decarbonization goals. In doing so, it establishes a comparative baseline for transmission and generation expansion scenario analyses in the forthcoming National Transmission Planning (NTP) Study Report.[1]

The baseline analysis for the Western Interconnection consists of two cases: the industry planning (Base) and High Renewables (High RE) cases…

The cases are analyzed in detail using production cost modeling and alternating current (AC) power flow modeling. Production cost modeling is used to understand how the Western Interconnection system will operate at an hourly level to meet electricity demand and reserve requirements for the two nodal baseline cases. Analysis from production cost modeling provides operational insights about the amount of CO_2 emissions, transmission utilization and congestion, the curtailment of wind and solar, and total system costs.

The AC power flow analysis showcases the resilience of the baseline cases against selected contingencies on interregional ties. The developed tools enable the extraction of power flow cases from production cost model simulations, regardless of generation mix, facilitating more in-depth reliability studies. Additionally, the database management system and interactive visualization allow the study team to analyze the system behavior of the baseline cases across numerous AC power flow hourly snapshots and contingencies.

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[1] Konstantinos Oikonomou, Bharat Vyakaranam, Tony B Nguyen, Kevin Harris, Eran Schweitzer, Nader Samaan, Chuan Qin, Fernando Bereta dos Reis, Michael M Abdelmalak, Michael Kintner-Meyer & Jeff Dagle, Pacific Northwest National Laboratory, "Western Interconnection Baseline Study," September 2024, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-36452.pdf

Authors comment: The above *"AC power flow analysis… of the baseline cases against selected contingencies…"* is frequently called a contingency analysis. A given contingency is the failure / loss of a given resource like a generation unit or transmission line. Potential contingencies are studied across wide ranges of simulated conditions.

For instance, if a given generator trips out during high system loading, its lost generation must be spread across other generation. If a given line is operating near it's limit and the redistribution of generation causes it to overload and trip-out, this could cause a cascading set of trips and take down a large part of the whole transmission system, resulting in a major blackout.

It is much better to discover vulnerabilities during computer simulations (continency analyses) and remediate the vulnerabilities rather than seeing blackouts during operation.

2. Purpose

The National Transmission Planning (NTP) Study identifies transmission that will provide broadscale benefits to electricity customers, inform regional and interregional transmission planning processes, and identify interregional and national strategies to accelerate decarbonization while maintaining system reliability. The NTP Study links several long- and short-term power systems models to test numerous interregional and regional transmission buildout scenarios through a wide range of economic, reliability, and resilience indicators on a national scale.

This report covers a baseline analysis for the Western Interconnection, including data development, analysis methodology, and discussion of results. The main scope of the baseline study is to evaluate the degree to which current industry planning processes meet national 2035 decarbonization goals. This analysis forms a baseline for the scenario analysis conducted in the NTP Study. It utilizes industry's most reliable data to account for future transmission projects across various stages of development, with a particular focus on those in the pipeline permitting stage. Additionally, it incorporates projections for changes in generation capacity (both additions and retirements). This baseline analysis outlines a probable trajectory for the future of the bulk power system within the Western Interconnection, with a horizon extending to 2030.

3. Methods

The study begins by compiling a comprehensive database of large transmission projects planned for development across the Western Interconnection by 2030. Following this, it develops a nodal High Renewables (High RE) version of the 2030 industry planning case (Base), which utilizes the Western Electricity Coordinating Council (WECC) 2030 Anchor Data Set (ADS). This High RE version integrates anticipated transmission projects and adds renewable capacity, leveraging both existing and new transmission capacity. Subsequently, the study employs production cost modeling to evaluate the positioning of the 2030 Base and High RE cases with the trajectory towards achieving the 2035 zero-emission target while identifying the potential limitations imposed by the transmission network on progress towards these goals. Lastly, through power flow analysis, the study examines the resilience of both baseline cases against specific interregional tie contingencies, affirming the viability of the baseline scenarios under different contingency events. Figure 1 summarizes the baseline analysis framework.

