The "Base Case": Summary of Current Resource Plans in the West and Their Effect on Regional Electricity Trading Patterns

Prepared for the State-Provincial Steering Committee

April 2015

Energy+Environmental Economics

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1 Introduction

Energy and Environmental Economics (E3) produced this report on behalf of the State-Provincial Steering Committee (SPSC) to describe the anticipated changes in resource mix and transmission path flows across the Western United States over the next decade.

This report provides an overview of today's energy infrastructure across the Western Electricity Coordinating Council (WECC) and explores how the system may evolve over the next 10 years under "Base Case" assumptions as well as more aggressive renewable energy policies.

Main findings include:

- Daily patterns of transmission flows change as renewables are added.
- The Western Interconnection does not experience substantially higher levels of congestion under the conditions examined (up to 28% renewables).
- On some paths, less congestion is observed due to coal plant retirements.
- Major changes to regional power flows may begin to occur at higher penetration levels of renewable energy.

2 Changing Resource Mixes in the Western Interconnection

2.1 The Western Interconnect Today

The WECC power system today is dominated by coal, gas, and hydro generation. Regional mixes vary, with hydro producing a large fraction of energy in the Northwest, coal used widely in the east, and gas dominant in California. WECC-wide, renewables provided 11% of generation in 2013 (Figure 1). Wind is the main source of renewable energy across the WECC, but solar is increasingly important in California and the Desert Southwest.

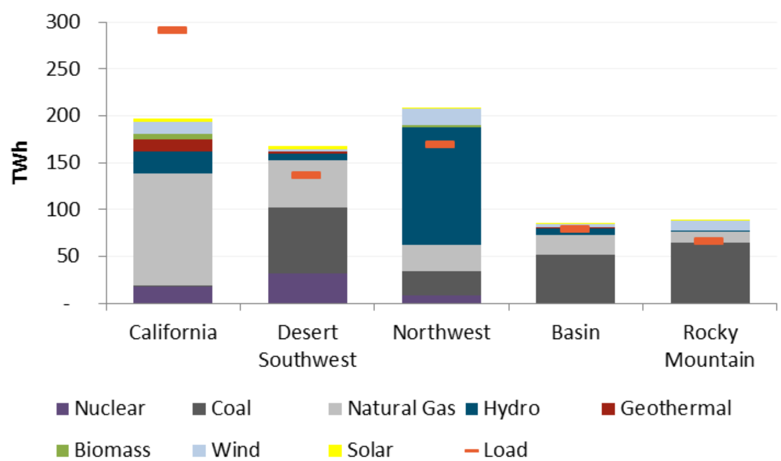


Figure 1. WECC Generation Mix, 2013. Source: EIA-906, EIA-920, and EIA-923

Resource plans for the next decade incorporate increasing levels of wind and solar, although natural gas will remain a large part of incremental resources across the WECC (Figure 2). Almost 8 GW of new solar capacity are expected to be added in California, 6 of it in Southern California, in addition to more than 2 GW of wind, geothermal, and biomass capacity. The Northwest is expected to add 2 GW of wind projects. Current resource plans include the retirement of 6 GW of coal capacity over the next decade

(Table 1) and additional retirements may be needed to comply with EPA requirements under Section 111 (d). A large amount of gas plant capacity will be retired in California.

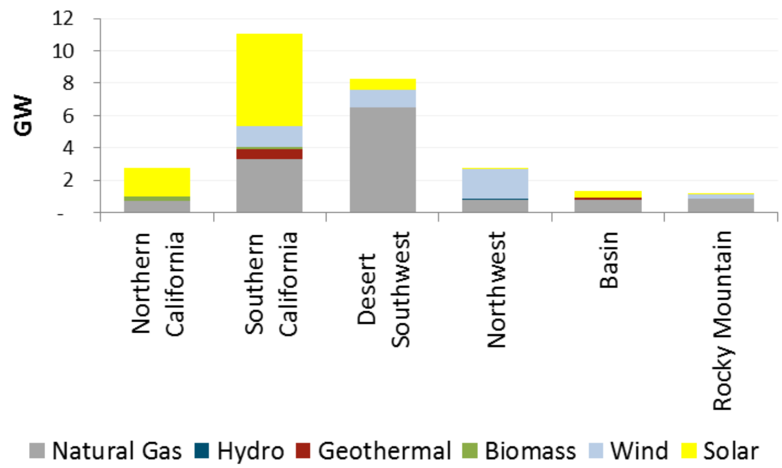


Figure 2. WECC Planned Capacity Additions, 2015-2024. Source: 2024 Common Case.

Table 1. Coal Plant Retirements. Source: 2024 TEPPC Common Case

Plant	Region	Capacity (MW)
Cholla	Desert Southwest	289
Navajo	Desert Southwest	803
Reid Gardner (1-4)	Desert Southwest	637
San Juan (2-3)	Desert Southwest	924
Naughton	Basin	350
North Valmy 1	Basin	277
Boardman	Northwest	642
Centralia 1	Northwest	730
J.E. Corette	Northwest	173
Cherokee (3-4)	Rocky Mountain	551
Neil Simpson ST1	Rocky Mountain	22
Valmont 5	Rocky Mountain	192

The western electricity system is already highly interconnected and features a dense transmission network connecting generation and load over long distances. The existing transmission can serve a large percentage of regional peak load, ranging from 19% for the Rocky Mountain region to 61% for the Northwest (Table 2). The major interconnectors serve two main purposes: 1) to interconnect neighboring regions for reliability and economic energy trading (most valuable between neighbors with load and resource diversity, e.g. COI, PDCI) and 2) to deliver resources from large out-of-zone generators, mostly minemouth coal generation and hydropower (Figure 2).

