SUPPORTING ADVANCED CONDUCTOR DEPLOYMENT: BARRIERS AND POLICY SOLUTIONS

A companion report to "The 2035 Report: Reconductoring with advanced conductors can accelerate the rapid transmission expansion required for a clean grid"

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ENERGY INNOVATION POLICY & TECHNOLOGY LLC

GridLAB

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EXECUTIVE SUMMARY

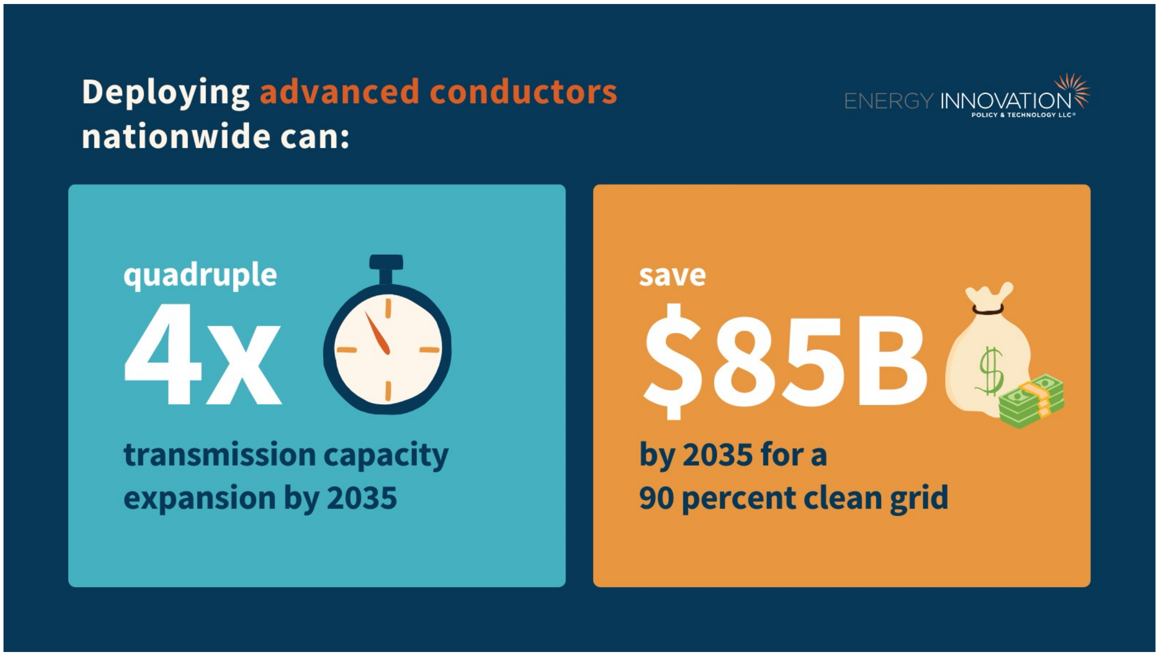
In 2005, Minnesota utility Xcel Energy urgently needed to bring more electricity into the Twin Cities, but a constrained urban environment made building an entirely new transmission line difficult. The existing transmission lines, which brought coal and nuclear power to the city, traversed an interstate, intersected two major highways, crossed various residential and industrial zones, and passed through protected wetlands and a National Wildlife Refuge. Building new towers and connecting new wires would have required a major permitting effort across multiple agencies, introducing opportunities for delay, extra cost, and potential failure at each step.

To overcome these hurdles, Xcel decided to replace the existing line with higher performance wire, increasing the transmission capacity along the same route and using the same towers. Because it only caused minimal disruption, the wire replacement process, referred to as "reconductoring," required only a 30-day notification to a single regulatory agency and eliminated the need for heavy equipment in environmentally sensitive areas, sidestepping many potential permitting reviews. After an eight-week construction period, the project successfully doubled the line's ampere rating and was completed on time.

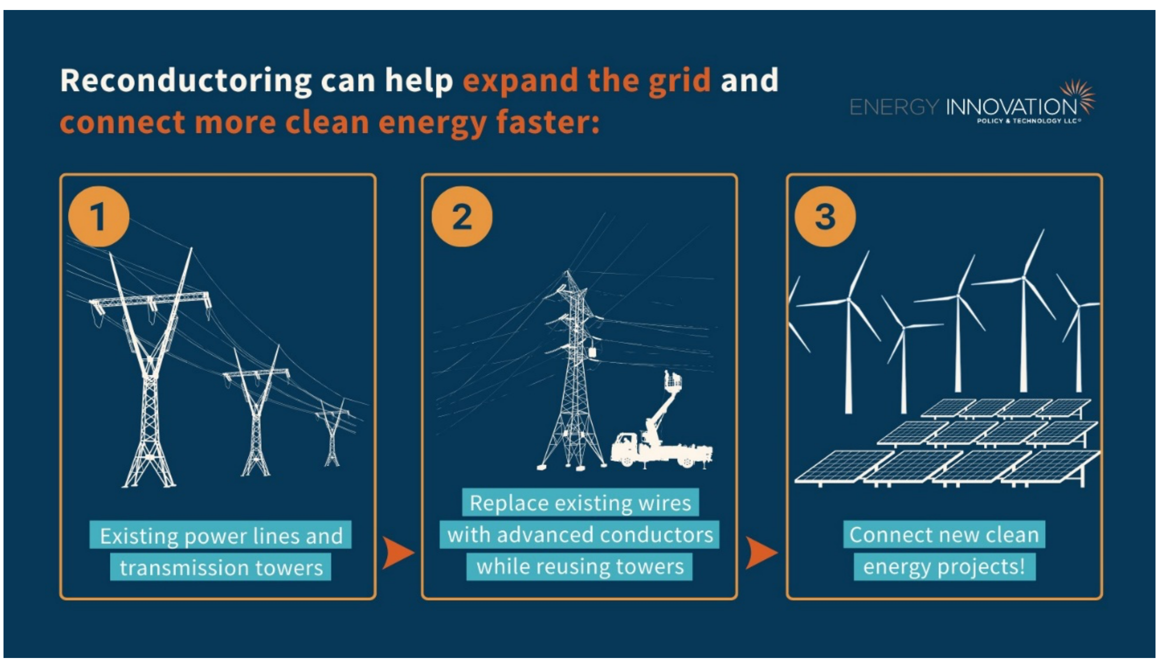
Now, nearly 20 years later, the United States is facing a severe lack of transmission capacity, creating long lead times for new renewable generators trying to connect to the grid, even as uneconomic generators (primarily coal) bring retirement dates forward. After 15 years of demand stagnation, the urgency to expand the grid is increasing—electricity demand is growing again due to a mixture of electrification, manufacturing growth, and demand for data processing. Increasingly extreme weather events like winter storms Uri and Elliott and wildfires in the West threaten resilience and demonstrate the value of stronger transmission ties between and within regions. With more variable resources in the system, there is a growing benefit to sharing resources across wider areas.

To address the near-term needs of providing market access to cost-effective and policy-aligned clean energy resources, the U.S. needs near-term solutions. New research from the University of California, Berkeley and GridLab, released alongside this report, shows that a comprehensive approach to reconductoring transmission lines with higher performance wires, here referred to as advanced conductors, could rapidly increase transmission capacity at a low cost, while utilities simultaneously redouble efforts to expand new transmission.[1]

The researchers found that wide scale reconductoring with advanced conductors could help quadruple the projected transmission capacity added by 2035. This would unlock a 90 percent clean electricity system in 2035 while saving $85 billion in energy system costs. Furthermore, by 2050 this strategy, along with a robust build-out of new transmission, would support a 100 percent clean electricity system at a total savings of $180 billion compared to business as usual.



Reconductoring with advanced conductors saves consumers money by reducing congestion and providing low-cost market access for new generation from clean resources sited near transmission—a major barrier facing the 2,000 gigawatts (GW) of clean energy resources in interconnection queues today.



Reconductoring is not a panacea—it does not reduce the urgency of fixing a broken permitting and cost allocation system for new transmission, and advanced conductors face important limitations in some circumstances.

UC Berkeley and GridLab find that new high-voltage transmission complements reconductoring with advanced conductors as part of a least-cost transmission portfolio. In practice, new transmission will be essential to meet growing demand and achieve national, state, and utility clean electricity goals. Advanced conductors help relieve current bottlenecks to connecting customers with new low-cost energy supply, including high costs and delays facing power plant interconnection requests, while efforts to build new transmission should continue apace. Current systems that govern planning, permitting, and allocating costs for transmission must become more supportive to match the huge savings, resilience, and pollution benefits associated with expanding transmission capacity via reconductoring and greenfield transmission.

Rather than try to address the whole transmission policy puzzle, this report focuses on the aspects of transmission policy related specifically to reconductoring with advanced conductors. Though advanced conductors are an established technology, the utility industry has yet to adopt them at a scale consistent with their potential. While utilities like Southern California Edison have embraced advanced conductors across more than two dozen reconductoring projects,[2] many others still only see them as a niche solution.

We interviewed more than a dozen industry stakeholders, including utilities, regulators, and system operators, to better understand barriers to the wider adoption envisioned in the UC Berkeley/GridLab report. Despite advantages like better efficiency, higher capacity, and improved reliability and resilience, the higher up-front cost of advanced conductors makes it difficult for utilities to justify wide, proactive use under current regulatory practice. Industry unfamiliarity with the technology, lack of comprehensive regional planning, and unclear permitting processes have exacerbated these issues. Other barriers to implementation include aging infrastructure that needs remediation or replacement, supply chain bottlenecks in transformers, and workforce limitations.

This report explores these barriers in detail, and recommends how policymakers at the federal, state, grid operator, and utility levels can help transmission owners implement these updates. Policymakers should address barriers to adoption in five primary areas:

- Alignment of utility incentives with the selection of advanced conductors
- Improvement of transmission planning
- Examination of efficiency standards for transmission lines
- Expansion of federal and state funding support
- Development of education and training for the workforce.

By addressing these areas comprehensively, state and federal policymakers can partner with utilities and technology providers to seize the opportunity provided by reconductoring with advanced conductors. 2023 was the hottest year on record, and the U.S. needs solutions to transform to a clean electricity system faster and more affordably. Advanced conductors, alongside other advanced transmission technologies, are a vital and untapped part of that solution.