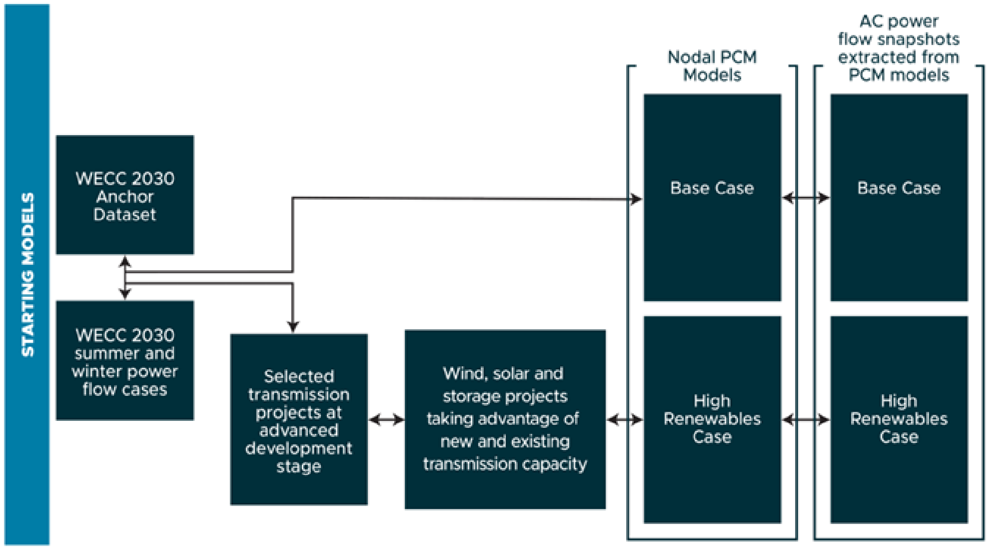
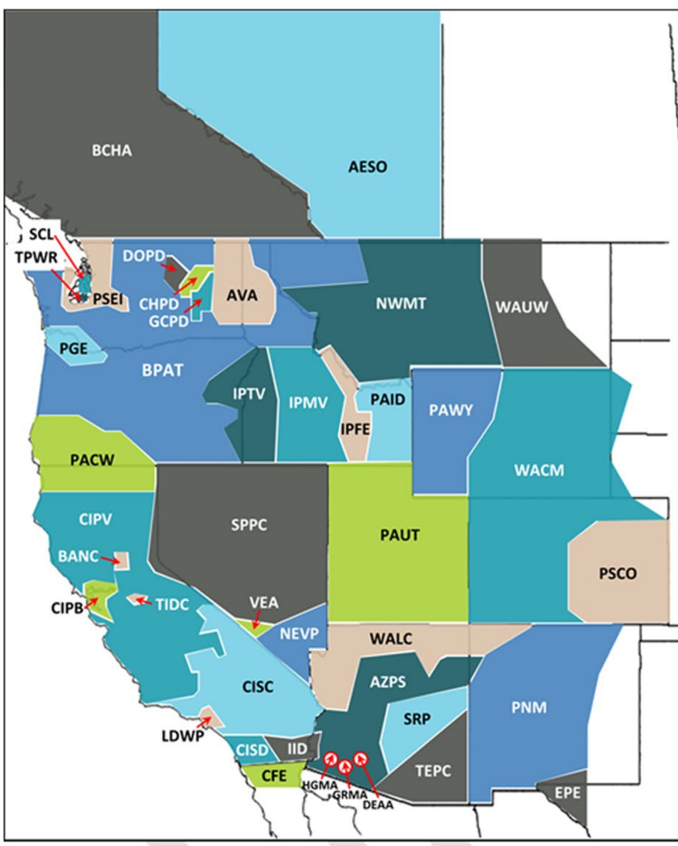


Figure 1. Baseline modeling framework.

4. The Western Grid

The Western Grid (Western Interconnection) provides electric power transmission services for the entities shown in the map and table below. Note that “PCM in the above figure is an abbreviation for Production Cost Modeling.



