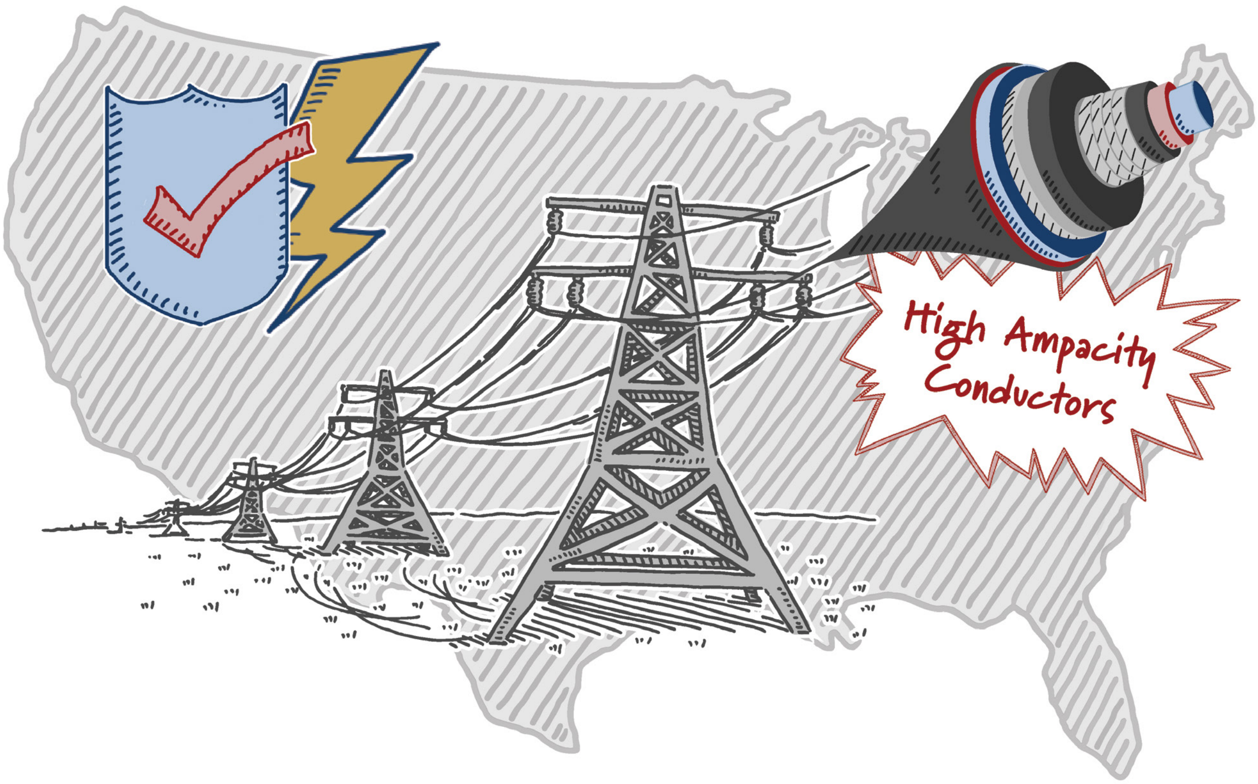

Amping Up the Grid

The Role of High Ampacity Conductors in Transmission Expansion

August 2026

Major Contributions

Authors: Casey Kelly & Will Bryant

Role: ClearPath authored this report and commissioned Evolved Energy Research to execute the modeling and analysis. All policy recommendations presented in this report reflect ClearPath's positions alone.

About ClearPath: ClearPath's mission is to accelerate American innovation to reduce global energy emissions. To advance this mission, ClearPath develops conservative, market-based policy solutions that empower the private sector to drive clean energy and manufacturing innovation while strengthening our nation's energy security, economic prosperity and global leadership.

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Role: Evolved Energy Research (EER) performed the technical modeling for the ERCOT grid, including model development, scenario design and the creation of analytical figures. EER's scope was limited to this technical assessment; the policy recommendations presented in this report were developed independently by ClearPath.

About EER: Evolved Energy Research (EER) develops and applies advanced energy-system models to help clients navigate their most consequential energy policy questions. We combine deep technical expertise with creative problem-solving to build, adapt and run models that capture the evolving interactions among energy demand, electricity generation, fuels, infrastructure, technology and public policy.

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Disclaimer

The findings, conclusions and recommendations expressed in this report are strictly those of the authors. Reviewers and discussants were not asked to concur with the judgments or opinions in this report. All errors are the authors' responsibility alone.

Executive Summary

America's electricity grid is the foundation of a modern and growing economy, yet the existing transmission system is rapidly approaching its capacity limits. The rapid rise of domestic manufacturing, the electrification of transportation and industrial sectors and the emergence of Artificial Intelligence (AI) are driving unprecedented electricity demand. At the same time, much of the electricity transmission system is more than 25 years old, and must be upgraded or replaced.[1] Expanding the grid is essential to meeting growing demand, keeping electricity affordable and ensuring America can outcompete China. Meeting future demand will require both new transmission infrastructure and innovative technologies that can expand the capacity of the existing grid.

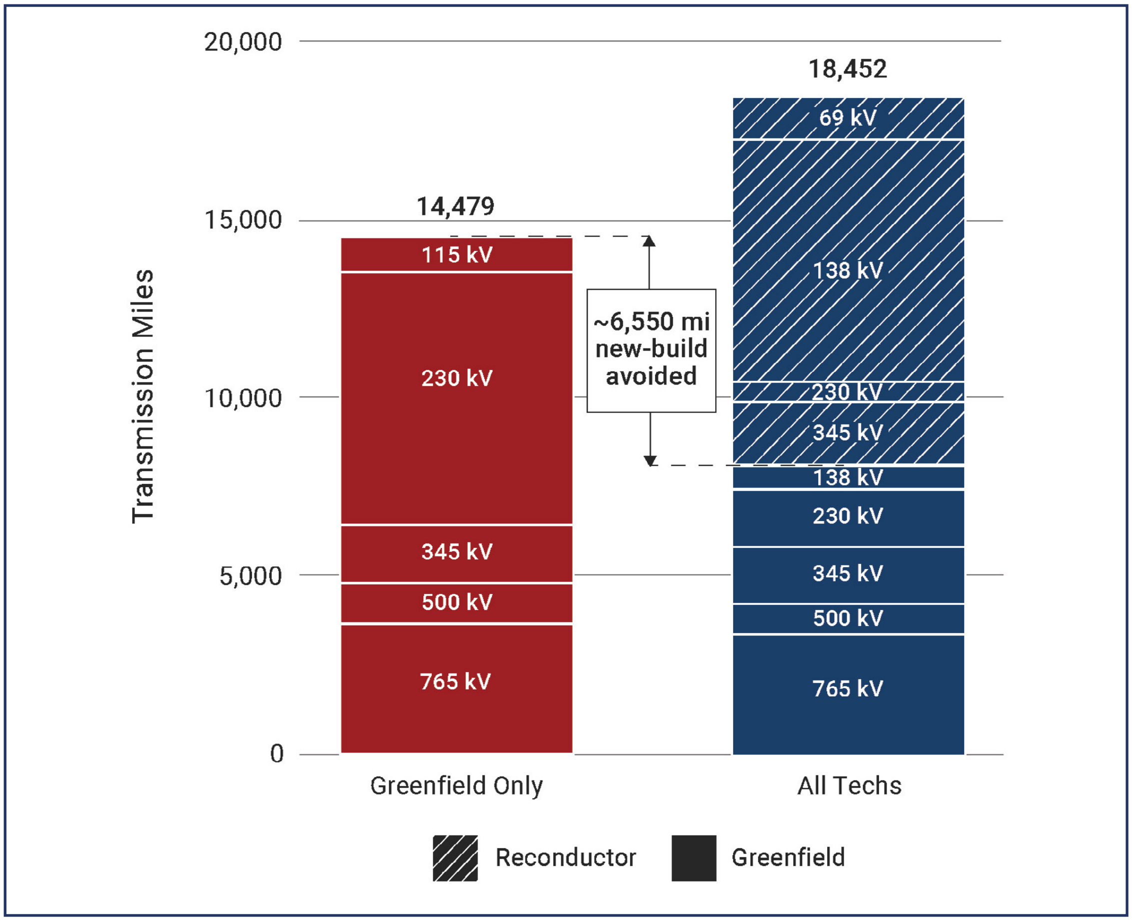
Greenfield transmission projects expand the grid by creating new paths that move electricity from new and remote generation sources to load centers. They are critical for unlocking remote resources, such as geothermal, and for enabling new power plants, including advanced nuclear reactors, to deliver power to the grid. But historically, many of these projects have taken a decade or more to complete due to barriers related to permitting, siting, cost allocation and litigation.

As a result of these challenges, increasing attention is paid towards innovative grid technologies that can unlock more capacity on existing infrastructure faster and at a lower cost than greenfield development. This suite of technologies includes conductors with higher ampacity, or current-carrying capacity, that replace existing wires to increase power transfer over existing transmission paths. However, these technologies are underutilized due to their perceived risk, misaligned investment incentives and limitations in today's transmission modeling tools.

Existing transmission software models can either plan for the long-term future of the grid or determine whether the system can operate reliably under worst-case conditions, but not both at the same time due to computational limitations. This means that existing models cannot optimize transmission expansion while also accounting for engineering and reliability constraints. As a result, long-term planning frameworks can't evaluate the cost-optimal mix of transmission expansion options – like greenfield transmission, reconductoring with high-ampacity conductors, or deployment of other innovative grid technologies – to meet growth while maintaining reliability.

To address these analytical limitations, Evolved Energy Research (EER) developed a proof-of-concept integrated transmission model that bridges the gap between capacity expansion and power flow modeling. Using the Electric Reliability Council of Texas (ERCOT) system as a test-bed, this report finds that an integrated modeling approach is both a possible and powerful means to identify the opportunity and role for high-ampacity conductors and high-voltage transmission to meet surging demand reliably and affordably.

Amping Up the Grid



Reconductoring avoids more than 6,000 miles of new greenfield transmission and 30% of transmission investment in the High Demand Growth scenario.

Key takeaways from this analysis include:

1. **Cost-optimal grid expansion requires both reconductoring and new greenfield transmission.** A reconductoring-only approach with commercially mature technologies could fail by 2030 without new greenfield transmission expansion. A greenfield-only approach is not fast enough to meet near-term demand growth and is more expensive and land-use-intensive.
2. **Composite Core Conductors are the workhorse of near-term grid expansion.** In the high data center demand case, nearly 75% of the capacity added to the grid by 2030 comes from reconductoring existing corridors. By 2040, reconductoring saves an estimated $20 billion in transmission investment and avoids 6,500 additional miles of greenfield transmission. Composite core conductors are the most cost-competitive technology deployed for reconductoring and for greenfield transmission, too.
3. **Greenfield transmission is essential to creating a network capable of supporting demand growth.** Greenfield transmission is vital for establishing new pathways, unlocking economic growth and energy resources across the state and maintaining reliability-based contingency standards.
4. **Transmission expansion of all types is an affordable technology solution that complements generation.** Transmission investment – for both reconductors and greenfield lines – is key to meeting demand growth and enabling energy addition affordably. Across all scenarios, expanding the bulk transmission system represents just 7-8% of total system investment by 2040.

Policy Recommendations:

1. **Regulatory Reform**

   - **Establish Conductor Standards with Rebuttable Presumptions:** Regulators could make high-ampacity composite conductors the default option in utility planning processes for lines facing thermal constraints while enabling utilities to make the case for alternative technologies.

2. **Support the Next Generation of Transmission Planning Tools and Practitioners**

   - **Fund Next-Generation Modeling Tools:** The Department of Energy (DOE) could provide grants, technical assistance and national laboratory model development to help grid operators and utilities develop and implement transmission planning tools that more effectively assess deployment opportunities for advanced transmission technologies.
   - **Enhance Data Access and Transparency:** Increasing access to information necessary to identify cost-effective deployment opportunities or barriers to advanced transmission technologies can facilitate cost-effective deployment.
   - **Expand Advanced Technology Evaluation to More Transmission Planning Processes:** State and Federal entities could provide additional direction for utilities and other transmission planning entities to evaluate advanced transmission technologies during all planning, generation interconnection and large-load interconnection processes.
   - **Integrate Interconnection Needs in Transmission Planning:** Improve coordination among transmission planning, load interconnection and generation interconnection to build more efficient transmission infrastructure.
   - **Leverage DOE Funding to Support Research, Development, Demonstration and Deployment:** Bipartisan federal initiatives, including the Transmission Facilitation Program (TFP)[2], Energy Dominance Financing (EDF)[3] and Speed to Power through Accelerated Reconductoring and other Key Advanced Transmission Technology Upgrades (SPARK)[4], provide crucial funding to de-risk and commercialize advanced grid technologies.

3. **Siting and Permitting Modernization**

   - **Effective Implementation of CITAP:** Ensure robust staffing and support for the Department of Energy's Coordinated Interagency Transmission Authorizations and Permits (CITAP) program to successfully reduce federal transmission permitting timelines.[5]
   - **Enact Federal Permitting Reforms:** Streamline environmental reviews under the National Environmental Policy Act (NEPA) and reform judicial review timelines to decrease litigation risks and delays for vital transmission projects.
   - **Improve Sub-National Coordination:** Encourage states, localities and Tribes to form multi-jurisdictional task forces to harmonize and streamline transmission approvals.

