RESULTS

Transmission

Net-Zero Northwest: Technical and Economic Pathways to 2050 **is an economy-wide deep decarbonization pathways analysis to guide actions that will put Idaho, Montana, Oregon, and Washington on the path to achieving net-zero emissions by 2050.**

Summary

The *Net-Zero Northwest (NZNW) Energy Pathways* analysis modeled a Core Case that assumes the four Northwest states will achieve net-zero emissions by 2050 with relatively unconstrained technology availability, as well as aggressive electrification and efficiency. In addition to the Core Case, we modeled several scenarios to understand the impacts of constrained transmission expansion and changes in transmission cost. The key takeaways include:

- **Expanding transmission across the Northwest lowers total decarbonization costs and increases options for meeting future net-zero goals.**
- **While expanding transmission across Western states will be difficult, without it, permitting challenges shift to local areas.**
- **Lowering Northwest electric loads shifts the region's energy production elsewhere, and the Northwest imports energy in the form of fuels via pipeline.**
- **Transmission planning must start now to overcome the challenges of building interstate transmission.**

Introduction

The *NZNW Energy Pathways* analysis examines low-cost pathways for how the Northwest could achieve economy-wide net-zero emissions by 2050. Net-zero in this study means that all remaining greenhouse gases released into the atmosphere from human activity must be offset by measures to remove carbon from the atmosphere.[1]

Electricity transmission is the backbone of a net-zero emissions energy system, delivering clean renewable energy to a largely electrified economy. While transmission expansion faces significant challenges that include cost uncertainties as well as potential siting and permitting difficulties, this analysis shows that expanding transmission lowers overall decarbonization costs for the Northwest. More importantly, expanding transmission maximizes the chances of meeting net-zero emission targets.

Modeling Transmission

The Core Case assumes relatively unconstrained transmission expansion aligned with available potential identified in The Nature Conservancy Power of Place-West study (TNC PoP).[2] Additional modeling of transmission scenarios explores the impacts of constrained transmission expansion, limited renewable energy development, reconductoring options, and changes in transmission cost.

The analysis does not represent the nodal transmission system in the region but uses a zonal transmission model. Therefore, the results focus on state-to-state transmission interties, rather than specific transmission lines. Cost estimates for interconnecting new plants, expansion of in-state transmission, and expansion of distribution based on peak load requirements are represented in the model, but their specific topology is not.

Cost Estimates

Estimating the cost of building new transmission in the Northwest is challenging because there has been little recent large-scale or interstate transmission development across the Western states. Lacking benchmark transmission costs over

Above: Electricity transmission. Photo credit: Thomas Despeyroux complex interregional corridors and difficult terrain and land use means that cost estimates for this study are uncertain.

The *NZNW Energy Pathways* analysis uses transmission cost assumptions from the TNC PoP, which applies GIS modeling to determine least-cost interstate transmission routes between existing substation endpoints. Cost assumptions and transmission routes account for existing transmission capacity; reconductoring opportunities at different voltages; options to co-locate new lines, expand existing corridors, or develop new transmission corridors; terrain type; and sensitive land use areas.

The TNC PoP's transmission costs are higher than the National Renewable Energy Laboratory's Regional Energy Deployment System (ReEDS)[3] transmission costs used in past Northwest analyses conducted by the Clean Energy Transition Institute and Evolved Energy Research,[4] which results in more limited (though still substantial) transmission expansion. While the TNC PoP dataset estimates cost impacts from multiple factors, a detailed study of specific interties and realized costs from new development would be needed to provide more accurate transmission cost estimates.

Regardless, the Core Case finds that transmission development is relatively insensitive to price over many interties, illustrating the value of interconnectedness in the West in a net-zero economy.

Findings

Expanding transmission across the Northwest is key to meeting net-zero emission targets and minimizing overall decarbonization costs.

The *NZNW Energy Pathways* transmission scenarios show that pursuing transmission on all fronts maximizes the chances of meeting net-zero goals while minimizing overall decarbonization costs. Expanding transmission particularly lowers costs for the coastal states of Washington and Oregon to access wind in Montana and Wyoming.

Transmission expansion across the Northwest also alleviates pressure on permitting local renewable energy projects, expands the number of pathways to achieving net-zero emissions, and limits the number of problems that can crop up along the way to meeting emissions goals.

The TNC PoP dataset's higher transmission costs limit new transmission build in early years compared to previous studies.

The higher TNC PoP costs for transmission compared to NREL ReEDS data used in previous studies drive reduced transmission expansion and greater development of in-state resources in Washington in the 2030s. By the 2040s, however, the value of transmission to lowering decarbonization costs is such that transmission expansion is economic despite the higher cost assumptions. By 2050, the transmission links between the mountain and coastal Northwest states are significantly strengthened to allow the flow of high-quality wind to coastal load centers.

If transmission is not increased, states with high-quality renewables (most notably Montana) use energy to produce clean fuels locally and export energy via pipelines and other fuels networks.

While expanding transmission across Western states will be difficult, without it, permitting challenges shift to local areas.

Getting high-quality wind from Montana and Wyoming to load centers is the largest driver of transmission expansion in the Northwest. Assuming new renewables and transmission can be built in the most cost-effective places, 56 gigawatts (GW) of wind are built in Montana by 2050. However, if siting and permitting all that wind in Montana (and Wyoming) is not possible, new transmission is not as necessary.

Similarly, if transmission is limited to reconductoring or if costs for transmission are higher, there will be less transmission expansion. However, failing to build the most cost-effective resources for the region, and/or the transmission to access them, will require more local resources. This, in turn, will require more local land and more local transmission, which will also face siting and permitting challenges. The uncertainty about when and where resources can be built will impact how energy is supplied to the future economy.