TEPPC Area	Area Description
AESO	Alberta Electric System Operator
AVA	Avista
AZPS	Arizona Public Service
BANC	Sacramento Municipal District
BCHA	British Columbia Hydro
BPAT	Bonneville Power Administration
CFE	Comision Federal de Electricidad
CHPD	Chelan Co PUD
CIPB	Pacific Gas & Electric Bay Area
CIPV	Pacific Gas & Electric Valley Area
CISC	Southern California Edison
CISD	San Diego Gas & Electric
DOPD	Douglas Co PUD
EPE	El Paso Electric
GCPD	Grant Co PUD
IID	Imperial Irrigation District
IPFE	Far East (Idaho Power)
IPMV	Magic Valley (Idaho Power)
IPTV	Treasure Valley (Idaho Power)
LDWP	Los Angeles Dept of Water & Power
NEVP	Nevada Power
NWMT	Northwestern Montana
PACW	PacifiCorp West
PAID	PacifiCorp East – Idaho
PAUT	PacifiCorp East – Utah
PAWY	PacifiCorp East - Wyoming
PGE	Portland Gen Electric
PNM	Public Service New Mexico
PSCO	Public Service Colorado (Xcel)
PSEI	Puget Sound Energy
SCL	Seattle City Light
SPPC	Sierra Pacific Power
SRP	Salt River Project
TEPC	Tucson Electric Power
TIDC	Turlock Irrigation District
TPWR	Tacoma Power
VEA	Valley Electric Association
WACM	Western Area Power Admin Colorado/Missouri
WALC	Western Area Power Admin Lower Colorado
WAUW	Western Area Power Admin Upper Missouri
N/A	DECA, LLC - Arlington Valley (DEAA)
N/A	Gila River Maricopa Arizona (GRMA)
N/A	Harquahala L.L.C. (HGMA)

All transmission capacity enhancements that exist in the baseline analysis are referred to as BTPs (baseline transmission projects).

Specifically, BTPs meet the following requirements:

- *They are sufficiently far along in the development pipeline.*
- *They are high capacity (≥345 kV).*
- *They are least 70 miles long.*

BTPs may or may not already be in the Base case. The 12 included BTPs are listed in Table 2 and shown on the map in Figure 7 (Next Page).

Table 2. Selected baseline transmission projects.

Transmission Project	***Reference***
Boardman to Hemingway (B2H)	*(NorthernGrid 2022), (CAISO 2022)*
Ten West Link	*(CAISO 2022)*
Gateway West	*(NorthernGrid 2022), (CAISO 2022)*
Gateway South	*(CAISO 2022)*
Southwest Intertie Project-North (SWIP-North)	*(NorthernGrid 2022), (CAISO 2022), (GDO n.d.)*
TransWest Express DC and AC (TWE)	*(CAISO 2022)*
Cross-Tie	*(NorthernGrid 2022), (CAISO 2022), (GDO n.d.)*
Sunzia DC	*(CAISO 2022)*
Greenlink Nevada West	*(NorthernGrid 2022), (CAISO 2022)*
Greenlink Nevada North	*(NorthernGrid 2022), (CAISO 2022)*
Colorado Power Pathway	*(WestConnect 2023)*
Southline	*(GDO n.d.), (Pacini and Green 2024)*

5. Key Findings

Shift in generation mix: *The High RE case displaces 15% of the fossil thermal generation energy with wind and solar. Thermal generation is replaced not only in areas with significant additions of new renewable capacity but also in areas with no or little new renewable capacity enabled by the augmented transmission system.*

Carbon reduction potential: *The High RE case reduces CO2 emissions by 73% from 2005 values. The highest percentage of emissions reduction occurs in the central western states (i.e., Utah, Nevada, Wyoming, Colorado, Arizona, New Mexico), where renewable energy replaces large thermal fossil generation.*

Capacity factor impacts of existing fossil units: *The High RE case decreases the capacity factors of coal and natural gas resources by 33% and 12%, respectively. The low-capacity factors may yield early retirements of fossil units because of low utilization and frequent cycling (startups and shutdowns), increasing operations and maintenance (O&M) costs.*