Table of Contents

Introduction

The American power industry is driving the revitalization of domestic manufacturing, transportation, oil and gas production, new industries like Artificial Intelligence (AI) and the digitalization of everyday life for Americans. Meeting this growing demand will require significant investment in our electricity grid, including in new and upgraded power generation, energy storage and transmission infrastructure, as well as changes to how this infrastructure is planned, permitted and built.

Over the past 20 years, most transmission investments have rebuilt aging assets or supported projects that solve for incremental growth needs at the local level, akin to repaving or building new local roads.[5] Notably, this local transmission growth has primarily used technologies invented in the 20th century. The smaller number of high-voltage transmission projects that connect multiple utility footprints and regions, akin to the interstate highway system, took a decade or more to go from planning to operation.[7] While all types of energy infrastructure face permitting and siting challenges, the scale and nature of these difficulties are outsized for overhead electric transmission lines. Interstate natural gas pipelines benefit from having a single entity – the Federal Energy Regulatory Commission (FERC) – coordinating all permits and siting approvals, and from the project ultimately being hidden from public view once complete.

Conversely, transmission lines traverse multiple jurisdictions, sometimes multiple states, which often require siting approvals and environmental assessments from local, state and federal entities. Transmission is typically overhead due to the prohibitive cost of underground lines, making them highly visible and drawing greater local opposition. When transmission lines trigger federal permitting and siting requirements, these permits take 4.3 years on average and have taken as long as 11 years.[8] Notably, according to the North American Electric Reliability Corporation (NERC) 2025 Long-term Reliability Assessment, 43% of all transmission lines planned or under construction for the next 10 years have been delayed from their original in-service date.[9] While the drivers for these delays vary by project and may include additional challenges such as supply chains and workforce, permit, siting, and litigation processes factor prominently.

As a result, many parts of the country lack sufficient transmission capacity, or “headroom,” to connect new demand and energy to the grid. New generation and load facilities across the country have been told that they must wait for new, high-voltage transmission lines to come online before they can receive full grid access. These wait times extend into the early 2030s, under the optimistic assumption that delays from supply chain backlogs, workforce shortages, siting and permitting approvals, or lawsuits will not affect the timing of these projects.[10]

Electric transmission, therefore, represents one of the biggest limitations on America’s economic growth, technological leadership and electric reliability and affordability. Improvements to the siting, permitting and litigation of electric transmission can accelerate grid expansion. Greater deployment and use of innovative technologies and the full range of available transmission solutions can also increase the capacity and capabilities of the existing system and new-build lines, bringing more energy and demand online faster. These solutions include upgrading existing lines with conductors that carry more capacity; uprating the voltage level at which transmission lines are operated; deploying high-voltage direct current systems; and leveraging grid-enhancing technologies, such as dynamic line ratings or topology optimization, to improve the performance of existing infrastructure.[11] For this analysis, we focused on the opportunity and role for innovative conductors that have higher ampacity, i.e., carry more current, to grow the grid at the pace and scale needed for meeting demand growth affordably.

Conductors are the power lines strung across tall steel towers that carry electrons. The rate of electrons flowing is current, measured in amperes; the energy carried by each electron is voltage, measured in volts; and the product of current and voltage is power or the rate of energy delivery, measured in watts. Innovations in materials and design have created new classes of conductors – Composite Core Conductors (CCC) and High-Temperature Superconductors (HTS) – that are higher in ampacity than conventional conductor technologies.

This analysis is designed to answer four core research questions using a proof-of-concept transmission planning model developed by Evolved Energy Research:

1. What is the cost-optimal mix of transmission expansion pathways and technology types to meet demand growth?
2. Under what circumstances is reconductoring an effective and economical way to expand grid capacity to accommodate large load growth and new generation?
3. To what extent can high-ampacity conductors reduce the need for new greenfield transmission, and how do these outcomes vary as conductor ampacity increases?
4. How does high-ampacity conductor deployment reduce land use and land-use conflicts?

Policy and Regulatory Background

The research questions at the core of this paper are questions being asked across the country in the rooms of utilities, grid planners, regulatory commissions and policymakers. Several states have passed legislation that requires utilities to evaluate advanced transmission technologies, including high-ampacity conductors, which is mirrored at the federal level through FERC Order 2023, Order 1920 and the Large Load Interconnection show-cause orders to all 6 Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs).[12] In a July 22 hearing before the Senate Committee on Energy and Natural Resources, FERC Chairman Laura Swett said, "This will save our consumers a lot of money… [RTOs] are now … forced to consider advanced transmission technologies in their study processes…"[13] The recent surge in policymaking and interest in innovative grid technologies, such as high-ampacity conductors, is arguably not driven by the emergence of new technologies, but by a growing recognition that many of these available innovative technologies remain significantly underutilized.

For most businesses operating in a competitive environment, the unprecedented surge in demand for their product or access to their system would lead the business to deploy technologies that enable them to meet that demand at a lower cost and out-compete other businesses, without government prodding. However, for electric utilities, business models and incentives are shaped by regulations rather than competitive market forces. These incentive structures, coupled with the incredibly steep mandate of 24/7/365 grid reliability, lead utilities to adopt risk-averse postures and follow incentives that can prevent the very types of tools needed to meet fast-growing demand at low cost. These forces also shape the organizational structure of transmission planning teams and the tools they use. Innovations in transmission technologies are primarily created outside of utilities and grid operators, leading to gaps between the capabilities of new technologies and industry's ability to model and evaluate their potential. Following FERC's Software Technical Conference in July 2026, Commissioner Rosner wrote an open letter acknowledging the gap in existing grid planning tool kits to evaluate new transmission technologies and calling on experts to share new modeling capabilities and tools that can fill this gap.[14] The urgency of demand growth, therefore, requires an evaluation of whether the current paradigms best position the industry to meet this growth.

Misaligned Economic Incentives and Risk Aversion

Investor-owned utilities are regulated entities whose profits are based on their approved capital investments, known as the rate base, and an approved rate of return, which is a regulator-set percentage. Raising a utility's rate base or rate of return increases profits. From the perspective of a business incentivized to maximize capital expenditures, high-ampacity conductors are less attractive than building greenfield transmission lines or rebuilding existing infrastructure to the exact same specification. This is due to the superior performance of high-ampacity conductors, which reduces costs over the lifetime of the line and mitigates the need for future upgrades, that the utility would be able to rate-base, by providing increased headroom. Additionally, new technologies may face regulatory scrutiny due to concerns that they may not perform as expected. As a result, conventional transmission technologies receive a double benefit because they are more profitable for utilities and more familiar to regulators.

For state and federal regulators, their roles require them to ensure utilities make the right investments to provide safe, reliable service while keeping rates "just and reasonable." Innovative transmission technologies, such as high-ampacity conductors, currently have higher upfront capital costs than conventional, steel-based conductors but offer lower lifetime costs due to their greater carrying capability and ability to reduce the need for future grid upgrades. Despite the better long-term value proposition, the use of a higher-cost technology, particularly one unfamiliar to a regulator, may lead to a more demanding approval process out of concern that the technology may not perform as expected or is simply not the least-cost solution from an upfront-cost perspective. For electric cooperatives and public power utilities, their not-for-profit business models make their deployment barriers more like those of the regulator than those of an investor-owned utility.

Technology deployment also faces challenges when regulators cannot effectively determine whether technologies were adequately evaluated or lack the authority to review projects, particularly given the multiple benefits that new technologies offer. How technology is evaluated, and the particular circumstances of a utility's system, are difficult for regulators to assess. They often lack deep engineering expertise or access to the data necessary to thoroughly review, or to have a third party replicate, the utility's analysis. Additionally, many utilities can perform in-kind infrastructure replacements, meaning they rebuild or replace equipment using the same products and specifications and include the cost of these projects in their rate base without needing regulatory approval. As a result, regulators interested in ensuring that all relevant technology solutions are evaluated may lack the resources to ensure that utilities use appropriate tools and achieve the best outcome for consumers, or may not have the authority to review utility investments at all.

Transmission Planning Silos

The development and advancement of analytical capabilities to evaluate conductors at different ampacity levels, as well as other grid-enhancing technologies, are essential and are facing greater regulatory pressure. These requirements for evaluation, as well as for making the results public and clearly communicating them, are a critical first step. Implementing these new directives successfully requires both new modeling tools and planning approaches.

Transmission planning has typically omitted considerations of specific conductor types until after projects have been selected. This approach, reflected in the current sequential and unidirectional transmission study process, prevents innovative technologies like composite core conductors from being properly evaluated for reconductoring and greenfield opportunities that may lower the overall cost of transmission expansion and yield savings from efficiency gains over the project's lifespan. Leveraging an analytical approach, akin to the model developed for this analysis, that combines multiple modeling approaches enables evaluation of conductors at various ampacity levels and a more appropriate evaluation of transmission solutions, ultimately selecting the most cost-effective option.

As modeling capabilities are siloed across different tools, transmission data and planning steps are typically siloed as well.[15] Within one utility, transmission planning is solely focused on transmission within that utility's footprint. Different teams may evaluate different transmission needs, such as asset replacement, interconnection and longer-term planning, on the utilities system using different modeling tools and with access to different types of data. Within regional planning frameworks, conducted by RTOs/ISOs in many parts of the country, utilities submit information to the regional planning entity, which can limit visibility into key information, such as the health of existing transmission structures and local transmission needs. Order 1920 addresses some of these data-siloing challenges by requiring utilities to publicly disclose and seek public feedback on their processes for identifying and addressing local transmission needs. Further, utilities must disclose lines slated for in-kind replacement so they may be assessed for "right-sizing" or upgrading the line's equipment, such as by using a higher-ampacity conductor, as a regionally significant line. By closing these data gaps, particularly in the context of regional planning, opportunities to reconductor lines with higher-ampacity conductors or deploy alternative advanced transmission technologies can be evaluated and selected as cost-effective means of growing the grid and enhancing reliability.

This analysis seeks to demonstrate the opportunity to plan transmission expansion using advanced analytical tools to build out the system more efficiently and affordably, and to provide policy recommendations that better align regulatory structures and incentives with the transmission technologies that offer the most affordable path to growth.

Methodology

Model Design

Evolved Energy Research developed a proof-of-concept transmission model that combines the capabilities of two distinct modeling approaches. The first is capacity expansion modeling, an analytical approach used to assess long-range grid planning. Because these models are used to capture larger spatial and temporal horizons, the representation of the transmission system is at a highly aggregated level. While they are appropriate for identifying the cost-optimal mix of energy resources and transmission capacity growth needs, they currently do not evaluate the specific technologies or infrastructure that can cost-optimally achieve this transmission growth. The second modeling approach is power flow modeling, which is typically used for system reliability assessments. This approach examines snapshots in time of the transmission system to identify reliability issues and other system behaviors under worst-case scenarios or specific operational conditions. The level of detail to characterize the transmission system in power flow modeling makes expanding the study scope to the spatial and temporal scale of capacity-expansion models computationally intractable.

By iterating between long-term planning and system reliability assessments, transmission growth and reliability needs can be assessed on a project-by-project basis to determine which growth pathway – reconductoring or new build – and conductor technology are cost-optimal.

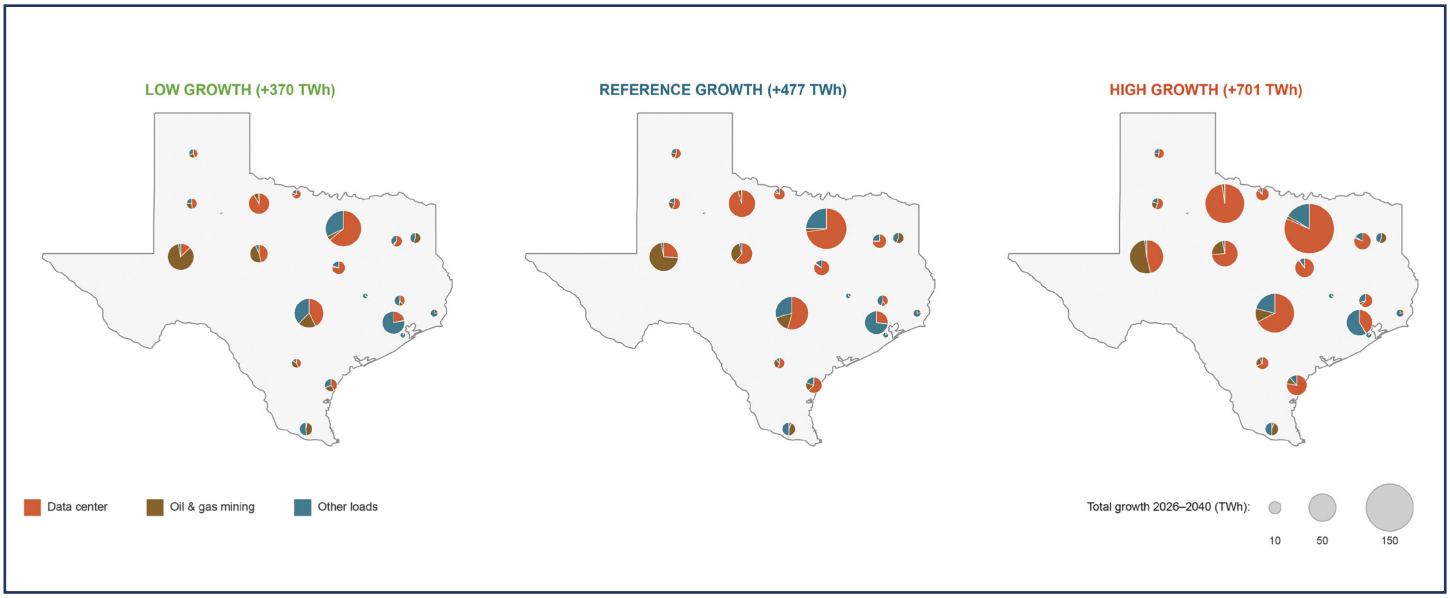
The Electric Reliability Council of Texas (ERCOT) was selected as the proof-of-concept study region because it provides an ideal environment for testing an integrated transmission planning framework. ERCOT is Texas's main grid operator, serving 90% of its electricity load. ERCOT load is set to grow significantly across the state over the

coming decades.[16] That growth creates a strong need for both new transmission infrastructure and upgrades to the existing grid, allowing the model to evaluate the tradeoffs among greenfield transmission and reconductoring with conductors of varying ampacity levels. This system also has limited electrical connections with neighboring systems, making it simpler to model than a grid with many affected neighboring systems.

