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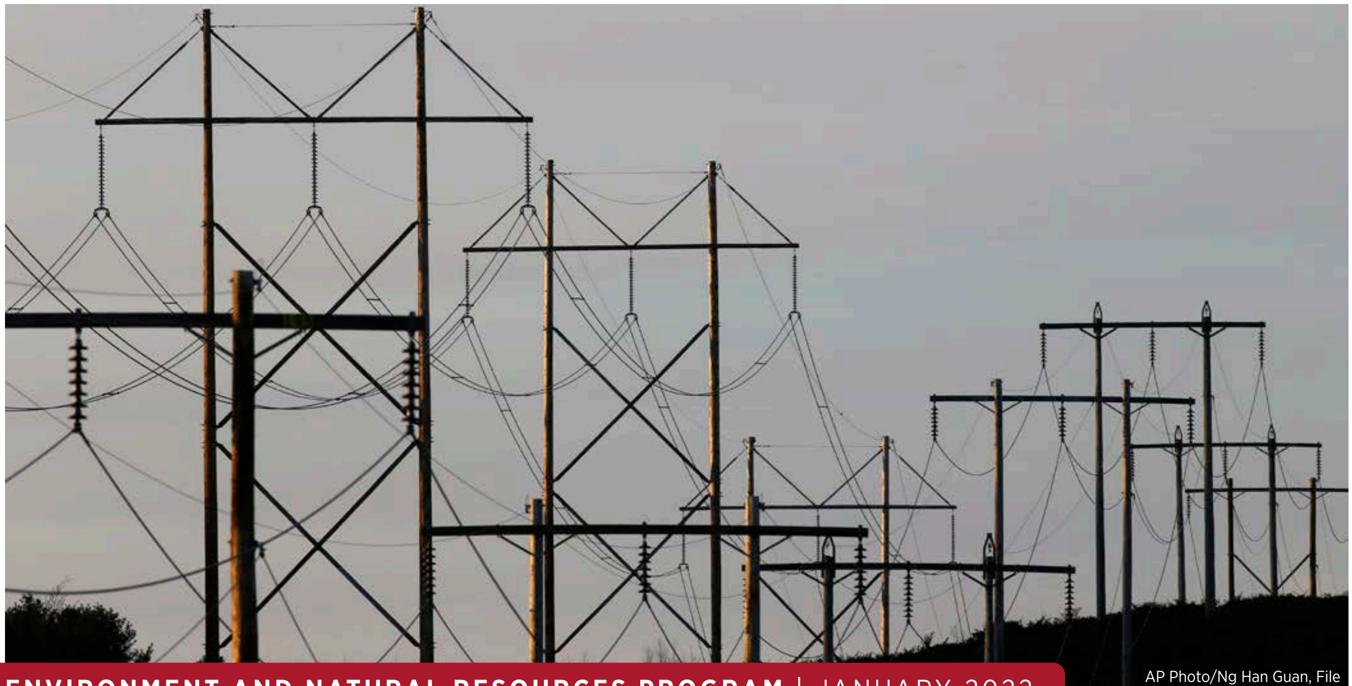

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The Challenges of Decarbonizing the U.S. Electric Grid by 2035

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The Biden administration has established a national goal of 100% carbon-free electricity by 2035 and reaching net-zero economy-wide greenhouse gas emissions by 2050.[1] To realize these goals, the United States must not only transition the production of power, but also build thousands of miles of upgraded or new transmission. The U.S. electric grid consists of 600,000 miles of transmission lines connected to over 1 million megawatts of electricity generation capacity.[2] Over 70% of these

1 The White House, April 2021. "FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies." Last retrieved December 3, 2021, from https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

2 Office of Electricity, U.S. Department of Energy. "Grid Modernization and the Smart Grid." Last retrieved December 3, 2021, from https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid.

lines are more than 25 years old, well into their approximately 50-year lifetime.[3] Furthermore, to meet President Biden's 2050 goal, experts claim that over a million miles of new transmission will have to be built over a three-decade time span.[4]

Most plausible pathways to net-zero emissions call for the electrification of multiple services, such as heating and transportation.[5] The resulting increase in electricity demand will require major upgrades to the grid, with some studies suggesting a 60% increase in peak demand by 2050.[6]

In the United States, the greatest potential wind energy resources are in the Midwest and along the two coasts,[7] while the greatest solar energy resources are in the Southwest and in Florida.[8] New transmission lines will be needed to carry the electricity from the areas where the renewable resources are most plentiful to distant load centers.