Table 2. Regional Import Capability. Based on non-simultaneous WECC Catalogue ratings: operational ratings are frequently much lower

Region	2012 Peak Load (GW)	Import Capability (GW)*	% Peak Load
California	59	21	**36%**
Northwest	28	17	**61%**
Southwest	28	15	**52%**
Basin	14	8	**60%**
Rocky Mountain	12	2	**19%**

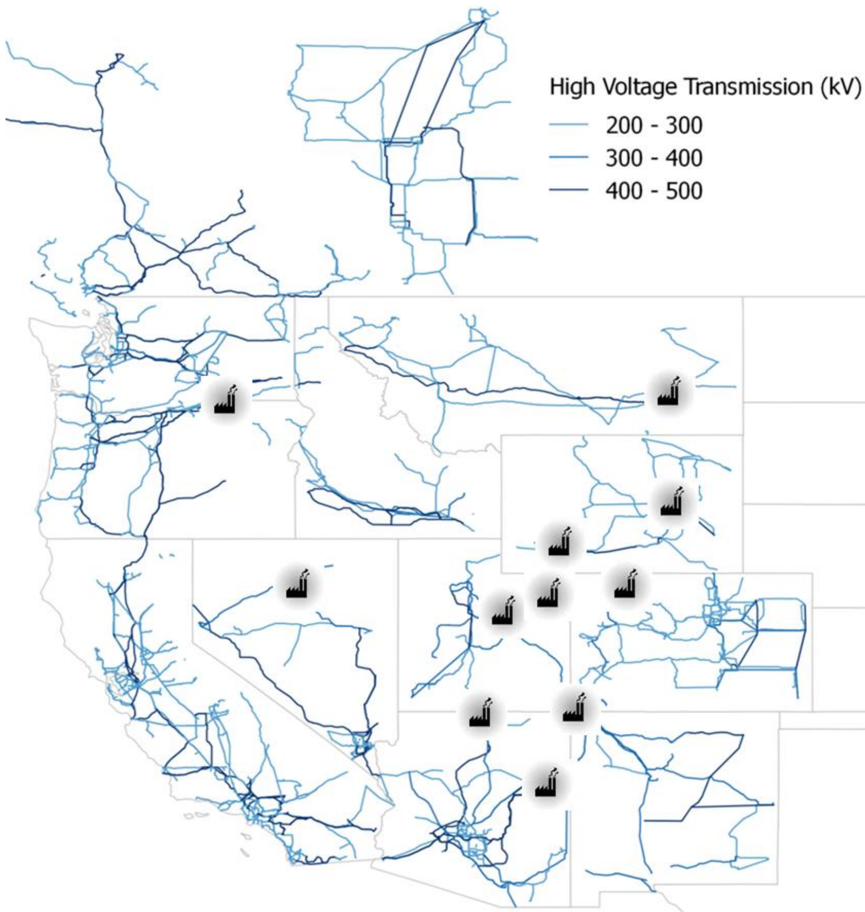


Figure 3. WECC High Voltage Transmission System and Location of Major Coal Plants. Source: WECC.

2.2 WECC Resource Plans

To understand how the changing resource mix may affect the flow patterns on the high voltage transmission system, we explored the results from two GridView cases developed for the Western Natural Gas-Electric Study.[1] The "Base Case" captures expected

[1] "Natural Gas Infrastructure Adequacy in the Western Interconnection: An Electric System Perspective," Energy and Environmental Economics, July 2014. https://ethree.com/documents/E3_WIEB_Ph2_Report_ExecSumm_07-28-14.pdf

renewable penetrations across the Western Interconnection in 2022 (Figure 4). The case reflects current Renewable Portfolio Standard (RPS) policies across the WECC. The "High Renewables Case" adds incremental wind and solar resources to evaluate the system operations and transmission flows at higher renewable penetration levels. State-specific RPS targets are adjusted upward, with the incremental mix consisting of 60% wind and 40% solar, replacing coal and natural gas (Figure 5). Outside of California, the higher targets are significantly more aggressive than current policy. The result is a need for 50 TWh of additional renewable generation. Total renewable penetration is 18% and 28% in the "Base Case" and "High Renewables Case" respectively.

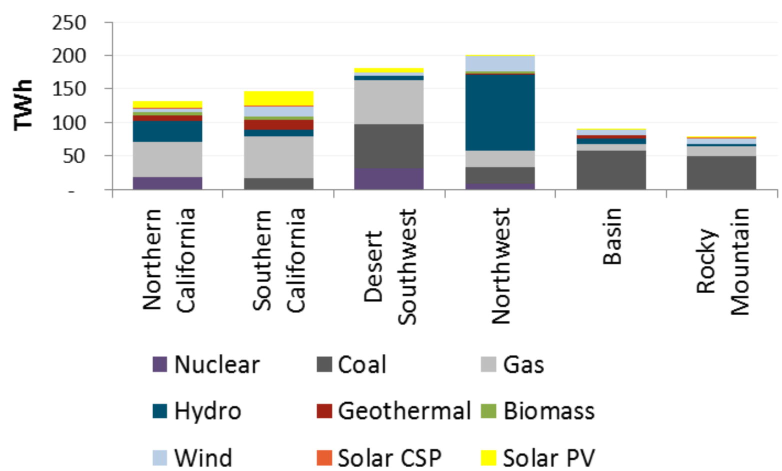


Figure 4. 'Base Case' Resource Mix.

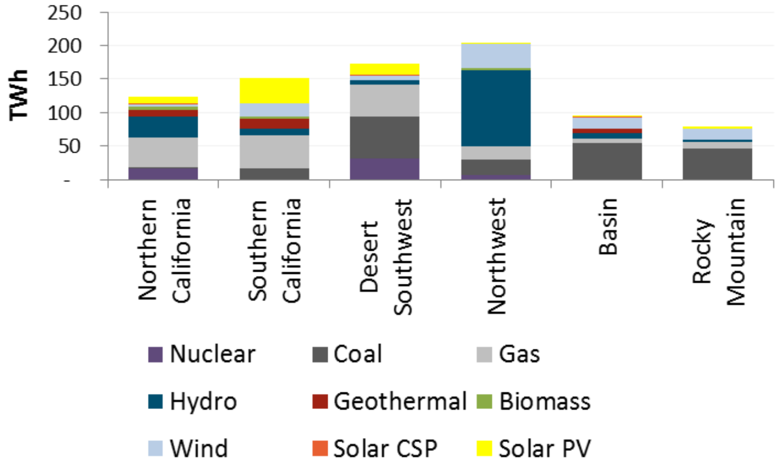


Figure 5. 'High Renewables Case' Resource Mix.

3 Observations on Power Flows across Major Inter-Regional Transmission Paths

3.1 Background

Historical path flows in this section are from an average hydrological year (2010). Future path flows are based on the GridView "Base Case" and "High Renewables Case" from the WIEB Natural Gas-Electric Study. Importantly, flows modeled in GridView are not reality and results should be interpreted with caution. The Base Case reflects current policy and trends and is built on the TEPPC 2022 Common Case, tuned to match historical regional power flow trends, including gas prices, hurdle rates, and flows from British Columbia to the Northwest. The High Renewables Case increases renewable generation levels as described in Section 2.2.