Although ERCOT's regulatory and market structure differs from other regions of the country, the underlying transmission physics and technology applications are broadly applicable. For example, the challenges of siting new transmission in densely developed areas or communities facing siting opposition are not unique to Texas. Likewise, the barriers to greater deployment of advanced transmission technologies, including carbon composite conductors and high-temperature superconductors, are common across multiple regulatory jurisdictions. The model design and data are not capable of planning transmission for the ERCOT system and should be understood as a distinct and separate analytical endeavor to demonstrate the benefits of using new modeling tools to evaluate innovative transmission technologies.

Notably, this model does not constrain the rate of transmission capacity growth either through reconductoring or greenfield. The resulting level and pace of transmission growth, therefore, do not reflect what may be possible given existing timelines for planning, permitting, siting, equipment and workforce acquisition and construction.

Figure 1. Drivers and scale of load growth in ERCOT through 2040.



More information on model development can be found in the technical appendix.

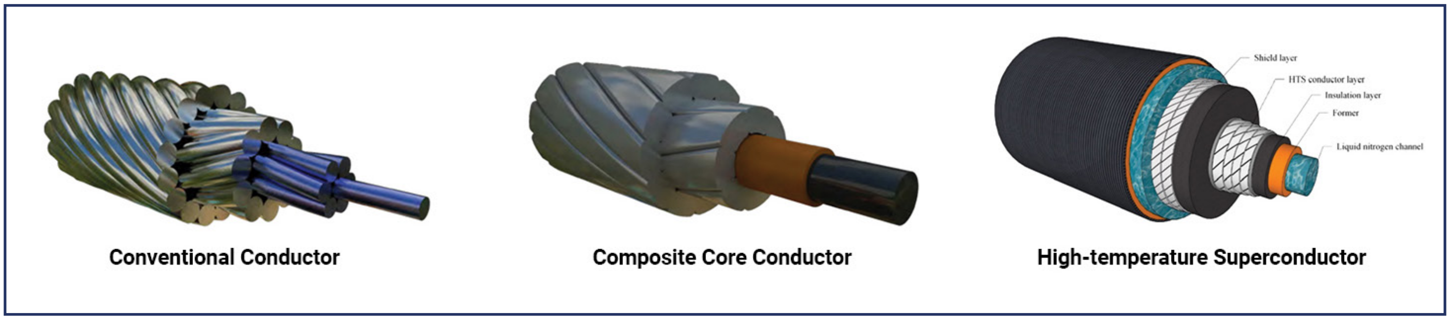
Conductor Technologies

Conventional conductors consist of a steel core that provides strength and stability, with aluminum stranding serving as the conductive material through which electrons flow. Types of conventional conductors include Aluminum Conductor Steel Reinforced (ACSR), the oldest and most widely deployed conductor and Aluminum Conductor Steel Supported (ACSS). ACSS was first introduced to the U.S. market in 1970 and achieves higher maximum operating temperatures and ampacity than ACSR due to the use of annealed steel to coat the core of the conductor, and different stranding shapes used in some ACSS designs.[17] Investments in American innovation have led to the discovery of novel conductor materials and designs to improve their performance, achieving greater reliability, resilience, electrical efficiency and carrying capacity. For example, new composite core conductors replace steel cores with composite cores made of materials such as carbon or ceramic fibers, which are lighter than steel and expand less as they heat up. As a result, more aluminum stranding can be added and arranged in innovative shapes to increase the useful current-carrying cross-sectional area, without necessarily changing the size of the conductor. Because the composite core expands less, it does not sag as much as steel core conductors, even as more current flows through the line. This means composite core conductors can be safely operated at a higher temperature without violating clearance requirements and reducing the risk of fire ignition from contact with vegetation. By reconductoring or replacing a conventional conductor with a composite-core conductor, the amount of energy transferred over the same right-of-way can double.[18]

Another emerging class of conductor technology is high-temperature superconductors (HTS). HTS technology differs from conventional and composite conductor technology because it requires cooling and may be deployed in both overhead and underground environments. Superconducting materials in the form of tape are surrounded by insulation, shielding and cooling materials such as liquid nitrogen.[19] The high temperatures reached by superconducting materials enable this conductor to carry seven times as much electrical current as conventional transmission conductors, with zero electrical resistance or thermal expansion because they are cooled to near -200°C. Conventional superconductors operate near absolute zero, making this technology "high-temperature" by comparison. While this class of technology is best suited for underground direct-current power transmission, some companies have demonstrated the ability to use it above ground for alternating current, which is what most of the grid uses. This technology can address the need to move large volumes of electricity in space- or siting-constrained environments because HTS achieves higher energy density and has no heat to dissipate or sagging to account for.[20] It is especially compatible with direct-current transmission, which is not constrained by electromagnetic induction, and it requires only one cable per circuit compared to three for conventional technologies. Using HTS technology for an overhead, alternating current line is still constrained by magnetic fields. This emerging technology is included in the study alongside composite conductors and conventional conductors to evaluate the full range of ampacity levels for cost-effectiveness, and to better understand the conditions that make each technology best suited for advancing grid growth.

The benefits of composite conductors and HTS most relevant to this report are their speed-to-power capabilities and cost savings. Because existing transmission tower structures can often be used or replaced within the existing right-of-way, reconductoring avoids the multi-year process of greenfield transmission development by eliminating the need for siting approval, permitting and construction, as well as the concomitant delays and legal challenges. Furthermore, siting constraints on greenfield transmission development may increase the value of

Figure 2. Representative cross-sections of conductors. Sources: INL, Fan et al. (2024).



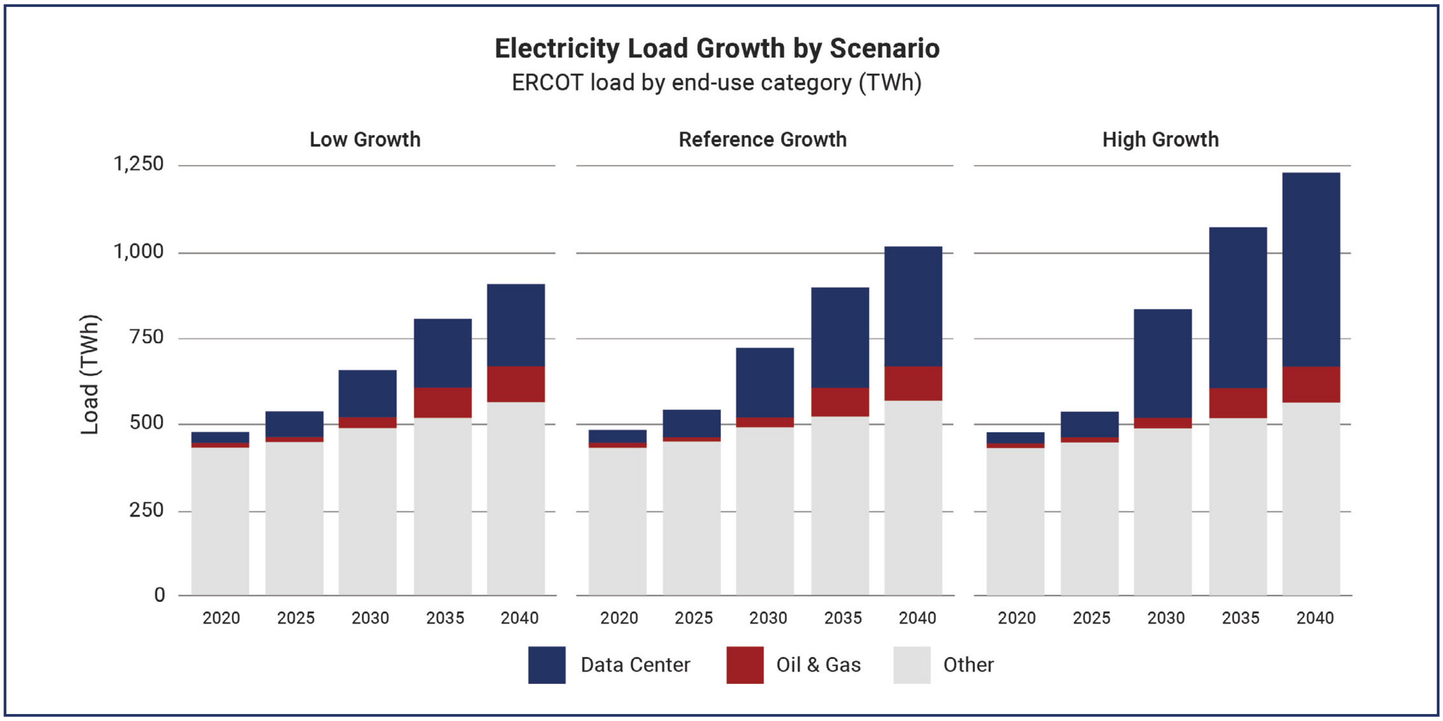
technologies with higher ampacities that can be deployed within the existing footprint. As a result, composite and HTS conductors can be deployed in under three years onto existing infrastructure to increase transfer capacity by two to seven times.[21] The avoided costs of building entirely new transmission lines, including the hard costs of the materials, soft costs from labor, savings accrued from reducing any congestion on the line earlier in time and avoiding additional upgrades in the future, can significantly reduce the lifetime cost to consumers for grid growth. Composite and HTS conductors will enable new generation and large loads to connect to the grid at least cost and on short timelines, driving energy addition and growth.

Scenario Design

Demand Growth Sensitivities

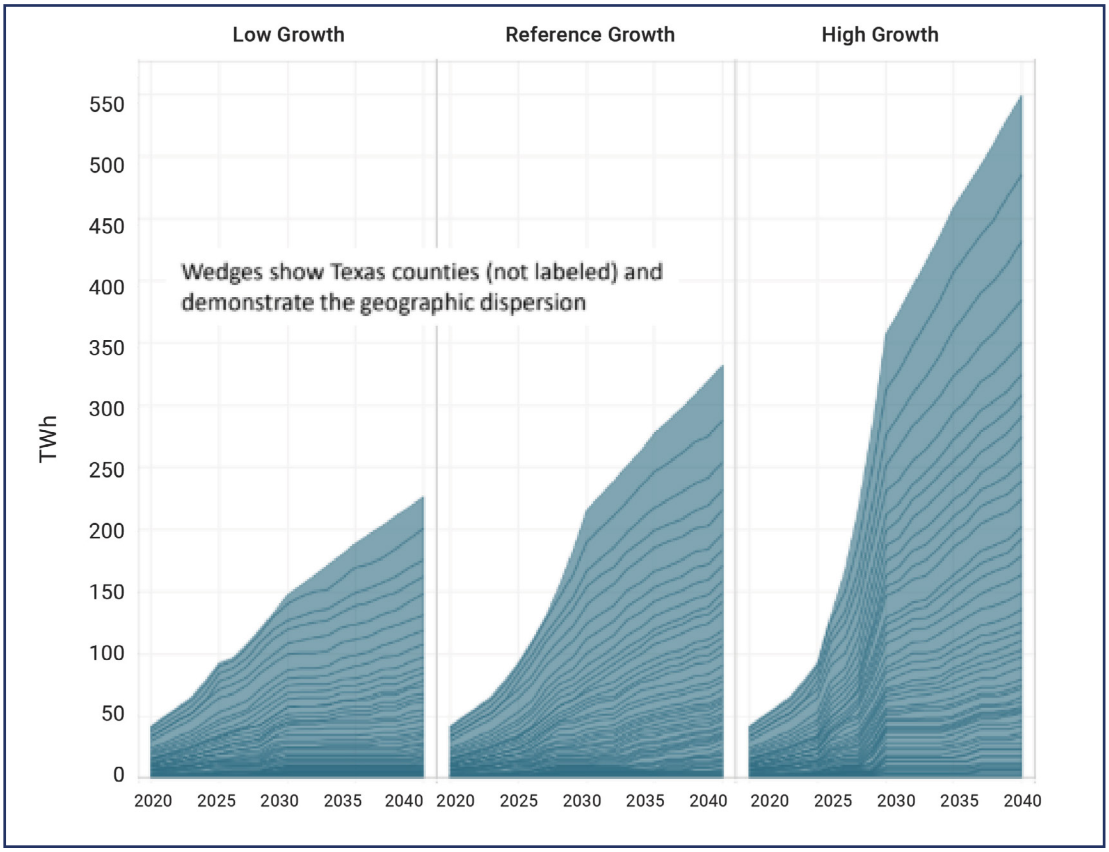
Demand growth in this analysis captures forecasted growth in electricity consumption from data centers, electrification of oil and gas production in the Permian Basin and population growth in the ERCOT footprint. Permian basin demand growth figures reflect the Reliability Plan for the Permian Basin Region, which forecasted oil and gas electricity demand of 32.83 TWh in 2030, up 137% from 13.85 TWh in 2025.[22] Increases in electricity demand associated with population growth were sourced from Evolved Energy Research. Both Permian Basin oil and gas production and population demand growth forecasts are held constant across the three data center demand growth scenarios.