Table 1. Summary of policy recommendations

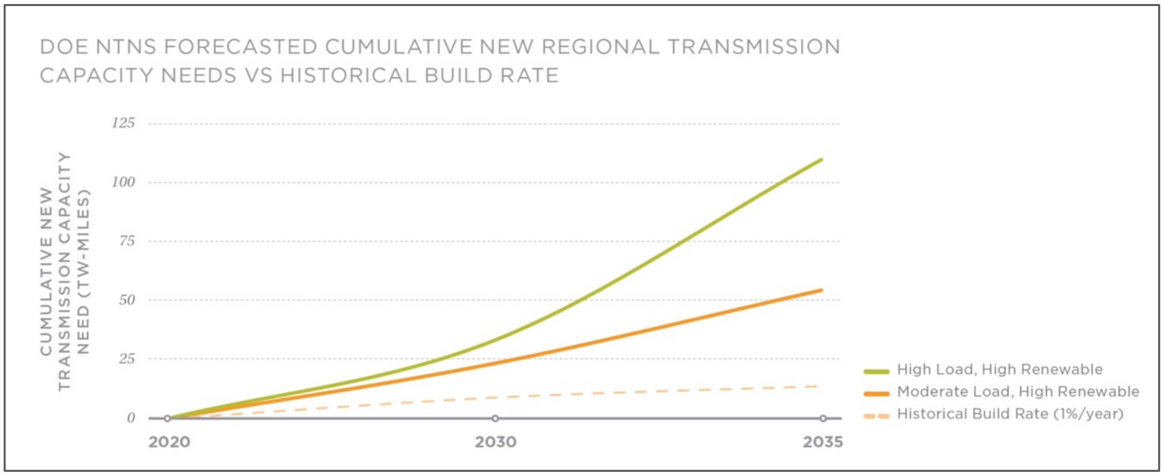
POLICY	ACTOR
Alignment of utility incentives	
Consider using performance-based regulation approaches that boost utility returns for money-saving measures and disincentivize excessive spending to achieve the same outcomes	**Utility regulators**
Investigate whether advanced conductors remove near-term transmission capacity constraints to unlock lower-cost transmission and generation options for customers and assess whether reconductoring provides opportunities for higher near-term growth while reducing cost pressure	**Utilities**
Direct the public utilities commission to develop a policy position on reconductoring and other technologies that increase throughput along existing rights of way, and establish cost-effectiveness criteria for advanced conductors that would be eligible for rate recovery	**State legislatures**
Proactively investigate the benefits of advanced conductors to develop a commission policy position on approval of projects	**Utility regulators**
Transmission planning	
Ensure that the proposed benefits in regional transmission plans consider the efficiency of the conductors used during the compliance process for the regional planning rule	**Federal Energy Regulatory Commission**
Create independent transmission monitors to objectively evaluate projects and provide visibility into areas where advanced conductors could create the most value	**Federal Energy Regulatory Commission**
Where utility planning is inadequate, create state transmission authorities to facilitate permitting and vetting new lines, identify opportunities for reconductoring with advanced conductors, and co-invest in projects to offset upfront costs as in Colorado and New Mexico	**States**
Require integrated resource plans to consider advanced conductors for new lines and reconductoring projects	**State legislatures**
Require utilities to study the benefits of advanced conductors on long term costs, efficiency, grid capacity, and reliability as a part of integrated resource planning	**State legislatures and regulators**
Efficiency standards	
Finalize efficiency standard analysis and proceed to rulemaking as quickly as possible	**Department of Energy/ Congress**
Foster and exchange best practices around advanced conductors, and consider developing an industry best practices manual around reconductoring and advanced conductors	**Utilities**
Federal and state support	
Continue to explicitly prioritize projects that reconductor transmission lines with advanced conductors in current funding streams	**Department of Energy**
Create new funding mechanisms specifically addressing expanding reconductoring opportunities focused on intraregional lines	**Congress**
Pass transmission investment tax credit with specific considerations for advanced conductors with requirement that lines between 100 and 300 kV use advanced conductors to qualify	**Congress**
Set a federal target for increased transmission capacity by 2030 to help accelerate deployment of advanced conductors in the short term	**White House**
Finalize Defense Production Act authorization process and appropriate funds to increase production at U.S. transformer facilities	**Department of Energy/ Congress**
Finalize planned expansion of transmission categorical exclusion to directly apply to reconductoring with advanced conductors	**Department of Energy**
Review state permitting processes to accelerate reconductoring, and adopt Department of Energy categorical exclusion to create consistency	**States**
Education and training	
Evaluate the workforce needs for reconductoring with advanced conductors	**Department of Energy**
Appropriate funds to programs like the Good Jobs Challenge that can support workforce training partnerships for transmission development	**Congress**
Work with manufacturers to develop standardized upskilling programs for current grid workers to work with advanced conductors	**Department of Labor**
Conduct research on applications of advanced conductors domestically and internationally to dispel uncertainties about technology readiness	**Department of Energy**

INTRODUCTION

The U.S. Department of Energy's (DOE) 2023 National Transmission Needs Study (NTNS) finds that to rapidly electrify the U.S. economy and decarbonize the grid, intraregional transmission must double, and interregional transmission capacity must increase by a factor of six by 2040.[3]

However, these transmission needs are not just a future problem—transmission constraints are already holding back development of wind, solar, and storage resources that are the cheapest available sources of power today. Delaying them delays hundreds of billions of potential consumer savings and millions of quality jobs.

Figure 1. Forecasted transmission needs vs. historical build rate



U.S. DOE's NTNS compared to the historical growth rate of 1 percent per year.[4] To meet a high-renewable energy future, the DOE estimates that the U.S. must increase its transmission capacity by 60 – 125 percent by 2035.

The U.S. has become a difficult place to build new transmission, which complicates the picture even further. Commissioning high-voltage transmission along new paths, or rights-of-way (ROWs), takes seven to ten years,[5] meaning any large project that enters planning stages now may just barely make it into service by 2035 without reforms. Complex interstate projects have taken even longer. For more than a decade, the U.S. has been averaging only a 1 percent annual increase in transmission capacity, a rate that must triple or quadruple to support a least-cost supply portfolio.[6]

It is critical for the U.S. to consider federal reforms to planning and cost allocation, and for states to address local siting and permitting barriers to remove this bottleneck. Any scenario that involves deep decarbonization implicates large investments in new transmission. Utilities with voluntary decarbonization goals and those facing state mandates must act now to facilitate building new transmission to keep those goals within reach. Ambitious U.S. commitments to the international community under the Paris Agreement imply similar if not even greater ambition.[7]

The Federal Energy Regulatory Commission (FERC) has aimed to address the transmission bottleneck by improving regional planning processes. Most notably, FERC has proposed to require the assessment of multiple scenarios over 20-year planning horizons, a cost-benefit analysis of lines that focuses on maximizing a broad set of benefits instead of reducing costs and using this broad set of benefits to better allocate costs. While this regional planning rule can go far to improve the build rate of new transmission lines that maximize consumer and reliability benefits, it will take years for this policy to have downstream effects and the policy depends on state and regional implementation.

While addressing those constraints, we must simultaneously make the most out of the existing grid, which is the subject of this report. Existing transmission facilities can be upgraded and complemented by advanced transmission technologies to increase the throughput of existing transmission ROWs without triggering significant new permitting requirements and at lower cost than adding new lines. Put simply, we can use what we have more efficiently while we build additional new transmission.

A companion report, “The 2035 Report: Reconductoring with advanced conductors can accelerate the rapid transmission expansion required for a clean grid”, referred to below as the “2035 Report 4.0”, by UC Berkeley and GridLab explores the many different technologies to increase throughput. The report paid special attention to reconductoring with advanced conductors as the most promising widespread solution to address transmission constraints in a low-carbon, high-renewables grid.[1] It finds that in general, this technology can be deployed within 18 to 36 months—three to five times faster than most greenfield transmission projects—and at a much lower cost.

The 2035 Report 4.0 finds that transmission owners can up to double the capacity of existing lines by swapping out conventional aluminum conductor steel reinforced (ACSR) cables with a variety of advanced conductor technologies.[2] Many of these technologies have additional benefits, including resilience to high temperatures and wildfires due to substantially reduced sag, and reduced losses of 10-30 percent.

Advanced conductors tend to be about two to three times the cost of conventional conductors, but when compared to the cost of a new transmission line to add a similar capacity increase, reconductoring with advanced conductors can be 50 to 75 percent cheaper. Energy savings from reduced losses can further offset the upfront cost. The 2035 Report 4.0 finds that if deployed nationwide, these advanced conductors could

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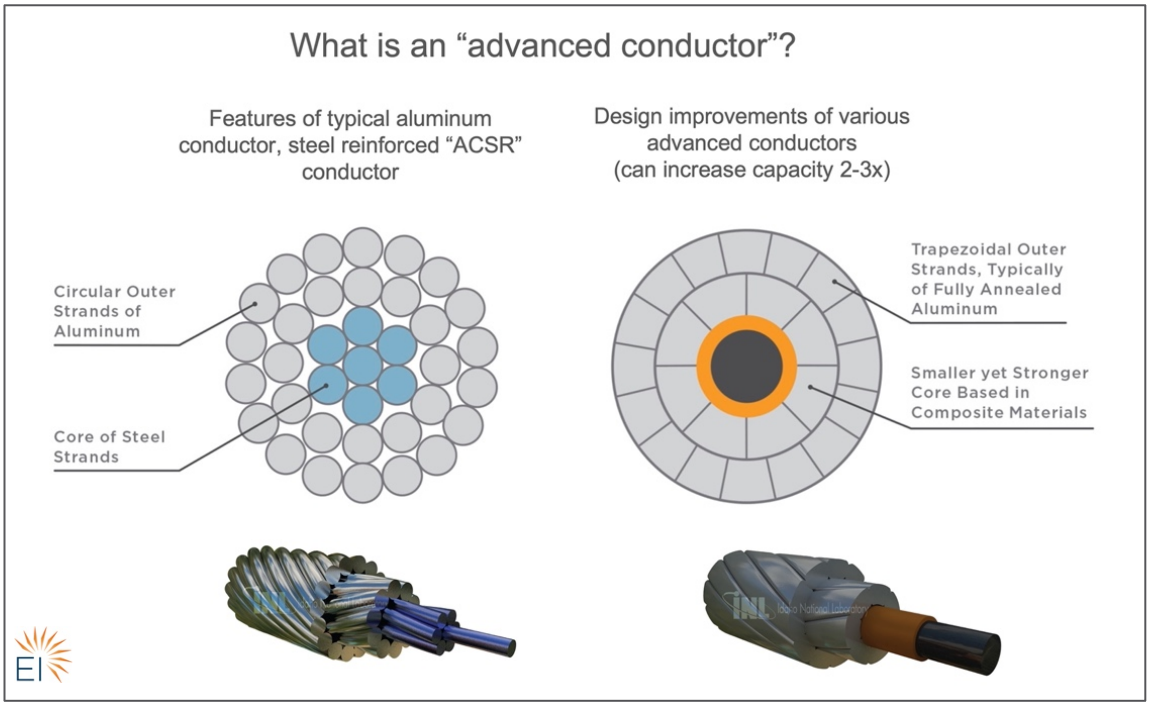
[1] A variety of conductor materials are used for transmission lines. Here, the term “advanced conductor” generally means a high-performance conductor that operates well at high temperatures and with low sag. Refer to the 2035 Report 4.0 for a more thorough analysis of the various types of conductors and their benefits.