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Lowering Northwest electric loads shifts the region's energy production elsewhere, and the Northwest imports energy in the form of fuels via pipeline.

Compared to their electric counterparts, lower-efficiency internal combustion engines and gas space heating require more energy in the form of clean liquid and gaseous fuels (including hydrogen, ammonia, biofuels, and electrofuel) in a net-zero economy. If fewer electric vehicles are sold than expected or gas continues to be used in buildings instead of electric appliances, end-use electric loads will be lower, but overall economy-wide energy demands will be higher.

If more internal combustion engines remain on the road, reaching net-zero targets by 2050 requires more clean fuels produced with electricity. Because of the lost efficiency compared to delivery of electricity straight to electric motors, electric loads are higher overall than in scenarios with more electric vehicles on the road. However, the location of the electricity load changes. Less electricity is needed where vehicles are located, requiring less expansion of transmission lines into load centers. But electric loads increase in locations where clean fuels are produced. These tend to be close to high-quality renewable resources where hydrogen and subsequent electrofuels can be most cost-effectively produced.

Less transmission expansion also decreases the utilization and economics of wind production and electrolysis in Montana, and it becomes more economic to use Southwest solar for hydrogen production. This leads to higher electric loads in places like Arizona and New Mexico, which have some of the best solar resources in the world and can produce clean fuels for import in greater volumes into the Northwest.

If more gas appliances remain in buildings, we see a similar impact. Electric loads decrease in load centers, reducing the need for transmission expansion to serve them, but the need for clean fuel is increased. Biofuels are favored economically to replace pipeline gas. In the Core Case, demand for biogas in the gas pipeline is met with Northwest sources. If more gas remains in buildings by 2050, the additional clean gas demand is met with sources outside of the Northwest, increasing energy imports into the region.

Transmission planning must start now to overcome the challenges of building interstate transmission.

Large-scale interstate transmission expansion in the Northwest does not happen until 2040 in our analysis, but investment is needed in the 2030s to ensure expanded transmission is available in 2040 and 2050. There is a chicken-and-egg problem with transmission expansion: transmission access is often required to develop new generation, but new generation is often required to justify investment in transmission. This issue is exacerbated when accessing remote resources across different planning jurisdictions and relying on developing large amounts of renewables that themselves face uncertain siting and permitting processes.

Transmission, Bonneville Lock & Dam, Columbia River Gorge. Photo credit: Eileen V. Quigley

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Transmission Capacity (Core Case)

Figure 1 shows transmission capacity in the Core Case, which assumes relatively unconstrained expansion, increasing from 2021 to 2050. Transmission capacity dictates the maximum flow that can occur on the line in either direction in any hour. Capacity results are displayed in GW by transmission intertie, which refer to the connections between states and not to specific transmission lines.

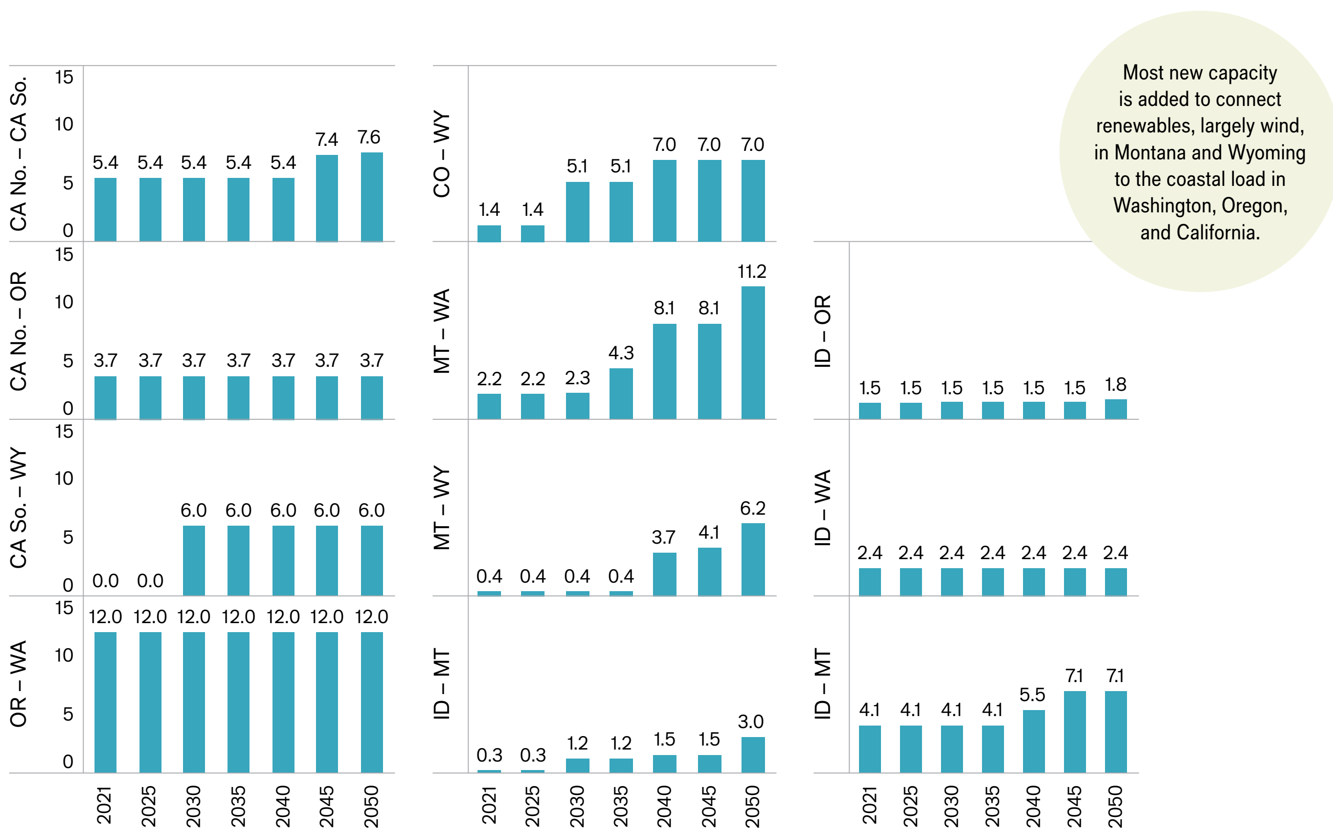
By the 2040s, transmission is important to reach net-zero emissions economically. Most new capacity is added to connect renewables, largely wind, in Montana and Wyoming to the coastal load in Washington, Oregon, and California.