Figure 3. Data centers and oil-and-gas electrification drive ERCOT load growth through 2040.



Data center demand growth estimates are highly uncertain. This study examines three data center growth ranges – Low, Reference and High – to evaluate and demonstrate how these assumptions affect model results. The estimates were developed by EER based on external industry forecasts. To determine the share of national demand occurring within Texas counties, data was downscaled using the Speed to Power map from the National Laboratory of the Rockies.[23] Low and High Growth scenarios reflect the outer bounds of estimates in the existing literature.

Figure 4. Data Center demand growth in Texas varies by county, with roughly 20 counties accounting for the majority of data-center-driven load growth.



Transmission Technology Scenarios

Four types of conductor technologies are presented in this analysis as available solutions for transmission upgrades. The first two are ACSR and ACSS: conventional, widely deployed technologies. ACSS technology offers the lowest-cost alternative to ACSR among the conductors in this analysis. The third type of conductor is the composite core conductor (CCC), reflecting the many types of CCC conductors produced by different companies. CCC offers greater ampacity than both ACSR and ACSS but carries a higher upfront cost. HTS technology is emerging, with commercial availability expected to begin in 2030 for this analysis. It offers the greatest opportunity to increase ampacity compared to ACSRs, but at a premium price. Reconductoring overhead transmission lines is the only expansion option for HTS due to the limited information available for greenfield deployment. For all technologies, the model assumes that a reconductor project costs 50% of the greenfield equivalent. This estimate is conservative, meaning that project costs may be much lower than 50% of the cost. This approach is intended to capture a variety of upgrades to tower and substation equipment that would likely accompany a reconductor but are hard to predict.

Table 1. The menu of technologies available to the model for both greenfield and reconductor projects.

Conductor	Ampacity (x ACSR)	Greenfield $/mi @ 345 kV	Reconductor $/mi @ 345 kV	Available
ACSR	1.0x	$4.0M	— (legacy)	2025
ACSS	1.6x	$4.3M	$2.2M	2025
ACCC	2.0x	$4.6M	$2.3M	2026
HTS	7.0x	—	$19.8M	2030

This study assesses the interplay among transmission expansion options, technology availability and data center demand growth rates to determine what constitutes optimal transmission expansion out to 2040. Three transmission expansion options – greenfield, reconductoring, or both – and two conductor technology options – all technologies or no HTS technology – are explored, with only the all-expansion option and no HTS technology studied under a single demand growth sensitivity. A final scenario in which the 765 kV transmission backbone that is planned and under development in ERCOT as part of the state's Strategic Transmission Expansion Plan is not included.

Table 2. The scenario matrix modeled in this analysis.

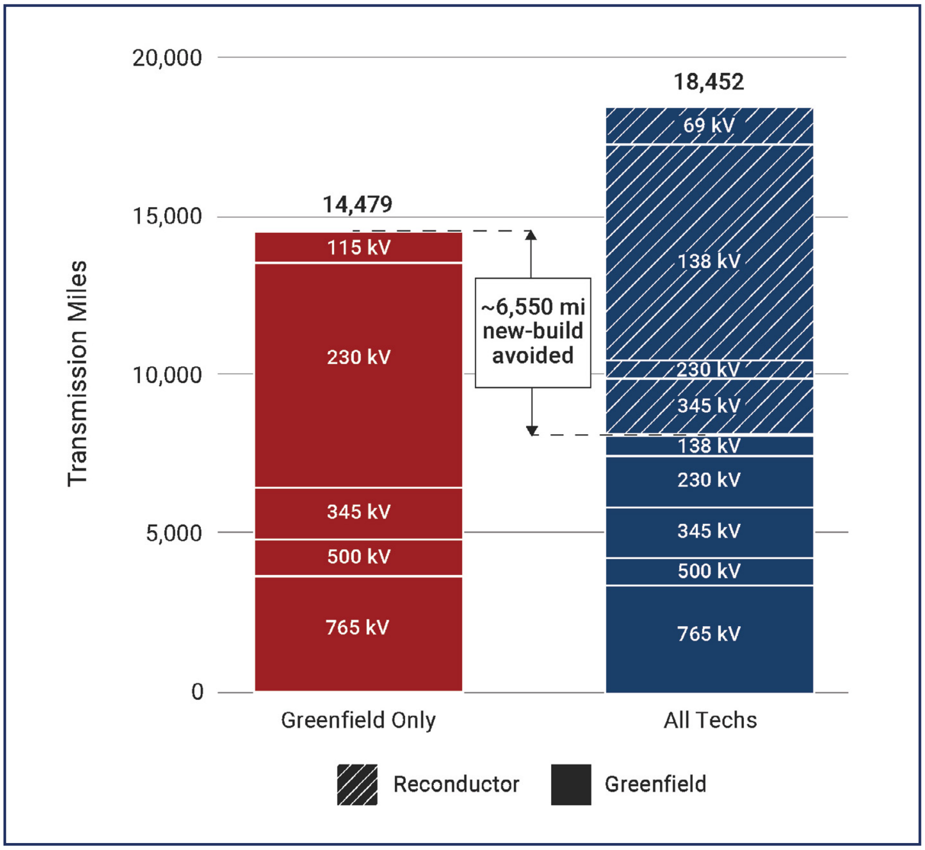
Expansion Options		All Expansion Options	Greenfield Expansion Only	Reconductor Expansion Only	Reconductor Expansion Only	All Expansion Options	No 765kV Backbone
Conductor Technology Options		All Technology Options	All Technology Options	All Technology Options	No HTS Technology	No HTS Technology	
Data Center Demand Growth Sensitivities	Low						
	Ref						
	High						

Key Takeaways

#1. Cost-optimal grid expansion that meets demand growth requires both reconductoring and building greenfield transmission

Growing the ERCOT grid at the scale and pace needed to maintain reliability without inhibiting economic growth requires reconductoring and greenfield transmission development. When all conductor technologies and grid expansion approaches are available, a mix of reconductoring and greenfield transmission is identified as the cost-optimal approach. With high demand growth and under the Greenfield-only approach to transmission expansion, an additional 6,500 miles of greenfield transmission, representing 118 square miles of new transmission rights-of-way, are developed; see Figure 5.

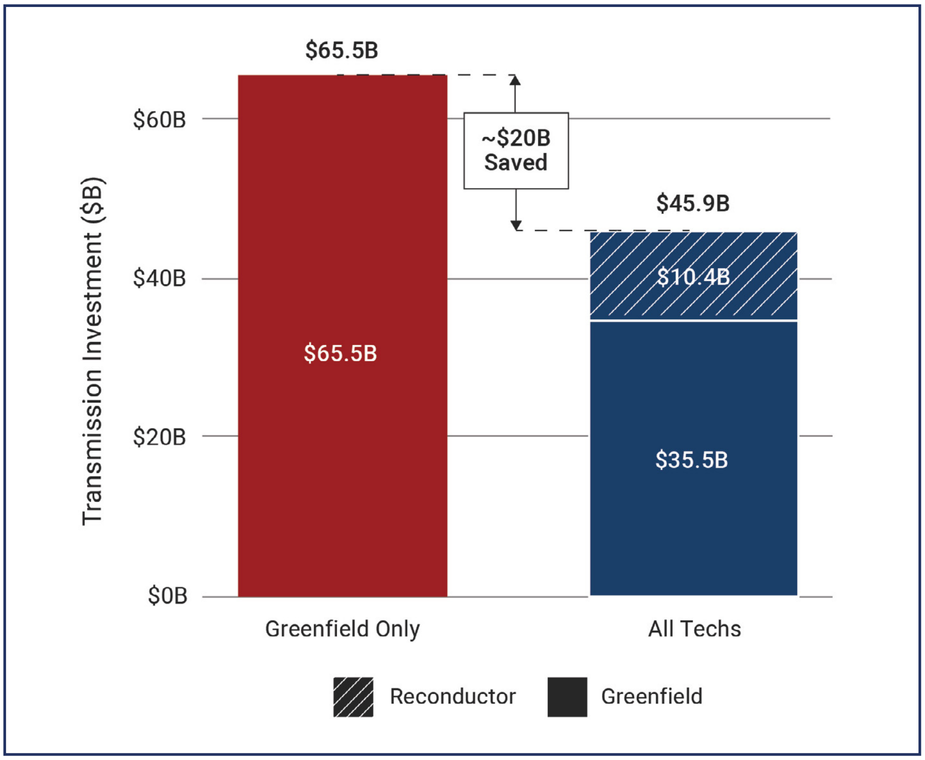
Figure 5. Reconductoring avoids more than 6,000 miles of new greenfield transmission in the High Growth scenario.



By enabling reconductoring with all types of ampacity conductors, a significant number of greenfield lines at mid-level high voltages, primarily 230 kV, are replaced by reconductoring lower-level high-voltage lines, primarily 138 kV in the ERCOT system. This pattern persisted across all scenarios, reflecting the cost-effectiveness of increasing the current of existing lines to increase power transfer capability versus building slightly higher voltage lines. As the voltage increases to 345 kV or higher, line limitations are typically no longer thermal, making reconductoring less viable. Overall, under the High Growth, All Technologies scenario, roughly 8,000 miles of greenfield transmission are built and 10,000 miles of ERCOT's existing 55,000-mile system are reconductored.

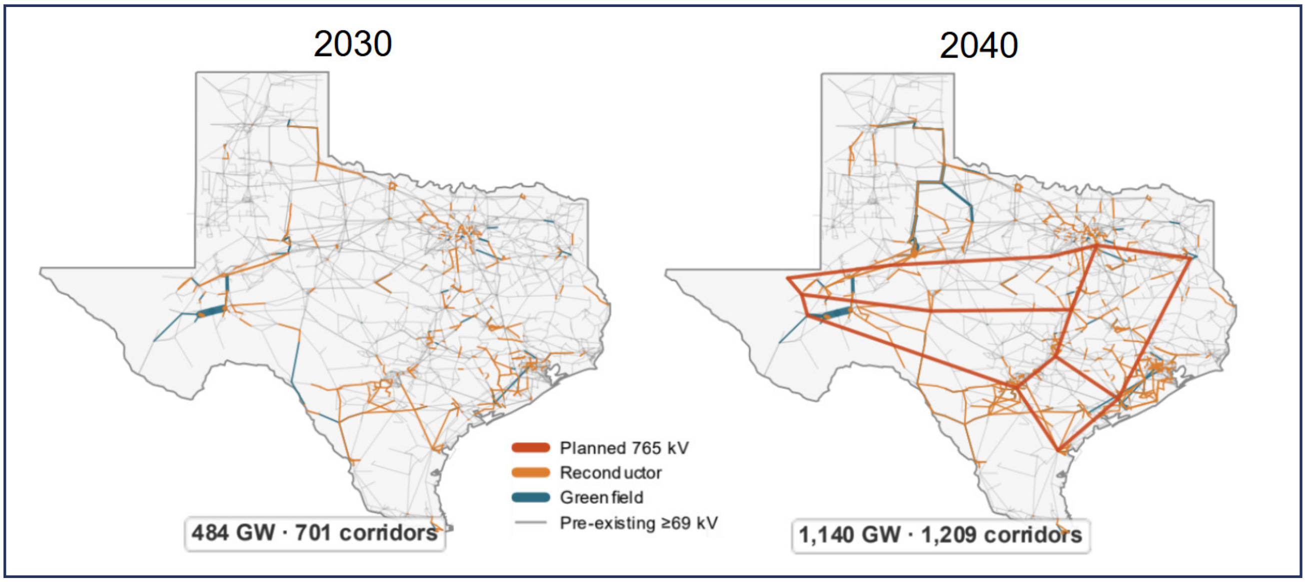
Reconductoring also reduces total transmission investment by $20 billion by 2040, a 30% reduction, compared to a Greenfield-only approach to expansion. Across scenarios, the majority of transmission investment was in reconductoring to address within-zone reliability constraints. These constraints include thermal limitations on existing lines, which composite core conductors were the most competitively positioned to relieve within zones on the system.

Figure 6. Reconductoring saves $20 billion of greenfield transmission investment in the High Demand Growth case.