[2] The capacity of the line refers to the amount of current that can flow through the line before it reaches its thermal limit. The thermal limit of a line, or “maximum operating temperature,” is a function of the conductor material, structure height, and voltage clearance requirements. Generally, most lines are limited by their thermal limit, but there are many cases in which other constraints such as stability, equipment ratings, line length, or other network issues may limit capacity.

nearly double the capacity of the existing high-voltage transmission system while saving billions, facilitating a cost-effective 90 percent clean electricity system by 2035. The production cost savings available to consumers through access to higher-quality wind and solar resources combined with lower overall transmission costs leads to savings of $85 billion by 2035 and $180 billion by 2050.

Figure 2. Advanced conductors compared to traditional conductors



Advanced conductor renderings courtesy of Idaho National Laboratory.[8]

While the 2035 Report 4.0 demonstrates advanced conductors are a promising technology already in wide use globally, it does not address the barriers to adoption that pervade the U.S. utility industry, nor does it suggest policies that overcome these barriers.

In this report, we summarize barriers to adoption, including the results of more than a dozen interviews with industry experts representing regional grid operators, state regulators, conductor technology providers, and regulated utilities. We then conclude with policy recommendations to address these barriers, with special attention to regulated transmission planning, federal financial support, training and workforce development, aligning regulated utility incentives, and developing conductor efficiency standards and best practices.

RECONDUCTORING TODAY—THE STATUS QUO

New transmission development in the U.S. has been declining, with the average build rate dropping by more than half through the 2010s.[9] In 2022, the U.S. transmission build rate declined by 50 percent year-over-year, to the fewest miles constructed in a decade.[10] At the same time, clear evidence exists of the need for new transmission to enable greater renewable energy interconnection, increase system reliability, and serve rapidly growing demand.[11] This paradox has driven recent efforts to expedite the permitting and construction of new transmission, including new programs and funding for transmission in the 2021 Infrastructure Investment and Jobs Act (IIJA) and FERC's leading efforts to reform regional planning processes.

However, new U.S. greenfield transmission still takes an average of seven to ten years to complete.[12] Meanwhile, of the approximately 700,000 circuit miles of existing transmission lines in the U.S.,[13] only 1 percent of lines are reconductored or rebuilt each year.[14] In addition, many of these reconductoring or rebuild projects are not using advanced conductors and are likely not appreciably increasing capacity. Even though advanced conductors have been available in the U.S. for more than two decades,[15] the technology is not being widely used to increase the existing system's capacity.

Transmission planning is organized myriad ways across the U.S., with varying levels of successful transmission development.[16] Independent system operators (ISOs), regional transmission operators (RTOs), and the Electric Reliability Council of Texas (ERCOT) manage the transmission system for most of the U.S., but their transmission planning methodologies vary. In addition, vertically integrated, non-ISO/RTO regions typically complete transmission planning on a disaggregated utility-by-utility or state-by-state basis, while also participating in regional planning under FERC's Order 1000.

The lack of uniform transmission planning practices across regions and utilities creates a complex patchwork of institutions, standards, and incentives that adds regional diversity to reconductoring barriers and the policy solutions to overcome them.

To investigate why advanced conductors are so underutilized, we conducted focused interviews with a diverse set of knowledgeable individuals directly involved in transmission planning, development, and equipment manufacturing to assess the state of the industry's use of advanced conductors. Interviewees selected for this study had experience in different regions of the country and different roles in the industry, including RTOs, state utility regulators, advanced conductor policy providers, and investor-owned utilities.[3] These interviews yielded general observations on reconductoring, alongside an assessment of existing barriers to reconductoring and success stories. These successes provide evidence to support recommendations that

[3] Interviewees consisted of six representatives from RTO/ISOs and utilities, two from advanced conductor original equipment manufacturers, two from renewable energy developers, and four from government and public utility commissions.

can be adopted at legislative, regulatory, and planning department levels to increase the nation's transmission capacity through reconductoring with advanced conductors.

Table 2. Summary of barriers to reconductoring with advanced conductors

BARRIER	EXPLANATION
Planning Barriers	
Workforce shortage	Utility and ISO/RTO teams lack capacity to fully evaluate reconductor alternatives including lifetime cost analysis
Load and generation forecasts	Load and generation growth forecasts are increasing exponentially, which is fundamentally changing the assumptions for transmission planning
Planning forecast window	The planning forecast window is not standardized across transmission planning entities. This limits uptake of advanced conductors which generally become more cost effective with longer planning windows
Data/information gaps	Utilities lack visibility into system health and performance which limits the ability to deploy tactical solutions like reconductoring with advanced conductors
Institutional Barriers	
Equipment standards and purchasing policies	Utilities are slow to adopt new equipment like advanced conductors, frequently taking months to years to independently evaluate the technology
Practice, training, and tools for the handling of advanced conductors	Utility workers must be adequately trained and armed with the proper tools before advanced conductors can be deployed
Less institutional resistance to in-kind replacements	In-kind replacements face less friction in company purchasing decisions and regulatory approvals, even if increasing the capacity is warranted
Historical failures	The first generation of advanced conductors (early 2000s) suffered failures and this causes hesitation for adoption
Alternative solutions	Advanced conductors are not always the best solution compared to alternatives like tower-raising, dual circuits, bundled ACSR, and HVDC conversion
Coordination Barriers	
Siloing between transmission owners	Different transmission owners have different equipment standards and planning practices which limits advanced conductor adoption
No holistic, long-term regional planning	Short-term, reliability-only planning methods tend to favor quick, marginal improvements compared to projects that offer long-term benefits
Permitting Barriers	
Limited space for construction	Some existing lines are so space constrained that reconductoring is incredibly difficult
New environmental permitting can be triggered	If utilities face similar permitting barriers for reconductoring as new build, they will pursue new build instead
Lack of clarity for permitting reconductoring	Many transmission entities do not have clarity whether reconductoring could offer expedited permitting
Up-front Cost Barriers	
"Gold plating" concerns	Regulators are wary of approving advanced conductors due to the increased cost
Existing upward rate pressure	Rate pressure in many jurisdictions is encouraging planning entities to propose low-cost, near-term solutions instead of solutions that reduce costs in the long-term
Technical Barriers	
Age and health of existing structures	Existing structures must be healthy enough to allow for reconductoring
Long lines (>50 miles) can't be reconductored	Lines longer than ~50 miles are not limited by the conductor and reconductoring with advanced conductors offers little to no benefit
Outages	Some critical lines cannot be taken out for months to be reconductored
Substation equipment	Increasing line capacity typically requires increasing transformer capacity as well and transformer supply chain delays are an industry-wide problem

PLANNING BARRIERS

Most transmission organizations employ transmission planners who analyze the system and propose upgrades to comply with reliability standards, serve new customers, and connect new power generation. Their role is essential to identifying opportunities for reconductoring and promoting advanced conductor technology. Most, but not all transmission planning interviewees expressed optimism about using advanced conductors in their future system plans. However, interviewees identified several roadblocks that have historically prevented them from prescribing reconductoring with advanced conductors as a preferred solution. These barriers include workforce shortages, rapidly changing load and generation portfolios, limited planning horizons, and lack of accurate system information.

A **workforce shortage** of power engineers combined with backlogged generator interconnection queues has limited the capacity of transmission planning departments to integrate new conductor technologies into their plans. Transmission planning departments are typically tasked with completing North American Electric Reliability Corporation (NERC) compliance studies, generator interconnection studies, load addition studies, transmission service studies, and long-range (10- to 20-year) transmission plans. When completing these studies, transmission planners must limit the solutions that they test to ensure studies are completed in a timely manner. Assessing the advantages of reconductoring with advanced conductors requires complex techno-economic modeling to demonstrate cost-effectiveness and feasibility. When faced with a zero-sum decision between meeting FERC-mandated study deadlines and investigating reconductoring with advanced conductors, the latter often gets deprioritized.

Load forecasts and renewable generator interconnection requests have both increased dramatically over the last five years, **complicating the task of "right-sizing" transmission proposals**. Tension exists between wanting to prescribe the lowest-cost solution to fit needs and growing uncertainty about load and generation futures. The faster load and generation demands on the system grow, the more valuable the additional capacity afforded by advanced conductors becomes. Historically, in many regions load growth has been modest or even decreased for decades. Those patterns are changing quickly,[17] and planners and regulators want to ensure transmission upgrades move fast enough to support this growth, but not overbuild to put unnecessary upward pressure on rates. Planners want assurances that if they propose higher-cost advanced conductors to create greater headroom on the transmission system, they will still receive company and regulatory approval.

The planning forecast window used for transmission plans across the U.S. is not standardized, with many utilities using a 10-year planning window, while others use a 15- or 20-year window. Generally, a shorter planning window reduces uncertainty in the model, but it leaves important long-run considerations off the table. Longer planning horizons can show higher future transmission capacity needs, lending more value to higher-cost, future-proofing technologies like advanced conductors. This is especially true when evaluating the lifetime costs of conductors, because advanced conductors generally reduce losses by 10-30 percent, compared to standard ACSR, over the course of multiple decades.

Transmission planning departments also frequently **lack adequate information** on the existing system's health, which limits their ability to quickly identify opportunities to reconductor with advanced conductors. Reconductoring savings and speed are greatest when the existing structures are robust. This data gap was described by interviewees as especially pronounced between utility transmission departments and ISO/RTO planning departments. Several ISO/RTO interviewees expressed they have to accept or trust proposals from their member utilities because investigating reconductoring solutions is either outside of their scope or technically untenable with the data they have on hand.

Southern California Edison (SCE) reduces wildfire risk and increases capacity in the Big Creek 230 kV Corridor with ACCC®

SCE originally planned to mitigate wildfire risk by raising or rebuilding towers to avoid clearance violations. Instead, SCE found that by reconductoring the line with an ACCC® advanced conductor, it could minimize or eliminate tower raising costs while nearly doubling corridor transmission capacity. This removed load-shedding mitigations that would have been needed had additional capacity been unavailable. The project was eligible for a capital maintenance permit and was completed quickly.