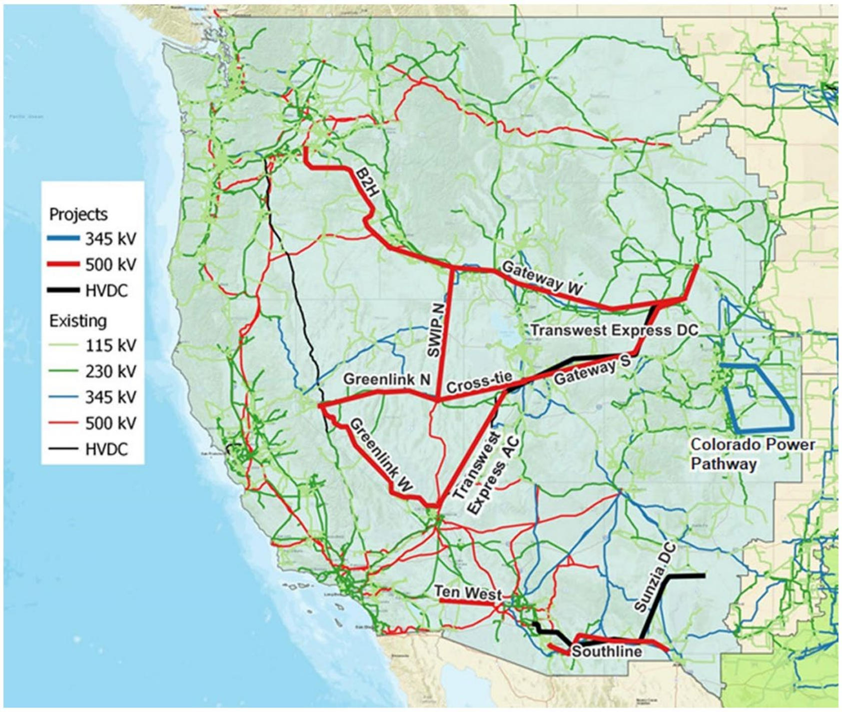


Figure 7. Selected baseline transmission projects.

Renewable curtailments: *Wind and solar curtailment increases in the High RE case by 5.8% and 2.4%, respectively, compared to those in the Base. Renewable curtailment peaks during springtime (i.e., March, April, May) as a result of Northwest hydropower runoffs combined with low-load conditions (due to lower heating and/or air-conditioning electricity demands) and solar overgeneration (due to favorable weather conditions). As more renewables are integrated into the Western Interconnection system, transmission saturation and overgeneration will lead to increased curtailments. Without further enhancements to the transfer capability of the transmission network or the addition of energy storage resources, any new renewable additions will significantly exacerbate curtailment issues.*

Reduction in generation costs: *Generation operational costs decrease by 32% in the High RE case compared to those in the Base case. Note, however, that capital costs for generation and transmission are not considered as part of this analysis and would be needed for a complete economic evaluation.*

Shift in energy transfers across regions: *California's annual net energy imports from the Northwest (mainly from Paths 65 and 66) are reduced by ~26% and increased from the Southwest (Basin and Southwest) by ~74% in the High RE case. The BTPs, combined with existing transmission capacity, facilitate increased power transfers to California by accessing newly integrated wind resources from areas with abundant wind, such as Wyoming and New Mexico. This is evidenced by increased power flows on Paths 27 and 46. The increase in power transfers from the Basin region results in California relying less on power imports from the Pacific Northwest (PNW), thus providing congestion relief on Paths 65 and 66.*

Primary frequency response participation: *The increased contribution from battery energy storage systems in the primary frequency response in the High RE case compared to that in the Base indicates the potentially significant role of this technology for reliability in a high renewables power system.*

System Resiliency: *The High RE case is resilient enough to withstand selected high-impact contingencies for the power flow hour modeled in this analysis. This finding suggests that the Western Interconnection can be operated reliably and affordably with a high penetration of renewables.*

Future areas of recommended study include additional contingency analyses for combined Eastern and Western Interconnection scenarios under many single and multiple contingencies and several different operating conditions. Additionally, future research should include contingency analyses using dynamic simulation to examine the developed grid models for characteristics such as the frequency response and voltage ride through during grid disturbances.

Final author's comments: Note that this is still very early in the timeline of this process. However, if you look at the last section of this paper, you will see that there are no looming disasters. Furthermore, as the study progresses and everything firms up, there will be many opportunities to make small changes in the designs to correct any issues seen in the current findings (like the above "Renewable curtailments.")

My main purpose in writing this is give readers a feeling for the huge amount of work that goes on with any major grid redesign and, in this case, there are two major parallel design-paths.