Demand growth also drove reliability constraints in the zone transfer capability. As a result, every scenario saw overall transfer capacity increase system-wide to maintain reliability at the lowest cost. Some transmission paths saw minimal increases in transfer capacity, while a few experienced decreases in transfer capacity needs as new generation and load emerged, changing power transfer distributions across the network. This underscores the evolving role and use of specific transmission paths over time, as economic development and shifting generation economics lead to shifting power flows.

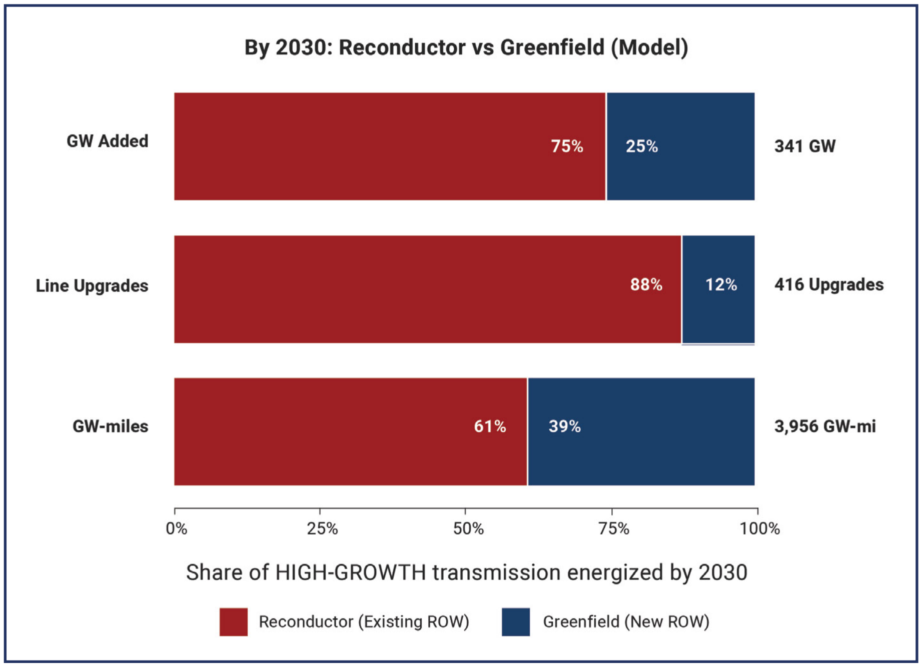
Figure 7. Transmission expansion included new greenfield transmission as well as reconductoring to increase the ampacity of existing lines. These maps show the High Growth All Techs case in 2030 and 2040.



#2. Composite Core Conductors are the workhorse of near-term grid expansion

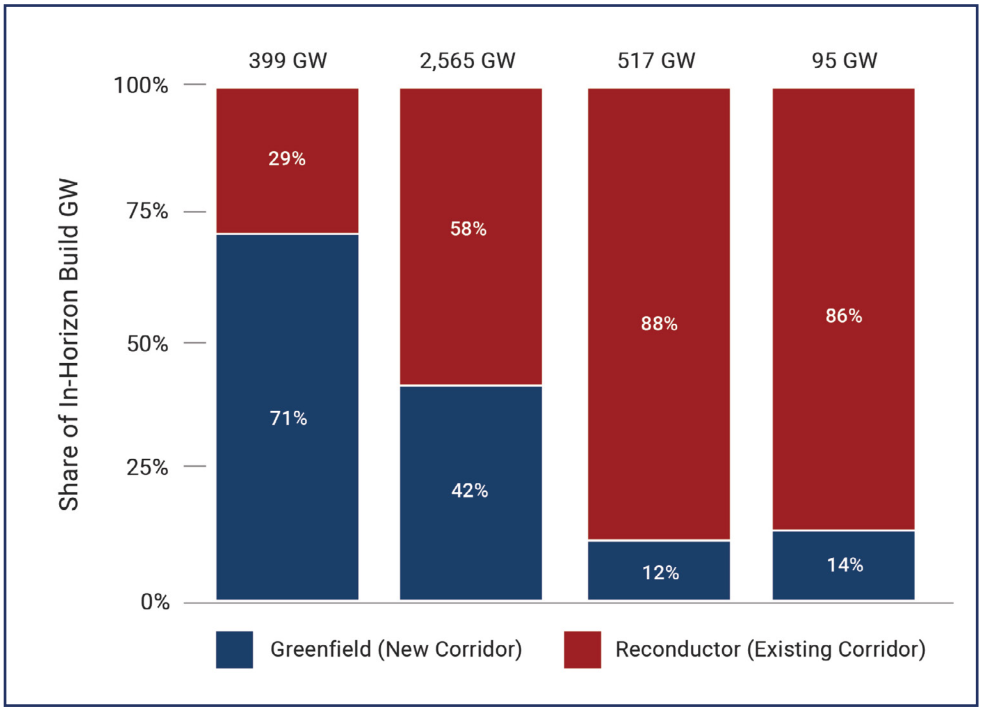
This analysis finds that under High Demand growth and with All Technologies available, 75% of the capacity added to the grid by 2030 is from reconductoring. Reconductoring cost-effectively solves thermal constraints that arise when more power must flow through existing transmission lines to meet growing load and enable new generation to meet demand. Up to 2030, reliability constraints can primarily be addressed through reconductoring, though not exclusively.

Figure 8. The share of GW additions, line upgrades and GW-miles that reconductoring and greenfield transmission contribute in the High Demand Growth scenario.



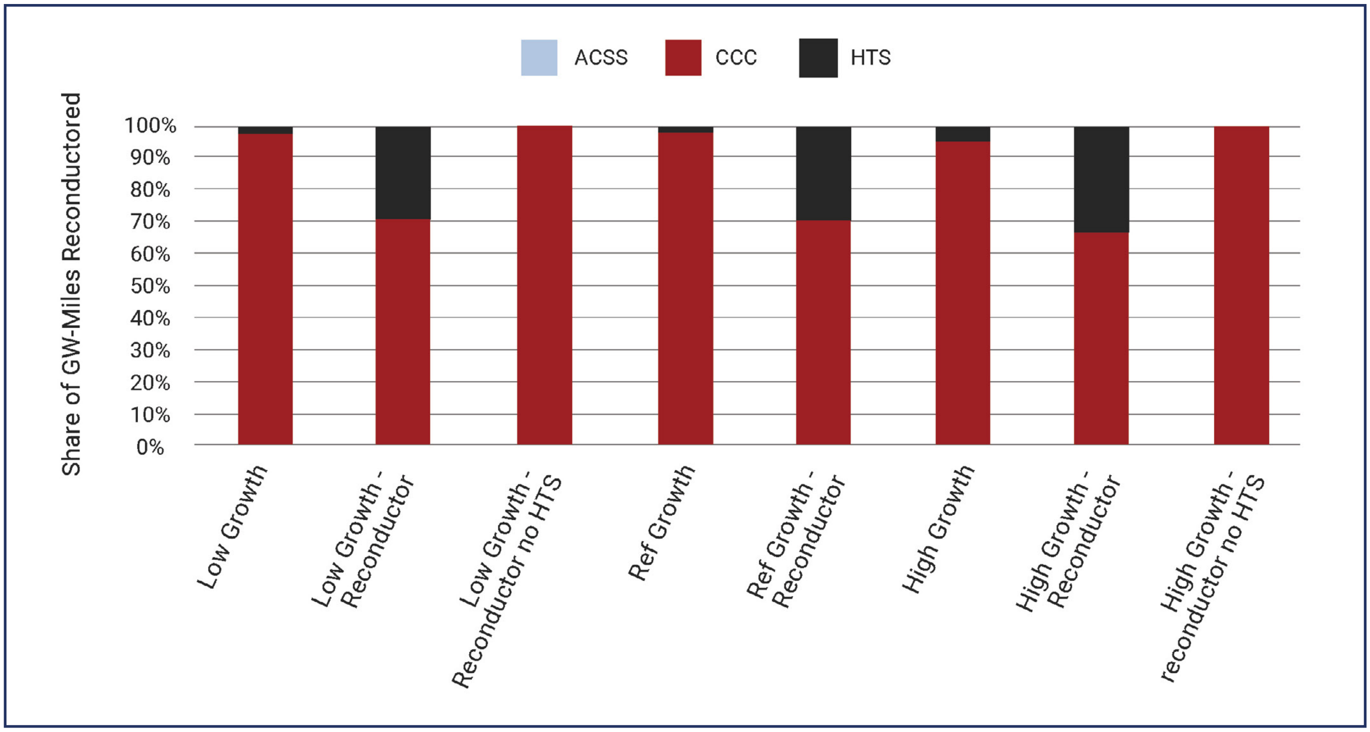
This analysis found that meshed transmission networks that have redundant paths for moving energy around the system are a key predictor of reconductoring. As the number of redundant paths increases from zero to two, the share of reconductoring as the cost-effective solution for the system constraint increases nearly threefold. Pre-redundancy on lower levels of high-voltage transmission, therefore, presents as very promising candidates for reconductoring in any system that mirrors these attributes.

Figure 9. Pre-existing parallel paths are a predictor of whether reconductoring or a greenfield expansion approach is the most cost-effective way to expand the system while maintaining reliability.



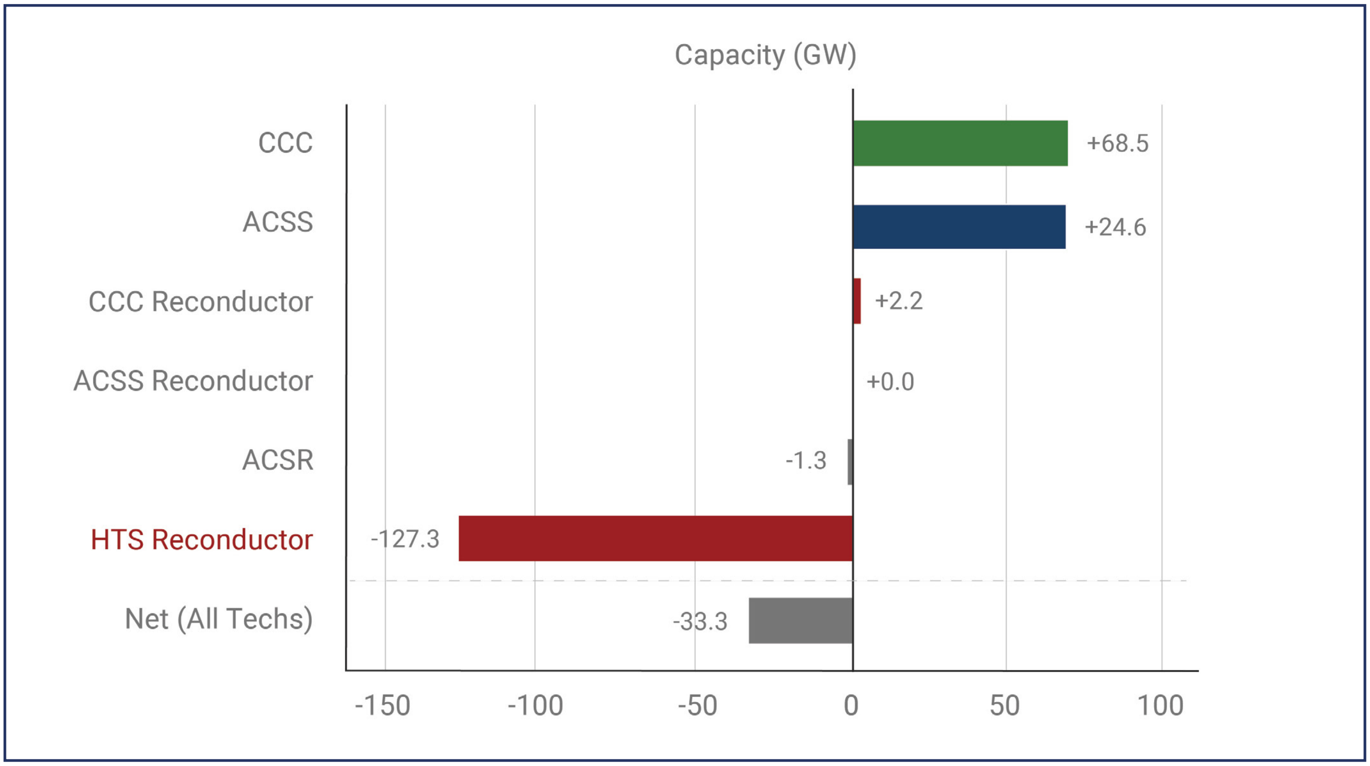
Across all scenarios, CCC are deployed most, reflecting their performance advantage over ACSS, despite a slightly higher upfront cost and CCC's cost advantage relative to HTS. ACSS conductors are not deployed for reconductoring in any scenario, whereas HTS conductors are deployed for very short lines that face significant thermal violations, making the higher cost for significantly greater ampacity and zero line losses the most cost-effective option.

Figure 10. Composite core reconductors provide the majority of GW-Miles for reconductoring.



HTS technology is not fully commercialized and has experienced limited deployments in operational environments on the bulk power system. In the Reconductoring Only, No HTS Scenarios, grid reliability fails in the absence of HTS conductors and the ability to construct greenfield transmission. Under the High Demand Growth and All Expansion Pathways and Technologies Except HTS scenario, the 127 GW of HTS removed was replaced with mostly greenfield transmission using predominantly CCC, followed by ACSS technology. While the cost difference between the two scenarios was minimal, many parts of the country, including major cities in the Northeast, may face even higher costs for greenfield transmission if HTS is unavailable. The niche role HTS can play in very space-constrained environments facing significant power transfer needs demonstrates the value in continued research, development and demonstration support for this class of technologies.