Some entities, like the Midcontinent Independent System Operator (MISO), prioritize reuse of existing ROWs in their long-range planning process, which provides credibility for reconductoring projects when they seek local permitting. Other **entities do not expressly identify the reuse of existing ROWs as a priority** in their transmission plans.

INSTITUTIONAL BARRIERS

Reconductoring is a well-established transmission industry practice, and all interviewees were at least somewhat familiar with advanced conductor technology. However, in an industry that is historically slow to adopt new technology, several interviewees expressed concern over the use of advanced conductors in areas from ordering to construction to operation.

Equipment standards and purchasing policies are rigid, slow to change, and individually managed by each utility. In many cases, utilities require completing extensive equipment vetting themselves rather than using successful implementation by peers or studies from national organizations to justify adoption. For example, Bonneville Power Administration (BPA) recently announced that it will begin investigating advanced conductors, but "[i]t can take months or years of physical testing and analysis to ensure the new conductor will function as engineered within BPA's transmission system."[18] BPA's approach—studying the technology itself rather than relying on real-world deployments or other peer organizations' testing to approve the technology—appears to be the status quo among transmission organizations. This "bottom-up" adoption strategy considerably slows integration of many emerging technologies, not just advanced conductors.[19]

Multiple interviewees stated that lack of **practice, training, and tools for the handling of advanced conductors** is a significant practical barrier. Advanced conductor manufacturers offer hands-on training when supplying their product to new customers, but some entities expressed that their construction and operations crews would not support adopting new practices at this time. The lack of spare conductors and trained staff was a key concern of construction staff when advanced conductors were proposed as a solution.

Less institutional resistance exists to in-kind replacement projects than replacement with higher-rated conductors, even though in-kind replacement projects often do not provide optimal outcomes. Replacement in-kind projects tend to offer the lowest near-term cost, which can reduce regulatory scrutiny at the expense of greater efficiency and transmission capacity down the road. Some interviewees expressed **concern over historical failures** of advanced conductors observed during the first generation of composite core conductor technology in the early 2000s. Consensus did not exist among the interviewees on whether composite core technology was ready for deployment, with some entities highlighting their enthusiastic adoption of the technology and others stating the technology needed significant further study before

NV Energy uses ACCC® to serve rapidly growing loads and renewable generation in Nevada

NV Energy has installed more than 125 miles of ACCC® over 25 lines in Nevada to increase the capacity of existing transmission corridors, reduce sag for public safety, and allow for rapid load growth. NV Energy started using ACCC® in 2009 on a 115 kV reconductor project to avoid replacing existing structures. After using advanced conductors over the past 15 years, NV Energy crews now prefer working with ACCC® to bundled ACSR, and projects using advanced conductors have faster construction timelines. Common technical barriers of purchasing, spare stock, training, and maintenance have been overcome, and NV Energy has planned another 18 projects using ACCC®. In designated "high-growth areas" where large data center and manufacturing load growth is projected, NV Energy has worked with regulators to require ACCC® instead of ACSR to provide the optionality to serve load that will come online quickly.

they would consider using it. As the 2035 Report 4.0 demonstrates, advanced conductors have been adopted at scale both domestically and internationally, indicating this barrier is more institutional than technological.

While most interviewees believed that advanced conductors offered some potential, they noted many **other solutions also increased transmission capacity** within existing ROWs and, depending on the scenario, may be preferred over reconductoring with advanced conductors. For example, upgrading to a higher voltage, tower raising and tensioning, dual circuit conversion, bundled ACSR, and high-voltage direct current (HVDC) conversion all increase transmission capacity or reduce losses similarly to, or in some cases better than, reconductoring with advanced conductors. Interest also exists whether superconductor technology may reach broad commercial adoption and offer greater benefits than the advanced conductors available today.[4]

BPA aims to add 6 GW of transmission capacity, mostly by reinforcing existing transmission lines

BPA has launched a $2 billion investment in a portfolio of transmission projects in the Pacific Northwest that are estimated to add at least 6 GW of transmission capacity. Most of these projects will reinforce existing transmission lines using reconductoring, rebuilding, and substation upgrades. Instead of the comprehensive approach to advanced conductors taken by NV Energy, BPA is only evaluating whether advanced conductors can be used on its system. This evaluation will be lengthy, with Transmission Line Engineering Group team lead David Atkinson stating, "We are very much in the early stages of identifying which cable sizes to settle on, getting all the cable specified, getting all its supporting hardware identified and qualified." It could take months to years of physical testing and analysis before BPA is able to add advanced conductors to its library of approved equipment.

[4] In 2021, Commonwealth Edison energized its first commercial superconductor project. The project was designated by FERC as a transmission asset and was approved for cost recovery. The project connects two

If feasible, transmission owners will typically pursue these alternatives instead of reconductoring. For example, ISO-NE utility VELCO recently changed the scope of a reconductoring project using advanced conductor steel supported (ACSS) conductor, a high-capacity conductor, to bundled ACSR when it found that despite higher up-front cost, the bundled ACSR solution reduced line energy losses enough to result in a lower lifetime expense.[20] In some cases, these are also viable alternatives, especially for very high capacity needs, but selecting the best option requires integrating choice between methods into planning. There does not seem to be a standard consensus on how to compare these various technologies and whether advanced conductors are being widely incorporated into these processes.

HVDC conversion alternative to new 500kV line may save millions and increase project speed for California Independent System Operator

The California Independent System Operator 2022-23 Transmission Plan proposed a new 180-mile 500 kV line between the Trout Canyon and Lugo substations, with an estimated cost of $1.5-2 billion. As an alternative, merchant developer Lotus Infrastructure proposed the "Mead - Adelanto Project Upgrade" (MAP Project) to convert the existing Mead-to-Adelanto 500kV line to HVDC while reusing the existing conductors, towers, and insulators to more than double the line capacity from approximately 1.3 GW to 3.5 GW. The developer says its proposal would materially reduce costs, environmental impacts, and permitting barriers. This project highlights savings that can be captured with other alternatives to new transmission beyond reconductoring with advanced conductors.

COORDINATION BARRIERS

U.S. transmission projects are planned and coordinated at a variety of levels, which requires different groups to align on technology adoption, cost allocation methods, and forecasting assumptions. This coordination occurs between departments inside single utilities, between neighboring utilities, and within state regulatory agencies, which all have differing goals and beliefs. These coordination barriers impact the industry in numerous ways. The responses collected below highlight how coordination complexity limits reconductoring with advanced conductors.

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substations in Chicago, increasing reliability and avoiding the need to acquire additional land and disturb existing infrastructure. The utility has plans to expand the project to connect additional substations in Chicago. See: M. Ross, "Utility Applications and Experience with Resilient Electric Grid Systems Utilizing High Temperature Superconductor Wires in Chicago," *Physica C: Superconductivity and Its Applications* 614 (November 15, 2023): 1354374, https://doi.org/10.1016/j.physc.2023.1354374.

Some interviewees described the failure of FERC Order 1000 to adequately spur regional transmission planning, especially in the non-ISO/RTO regions of the West and Southeast. The perception is that instead of triggering large, interregional transmission projects, the order paradoxically incentivized incumbent utilities to focus on smaller, local transmission projects. This, some interviewees believed, has supported a **siloing between transmission owners** preventing wider adoption of emerging technologies like advanced conductors. The suggestion of a programmatic reconductoring effort to increase system-wide capacity (as opposed to a "line-by-line" strategy) was not viewed as feasible to implement without better systems of regional coordination.

In many regions in the U.S., **no holistic approach exists to regional planning that incorporates long-term lifetime analysis** of transmission project alternatives. Instead, compliance with NERC's reliability criteria or individual generator interconnections drive which transmission projects are most urgently pursued. This "line-by-line" transmission project planning does not capture value streams afforded by advanced conductors like reduction in losses, wildfire risk prevention, and increased headroom for new generation that is more cost effective than incumbent power sources.

Tension remains between the views of transmission planners and transmission implementers on the subject of advanced conductors. Most RTO transmission planners, transmission owners, and utilities expressed moderate to strong support for using advanced conductors, particularly in reconductoring projects, but reported facing resistance from their facility design engineers and construction project managers. One interviewee stated it took a decade for construction crews to accept composite core advanced conductors (due to the new installation practices), but now the crews prefer advanced conductors to the alternative of bundled ACSR. Some ISO/RTO interviewees noted they are required to follow **equipment and construction standards** of their member transmission owners, which limits their ability to suggest reconductoring with advanced conductors as an alternative. ISO/RTO transmission planners generally defer to the transmission owner for conductor selection.

PERMITTING BARRIERS

Reconductoring is typically assumed to be far easier to permit than new greenfield transmission, often only requiring a maintenance permit. However, many interviewees observed this assumption is not always true and reconductoring can trigger lengthy permitting under environmental and local permitting rules. In addition, some of the best candidates for reconductoring can be older lines located in densely populated and growing areas, which makes the reconductoring process far more difficult than in a rural or more open area. The permitting barriers mentioned in the interviews include the following:

Older lines were often constructed with little to no environmental permitting, and material upgrades including reconductoring can **trigger new environmental permitting** at the state or federal level. In response to this concern, the DOE has issued a notice of proposed rulemaking to amend its regulations governing compliance with the National Environmental Policy Act. The proposed changes would broaden categorical exclusions to environmental review requirements for upgrading and rebuilding transmission lines.[21]

Old lines in dense urban areas with growing electric load can be excellent candidates for reconductoring but face unique challenges associated with construction and local permitting. Typically, these older lines also had much smaller clearances at the time of construction. After the lines were constructed, in many cases buildings were erected around the lines, **limiting available space for construction**. In these areas, it now can be difficult or impossible to complete reconductoring work. This is especially true for rebuild projects where the existing line must stay in service to serve load while new structures are built. However, while not all lines will ultimately be perfect candidates for reconductoring with advanced conductors, the 2035 Report 4.0 demonstrates that focus should be expanded to include rural lines enabling new renewable generation to access the transmission system.

A clear consensus is lacking among interviewees on permitting requirements for reconductoring. Many believed the process in their region was quicker than permitting new lines but also cautioned that reconductoring can trigger public hearings that can delay or terminate the project. Several interviewees did not agree reconductoring with advanced conductors would only require a maintenance permit and noted **permitting that requires public oversight** can often paradoxically limit reconductoring in favor of new transmission. The main advantage of reconductoring with advanced conductors is speed, and when reconductoring projects face permitting timelines similar to greenfield transmission, planners will instead tend to move forward with greenfield transmission.