3.2 Northwest to California (Paths 65 and 66)

3.2.1 DIURNAL AND SEASONAL PATTERNS

Historical flows from Northwest into California on Path 65, the Pacific DC Intertie (PDCI), and Path 66 California Oregon Intertie (COI) have historically been higher in the afternoons and in the summer. As the penetration level of renewables is increased in the Base Case and High Renewables Case, flows on PDCI and COI become more variable. Relative to historical patterns, imports into California are lower during the summer and fall, and during daylight hours due largely to the availability of California in-state solar generation to meet the state's daytime and summer loads. Outside of the daytime hours, flows into California are higher than historically observed, as Northwest wind tends to produce at night and hydro output is also shifted to hours in which the market is more favorable.

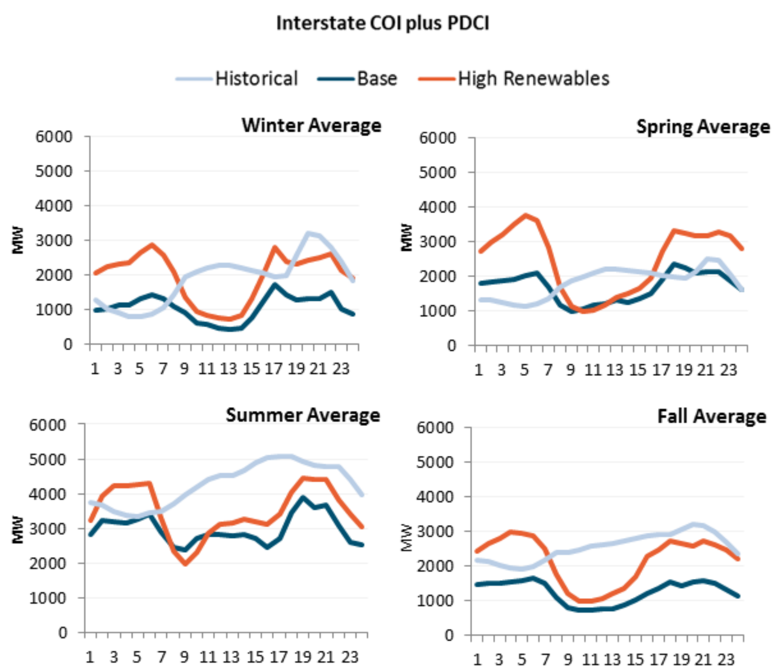


Figure 6. Northwest to California (PDCI and COI) Average Flow by Hour and Season

3.2.2 CONGESTION ASSESSMENT

While congestion is not present in the historical data, more frequent congestion is observed in the North to South direction on PDCI and COI at higher renewable penetrations, especially in High Renewables Case, driven largely by increase in Northwest wind generation. In the Base Case, line loading is above 75% of path rating in 2% of all hours; in the High Renewables Case, more than 10% of hours exhibit loading of more than 75% of the path rating. Congestion does not occur in any of the cases in the South to North direction. Unlike in the historical data, however, the Base Case and High Renewables Case do include a few hours of South to North flows, likely under conditions of high solar generation in California and high net load in the Northwest.

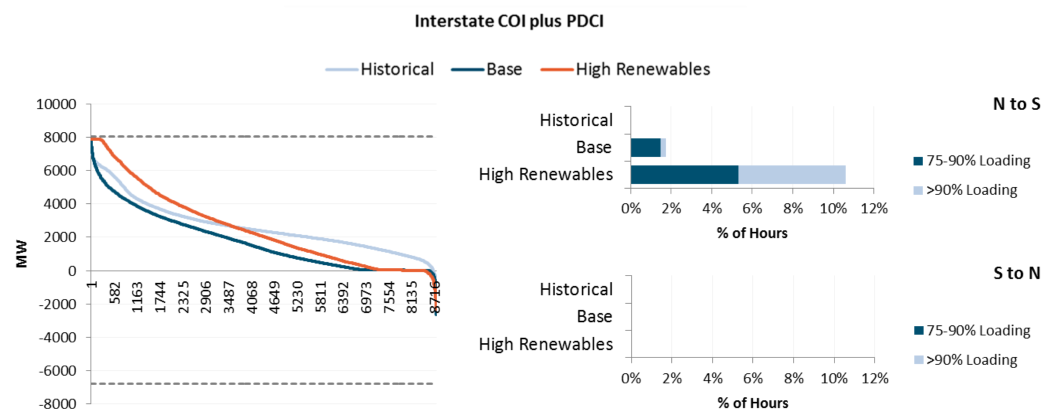


Figure 7. Northwest to California (PDCI and COI) Congestion

3.3 Southwest to California (Path 46)

3.3.1 DIURNAL AND SEASONAL PATTERNS

In the Base Case and High Renewables Case, Path 46 flows from the Southwest region into California are lower relative to historical levels due to coal retirements and decreased generation levels in the Southwest. Flows remain fairly constant across seasons and hours, with a diurnal pattern opposite that in the Northwest to California direction – higher during the day than at night – because of increased daytime solar production in the middle of the day in the Desert Southwest.