Build-out happens gradually from 2030 to 2050 in the model, but transmission is more likely to be built sporadically over the 20 years and costs will be a key determinant. The lower the cost of intertie expansion, the earlier and greater the expansion would be.

The following intertie expansions are key to lowering the costs of decarbonization and expanding the resource options available to reach net-zero throughout the Western grid:

Montana-Washington: This intertie is extremely valuable and would build out to 11.2 GW capacity by 2050 to enable exports of low-cost, high-capacity wind from Montana to Washington, Oregon, and Northern California load centers.

Figure 1. Transmission Intertie Capacity—Core Case (GW)



Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, p. 43.

Montana-Wyoming: This intertie connects two renewable production centers to each other, rather than renewable production centers to the load centers, and creates more supply diversity for the coastal markets (Oregon, Washington, and California) that get power from Montana and Wyoming wind.

- Electricity is exported in both directions in increasing amounts as this intertie expands.
- On net, more electricity is exported from Wyoming to Montana, contributing to electricity exports to coastal Northwest states, as well as new electrolysis and direct air capture loads in Montana in the 2040s.

Wyoming-Colorado and Wyoming-California South: Exports south drive expansion of Wyoming wind and expand markets for Northwest electricity exports.

- During some hours of the year, renewables are being imported from Wyoming to Montana, and in other hours they are being exported. The expansion of transmission to Colorado and California allows greater exports from the Northwest during those hours because it provides access to markets that need the power.

TRANSMISSION SCENARIOS

The *NZNW Energy Pathways* analysis explored several scenarios that changed assumptions in the Core Case to probe the impacts of constrained transmission (TX) expansion and changes in transmission cost. Specifically, we asked the following questions:

TX 1 LOWER-COST:
What if transmission cost 50% less?

This scenario explores opportunities for additional transmission expansion if costs were lower than the Core Case's conservative assumptions. In this scenario, the 50% less cost adjustment was applied only to terrain-/land-use-related costs, and not to the technology.

TX 2 HIGHER-COST:
What if transmission cost 50% more?

This scenario indicates the level of economic transmission expansion even if costs exceed the Core Case's conservative estimates. As with **TX1–Lower-Cost**, the cost adjustment (50% higher in this case versus 50% lower in the prior scenario) is applied only to the terrain-/land-use-related costs, and not to the technology.

TX 3 NO EXPANSION:
What if transmission cannot be expanded in the Northwest?

This is a bookend case to show how states in the Northwest could meet their goals in the absence of any transmission expansion, demonstrating the additional cost of decarbonizing without transmission expansion and providing a rationale for pursuing transmission planning.

TX 4 LIMITED WIND:
What if Montana and Wyoming are limited to 10 GW of onshore wind development?

The Core Case results show 56 GW of new onshore wind built in Montana by 2050, which drives significant transmission build. This scenario explores what happens if Montana and Wyoming face opposition to siting these wind resources and only 10 GW of onshore wind are built in each state.

TX 5 NO EAST-WEST:
What if it is not possible to expand transmission from east to west in the Northwest?

In past studies, east-to-west transmission connections have driven investment patterns. This scenario explores the impact on local resource investments if expansion from the mountain states to the coastal states is not allowed.

TX 6 RECONDUCTOR ONLY:
What if only reconductoring were allowed?

Developing new transmission corridors will be difficult and is uncertain. Reconductoring lines upgrades existing wire or cable to carry more electricity. This scenario explores the bookend case in which no new transmission can be built, but existing lines can be reconductored.