UP-FRONT COST BARRIERS

Calculating and assigning cost responsibility for transmission projects is an ongoing discussion across the U.S. Although that discussion was beyond the scope of the interviews, the topic was raised through the lens of reconductoring. Several respondents noted up-front cost as the primary limiting factor to adoption of advanced conductors, which is exacerbated when projects straddle multiple utilities or states.

Planners noted that regulators are adamantly opposed to **projects that appear like "gold plating"** (the industry term for projects built with more capability than needed to allow utilities greater capital deployment). Since the up-front cost of advanced conductors is approximately two to four times that of standard ACSR,[22] regulators and consumer advocates want to ensure additional near-term capacity is needed to justify the additional expense.

Many regions are already seeing large rate increases because wildfires and extreme weather are causing grid planners and regulators to look elsewhere for opportunities

Montana's Public Service Commission embraces advanced conductors to simultaneously address wildfire resilience, reduce losses, and increase system capacity to save customers money

Montana utility regulators are allowing NorthWestern Energy to use advanced conductors despite their higher initial expenses by acknowledging significant long-term benefits. Per Montana Public Service Commissioner Randy Pinnoci, "Replacing old power lines with advanced, high-efficiency lines is the utility-scale equivalent of replacing an old lightbulb with a new, LED lightbulb—it's safer, more resilient, and more efficient." NorthWestern's 105-mile, 100 kV transmission line from Great Falls to Two Dot was approved including advanced conductors despite the higher up-front capital expense because customers will save money over the lifetime of the project. As explained by Commissioner Pinnoci, "In some circumstances, switching to high-efficiency power line can cut line losses by a third, and with time, the upgrades can pay for themselves. Better efficiency also makes better use of base load power generation and reduces the need to purchase energy at peak market prices."

to cut costs. This limits the desire to pursue projects with higher up-front costs like reconductoring with advanced conductors, despite the long-term benefits of advanced conductors that more than make up for these costs.

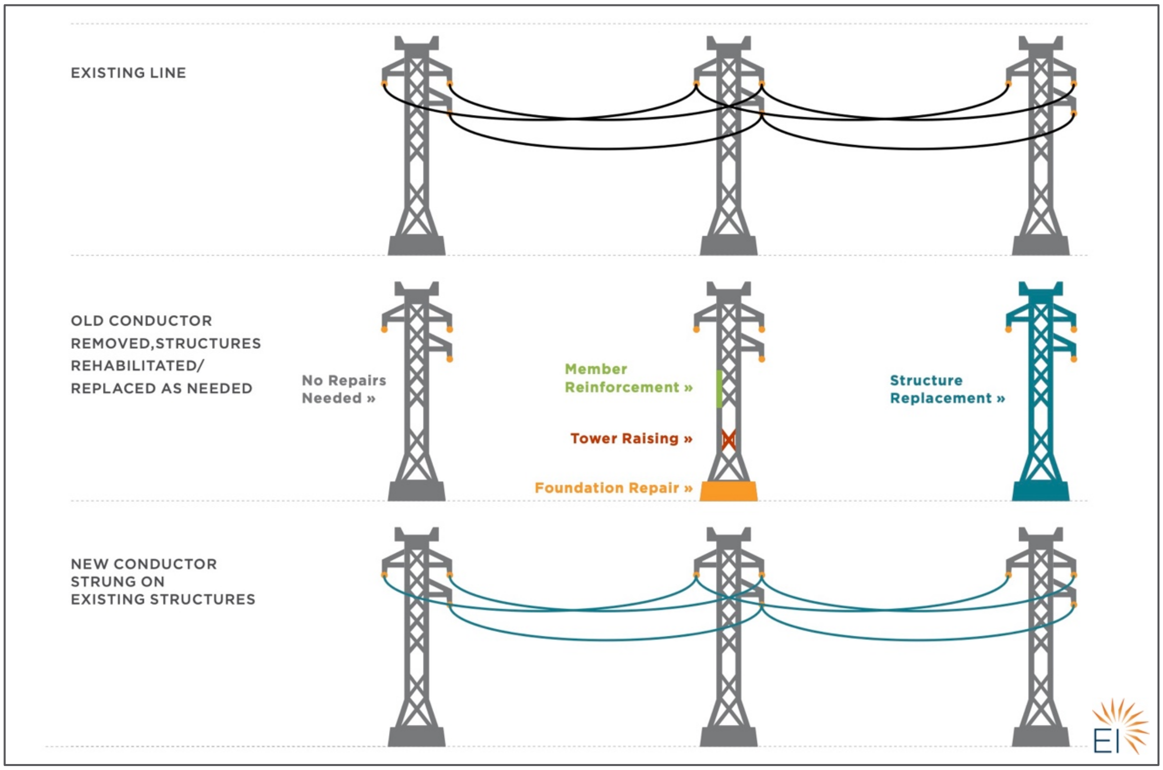
TECHNICAL BARRIERS

Beyond planning, coordination, and institutional barriers, technical barriers are limiting advanced conductor deployment. Many of these are surmountable with approaches explored in the 2035 Report 4.0, while others need policy fixes as explored below.

All interviewees viewed reconductoring with standard conductors as a well-established industry practice and something that should be pursued under the right technical conditions. However, consensus does not exist on what the right conditions are for reconductoring with advanced conductors. While many technical barriers could complicate a reconductoring project and make it unviable, different regions vary on their willingness to implement mitigation measures that could overcome these challenges.

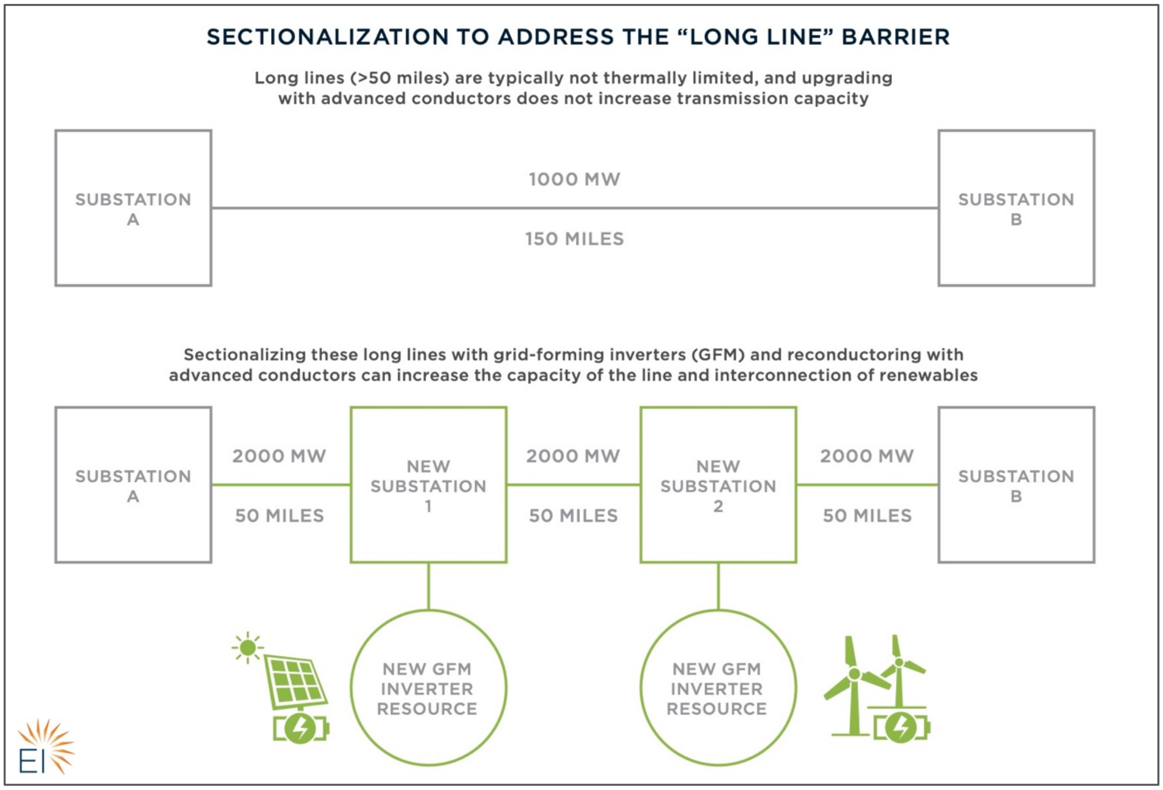
Broad concern suggests the **age and health of the existing structures** of the U.S. transmission system could eliminate viability of specific reconductoring projects. For example, an Idaho National Laboratory study finds that approximately 30 percent of existing transmission lines will need to be entirely rebuilt in the next decade.[23] If existing structures are no longer safe, a reconductoring project may no longer be financially feasible. However, little awareness exists of targeted structure rehabilitation strategies to mitigate these concerns which have been used in many U.S. regions (for example, companies like AmpJack provide services like tower raising in place and structural damage remediation that could enable reconductoring even on aged lines.)[24]

Figure 3. Reconductoring with tower remediation



Universally, transmission planning interviewees do not believe reconductoring with advanced conductors is a meaningful strategy for **“long lines”** (longer than approximately 50 miles), as these lines are almost never limited by the conductor material. Advanced conductors alone can only increase the thermal of a line, and they do not increase the stability or voltage drop limitations that set the capacity limits for long lines. Furthermore, interviewees assume, especially in the western U.S., that the most important place to increase transmission capacity is long, interstate lines. Therefore, reconductoring with advanced conductors is not a focus in many transmission plans because it is considered a method to increase key system capacity. No interviewees were aware of the solution proposed by researchers in the 2035 Report 4.0 to use sectionalizing substations with grid-forming inverters to realize the benefits of advanced conductors on long transmission lines.

Figure 4. Sectionalization of long lines can enable reconductoring capacity increases



Several transmission planning interviewees expressed concern that **NERC Transmission System Planning Performance Requirements** limit the ability to reconductor existing lines. Taking lines out of service to reconductor shifts the loading to surrounding, parallel lines during construction. While often not actually a violation of NERC requirements, it does increase the risk to lose load, and this risk is often viewed as untenable. Additionally, the heavily loaded lines that are the best candidates for reconductoring are often those that system operators can least afford to take out of service. Live line reconductoring is not common, but there is at least one example of this practice identified in the U.S., by AEP in Texas.