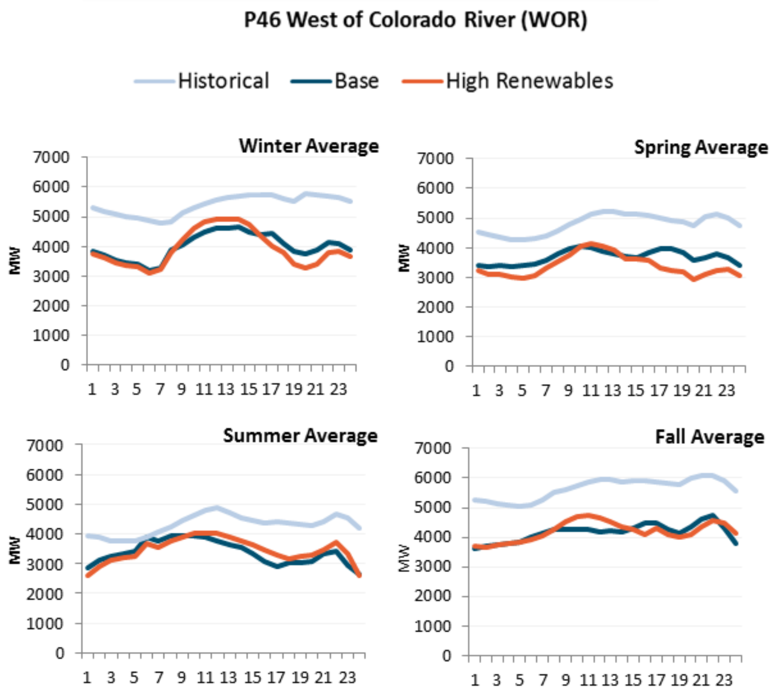


Figure 8. Southwest to California (Path 46) Average Flow by Hour and Season

3.3.2 CONGESTION ASSESSMENT

Driven largely by coal retirements, Path 46 flows are consistently lower in the Base Case and High Renewables Case relative to historical levels. Congestion is not observed on Path 46 in any of the three cases.

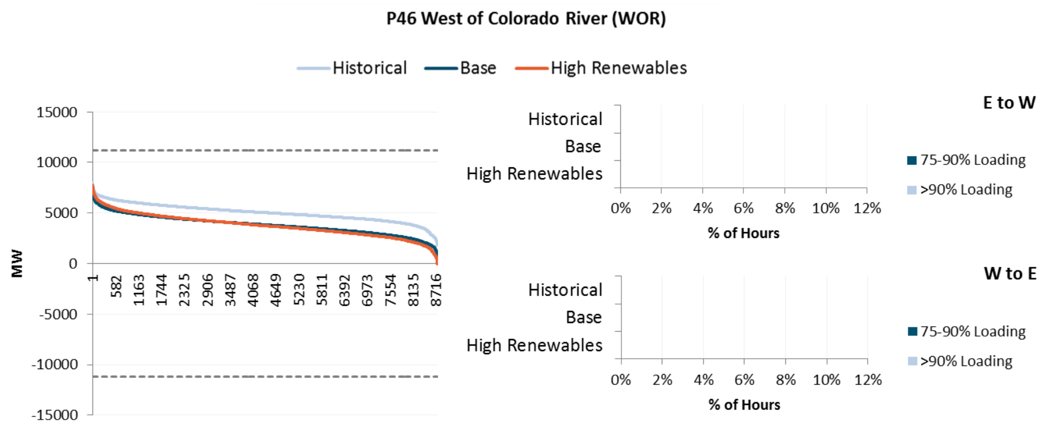


Figure 9. Southwest to California (Path 46) Congestion

3.4 Basin to Southwest (Paths 35, 78, and 79)

3.4.1 DIURNAL AND SEASONAL PATTERNS

Transfer levels between the Basin and the Southwest regions on Paths 35, 78, and 79 are relatively low, on the order of a few hundred MW in most hours. Historical flows are largely from the North to the load centers in the Southwest, but, as solar is added to the Southwest resource mix in the Base Case and High Renewables Case, flows between the Southwest and Basin regions shift during the daytime hours when solar production is high and is exported to the Basin. The direction of flows outside of the daytime hours remains from North to South.

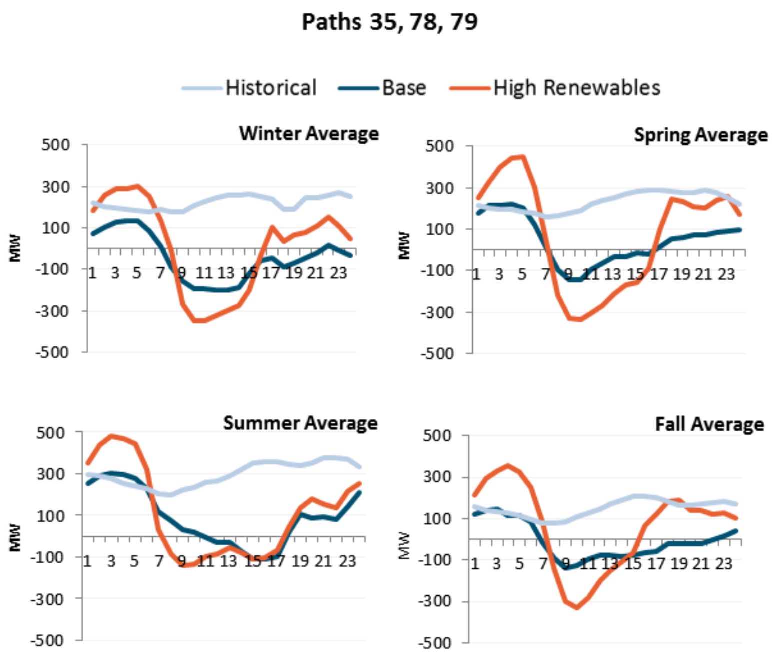


Figure 10. Basin to Southwest (Paths 35, 78, 79) Average Flow by Hour and Season

3.4.2 CONGESTION ASSESSMENT

While flows are almost always from the Basin into the Northwest in the historical data, the direction is reversed in about 50% of hours in the Base Case and High Renewables Case. Congestion is not observed between the Basin and Southwest regions in any of the three cases.

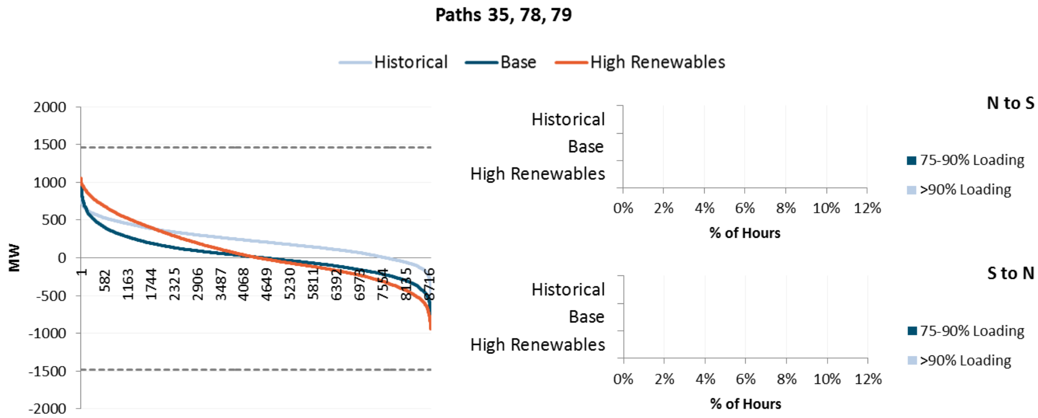


Figure 11. Basin to Southwest (Paths 35, 78, 79) Congestion

3.5 Rocky Mountain to Southwest (Path 31)

3.5.1 DIURNAL AND SEASONAL PATTERNS

Historical average transfer levels between the Rocky Mountain and the Southwest are low, rarely exceeding 200 MW, and are relatively constant across hour of day and season. As renewables are added in the Base Case and High Renewables Case, the variability in flows increases both within the day and from season to season. During the daylight hours, energy flows are largely from South to North, driven by solar generation in the Southwest. At night, the pattern is the opposite and North to South flows are higher relative to historical levels due to wind additions in the Rockies.