Figure 11. When HTS technology is not available, system expansion is primarily achieved through greenfield transmission using composite-core conductors.

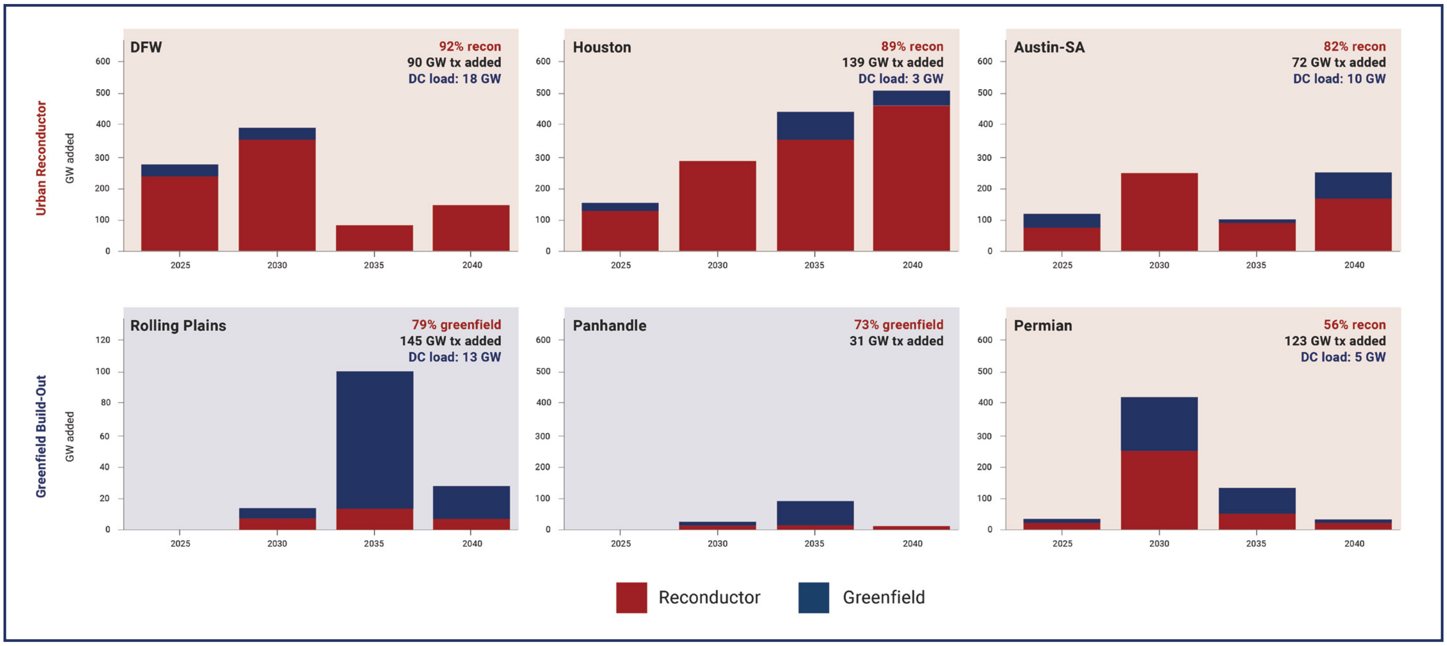


#3. Greenfield transmission is essential to creating a network capable of supporting demand growth

Without greenfield transmission development, no scenario can maintain reliable operations while the system faces large load growth. Greenfield transmission is essential for unlocking energy resources and enabling economic growth in areas with inadequate or no access to the transmission grid. Parts of Texas with limited existing transmission infrastructure see greater development of greenfield transmission to establish foundational paths for power and to address reliability constraints associated with the network's structure. Expanding the transmission topology and making more parts of the system into networked infrastructure are essential to reliably integrate the volume of new demand and energy seeking to connect in the near-term and position the system to more readily meet long-term growth.

While dense urban areas have seen transmission capacity growth met primarily through reconductoring, greenfield lines remain essential for growing the grid reliably and at the least cost. This is because greenfield lines uniquely address N-1 contingency risks. The transmission network must be able to sustain any one line going offline and that power to flow to other parts of the system without triggering cascading reliability challenges. Greenfield transmission, particularly redundant paths, enables lines to be reconductored and their greater ampacity to be fully utilized without risking cascading reliability challenges if a line goes offline.

Figure 12. Dense urban areas address capacity constraints through reconductoring; sparse rural zones require new greenfield builds at higher voltages; and the highest-growth zones—like the Permian Basin—demand a strategic mix of both.

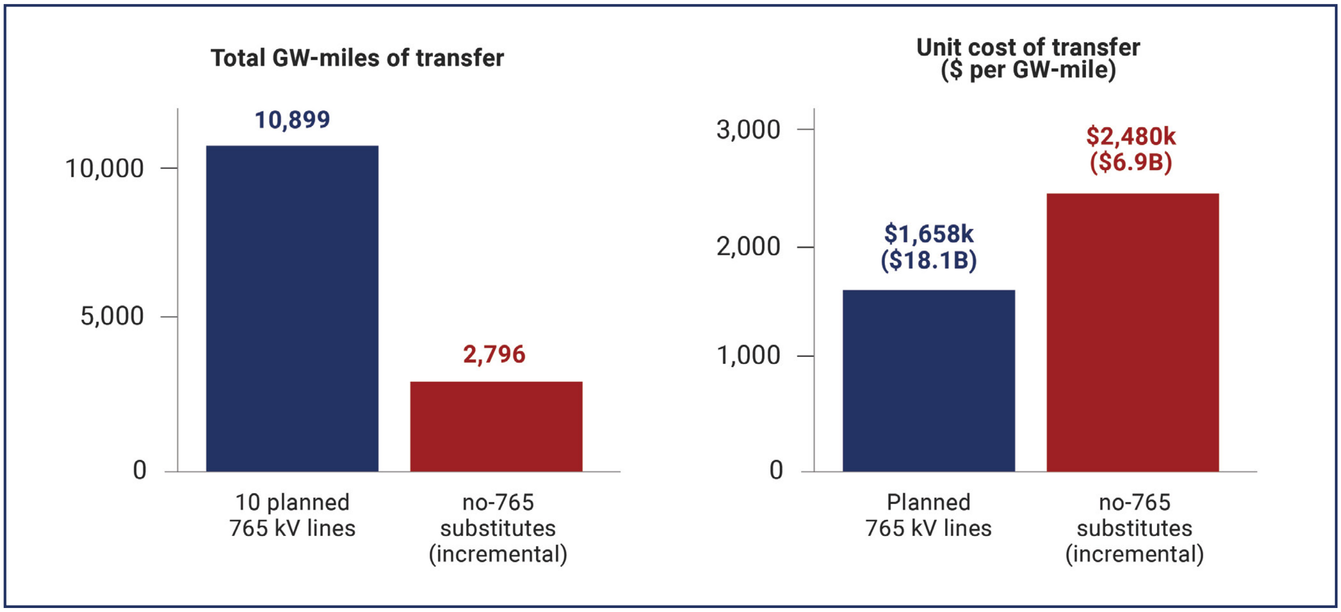


Similarly, on the part of the transmission system with long radial connections between nodes, reconductoring can amplify reliability risks unless it is accompanied by a greenfield buildout that solves the structure problem. In this way, greenfield lines often provide value to the grid by upgrading the voltage level to solve a network problem. When new greenfield transmission is required to reinforce an existing 138 kV line, it builds a parallel 230 kV line 61% of the time. These voltage step-ups along parallel paths add almost 30,000 GW-miles of capacity to the system in the High Growth load scenario. Almost all new transmission capacity at or above 500 kV was added through greenfield expansion. Ultimately, economic development in the form of demand growth and energy addition is limited by the topology or structure of the existing system.

As the grid faces new strategic and structural shifts in the size and location of demand, the backbone transmission system and its topology must evolve. ERCOT and the State of Texas endeavored to do just that with the Strategic Transmission Expansion Plan, which will establish a new 765-kV backbone connecting significant, growing load centers on the state's west and east sides. While this backbone was reflected in most scenarios in this analysis, we ran one scenario without it. This study was not designed to replicate the identification of this specific portfolio of projects. Rather, the goal of this exercise is to understand how high-ampacity conductors can address demand growth needs in the absence of an established 765 kV backbone and the ability to deploy similarly high-voltage transmission lines.

This scenario found that without the planned 765 kV backbone, this model built 12 times as many lines, each 3.5 times smaller. As a result, far fewer GW-miles of transfer capability were built, and at nearly double the price on a per GW-mile basis. While the overall investment is three times greater for the 765 kV backbone, the structural expansion these projects represent demonstrates the economies of scale achieved with higher-voltage lines that can carry more power over a smaller right-of-way footprint. The grid operator Southwest Power Pool (SPP), similarly, found 765 kV lines to be the optimal choice compared to the four to six 345 kV lines needed to replicate the power transfer capability of a single 765 kV line.[24]

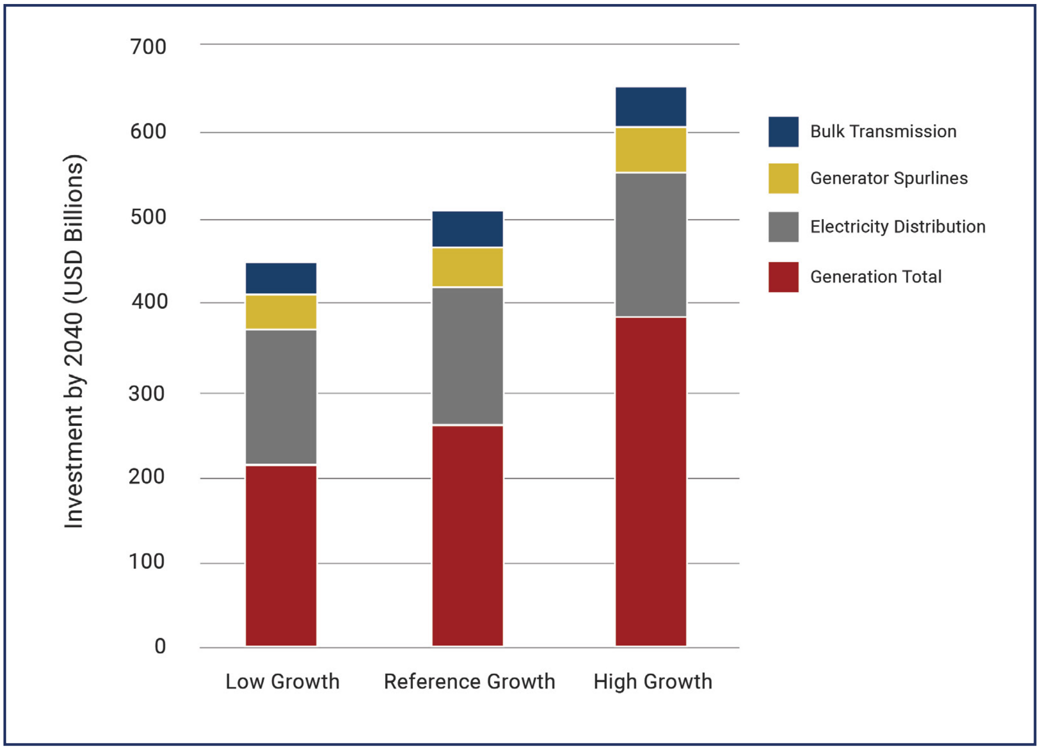
Figure 13. The 765 kV backbone planned in ERCOT demonstrates the value of strategic transmission expansion that takes advantage of the economies of scale from higher voltages.



#4: Transmission expansion of all types is an affordable technology solution that complements generation

Transmission investment – for both reconductoring and greenfield lines – is key to meeting demand growth and enabling the least-cost addition of energy. Across all load growth scenarios, investment in expanding the bulk power system represents 7-8% of total system investment costs by 2040. Bulk transmission system investment ranges from $38 billion in the low-demand growth scenario to $45 billion in the high-demand growth scenario by 2040, while investment in generation ranges from $212 billion to $385 billion in the low- and high-demand growth scenarios, respectively. This growth in generation investment captures 86% of the total increase between low and high demand levels, as shown in Figure 14.

Figure 14. Transmission investment remains a smaller share of total system costs across growth scenarios and is key to enabling investment in generation.



All generation technologies see large increases in investment to meet the high-demand scenario. Notably, Texas's geothermal resource is leveraged heavily within data center load hubs in Dallas and Austin, which drives $17 to $91 billion invested into roughly 6 to 24 GW of geothermal from the low to high demand scenarios. While locating generation closer to load can mitigate transmission needs, transmission can also mitigate generation needs by enabling existing assets to increase their capacity factor and overcome congestion, thereby meeting growing loads. Further, transmission and its role in the system can evolve as new demand and generation technologies emerge and power flows change. Transmission is a unique tool that enables all kinds of investments in energy generation, storage and new demand to access the electricity market reliably and affordably.