Reconductoring while energized; advanced conductors save reliability in Texas

The southeastern Texas Lower Rio Grande Valley reconductoring project was the longest in the world when it was completed. The project, finished in 2016, involved reconductoring two 120-mile transmission lines while energized with ACCC® conductor. The project increased the summer peak rating by 75 percent. Motivating factors included rapid population growth and seasonal peak demands. Conventional solutions such as new lines were considered but were seen as too risky due to permitting delays. Energized reconductoring of the line emerged as the only option, which did not require time-intensive permitting for new land acquisition and was approved the same day it was presented to ERCOT's Board of Directors in 2011. The $225 million project was completed several months ahead of schedule and millions of dollars under budget.

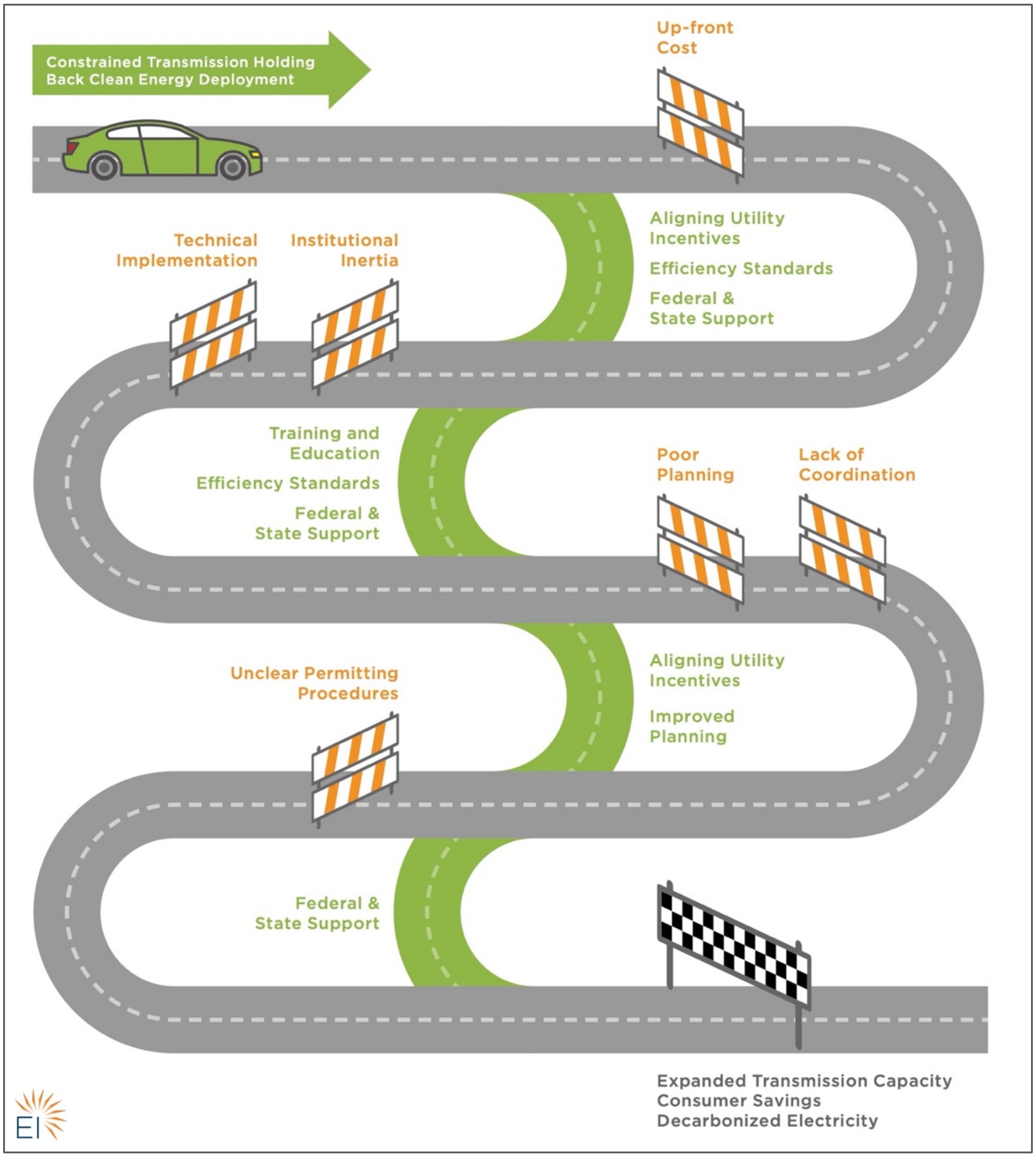
Some ISOs have specific **limitations on how much power can be transmitted in a single transmission corridor** to reduce the system impacts from a single line outage. In these cases, reconductoring with advanced conductors could push these lines over the ISO-imposed limits. Concerns over wildfire threats, which can take lines out of service for many days, exacerbate fears of increasing the size of single transmission line contingencies. For this reason, transmission planners view geographically diverse paths for transmission as more reliable than plans that upgrade existing paths to carry increased amounts of power.

Reconductoring transmission lines with advanced conductors often requires **replacing substation equipment** at the terminal substations. Several interviewees identified supply chain delays in acquiring large power transformers and breakers as a barrier to reconductoring with higher-rated conductors. In many cases, there is no reason to upgrade the conductor of the line if the substations it connects to cannot also be upgraded.

The transformer supply chain shortage has many causes, but interviewees expressed concerns about the limited domestic transformer manufacturing capacity. The U.S. currently manufactures only 20 percent of its large transformer demand.[25]

Many of these technical barriers, such as supply chain issues, reluctance to use new technology, and lack of consideration of advanced conductors compared to other technologies, can be addressed through public policy as detailed below. Others can be addressed by emerging approaches such as line sectionalization, targeted structure rehabilitation, and live line reconductoring.

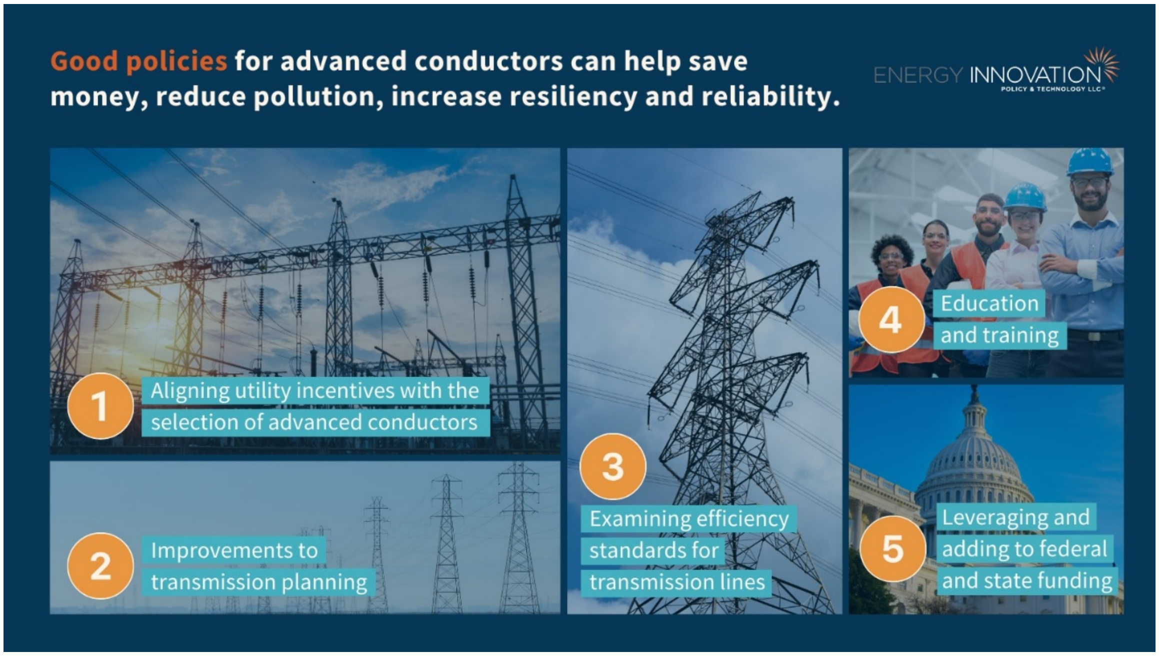
Figure 5. Overcoming barriers to reconductoring with advanced conductors through policy



POLICY RECOMMENDATIONS

While reconductoring existing transmission ROWs with advanced conductors faces diverse barriers, the benefits of widespread use are so promising, and the urgency of expanding transmission capacity so great, that focused policy efforts to ensure its adoption across the U.S. are needed now. Policy support at the state, regional, and federal levels could help deliver the benefits of advanced conductor technology to the U.S. electricity grid and its customers.

- First, aligning utility incentives around investment in advanced conductors is necessary to unlock the largest source of available capital for these upgraded lines.
- Second, transmission planning processes must be updated to accurately and adequately consider advanced conductor benefits and select them over other options that lack the same long-term cost-savings for customers.
- Third, developing conductor efficiency standards for transmission lines, akin to appliance efficiency standards, then promoting or requiring their use for every transmission project would help make their no-regrets use universal in both new-build and upgrade projects.
- Fourth, federal and state government support could steer transmission investments toward advanced conductor technology and provide the additional education and certainty that the industry needs to build confidence.
- Fifth, education and training on the technology and its benefits for planners and installers would reduce institutional inertia surrounding implementation.



ALIGNMENT OF UTILITY INCENTIVES

Given the benefits of advanced conductors, one might expect utilities would rush to adopt them – but advanced conductor adoption has been relatively slow. Like other efficient or advanced technologies that replace traditional utility business practices, reconductoring with advanced conductors presents challenges under current regulatory incentives. This can exacerbate barriers like utility planning alignment and workforce development. As has been true with other efficiency technologies, aligning utility incentives with the benefits technology provides will be key to wider adoption.

Utility business models are misaligned with advanced conductors in at least three ways.

- First, reconductoring with advanced conductors can appear as a lower capital expenditure opportunity when higher capital expenditures associated with a new transmission build create more opportunity to earn returns.
- Second, the scope of costs and benefits in utility plans may not align with the business case for advanced conductors.
- Third, incumbent transmission owning utilities face incentives to disregard the benefits regional and interregional transmission investments and independent regional transmission operators where none exists.

Correcting for Capital Expenditure Bias

As the 2035 Report 4.0 shows, widely embracing reconductoring with advanced conductors can reduce overall transmission capital expenditures compared to pursuing new greenfield development alone, and help rapidly integrate cost-effective clean energy. These avoided capital expenditures represent an opportunity cost for utility investors, who lose out on potential value when they pursue cheaper, less capital-intensive alternatives.[26] Where regulators encounter this barrier, they can consider using performance-based regulation approaches that boost utility returns for money-saving measures and penalize excessive spending to achieve the same outcomes.[27]

Despite the capital expenditure bias, embracing advanced conductors can also serve utilities' long-term interest. Utilities face rising costs from a range of factors, including volatile fuel costs, inflation-driven component price increases of generation and infrastructure, infrastructure upgrades to meet demand growth, and increased natural disaster recovery costs.[28] Peak demand is growing again due to booms in manufacturing, data processing and electrification.[29] Unlike the last 15 years, utility growth in the short and medium term is less likely to be constrained by the ability to justify deploying capital. Reconductoring is a cost-saving solution that creates headroom to reallocate capital for other expenditures while keeping rates manageable.