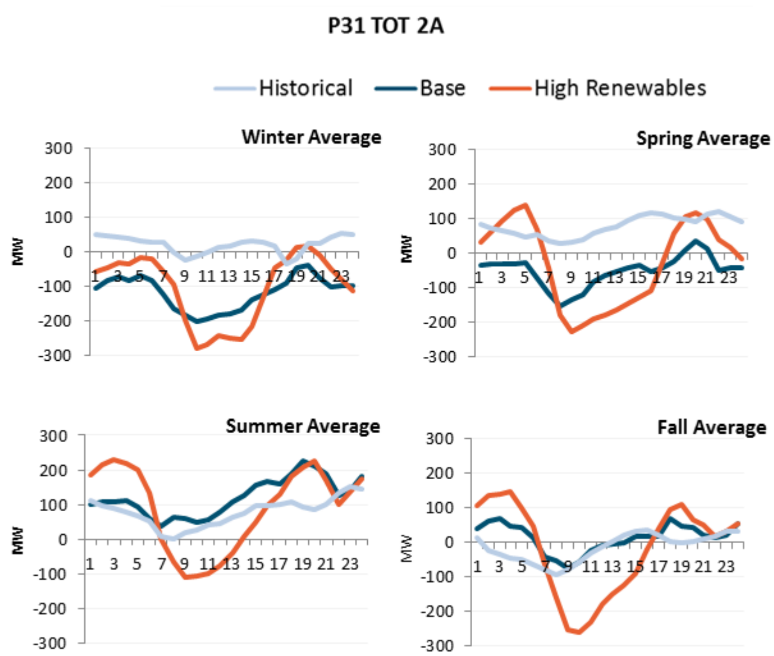


Figure 12. Rocky Mountain to Southwest (Path 31) Average Flow by Hour and Season

3.5.2 CONGESTION ASSESSMENT

Congestion on Path 31 between the Rocky Mountain and Southwest region is not present in the historical data. However, the frequency of high line loading increases in both directions with additional renewables, suggestion transmission capacity expansion between the two regions might be beneficial under higher renewables. In the High Renewables Case, Path 31 is loaded at more than 75% of its rating in 4% of hours in the North to South direction and an additional 4% of hours in the South to North Direction.

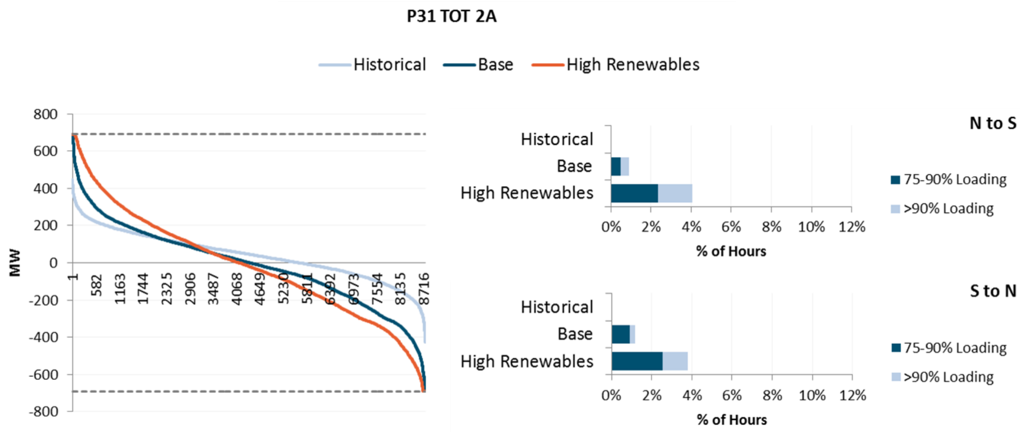


Figure 13. Rocky Mountain to Southwest (Path 31) Congestion

3.6 Rocky Mountain to Basin (Path 30)

3.6.1 DIURNAL AND SEASONAL PATTERNS

Relative to the historical data, flows from the Rocky Mountain into the Basin region are generally lower in the two GridView cases as coal plants are retired and replaced with renewables. The changes in resource mix result in more variable flows, but westbound flows are consistently higher than historical around sundown.

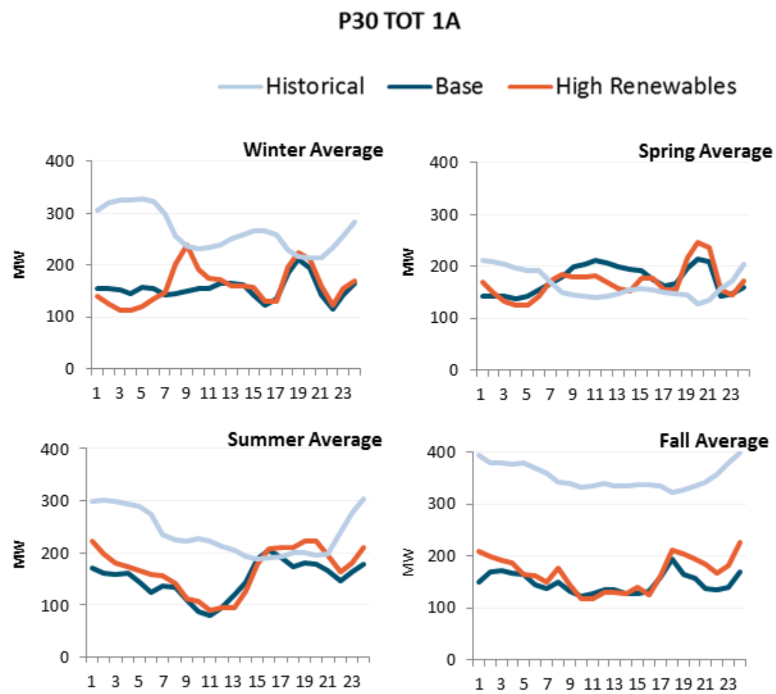


Figure 14. Rocky Mountain to Basin (Path 30) Average Flow by Hour and Season

3.6.2 CONGESTION ASSESSMENT

Path 30 line loading is similar across the three cases investigated. Congestion is observed in the East to West direction. The Base Case has lower congestion levels than the historical data due to coal retirements, but as incremental renewables are added in the High Renewables Case, congestion increases again and exceeds historical levels. Path 30 loading exceeds 75% of the rating in 2% of hours in historical data, 1% of hours in the Base Case, and 4% of hours in the High Renewables Case.