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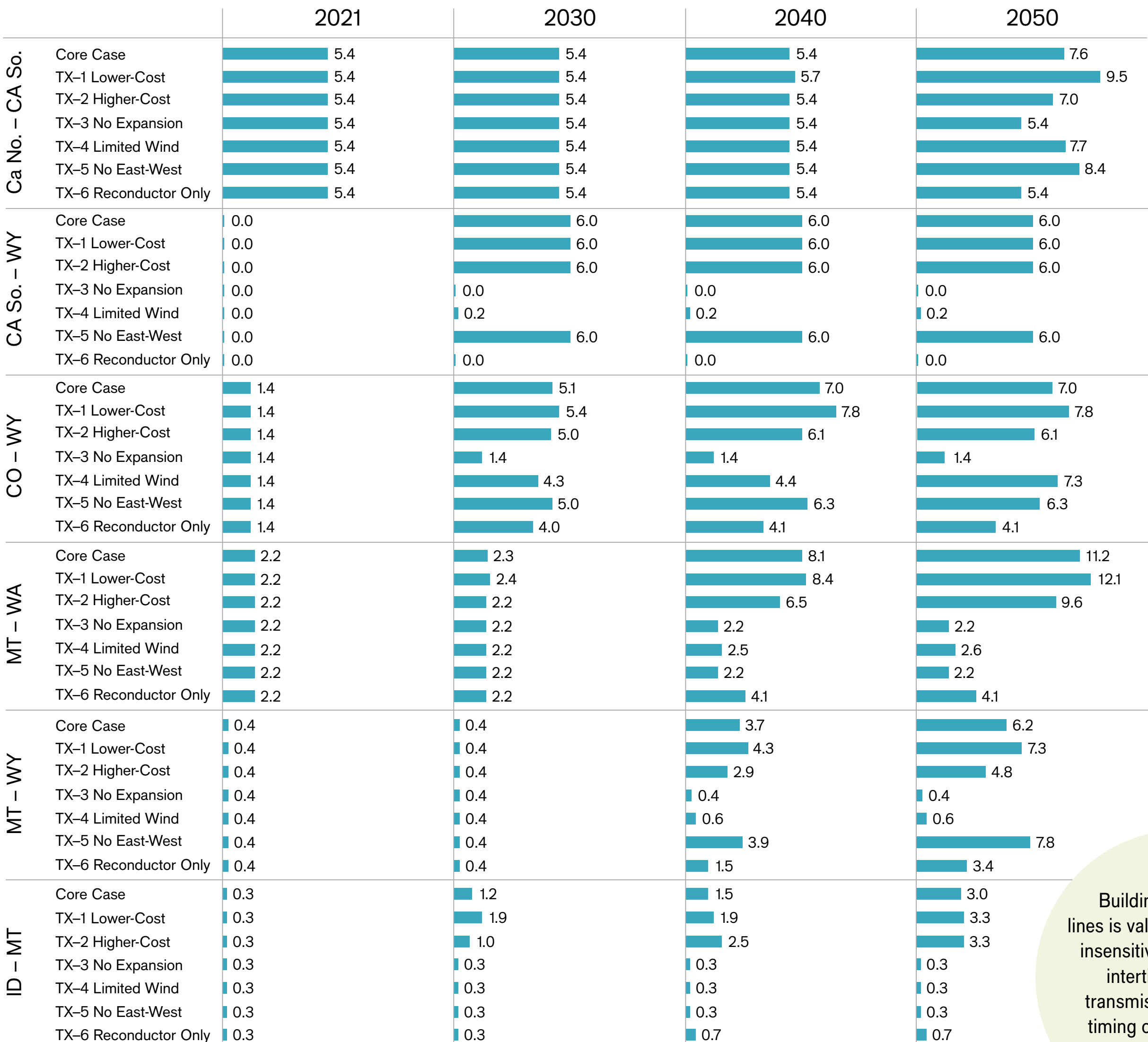
Transmission Capacity (Scenarios)

Figure 2 shows the change in transmission capacity for key transmission interties in 2021, 2030, 2040, and 2050 for each of the six transmission scenarios modeled. Each of the sensitivity scenarios is compared to the relatively unconstrained Core Case.

The different costs in **TX1–Lower-Cost** and **TX2 – Higher-Cost Transmission** generally do not impact how much transmission is built as much as they affect *when* the transmission is built. This finding indicates that building transmission lines is valuable and relatively insensitive to cost. For key interties, lower-cost transmission accelerates timing of transmission build, and higher costs decelerate expansion.

Figure 2. Transmission Intertie Capacity—Scenarios (GW)



Building transmission lines is valuable and relatively insensitive to cost. For key interties, the cost of transmission impacts the timing of when it is built, but not how much is built overall.

Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, pp. 75-76.

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California North–California South: After 2040, this intertie becomes a bottleneck, and we see this line gets built out significantly to allow Southwest solar to flow to the north and Northwest wind to flow south.

California South–Wyoming: In general, transmission between Oregon, Washington, and California largely serves to bring wind from Montana and Wyoming through Washington and then south down the coast. The *California South–Wyoming* intertie bypasses these Northwestern transmission options to import directly from Wyoming into California.

- In the Core Case, this intertie is already built to the maximum extent (6 GW) permitted in the modeling (based on the potentials identified in the TNC PoP study), showing that bypassing Northwestern transmission options is economically favorable, if available. The model would build more if permitted.
- Even in **TX2–Higher-Cost**, the whole 6 GW is still built by 2050.
- If Montana and Wyoming are limited to 10 GW of wind potential each (**TX4–Limited Wind**), then the *California South–Wyoming* expansion is significantly curtailed (only expanding to 0.2 GW by 2050) because there is less available wind energy to transport.

Colorado-Wyoming: Wyoming exports through Colorado are valuable for sending cheap wind energy south to predominantly solar states.

Montana-Washington: The *Montana-Washington* connection is also valuable by 2050, facilitating wind exports from Montana to load centers in Washington.

- This intertie is somewhat sensitive to cost changes. **TX1–Lower-Cost** results in an additional 1.8 GW of expansion relative to the Core Case. However, we still see substantial expansion even with high costs (**TX2–Higher-Cost**).
- Reconductoring this intertie is expensive, yet is still expanded if only reconductoring is available, as modeled in **TX6–Reconductor Only**. This shows that this line is extremely valuable for accessing high-quality resources.

Idaho-Montana: This is another valuable pathway like *Montana-Washington* because it transports high-quality wind resources from Montana. Electricity can be exported via transmission expansion of *Montana-Washington*, or through expansion of this *Idaho-Montana* intertie, and then travel from Idaho to Washington or Oregon.

Montana-Wyoming: Electricity is exported in both directions (on net, more from Wyoming to Montana) in increasing amounts as this intertie expands. This intertie is built out even in the **TX2–Higher-Cost**, showing its value for accessing renewables. However, it is only useful if Montana and Wyoming wind materializes, as seen in **TX4–Limited Wind** where this intertie is not expanded.