Integration of renewables is a challenge due to the intermittent nature of wind and solar power.[9] Solutions to the intermittency problem include a combination of relying on clean backup power sources (hydroelectric facilities, hydrogen fuels, and, in the short term, natural gas), storage, and demand responses.[10] The lower capacity factors for wind and solar generation[11] mean that transmission dedicated to variable renewable power will also have lower utilization rates than transmission supporting firm power sources and higher costs per unit of power transported. Hence in the future, the costs of upgrading and expanding the grid may become a much higher percentage of the overall costs of the electric system.

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3 American Society of Civil Engineers, 2021. "2021 Report Card for America's Infrastructure: Energy." https://infrastructurereportcard.org/wp-content/uploads/2020/12/Energy-2021.pdf.

4 The National Academies of Sciences Engineering Medicine, 2021. "Accelerating Decarbonization in the United States Technology Policy and Societal Dimensions." https://www.nationalacademies.org/our-work/accelerating-decarbonization-in-the-united-states-technology-policy-and-societal-dimensions.

5 E.g., Williams, J.H., R.A. Jones, B. Haley, G. Kwok, J. Hargreaves, J. Farbes, and M.S. Torn, 2021. "Carbon-Neutral Pathways for the United States." *AGU Advances*, 2(1), e2020AV000284. https://doi.org/10.1029/2020AV000284.

6 Larson, E., C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, 2020. "Net-Zero America: Potential Pathways, Infrastructure, and Impacts, interim report." Princeton University. Princeton, NJ, United States. https://netzeroamerica.princeton.edu/the-report.

7 Roberts, B.J., 2017. "Wind Resource Maps." National Renewable Energy Laboratory. https://www.nrel.gov/gis/wind-resource-maps.html; Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa, 2015. "Overview and Meteorological Validation of the Wind Integration National Dataset Toolkit." Technical Report, NREL/TP-5000-61740. Golden, CO: National Renewable Energy Laboratory.

8 Roberts, B.J., 2018. "Solar Resource Maps." National Renewable Energy Laboratory. https://www.nrel.gov/gis/solar-resource-maps.html; Sengupta, M., Y. Xie, A. Lopez, A. Habte, G. Maclaurin, and J. Shelby, 2018. "The National Solar Radiation Data Base (NSRDB)." *Renewable and Sustainable Energy Reviews* 89 (June): 51-60.

9 Bird, L., M. Milligan, and D. Lew, 2013. "Integrating Variable Renewable Energy: Challenges and Solutions." National Renewable Energy Lab. NREL/TP-6A20-60451. Golden, CO, United States. https://doi.org/10.2172/1097911.

10 E.g., Larson et al., 2020.

11 U.S. Energy Information Agency, 2021. "Electric Power Monthly." U.S. Department of Energy. Washington, D.C., United States. https://www.eia.gov/electricity/monthly/.

If solar and wind systems are built at community scale through greater reliance on mini-grids, substantial investments in the grid will still be needed. The electric grid was designed for flows from the high voltage grid to the distribution system and then final customer loads. In a scenario in which electricity systems rely on distributive energy systems like roof-top solar collectors and many small generators, power flows need to be reversed. Local distribution systems will need to be upgraded with new infrastructure, such as smarter transformers, to manage and to monitor power flows in and out of the local distribution system in order to avoid overloads. Further reforms will be needed to give hundreds of grid operators the ability to monitor and manage the interaction between local suppliers and local loads while retaining voltage and frequency levels. Modeling studies of the economics of achieving a net-zero carbon emissions grid generally find that centralized wind and solar generation is significantly cheaper than the mini-grid option.[12] This conclusion assumes that new transmission can be approved, sited and constructed in a reasonable time frame and that these lines will not have to be buried to satisfy local interests. If these assumptions prove wrong, community level grids may look more promising.

Recent studies have concluded that the efforts to create an emissions-free electricity sector will require a massive expansion of the electric grid in order to reach net-zero emissions by mid-century, with total transmission capacity increasing by 2–5 times from current levels and transmission investments totaling up to $2.4 trillion.[13] There are multiple technical, economic, and public policy challenges to expanding the grid by this magnitude.

First, there is a lack of coordination between regional and national transmission planning. The organizations responsible for regional transmission planning are often legally constrained from prioritizing the reduction of carbon emissions. Furthermore, construction of new transmission requires an extensive siting and permitting process that can stretch for over a decade and may put the goal of a carbon-free electric grid by 2035 out of reach. The result is an economic-based chicken and egg problem, with transmission developers hesitant to build, not knowing whether the generators will provide the power to fill the new lines, and investors in new renewable generation are equally reluctant to invest when the availability of transmission to move their power is in doubt.[14] We focus in this policy brief on the transmission challenges in an electricity system heavily reliant on intermittent renewables. If left unsolved, these obstacles could significantly raise the costs of a widespread expansion of utility scale renewable power.