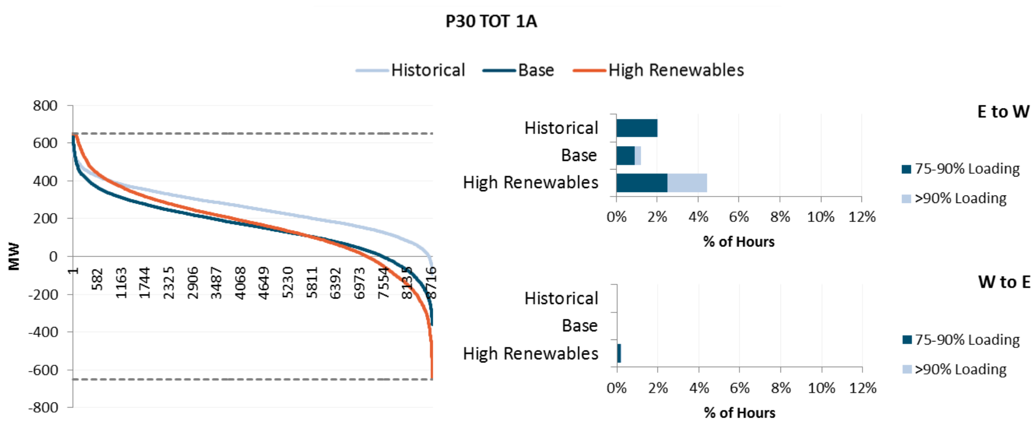


Figure 15. Rocky Mountain to Basin (Path 30) Congestion

3.7 Basin to Northwest (Path 14)

3.7.1 DIURNAL AND SEASONAL PATTERNS

Flows between the Basin to the Northwest on Path 14 differ considerably across the historical data and the two GridView cases. In general, flows decrease relative to historical levels, especially outside of the daytime hours. In the summer, Path 14 flows in the Base Case and High Renewables Case shift direction relative to the historical patterns: energy is exported from the Northwest into the Basin due to high hydro and wind conditions as well as low load in the Northwest.

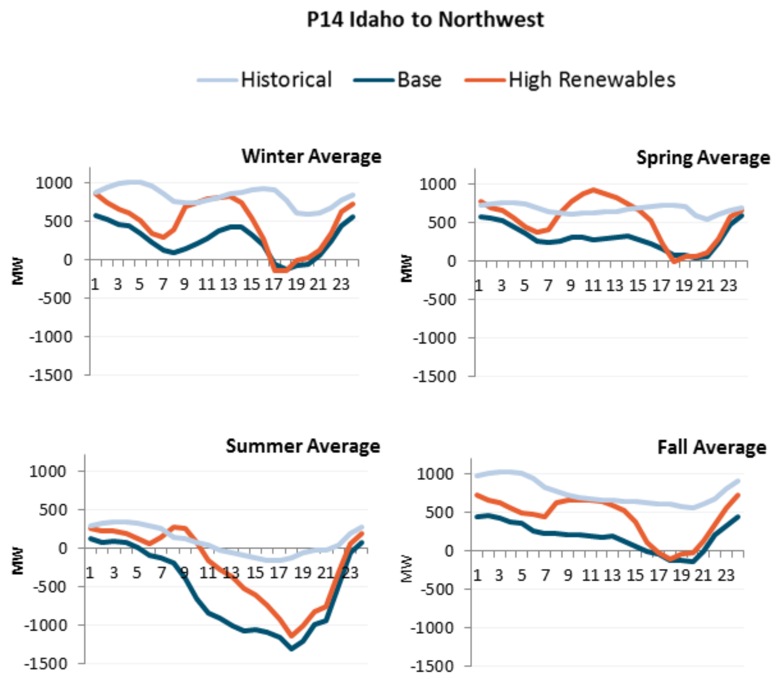


Figure 16. Basin to Northwest (Path 14) Average Flow by Hour and Season

3.7.2 CONGESTION ASSESSMENT

Flows between the Basin and Northwest exhibit more variability in the Base Case and High Renewables Case relative to historical patterns, but little congestion is observed. High levels of flows into the Northwest are more frequent in the High Renewables Case, but congestion in this direction occurs in less than 1% of hours. In the West to East direction, Path 14 experiences loading levels of more than 75% of path rating in about 2% of hours in both the Base Case and the High Renewables Case.

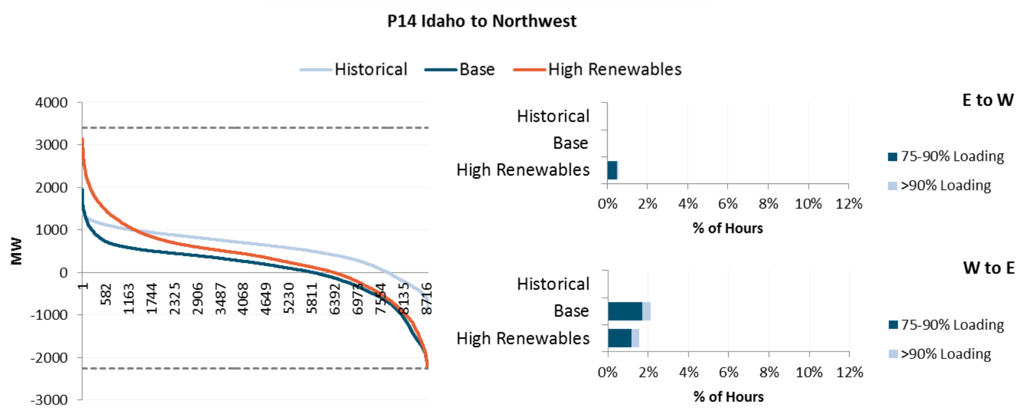


Figure 17. Basin to Northwest (Path 14) Congestion

3.8 Intra-California (Path 26)

3.8.1 DIURNAL AND SEASONAL PATTERNS

Historical flows on Path 26 are largely into Southern California, with higher levels observed in the afternoon and evening hours. The solar build-out in Southern California in the Base Case and High Renewables Case results in overgeneration conditions during the day in Southern California and a new flow pattern on Path 26 from South to North in the middle of the day. This result is particularly pronounced in the spring months, but flows into Southern California are reduced even in the peak summer months and often reverse direction relative to historical patterns in the early morning hours when Southern California load is low.