Transmission, Bonneville Lock & Dam, Columbia River Gorge. Photo credit: Eileen V. Quigley

Type of Transmission Expansion

The relative costs of HVAC, HVDC, and reconductoring options vary with line characteristics and have a high level of uncertainty; more line-specific and real-world data are needed.

Figure 3 shows the change in transmission capacity in GW for four key transmission interties in 2021, 2030, 2040, and 2050, and the type of transmission that would be built. The figure compares five transmission scenarios (excluding **TX3–No Transmission Expansion**) to the Core Case.

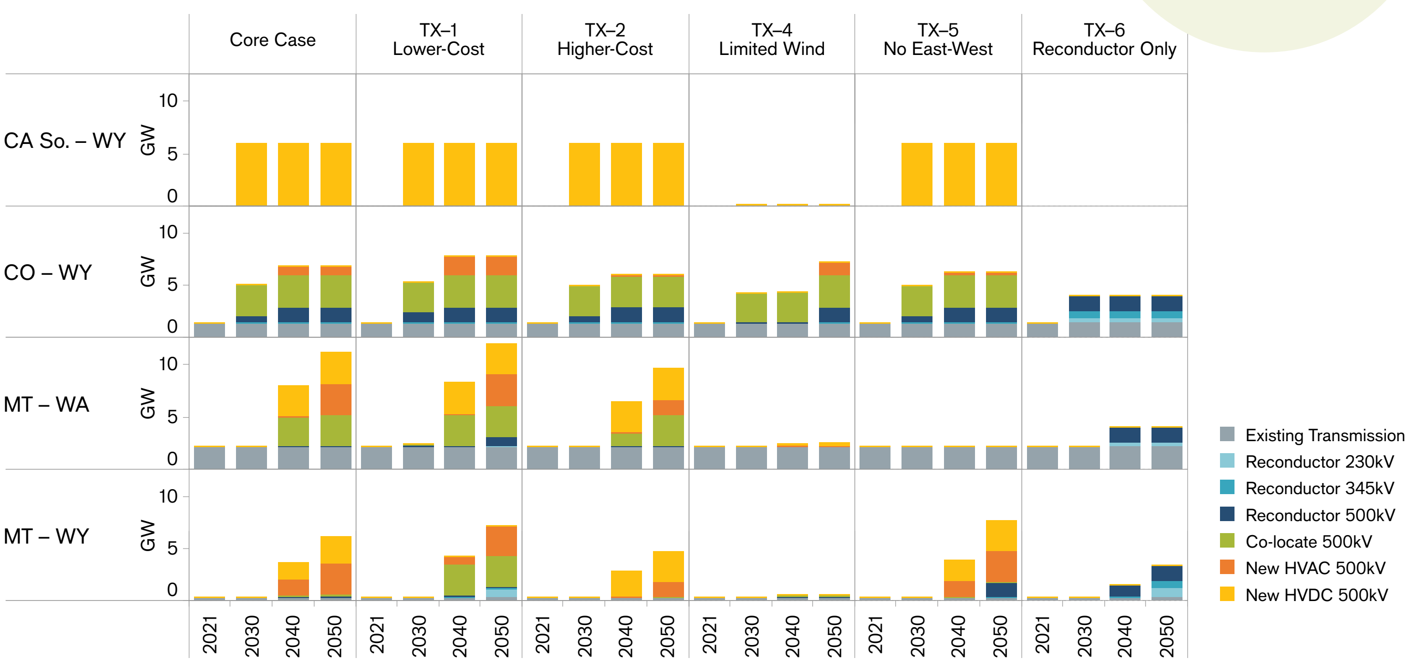
Transmission expansion is shown by type. Reconductoring lines means upgrading the existing wire or cable to carry more electricity. Co-locating means adding a new transmission line to pre-existing infrastructure or adjacent to an existing transmission line. High-voltage alternating current (HVAC) lines and high-voltage direct current (HVDC) lines are generally used for transmission over long distances.

The relative costs of HVAC, HVDC, and reconductoring options vary with line characteristics such as length and impact of terrain/land use. These costs also have a high level of uncertainty, and more line-specific and real-world data are needed.

The TNC PoP transmission costs used for this study are high level and lack detailed line-specific analysis. Furthermore, the modeling uses a zonal representation rather than the nodal and power flow modeling necessary for transmission planning. Therefore, these results do not indicate exactly where to reconductor lines vs. build new HVDC lines vs. build conventional AC lines, etc., but rather show that there are cost

Transmission expansion options (HVAC, HVDC, and reconductoring) vary based on length and terrain/land-use considerations. However, there is a high level of uncertainty, and more line-specific and real-world data is needed.

Figure 3. Type of Transmission Expansion for Select Interties—Scenarios (GW)



Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, p. 77.

trade-offs to be examined when doing a more detailed study on the following transmission interties:

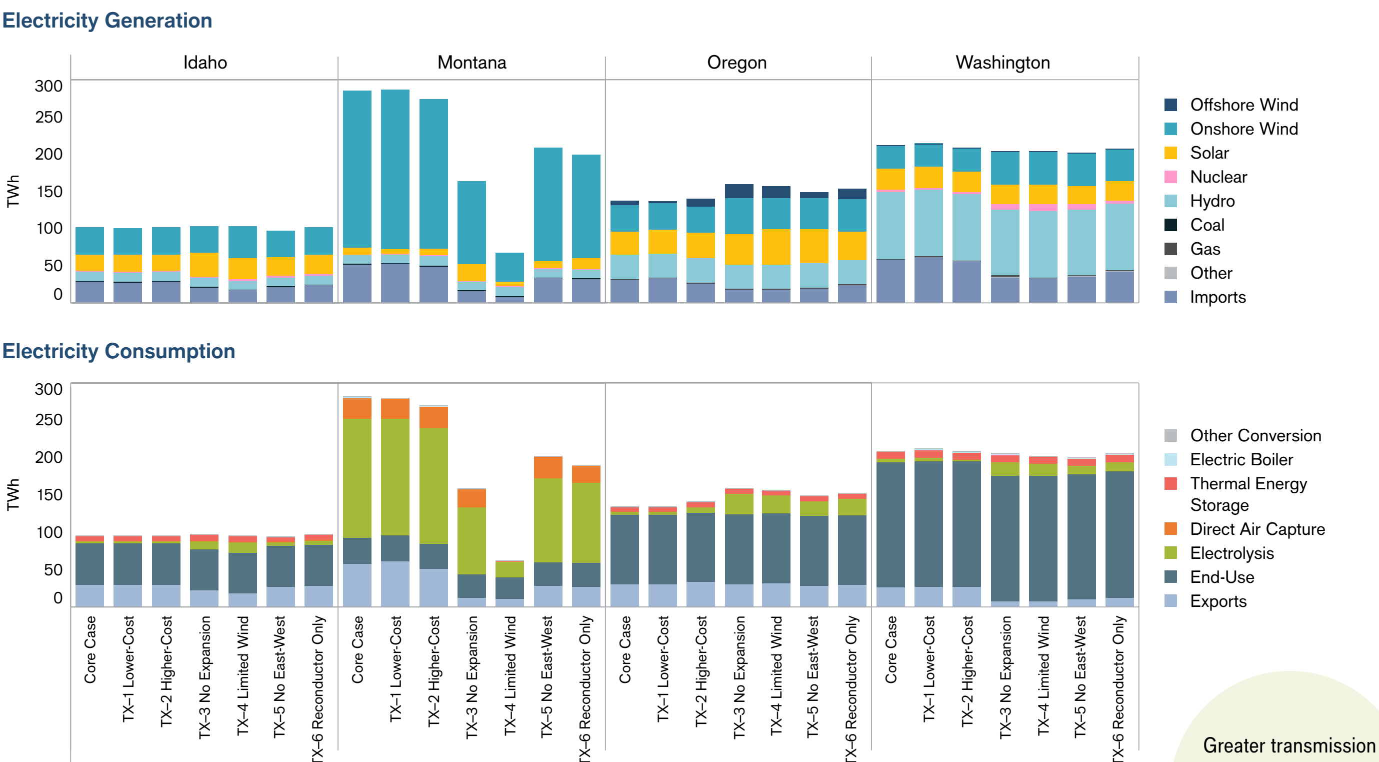
- The *California South–Wyoming* HVDC line is built to its full 6 GW potential in all scenarios where it is allowed and where Wyoming wind is available (i.e., not **TX4–Limited Wind**), demonstrating its value in enabling electricity to move and its relative insensitivity to cost.
- Reconductoring and co-location are cost-effective on the *Colorado-Wyoming* route.
- The *Montana-Washington* intertie favors HVDC due to its long distance. In addition to HVDC, it builds all available transmission options because the out-of-state wind is so valuable.
- A combination of options is economic from *Montana-Wyoming* unless wind development is constrained (**TX4–Limited Wind**).

The modeling also investigated the impact of high-temperature, low-sag (HTLS) conductors, which operate at a higher ampacity but cost more. The ability to expand transmission in the future is uncertain and if expansion options are limited to reconductoring along existing corridors, reconductoring with HTLS conductors can help access high-quality renewables economically by increasing the total transmission capacity. See pages 80-87 of the *NZNW Energy Pathways Technical Report* for full HTLS scenario results.

Impacts of Transmission Expansion on Electricity Balance

Figure 4 shows the impact of the six different transmission scenarios on the Northwest electricity balance in 2050, compared to the Core Case, shown in terawatt-hours (TWh).

Figure 4. Electricity Balance in 2050—Transmission Scenarios (TWh)



Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, p. 78.

Greater transmission connectivity increases wind investments and hydrogen production in Montana.

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Greater transmission connectivity—as seen in the Core Case, **TX1–Lower-Cost**, and **TX2–Higher-Cost**—improves the utilization and thus the economics of wind generation, therefore increasing wind investments, hydrogen production, and exports in Montana when compared to scenarios that constrain transmission (**TX3–No Transmission Expansion**, **TX4–Limited Wind**, **TX5–No East-West**, and **TX6–Reconductor Only**).

Similarly, transmission connectivity allows Oregon to import power from high-quality resources in Montana, rather than siting renewable energy resources and electrolysis in state, seen by the lower renewable energy and electrolysis investment in the scenarios that do not constrain transmission (Core Case, **TX1–Lower-Cost**, and **TX2–Higher-Cost**).

Additionally, when transmission is more available, Washington relies more on other markets, importing more from Montana and exporting more to Oregon.