Conclusion & Policy Recommendations

Grid growth is essential, but it faces several barriers that threaten to undermine energy addition, reliability and affordability. This analysis found the cost-optimal path to growth that keeps pace with demand includes a mix of greenfield transmission and reconductoring with high-ampacity conductors.

This study modeled transmission expansion only within the ERCOT system, but it holds lessons for transmission planners and investors everywhere. In Texas, we saw that reconductoring was a cost-optimal solution for meshed networks with redundant paths. These conditions hold in the metropolitan area between Dallas and Austin, and in much of the Northeast and Mid-Atlantic parts of the U.S. Major cities and metropolitan areas across the country, including in the Southeast and West, likely also share these system characteristics. For the PJM region in particular, high-ampacity conductors could provide much-needed headroom on timelines that enable, rather than limit, energy addition and demand growth, because they avoid challenges of permitting, siting and building transmission in this densely populated part of the country. In parts of the country where greenfield transmission is not feasible due to challenging terrain or social acceptance, reconductors will be all the more valuable. This study also shows that, for all their benefits, reconductoring with high-ampacity conductors can not always substitute for greenfield transmission development. In areas with sparser topology and new pockets of load or generation – like much of the Western U.S. – greenfield development is irreplaceable. As the Western interconnection and other more radial systems face topology limitations, new high-voltage transmission lines will be critical to ensure reliability.

However, the barriers to pursuing either pathway are significant and require policymakers' attention and action. A greenfield transmission line can take as many as 20 years to move from planning to construction to operation. Meanwhile, newer technologies face regulatory barriers that can prevent the deployment of the very types of tools needed to meet fast-growing demand affordably. Barriers to grid expansion are therefore an urgent matter that, if left unaddressed, threaten to undermine U.S. competitiveness in emerging industries like AI, energy dominance and affordability for American homes and businesses.

Regulatory Reform

Many policy proposals seek to address this incentive misalignment through performance-based ratemaking mechanisms that add percentage points to a utility's rate of return for investing in specific technologies. For example, Montana passed House Bill 729 in 2023 to give their Public Utility Commission authority to develop criteria for evaluating higher-performing conductors and provide a higher rate of return for those investments.[25] These incentive-based approaches can encourage deployment, but their effectiveness depends on providing a sufficient financial disincentive to the conventional alternative. In scenarios where a business must decide between building a greenfield transmission line and reconductoring with a composite core conductor, the former project may remain the most attractive option for maximizing profit due to the sheer size of the capital investment, even if reconductoring with a composite core conductor increases the rate of return. This dynamic highlights the need for regulatory frameworks that better align utility incentives with least-cost, performance-driven outcomes, allowing innovative grid technologies to compete on a level playing field when they can meet system needs at a lower total cost of ownership.

Policy Recommendation

- **Establish Conductor Standards with Rebuttable Presumptions:** By starting planning and regulatory processes with the best available technology as the default, these processes can provide discipline for selecting the most effective approach to address system needs and reduce regulatory friction. For example, this analysis found that composite core conductors were consistently the most cost-effective technology for increasing grid capacity in parts of the system with existing redundancy, operating at low-to mid-level voltages and facing thermal constraints. By classifying the types of transmission system needs and conditions and providing a presumption of prudence for the best available conductor technology to address those needs, the burden on regulators is reduced while enabling utilities to make the case for not using that technology.

Support the Next Generation of Transmission Planning Tools and Practitioners

Advancements in analytical capabilities and grid-enhancing technologies are becoming increasingly necessary due to growing regulatory pressure, new reporting requirements and meeting the challenges of rapidly rising demand growth. Historically, transmission planning has ignored specific conductor types until late in the project selection process, preventing cost-saving innovations like composite core conductors from being properly evaluated. This issue is compounded by siloed data, tools and teams across local utilities and regional planning entities. Recent FERC Orders and State legislation address these challenges by mandating public disclosures on local planning processes and lines slated for in-kind replacement. Ultimately, closing these data gaps and leveraging integrated, multi-approach modeling allows grid planners to evaluate higher-ampacity conductors, along with the broader suite of transmission technologies and solutions, and select the most cost-effective grid expansion options.

Policy Recommendations

- **Fund Next-Generation Modeling Tools:** The Department of Energy (DOE) and its National Laboratories are well-positioned to support the development and adoption of advanced modeling tools that enable more accurate evaluation of advanced transmission technologies. Through competitive awards, such as grants to the private sector and academia and National Laboratory calls, the DOE can support advancements in the tools and capabilities needed to represent advanced transmission technology in transmission models. Additionally, the DOE can provide technical assistance and workforce training to utilities and grid operators to support their adoption of new tools and technologies.
- **Data Access and Transparency Improvements:** State and Federal regulators can provide greater direction to transmission planning entities to disclose the information and decision-making rationale behind their technology selection decisions. Additionally, regulators and legislators can direct utilities to improve access to the information necessary for the regulators, consumer advocates and other parties to understand and potentially replicate the assessment of advanced transmission technologies. This increased data access and transparency must comply with Critical Energy Infrastructure Information and other security protocols.
- **Expand Advanced Technology Evaluation to More Transmission Planning Processes:** California, Colorado, Indiana, Minnesota, New Mexico, South Carolina and Virginia have passed legislation directing utilities to consider or evaluate advanced transmission technologies in the Integrated Resource Planning process or in other transmission studies conducted by their utilities.[26] More States can follow suit and expand this directive to include the evaluation of these technologies for large-load interconnection if their utilities are outside the RTOs/ISOs that FERC targeted in its show-cause orders. Additionally,

the administrators of Power Marketing Administrations (PMAs) and the federal legislature can take action to promote the deployment of advanced transmission technology on PMA systems. PMAs are not jurisdictional to States or FERC and, therefore, are not required to comply with new requirements for the evaluation of advanced transmission technologies in generation interconnection, large load interconnection, or other transmission planning processes.

- **Integrate Interconnection Needs in Transmission Planning:** The siloing of interconnection processes for generation and large loads from transmission planning is a core challenge. Currently, these three processes run in parallel, missing crucial opportunities to share upgrade costs and build more efficient transmission infrastructure. Comprehensive, long-term transmission planning can also enable earlier provision of information on the timing and cost of transmission and other network upgrades to projects, reducing uncertainty and speculation.
- **Leverage DOE Funding to Support Research, Development, Demonstration, and Deployment:** Bipartisan funding opportunities and financial support, such as the Transmission Facilitation Program (TFP), Energy Dominance Financing Program (EDF) and Speed to Power through Accelerated Reconductoring and other Key Advanced Transmission Technology Upgrades (SPARK), can further support conductor innovation, de-risking, and deployment.[26] For more commercially mature technologies like composite core conductors, loans to public power and electric cooperatives can support these less-well capitalized utilities to bring cost-saving technologies to their consumers. High-temperature superconductors are better positioned to receive demonstration support through programs like SPARK. Overall, continued support in material science R&D and test-beds are crucial for keeping American innovators on the forefront of grid technologies.

Siting and Permitting Modernization

Over the past two decades, transmission investment has focused largely on local, incremental upgrades with legacy technologies. Regional and interstate projects have repeatedly stalled due to multi-jurisdictional siting and permit requirements as well as litigation. Consequently, available grid capacity is shrinking, forcing new generation facilities and large commercial customers to face wait times of up to seven years – optimistically – for grid access. Streamlining these planning and permitting frameworks is essential to expanding grid capacity and resolving these critical delays.

Policy Recommendations

- **Effective Implementation of CITAP:** DOE established the Coordinated Interagency Transmission Authorizations and Permits (CITAP) program in 2024 to reduce federal permitting timelines for transmission to two years. It aligns strongly with the Fiscal Responsibility Act provisions through its lead-agency approach, enhanced coordination among federal entities, the establishment of a single administrative record and an online portal for transparency and tracking of permitting schedules. Adequately staffing the program and conducting education and outreach activities to sub-national governments and Tribal governments can enhance the use of this program and facilitate faster federal permitting of transmission.
- **Enact Federal Permitting Reforms:** Modernization of environmental laws and regulations, like the National Environmental Policy Act, and judicial review reforms can significantly improve the speed and predictability of the federal permitting process without sacrificing environmental protection or public input opportunities. Reforms to the Administrative Procedures Act can likewise reduce permit uncertainty and litigation risk for projects by clarifying what constitutes a final agency action for purposes of a legal challenge under the Act.

- **Improved Sub-National Coordination:** Transmission siting and permitting largely occur at the sub-national level, creating a patchwork of entities responsible for approving and authorizing segments of a transmission line that may span several jurisdictions. Efforts like the Western Transmission Permitting Task Force are one example of how States can improve coordination and prioritize efficient transmission development.[28]

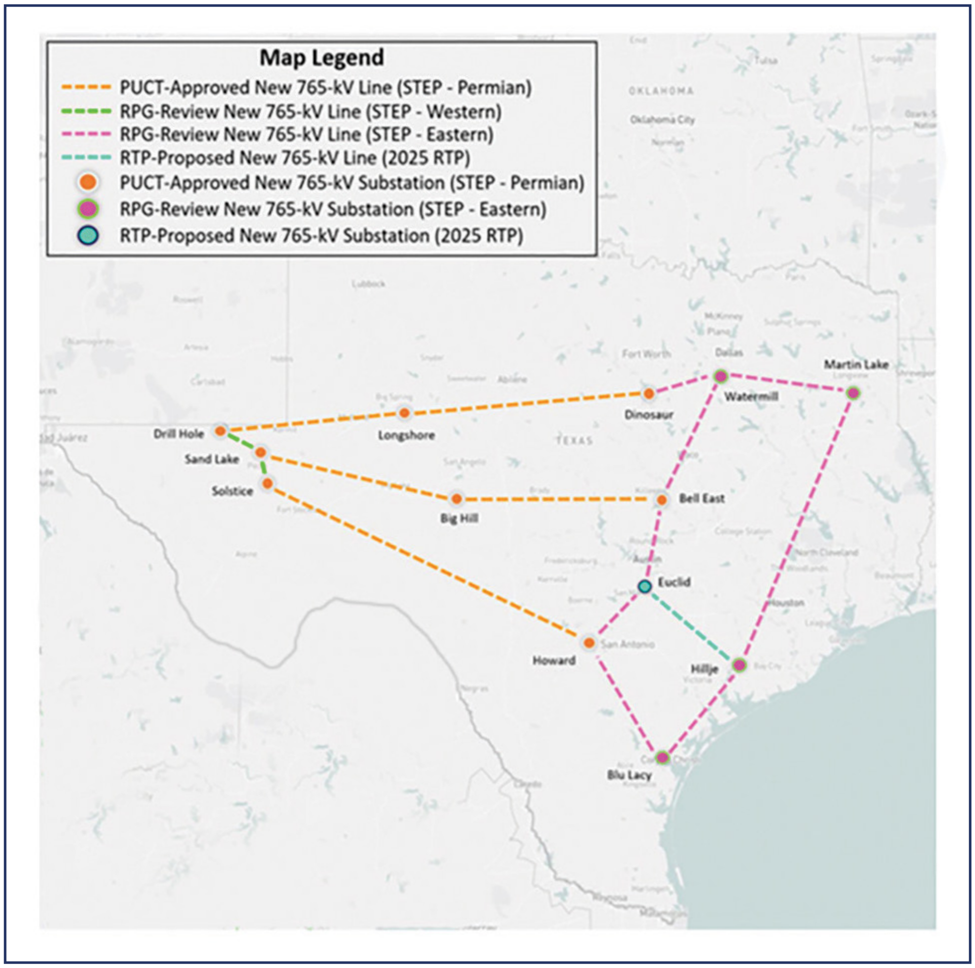
Appendix

Model Development

A comprehensive technical appendix for the model can be found here: https://www.evolved.energy/posts/reconductor-or-greenfield

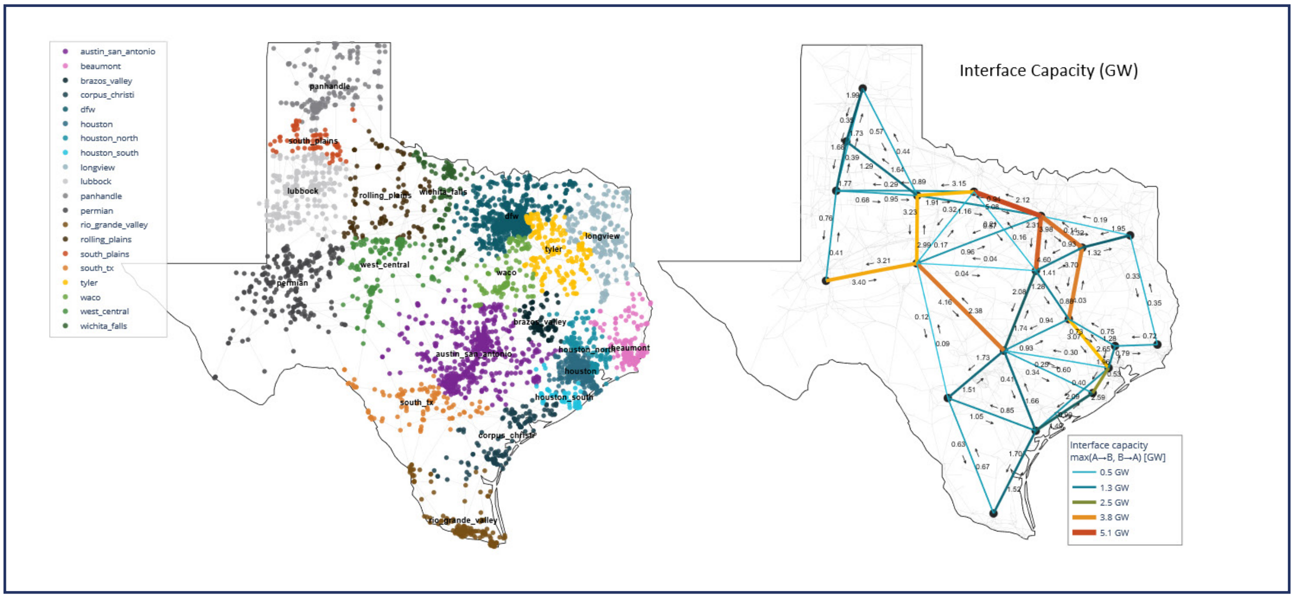
The EER team leveraged publicly available information on the location and attributes of electric assets and infrastructure on the ERCOT grid from the Homeland Infrastructure Foundation Level (HIFLD) dataset and OpenStreetMap (OSM). Additional information on currently planned and approved transmission lines expected to come online within the study horizon of 2040 is also represented. This includes the transmission lines, substations and other supporting infrastructure approved in the Strategic Transmission Expansion Plan, see Figure A1.[29] This 765-kV backbone is included in all but one scenario in this analysis.