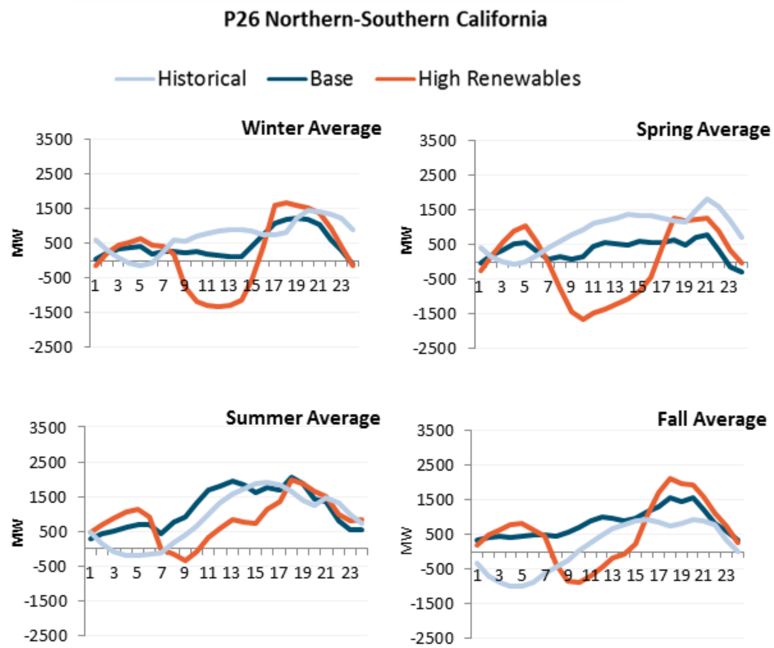


Figure 18. Intra-California (Path 26) Average Flow by Hour and Season

3.8.2 CONGESTION ASSESSMENT

The congestion frequency from North to South on Path 26 remains unchanged between the historical data and the high renewables cases. On the other hand, while almost no congestion has occurred in the South to North direction historically and in the Base Case, line loading of more than 75% of path rating is observed in 5% of hours in the High Renewables Case, suggesting path upgrades may be beneficial in scenarios with high levels of solar deployment in Southern California.

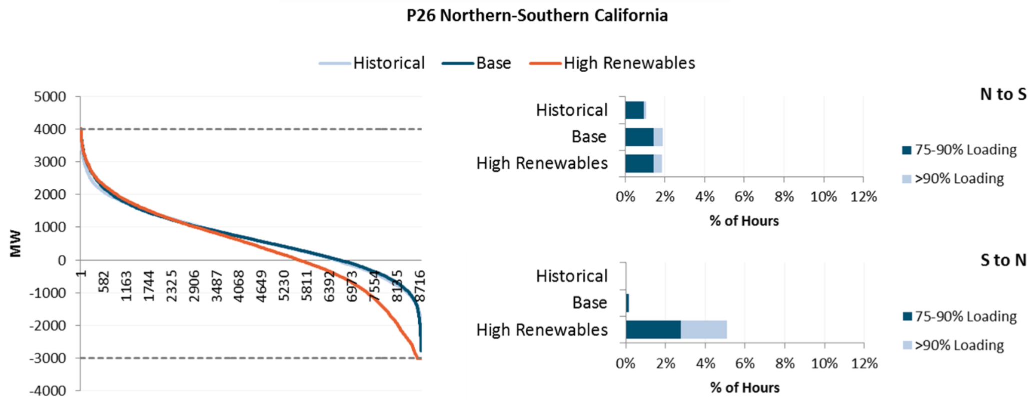


Figure 19. Intra-California (Path 26) Congestion

3.9 Intra-Northwest

Intra-Northwest flows on Path 8 do not change substantially across the three cases. Flows on remain from East to West and are relatively stable within the day and across seasons. No congestion occurs on Path 8.

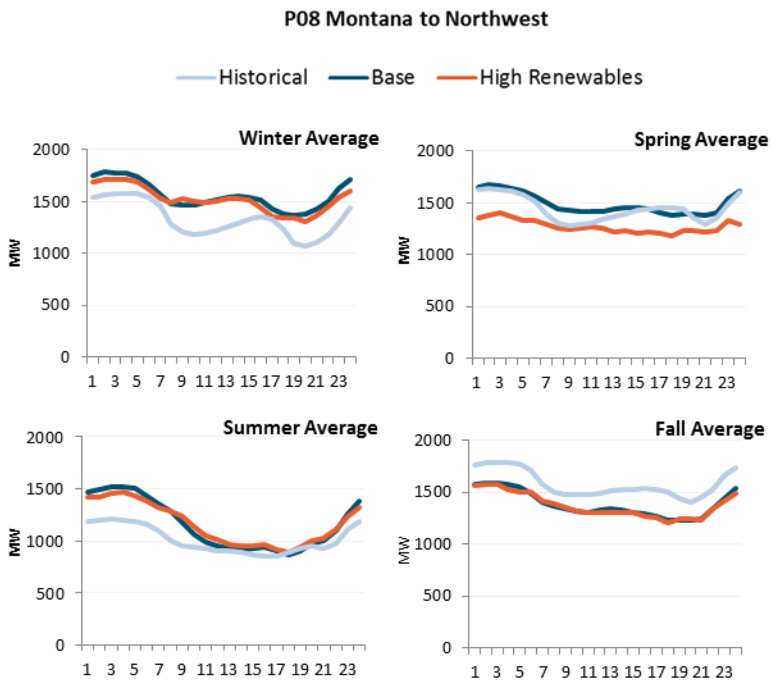


Figure 20. Intra-Northwest (Path 8) Average Flow by Hour and Season

3.10 Intra-Southwest

Path 22 has been congested historically, with East to West flows exceeding 75% of path rating in close to 15% of hours in 2010. Flows are reduced in the two GridView cases, especially in the middle of day, due to coal plant retirements at Four Corner as well as solar development near the load centers. Path 22 experiences less congestion as a result. Loading levels exceed 75% in 1% of hours in the High Renewables Case.