Cost Impacts

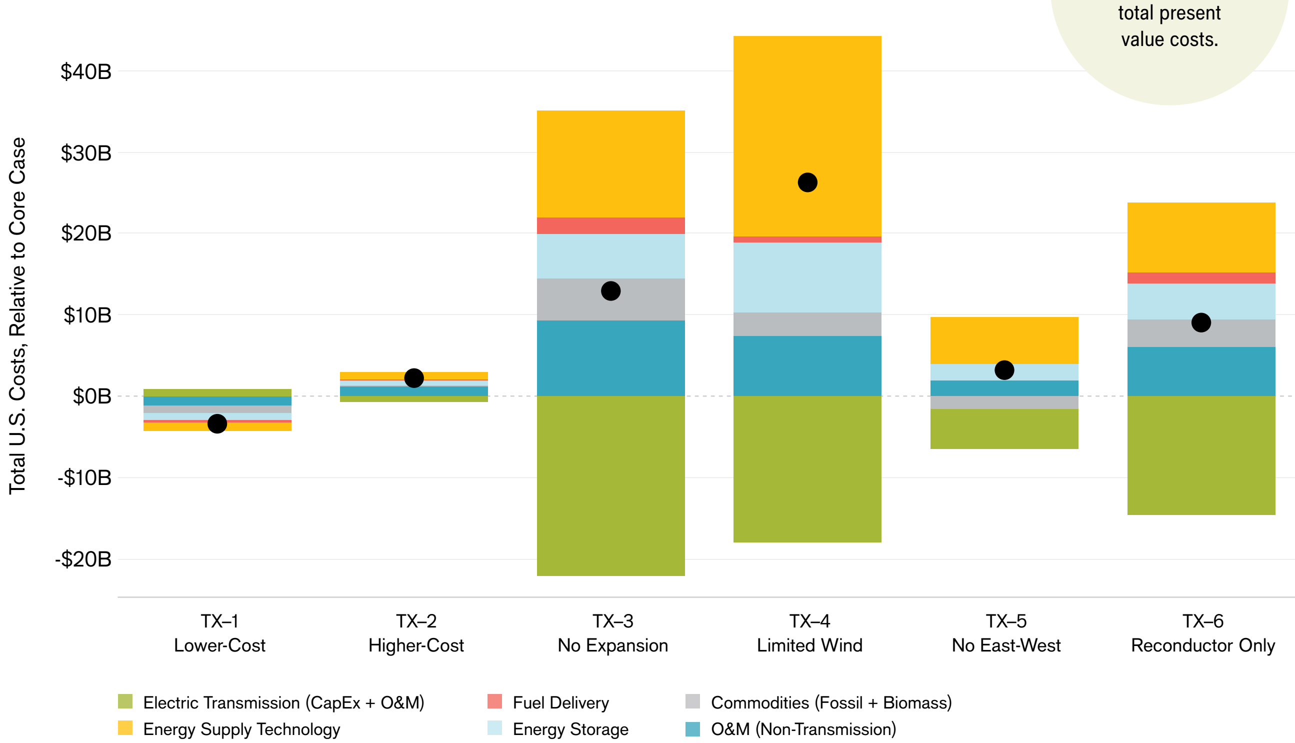
Severely constraining transmission expansion significantly increases total present value costs.

Figure 5 shows the cost impacts of the various sensitivity scenarios compared to the Core Case. Costs are presented as total present value costs and shown for the entire U.S. due to the interconnected nature of the transmission system. For the total present value costs, the cost difference in each year is discounted back to 2021 dollars using a 3% annual discount rate.

Overall, it is cheaper to have a more interconnected network, even with the higher TNC PoP transmission costs used in this study. Severely constraining transmission expansion significantly increases total present value costs. In both **TX3–No Expansion** and **TX6–Reconductor Only**, the present value costs through 2050 increase by $13 billion and $9 billion, respectively.

Figure 5. Cost Impacts Relative to the Core Case—Transmission Scenarios (Total U.S. Costs, Billions of Dollars)

Constraining transmission expansion increases total present value costs.



Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, p. 85.

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When transmission expansion is unconstrained, new transmission is built in large part to access low-cost and high-capacity factor resources that are far away and are complementary in production shape to other resources. For example, wind in Montana is a valuable output shape for the Southwest, where a significant amount of clean solar energy is produced in the middle of the day.

High-quality wind is generally not available in large quantities close to the largest load centers in the West. Offshore wind is, but offshore wind costs are still high compared to solar. If transmission is constrained, access to those wind resources is constrained and leads to increased reliance on local resources throughout the West, particularly solar in California and Arizona.

However, adding more solar to an already solar-heavy system will increase the energy supply when the sun is shining. This is inconvenient because end-use loads cannot easily be shifted to times when solar output is high.

The model builds more storage to balance the additional solar capacity. At this point, it also becomes more economic to invest in clean fuels production to use the excess solar. The increases in storage, solar PV, and hydrogen investment *outweigh* the reduced transmission and fossil fuel costs, leading to overall higher costs from transmission constraints.

TX4–Limited Wind dramatically increases total costs because it forces a wind-to-solar shift while also requiring more fossil fuel and biomass use to meet energy demand.

Variations in transmission cost have a lower impact on total costs.

TX1–Lower-Cost, and **TX2–Higher-Cost**, which explore variations in transmission cost (50% less expensive or 50% more expensive, respectively), have lower impact on total costs.

The transmission cost differences shift investments between transmission and local resource development, leading to small overall impact. In **TX1–Lower-Cost**, lower-cost transmission is built in greater quantities, increasing energy imports and exports from resources further afield. In **TX2–Higher-Cost**, higher-cost transmission is built in lower quantities, driving investment in resources closer to load centers.

Costs for reconductoring vary by line and are favored only on some interties.

Reconductoring options vary with line characteristics, such as length and terrain/land-use considerations. These relative costs have a high level of uncertainty, with cost trade-offs to be examined, and more line-specific and real-world data is needed for a more detailed study on transmission corridors and reconductoring options.

The analysis shows that reconductoring is a good option if expansion isn't possible, but its value is corridor-specific. If transmission expansion continues to be difficult to execute because of permitting and cross-jurisdictional coordination issues, specific reconductoring projects warrant further study.

Transmission expansion increases the options for meeting net-zero targets, which is even more important than the relatively low cost impacts of constraining transmission.

The cost impacts of transmission constraints are relatively low compared to some other factors, like slower electrification or resource constraints on high-value renewables, such as **TX4–Limited Wind**. The substitution effect explains this result: if transmission is constrained, resources are diverted into other uses and energy is shifted to different places, meaning that the marginal cost impacts of constraining transmission are less than other threats like slower electrification.