Figure A1. ERCOT's proposed 765 kV backbone is slated to commence operations by 2035.



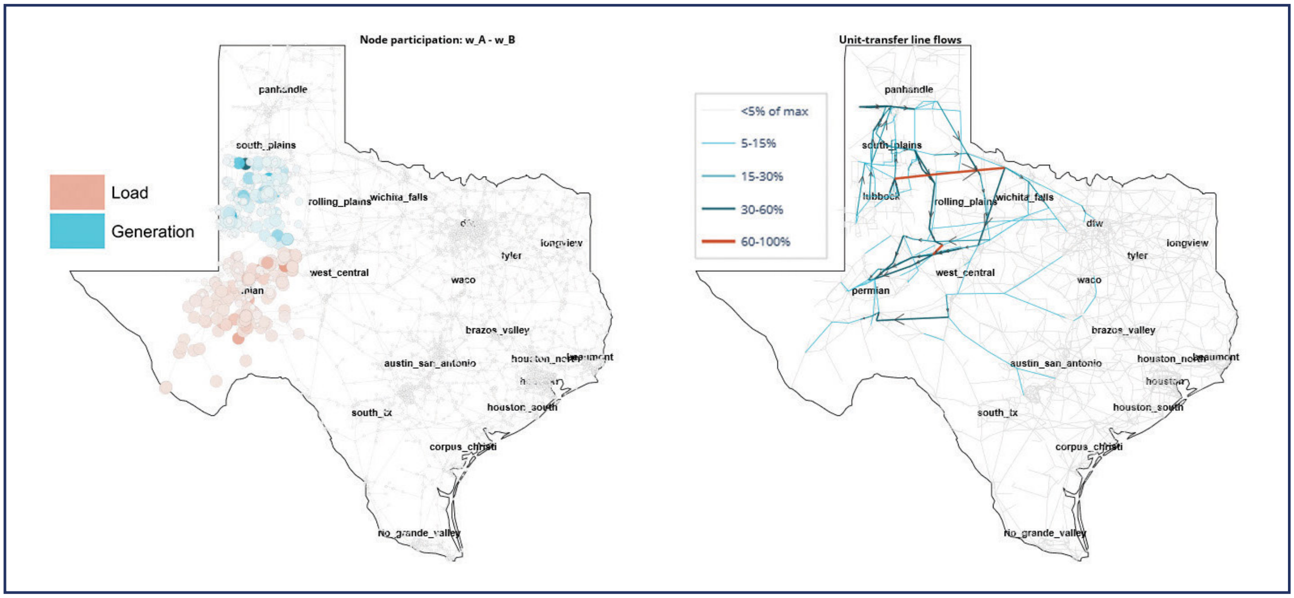
The ERCOT system was divided into 20 zones using a spectral clustering algorithm that groups strongly connected electrical buses; see Figure A2. Electric buses are like the train stations of the grid; they serve as interconnections among different grid elements and ensure that the trains coordinate on operational characteristics. From these zones, the Evolved team calculated transfer capacities between zones to establish thermal transfer limits along paths.

Figure A2. Generation shift keys allow the model to switch between the full nodal network (left) and capacity expansion zones (right).



The modeling itself starts with the Regional Investment and Operations Platform (RIO). To the existing capacity expansion model, new constraints were added so that transmission flows were consistent by the laws of physics: electricity flows along the path of least resistance rather than the most direct or cheapest path. In addition to the power flow constraints derived from Kirchhoff's laws, thermal limits are also enforced on zone-to-zone transfer capability. Power Transfer Distribution Factors (PTDFs) computed on the full nodal network—every bus and line—are used between model years to derive those transfer limits, screen for reliability violations and develop the transmission supply curves offered to the optimization. As shown in Figure A3 below, the locations and volumes of power injections and withdrawals across a network cause power to flow through multiple lines, illustrating the complexity of grid operations. The model also performs N-1 contingency screening, which is an industry standard for grid reliability. This standard requires that the grid be able to withstand the loss of one asset or transmission line so that the remaining lines are not overloaded or do not experience additional reliability-criteria violations. When power lines are overloaded, temperatures can rise beyond safe operating levels, leading to equipment degradation and potential failure. The model tests system stress during nine representative periods that include the coincident gross load peak; peak generation output from solar, wind and thermal resources; and other extremes that push the transmission system to its limits.

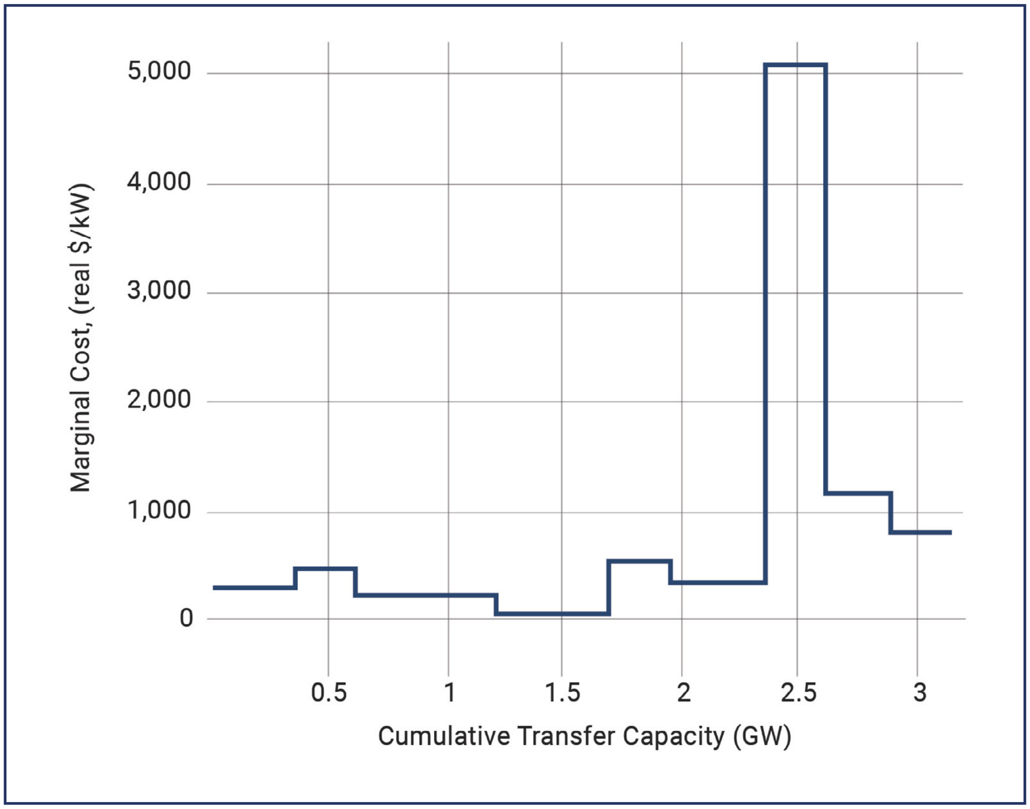
Figure A3. A typical injection/withdrawal scenario shows how real-world power flow causes system stress well beyond the original zones, which would not be captured by a pipe-flow transmission model.



Transmission lines can become thermally overloaded due to increased power flows driven by load growth, generation additions, or contingency conditions. The advancement in this modeling approach is the ability to determine the appropriate upgrade to address thermal constraints from both reliability and economic perspectives, evaluating different conductor technologies alongside conventional transmission solutions, such as parallel circuits. As the model moves between capacity expansion and power flow modeling, transmission upgrades can enable new capacity investment, allowing the model to forgo a wires solution when siting new generation or storage would relieve a constraint at least cost. This computational approach to addressing reliability violations and selecting the cost-effective upgrade on a line-by-line basis provides a more rigorous and realistic approach than an average expansion cost.

This approach also more accurately reflects the nature of real-world transmission investments in that they are lumpy, non-linear and asymmetrical. They are lumpy and nonlinear, in that the size of an investment is not always proportional to the additional capacity it unlocks. Figure A4 shows an example of a nonlinear transmission supply curve generated by the model's injection/withdrawal process. One can observe that some investments are low-cost and provide significant capacity additions, such as those between 0.5 and 1.5 gigawatts, while the highest-marginal-cost investment yields only a fraction of additional capacity. Transmission investments are asymmetrical in that investments that increase the ability to carry more current in one direction of a line may not provide the same additional carrying capacity on the line if the power were to move in the opposite direction. This underscores the importance of the broader network and its ability to handle contingencies. If these reliability constraints can not be handled, a line's potential carrying capacity cannot be fully utilized.

Figure A4. Power flow modeling reveals significant nonlinearities in transmission supply.



The EER team benchmarked this approach using Regional Energy Deployment System (ReEDS) inter-zonal transfer limits to ensure adequate alignment between the analysis outcomes and real-world decisions.[30] Additionally, EER employed an optimal transmission path approach, leveraging a proprietary transmission cost surface that applies price multipliers to land units based on land type, slope and environmental exclusions. This cost surface was also informed by a comparison between planned and final transmission paths to account for additional development constraints not already quantified in available datasets. This analytical approach reflects that the most direct path is often neither the cheapest nor the optimal for developing transmission lines due to technological or societal constraints on infrastructure development.

Annual generation additions are capped at the current rate of projects that finalize interconnection agreements in ERCOT. New natural gas generation deployments are constrained to reflect current supply chain limitations, but these constraints are removed after 2030, reflecting expectations that manufacturing capacity will increase to meet market demand. This analysis reflects current federal and state policies, including the new phase-out of tax credits for wind and solar technologies starting in 2026.

Model Limitations and Opportunities for Future Work

The model developed for this analysis is a proof of concept for how planning tools can evolve to improve technology evaluation. Built off of only publicly available data, this effort seeks to demonstrate how integrated capacity-expansion and power-flow modeling is both possible and powerful. While the model provides strong directional guidance, its simplified assumptions naturally constrain the precision of our results.

First, there is a risk of overstating the value of high-ampacity conductors because projects may require expensive structural rebuilds, such as new towers and terminal equipment, and the replacement of aging assets. Existing infrastructure may be at the end of life, making a line rebuild more suitable than reconductoring on existing towers. Because asset age and health data are not publicly available, these considerations are not reflected in our model decisions. Additionally, true project costs must account for spillover impacts on adjacent equipment and the temporary facilities required to support grid outages during construction, particularly in dense areas. In the real world, taking lines out of service can affect reliability. While energized reconductoring is sometimes an option, it is not a universal workaround and is not accounted for in the model.

The model did not constrain transmission expansion to account for the time required to reconductor or build new transmission lines. As a result, the pace of transmission expansion in this model does not accurately reflect what can reasonably be achieved in practice.

Next, the model does not capture all physics-based impacts and considerations. This analysis assesses thermal limits only and does not represent stability constraints; this is considered reasonable because most ERCOT lines are short enough to be thermally limited, though it is flagged as an area for future work. The model also assumes that reconductoring leaves a line’s electrical impedance essentially unchanged which may not be the case in practice. Furthermore, standard reconductoring yields no capacity gain for underground cables—where thermal limits are governed by insulation temperature and heat dissipation rather than sag—a constraint ignored here due to ERCOT’s low share of underground lines, but relevant for urban grids.

Additionally, voltage uprating of existing lines is not modeled, though higher-voltage parallel paths are modeled, as uprating in practice accounts for less than 10% of transmission capacity expansion, and lower-voltage lines like 69 kV are typically upgraded in voltage due to age rather than being reconductored.

Finally, the mapping from zone to bus is also imperfect, sometimes ignoring the flexibility of within-zone redispatch to solve transmission problems or unrealistically spreading dispatch and load across buses, preventing local transmission overloads. Additionally, transmission losses are not updated to reflect nodal system changes, meaning that reconductoring instead of building greenfield lines generally tends to increase losses as the system grows, but decreases them at a given load level.

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