Utilities can embrace advanced conductors to mitigate rising costs and remove near-term transmission capacity constraints that are slowing capital expenditures on generation and demand growth.

Establishing Standards for Prudent Investment

Utilities also face regulatory environments that may not align with wide adoption of advanced conductors. The objective of long-term planning overseen by regulators is achieving the best or "least cost" resource mix for the utility and its customers that ensure reliable service for all, given any other policy constraints the utility must meet.[30] Least cost frameworks are open to consider a wide array of benefits, but regulatory precedent may not support some novel or relatively unknown benefits of advanced conductors that justify their upfront cost. These may include wildfire resilience, access to lower-cost generation capacity and energy, lower congestion and curtailment, longer lifetime, reduced line losses, renewable energy integration benefits, and future-proofing against higher load growth.[31] Furthermore, state or regional plans may not examine scenarios far enough into the future to capture the full benefits or avoided costs associated with reconductoring with advanced conductors. The reduced risk and faster timeline associated with reusing existing ROWs may also be outside of traditional benefits considered.

Montana legislation incentivizes reconductoring with advanced conductors

Montana House Bill 729, signed into law in May 2023, is a measure to provide utilities incentives for reconductoring with advanced conductors. This bill allows the Montana Public Service Commission to approve cost-effectiveness criteria for advanced conductors and to grant utilities a return-on-investment adder for using advanced conductors (defined as a conductor of equal diameter to those existing on the system that reduces electrical resistance by at least 10 percent).

State policymakers can help ensure regulated transmission providers consider the full range of benefits. State legislatures can encourage advanced conductor adoption by de-risking the technology for regulated utilities, as was done in Montana. Montana's HB 729 allowed the state Public Service Commission (PSC) to establish cost-effectiveness criteria for advanced conductors that would be eligible for rate recovery. The statute allows the PSC to "consider decreased electrical losses and any other relevant consumer, environmental, and system benefits provided by advanced conductors."[32]

State utility regulators can also investigate the benefits of advanced conductors on their own accord. The Montana PSC kicked off an investigatory proceeding to develop a commission policy position on advanced conductors before the legislation passed.[33] By convening technology providers and the regulated utility, the PSC was able to hold NorthWestern Energy accountable to begin identifying applications of the technology to its system in a collaborative approach.[34] Similarly, a Massachusetts law created a working group to evaluate future transmission technologies, putting research on advanced transmission technologies including advanced conductors in front of regulators.[35] Regulators can also pay special attention in rate cases to end-of-life transmission replacements, and require utilities to justify their selection of conventional conductors for rebuild or replacement projects.

Encouraging Investment in Regional Lines

Finally, incumbent utilities that own transmission face incentives to disengage from regionally beneficial transmission upgrades, including reconductoring with advanced conductors. FERC's Order 1000 created a regional planning regime that established regional planning entities and was meant to encourage long-term regional planning for a broader set of regionally shared benefits than near-term cost minimization. However, Order 1000 hasn't panned out the way it was planned—utility spending on transmission has increased since 2012 when the Order passed, but spending on regional high-voltage transmission projects has remained stubbornly low.[36]

Something must change to highlight the value of regional and interregional transmission, which reconductoring with advanced conductors can help serve. Utility incentives to maintain monopolies over generation and transmission, especially in non-RTO or vertically integrated regions, reduce the likelihood that utilities will proactively identify line upgrades or new lines that would reduce congestion or enable greater regional competition for transmission and power. FERC's regional planning rule can help, but state regulators and legislators in non-RTO regions should also skeptically evaluate whether the monopoly structures limiting competition and visibility of regional benefits underlying their industries continue to serve customers' best interest. State regulators in the West should continue to focus on building institutions for regional transactions and transmission planning, and those in the Southeast should get started in earnest, using collaboration frameworks established in the West and SPP as examples for how to begin incrementally.[37]

TRANSMISSION PLANNING

America's transmission planning process is highly fragmented, with regions taking different approaches to time horizons, benefits, cost allocations, and priorities. This has slowed regional transmission investments in the last decade to record low levels as utilities have focused on local projects. To deploy advanced conductors, several changes are needed to transmission planning to appropriately integrate this technology, both at the regional planning level and at the individual utility level.

MISO Long-Range Transmission Planning Tranche 1 leverages existing footprint to enable more than 53 GW of clean generation

The MISO Long-Range Transmission Planning (LRTP) process prioritizes re-use of existing ROWs, resulting in approximately 90 percent of the Tranche 1 projects re-using the system's existing footprint. To enable this result, MISO planning staff conducted an internal assessment of the viability of reconductoring or rebuilding transmission circuits throughout the MISO region. Reconductoring options with advanced conductors were included in the holistic long-range planning process, resulting in proactive identification of project options. LRTP projects are also designed with consideration of future circuit upgrade options to provide increased flexibility for future system needs, with some of the planned circuits designed to be potentially operated at a higher voltage and some potentially converted to HVDC. It is also noteworthy that the MISO planning process is conducted over a large region, enabling identification of cost-effective long-range solutions spanning MISO's footprint, and providing bidders with much more detail about the existing system to promote reuse of existing ROWs.

Regional Planning Processes

The upcoming FERC regional planning rule takes important steps toward updating regional planning processes to require forward-looking planning that accounts for multiple benefits.[38] Requiring a 20-year planning horizon clarifies the cost-benefit analysis of advanced conductors, due to both additional transmission capacity gains and improved efficiency. In addition to regional evaluation of transmission plans, the regional planning rule proposes requiring that transmission owners consider "right-sizing" lines that need to be re-built, instead of simply replacing in kind, which would encourage techniques to increase transmission capacity within existing ROWs. As regions come into compliance with the rule, and particularly as they define the benefits to measure against costs, FERC should ensure the proposed benefits consider the efficiency of the conductors used so consumers get the most value out of investments in the transmission grid via the use of advanced conductors.

In addition to the regional planning rule, FERC Order 2023 on generator interconnection reforms already required transmission providers consider alternatives to new transmission lines when upgrades are needed to connect a new generator, including the use of advanced conductors.[39] However, integration of the interconnection process with transmission planning would go even further to properly consider advanced transmission technologies like advanced conductors, and FERC should consider implementing such reforms in future rulemakings.

FERC should also consider additional actions beyond these two rulemakings and their compliance processes, such as the creation of independent transmission monitors (ITMs). Many states lack substantial review over transmission planning—for example, in California, 63 percent of projects from 2019 to 2022 were self-approved as "repair and replacement" projects.[40] An ITM could add transmission planning expertise capacity for states and regions to objectively evaluate transmission projects and ensure that transmission owners are considering projects that add significant value to customers at lower cost, like reconductoring with advanced conductors. An ITM could also help identify areas where reconductoring could create the most value, particularly for third party entities that may want to enter the market but lack visibility into the areas of highest need and opportunity for reconductoring. There could also be a role for the ITM to support coordination between ISO/RTOs and their member utilities on vetting and standardizing equipment, including advanced conductors.

States should consider creating independent transmission authorities, such as in Colorado and New Mexico. In New Mexico, the NM Renewable Energy Transmission Authority (NM RETA) enables transmission line development as an investor and co-developer and has already collaborated on two operational lines with four more in development.[41] State transmission authorities should not only focus on building new lines, but also explore opportunities for reconductoring with advanced conductors. Here, co-investment from the state authority could help offset the up-front costs and prioritize the long-term investment benefits, particularly with respect to state public policy goals.

Utility Planning Processes

State legislators and regulators, recognizing advanced conductors can have benefits that are not always borne out in regulatory processes, should proactively ensure utilities are considering advanced conductors, both building new lines and reconductoring old lines. In Virginia, the state legislature passed a bill that would require utilities' integrated resource plans to assess the potential of both advanced conductors and grid-enhancing technologies (GETs), which include dynamic line ratings, advanced power flow, and topology optimization software, for instance.[42] And in California, legislators have introduced a bill signifying their intent to integrate advanced conductors into the state's transmission system to increase efficiency and reduce costs to ratepayers.[43] This is alongside a bill requiring the public utilities commission (PUC) to study benefits from advanced conductors and GETs, particularly on cost, efficiency, and grid capacity and reliability improvements.[44] Other state legislators should follow these examples to send a strong signal to utilities and their regulators that advanced conductors not only are permitted under least-cost regulation, but also are a priority.

For vertically integrated utilities, electricity regulators should also require utilities to include transmission planning in integrated resource plans to better co-optimize generation and transmission planning. For many utilities, generation and transmission planning occur in separate silos, which miss opportunities for savings. For example, the 2035 Report 4.0 found it can be cheaper on a system-wide level to sacrifice small economic efficiency on the generation side to avoid much larger additional transmission spend. In fact siting new generation, particularly wind and solar, close to existing transmission lines can be very cost effective. Since reconductoring an existing ROW with advanced conductors is much cheaper and faster than building an entirely new line, this can be the least-cost system-wide approach.

EFFICIENCY STANDARDS

Another approach to encourage wider use of advanced conductors is creating industry energy efficiency standards. Along with offering significantly increased thermal capacity that is vital to integrating renewable energy projects demonstrated in the 2035 Report 4.0, advanced conductors reduce transmission losses between 10 and 30 percent.[45] Grid Strategies estimated nationwide adoption of this technology could save consumers $2.2 billion annually via loss reduction, in addition to the consumer benefits of access to low-cost renewables.[46] Efficiency standards would form a backstop to ensure adoption of this vital technology where utility adoption is too slow or regulatory support is lacking.

The DOE has authority under 42 U.S. Code Subchapter III, Part 1-A to promulgate efficiency standards for industrial equipment. While the law does not explicitly authorize the DOE to issue efficiency standards for transmission conductors, it does provide authority for the agency to identify certain industrial equipment for standards that would be necessary "in order to conserve the energy resources of the Nation."