However, not being able to expand transmission puts stress on getting local renewables sited and permitted at rates that could be difficult to achieve.

With transmission expansion, there is greater access to diverse resources and therefore fewer potential challenges to overcome with state politics, local permitting challenges, etc., that could jeopardize meeting net-zero emission targets.

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Cost estimates for new transmission include a large amount of uncertainty.

There has been little recent large-scale or interstate transmission development across the West to benchmark transmission costs over complex interregional corridors and difficult terrain and land use. The TNC PoP dataset estimates cost impacts from multiple factors, but a detailed study of specific interties and realized costs from new development is needed to improve transmission cost estimates.

Table 1 shows recently constructed 500kV lines in the West, which faced cost overruns in several cases. There is a wide range of cost estimates when comparing the actual cost to what would have been benchmarked using the ReEDS and TNC PoP datasets.

Despite these cost uncertainties, the *NZNW Energy Pathways* analysis shows that transmission development is relatively insensitive to price over many interties, illustrating the value of interconnectedness in the West in a net-zero economy.

Table 1. Western States Transmission Cost Benchmarking

Line	Description	Actual or Estimated Cost $/MW-Mile	ReEDS Benchmark $/MW-Mile	TNC PoP Benchmark $/MW-Mile
West of Devers	220 kV reconductor in Southern California, completed 2021	$7,000	$2,333	$2,500
Boardman to Hemingway	Approved but not constructed, 500 kV Idaho to Oregon	$4,100	$1,347	$7,700
TransWest	Permitted 500 kV Wyoming to Nevada, both DC and AC segments	$2,700	$1,347	$6,000-$6,700
Tehachapi	500 kV line in Southern California, completed 2016	$3,500	$1,347	$6,700

Source: Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023, p. 287.

Conclusion

More extensive transmission lowers total decarbonization costs and increases options for meeting future net-zero goals.

In addition to cost uncertainties, multiple factors impact the feasibility of transmission expansion, including:

- Physical factors, such as line length, terrain, land use, and fire risk.
- Whether the line is contained in a single planning area and/or state, or whether it crosses multiple jurisdictions.
- Whether markets exist to make development of the line profitable.
- Whether market structures or policies mitigate risks to transmission developers.

Even when considering these potential challenges, expanding transmission gives the Northwest more options for clean energy. Transmission expansion allows access to imports from other states, and power exports from renewable-rich regions allow renewables to be located where they are most feasible.

Limiting transmission, on the other hand, puts greater stress on siting and permitting local resources, a major challenge to achieving net-zero emission targets by 2050.

By comparing scenarios that vary the level of transmission development feasibility, this analysis demonstrates that more extensive transmission development lowers total decarbonization costs and increases optionality for meeting future net-zero goals—suggesting that policymakers should seek to address feasibility issues where possible.

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Glossary

For a full list of Net-Zero Northwest terms and definitions, please see: www.nznw.org/glossary

Co-location: When referring to transmission, adding a new transmission line to pre-existing transmission infrastructure or adjacent to an existing transmission line. Co-location can help minimize land use and environmental impact.

High-temperature, low-sag (HTLS) conductors: Conductors that can withstand operating temperatures of up to 210°C, thus carrying higher power compared to conventional conductors.

High-voltage alternating current (HVAC): Alternating current is an electric current in which the direction of the flow of electrons switches back and forth at regular intervals, and is the form in which electric power is typically delivered to consumers. The voltage may be increased or decreased with a transformer, allowing the power to be transmitted through power lines more efficiently at high voltage.

High-voltage direct current (HVDC): Direct current is an electric current that flows in one direction, in contrast to the more common alternating current (see above). HVDC power systems are often used for transmission of bulk power over long distances because DC lines have lower losses and improved efficiency compared to AC lines.

Net-zero emissions: In this study, net-zero emissions means that all remaining greenhouse gases released into the atmosphere from human activity must be offset by measures to remove carbon from the atmosphere.

Reconductoring: Installing new conductor wires on existing towers to increase the capacity of existing transmission lines.

Transmission capacity: Dictates the maximum electricity flow that can occur on the line in either direction in any hour.

Transmission intertie: An intertie is a collection of transmission corridors and lines, and in this study is used to refer to the connections between states (e.g., the Montana to Washington intertie).

Transmission line: Conductors, insulators, supporting structures, and associated equipment used by electrical power systems to transfer electricity from one point to another.

Zonal transmission model: A representation of electric transmission that models electricity flows between large geographic zones. In this study, a zone can be a state, multiple states, or a portion of a state. The alternative to a zonal model is a nodal model, which represents electricity flows at a more geographically granular level.

Endnotes

1 Note that the net-zero definition in this study applies to anthropogenic emissions and negative emissions technologies. This is driven by the policy definition of net-zero in Washington. However, net-zero can also be applied to all emissions including natural sources and sinks.

2 The Nature Conservancy. "Power of Place-West: High Electrification the Best Path for Meeting Climate and Land Conservation Goals." September 13, 2022. https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/power-of-place/

3 The National Renewable Energy Laboratory. "Regional Energy Deployment System (ReEDS)." https://www.nrel.gov/analysis/reeds/

4 The Clean Energy Transition Institute. "Deep Decarbonization Pathways." https://www.cleanenergytransition.org/projects/deep-decarbonization-pathways

Source

Evolved Energy Research. *Net-Zero Northwest Energy Pathways Analysis Technical Report*, June 2023. https://www.nznw.org/files/energy-technical-report

Black transmission towers under green sky. Photo credit: Sonneveld

For more information, please see
Net-Zero Northwest Energy Pathways