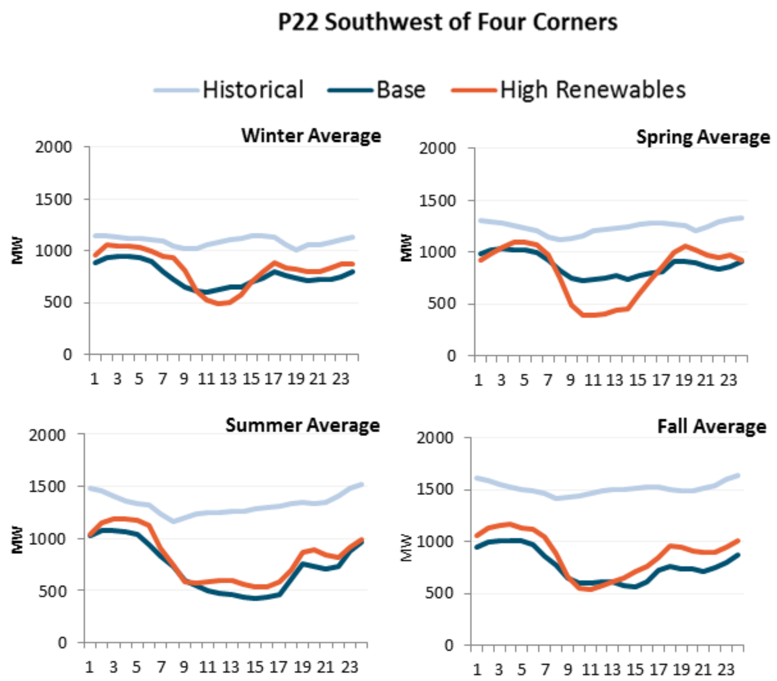


Figure 21. Intra-Southwest (Path 22) Average Flow by Hour and Season

4 Conclusion

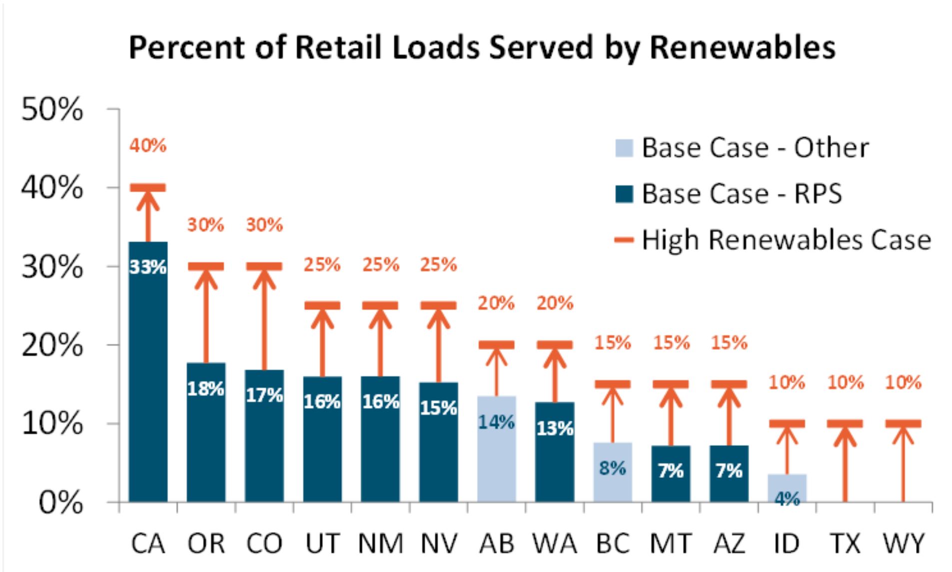
Energy infrastructure across the Western Electricity Coordinating Council (WECC) will evolve over the next 10 years as renewables are added to the system and existing coal capacity is retired. Daily patterns of transmission flows change as a result of the generation patterns of wind and solar. In particular, higher solar penetration has a noticeable diurnal effect on transfers across regions. While regional flows do exhibit more variability, the transmission system does not generally experience substantially higher levels of congestion under the conditions examined. In some cases, less congestion is observed, largely due to coal plant retirements. Major changes to regional power flows may begin to occur at higher penetration levels of renewables and higher reliance on solar would exacerbate the trends observed here.

APPENDIX

Results in this report are based on two main data sources: the WECC 2024 Common Case and the Western Natural Gas-Electric Study conducted by E3 for the Western Interstate Energy Board and State-Provincial Steering Committee.

The Common Case is a production cost model that represents a realistic 10-year scenario based on the most recent Western Interconnection developments, policies, and plans. It is developed through extensive input from stakeholders based on balancing authorities' submittals of expected loads and generation, with adjustments made to ensure consistency and compliance with policy goals. The Common Case is built to meet traditional standards of reliability. It is used by the Transmission Expansion Planning Policy Committee (TEPPC) as well as in FERC Order 890 and 1000 planning studies, independent developer studies, market and integration studies (e.g. Energy Imbalance Market), etc. The 2024 Common Case can be downloaded from **https://www.wecc.biz/Reliability/2024-Common-Case.zip**.

The Western Natural Gas-Electric Study was performed by E3 in partnership with DNV GL to explore the operational flexibility and adequacy of the natural gas infrastructure to meet electric industry requirements in the Western Interconnection. As part of the analysis, E3 evaluated the reliability and operations of the Western Interconnection using ABB's GridView software. Electric sector operations were simulated on an hourly basis across the Western Interconnection for a range of scenarios. The "Base Case," results from which are presented in this report, reflects current Renewable Portfolio Standard (RPS) policies across the WECC. The "High Renewables Case" adds incremental wind and solar resources to evaluate system operations and transmission flows at higher renewable penetration levels.



The Western Natural Gas-Electric Study is available at **http://westernenergyboard.org/natural-gas/study/**.