To resolve any legal ambiguity, Congress could further clarify the DOE's authority to promulgate standards specifically for transmission conductors, as it did in 1992 for distribution transformers, another key piece of electric grid infrastructure.[47] In the FY-23 Energy & Water Development Appropriations bill, the U.S. House of Representatives directed the DOE to study the benefits of such an efficiency standard.[48] The DOE should promptly finalize this analysis and proceed to rulemaking, and Congress should continue to appropriate funds for the study and rulemaking process. Similar to the distribution transformer program, Congress could also authorize the DOE to make grants to utilities or manufacturers to reduce the up-front cost of advanced conductors.

Even without mandatory technology standards, industry can do much more to study and support advanced conductor adoption. Electric utilities can make headroom for investments in load growth, auxiliary equipment, and renewable generation if they proactively approach reconductoring with advanced conductors. By working together through industry-backed research organizations like EEI, EPRI, and ESIG, the industry can establish a robust record and foster best practices around this technology to facilitate state and federal adoption of appropriate standards and potential public funding. The industry can also foster the exchange of best practices between utilities for using advanced conductors to implement novel planning approaches such as line segmentation explored in the 2035 Report 4.0, as well as identify synergies with utility and state clean energy and net-zero goals.

FEDERAL AND STATE SUPPORT

Using Existing Funding Sources

The federal government has allocated modest funds to the resilience of transmission infrastructure through the Inflation Reduction Act (IRA) and the IIJA, but the funds are barely reaching projects that aim to reconductor existing transmission lines with advanced conductors.

The IIJA funding available for reconductoring largely flows through the Grid Resilience and Innovation Partnerships (GRIP) program at the DOE's Grid Deployment Office, which has $10.5 billion available to upgrade the transmission and distribution system. This office has already completed the first round of funding, announcing $3.46 billion in investments in October 2023, and another round of funding at $3.9 billion in November 2023. Of the first tranche of funded projects, only two of 58 explicitly mention upgrading conductors on transmission lines to increase capacity.[49] These two projects will receive $196 million of federal funding, representing only about 5 percent of the funds awarded. Three others aim to harden both transmission and distribution lines to increase resiliency, but they do not explicitly use advanced conductors.

With more than $6.5 billion left to award through the GRIP program, the DOE should aim to significantly increase the percentage of funds granted to projects that reconductor existing transmission lines with advanced conductors. To do so, the DOE should continue explicitly prioritizing applications for projects that reconductor transmission lines with advanced conductors,[50] and add use of advanced conductors as a criterion to evaluate applications, particularly for projects that are already seeking to upgrade existing transmission lines.

The DOE should apply the same lens to other IIJA and IRA funding programs, including the Grid Resilience State and Tribal Formula Grants, which will distribute $2.3 billion to states and Tribes over the course of five years, and the Transmission Facilitation Program, which aims to fund new, shovel-ready transmission lines. For projects funded by this program, the DOE should encourage using advanced conductors in new line construction to expand transmission capacity as quickly as possible. The DOE Loan Programs Office has identified reconductoring with advanced conductors as an eligible application of the Energy Infrastructure Reinvestment program authorized by the IRA and should continue promoting advanced conductors in all projects funded by the program.

Longstanding programs can also help. State Energy Program grants that offer states federal matching block grants for state energy office activities on efficiency can be used to study state-specific opportunities and benefits of reconductoring. These studies can consider cost savings as well as efficiency, land-use, and resilience benefits in state planning. In addition, the State Climate Pollution Reduction Grants, which are currently moving from plan submissions to the U.S. Environmental Protection Agency and toward implementation, could include advanced conductors in any state general support for clean energy deployment. Implementation grants are funded with approximately $4.6 billion.[51]

Additional Congressional Support

Congress should continue expanding funding opportunities for reconductoring via new legislation and appropriate all authorized funds to these existing programs each year. Additionally, as many of the projects funded by the GRIP program are at more local scales, creating new funding mechanisms that target expanded reconductoring of intraregional lines can enable the type of upgrades studied in the 2035 Report 4.0.

Beyond grant funding, tax policy has an important role to play. Both the House of Representatives and the Senate have proposed bills to expand the investment tax credit to transmission lines. Expanding the tax credit would create an important incentive to reconductor transmission lines studied in the 2035 Report 4.0 by requiring new lines between 100 kV and 300 kV to use advanced conductors in order to qualify for the incentive. This incentive should be technology neutral, based on the resistance of the conductor. For example, the 100 - 300 kV incentive could apply to conductors that have a direct electrical resistance at least 10 percent lower than existing conductors of a similar diameter, as in the Montana bill on conductor efficiency.

National Target for Increased Transmission Capacity

Despite thousands of miles of advanced conductors deployed in the U.S. and around the world, utilities have been slow to move forward with their widespread use. Instead, advanced conductors are presently used primarily when no other option will work—such as long river crossings where high-strength lines are required and in projects facing time and space constraints.

To coordinate federal resources and create certainty for manufacturers of advanced conductors and utilities, the president should consider setting a federal target for increased transmission capacity by 2030, which would help accelerate deployment of advanced conductors to meet short-term transmission needs. Setting a target for 2030 would help deploy the 30 percent of additional transmission capacity the country needs to cost-effectively integrate new wind and solar energy onto the grid. This would help create certainty to guide manufacturers, labor organizations, and supply chain companies. The DOE could also strengthen support for reconductoring with advanced conductors by commissioning a federal study on the potential for sectionalizing substations with grid-forming inverters to increase the number of lines that are good candidates for reconductoring with advanced conductors, validating results shown in the 2035 Report 4.0.

Defense Production Act Funding for Transformer Supply Chain

Long lead times for new large power transformers are creating a supply chain bottleneck across the electricity system, as they are needed to install new generation and transmission as well as for many projects that involve reconductoring with advanced conductors due to the changes in current across the lines.

Currently, only eight companies in the U.S. produce transformers, accounting for just 20 percent of national transformer supply.[52] Providing emergency funding via the Defense Production Act (DPA) to ramp up production by these companies could alleviate the shortage, enabling expansion of the entire U.S. electricity grid in addition to the use of advanced conductors. In 2022, President Biden declared that transformers are essential to national defense,[53] and the DOE subsequently issued a Request for Information on use of the DPA for transformer manufacturing.[54] The DOE should finalize this process, and Congress should appropriate funds to increase production at U.S. transformer facilities as soon as possible.

To further shore up the supply chain, the DOE could extend DPA to the materials and components needed to manufacture transformers, alongside creating a backstop procurement program to foster certainty that demand for transformers will continue beyond the current surge.

California legislature removes hurdle for reconductoring projects

California Senate Bill 529 (Hertzberg, 2022) required the California PUC to update its General Order (GO) 131 to allow utilities to use a streamlined permit-to-construct process when expanding or upgrading existing transmission facilities. The legislation directs the PUC to exempt projects of an "extension, expansion, upgrade, or other modification of an existing electrical transmission facility, including transmission lines and substations" from the need to seek a Certificate of Public Convenience and Necessity. Instead, these projects will be routed through an expedited permit to construct process.

Permitting

While re-using existing ROWs can require a less onerous permitting process, the DOE should simplify the federal permitting process for reconductoring with advanced conductors via a categorical exclusion to environmental review under the National Environmental Policy Act.

This would eliminate the potential for many of these projects to trigger the need for lengthy environmental impact statement processes. The DOE has had a categorical exclusion in place for repair and maintenance of transmission facilities since 2011,[55] but it specifies replacement with conductors of the same nominal voltage as the existing conductors. The DOE should finalize its planned expansion of this categorical exclusion to apply directly to reconductoring with advanced conductors as soon as possible.[56]

States, too, can accelerate the permitting process for advanced conductors, and should review their permitting processes to identify ways to accelerate reconductoring. For example, California passed a bill directing its PUC to specify a shortened process for permitting modifications to transmission lines compared to constructing new lines. To create consistency, where applicable, states should adopt the same categorical exclusion that the DOE finalizes.

EDUCATION AND TRAINING

Academic institutions, researchers, and the DOE's national laboratories can help address many of the educational and training barriers that have prevented uptake of advanced conductors.

First, despite the many successful installations of advanced conductors in the U.S. and internationally, skepticism remains regarding their widespread use. These thought leaders should study and present success stories and novel solutions to industry, regulators, and legislators to combat objections and myths. For example, the generally held belief that reconductoring does not address operating limits of "long lines" can be addressed with the novel "sectionalization" technique offered in the 2035 Report 4.0. National laboratories should consider advanced conductors in technology assessments, such as the National Renewable Energy Laboratory Annual Technology Baseline, to support confidence in the technology's readiness. In addition, though the historical failures of the first wave of advanced conductors occurred nearly two decades ago, the belief remains in much of the industry that advanced conductors are not ready for commercial adoption. Authoritative research should investigate how the industry has improved and publish findings to dispel this belief.

Second, preparing the workforce for installation of advanced conductors and a comprehensive build-out of new transmission lines is a crucial step in bringing the vision of the 2035 Report 4.0 to fruition. The U.S. Department of Labor, U.S. Department of Commerce, U.S. Department of Education, organized labor, and systems of higher education should evaluate the workforce needs for a highly electrified economy, and Congress should appropriate funds to training programs, particularly those focused on preparing existing workers to use advanced conductor technology. This workforce expansion will need to encompass power system engineers, electricians, and linemen, alongside welders, construction workers, crane operators, and other skilled laborers to address the aging health of structures and leverage the existing transmission system's ROWs. Expanding existing union training programs, particularly those through the International Brotherhood of Electrical Workers, developing community college programs, and creating opportunities to upskill the current workforce to work with advanced conductors will all be essential pieces of the puzzle. Some manufacturers, like CTC Global, already offer comprehensive trainings to installers on how to use their

ACCC® technology, providing a potential blueprint for rapid preparation of existing workers.[57] Models for workforce expansion already exist at the federal level, as shown via the Good Jobs Challenge created by the American Rescue Plan, which funded 32 workforce training partnerships across a variety of industries including grid modernization.[58]

CONCLUSION

Advanced conductors present an important near-term opportunity to expand the transmission grid along existing transmission ROWs, particularly as the U.S. electricity system strains under the combined weight of new generators and new demand trying to come online. While research shows the vast potential for customer savings and clean energy deployment, using these conductors has lagged as utilities and their regulators avoid higher up-front costs despite significant benefits, instead sticking to the status quo.

Now, with few other options left to quickly expand the transmission system, federal and state policymakers, utility regulators, and grid operators must act to enable widespread use of advanced conductors while simultaneously smoothing the path for new transmission build in the long-term. Key policies to deploy advanced conductors quickly include new legislation to require consideration of advanced conductors by utilities, technology standards to their drive adoption, clear permitting procedures for reconductoring, additional funding, and improved planning processes. The technology is ready, and now is the time for implementation.

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