12 E.g., Larson et al., 2020; William et al., 2021.

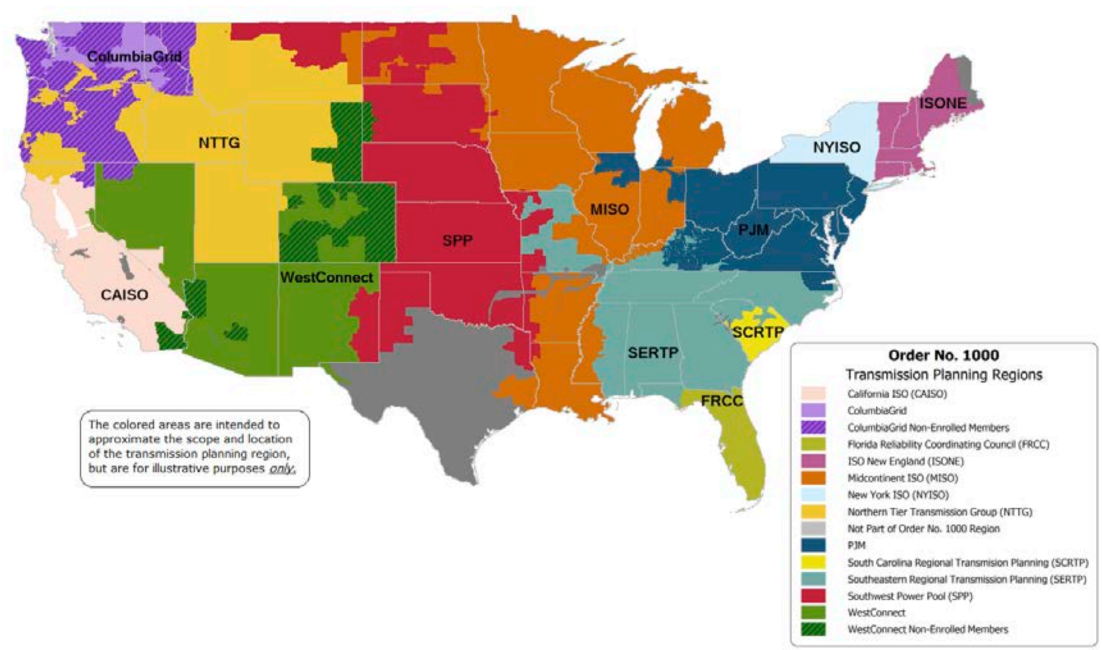
13 Larson et al., 2020; Williams et al., 2021.

14 The National Academies of Sciences Engineering Medicine, 2021.

Transmission Planning—Current Processes and Challenges

The continental U.S. electric grid comprises three separate grids: the Eastern Interconnection, the Western Interconnection, and the ERCOT Interconnection (Texas).[15] Underpinning these grids, transmission planning is generally done at a regional or sub-regional level under the auspices of Independent Service Operators (ISO)/Regional Transmission Organizations (RTOs), local balancing authorities (BAs), or in the case of the Southeast, utility companies (e.g., Duke Energy or Southern Company).[16] The Federal Energy Regulatory Commission's (FERC) Order 1000 directed that public utility providers must participate in regional transmission planning processes, designating 11 transmission planning regions, including the six ISO/RTOs (Texas's ERCOT is not under FERC's jurisdiction) and five planning associations set up by transmission owners and utilities.[17]

Figure 1. Transmission Planning Regions as Designated by FERC Order 1000



Source: Federal Energy Regulatory Commission.[18]

15 Office of Electricity Delivery and Energy Reliability, 2015. "United States Electricity Industry Primer." U.S. Department of Energy.DOE/OE-0017. https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf.

16 Staff of the Federal Energy Regulatory Commission, 2020. "Energy Primer: A Handbook for Energy Market Basics." https://www.ferc.gov/media/energy-primer-updated-6320.

17 Federal Energy Regulatory Commission, 2021. "Regions Map Printable Version Order No. 1000." Last retrieved December 3, 2021 from https://www.ferc.gov/media/regions-map-printable-version-order-no-1000.

18 Ibid.

All 11 transmission planning entities are required to produce plans to advance grid efficiency and cost effectiveness.[19] Each ISO/RTO develops annual to tri-annual transmission plans to improve regional grid operations, ensure performance reliability and cost certainty in the system, and incorporate input from stakeholders such as utility companies, public officials, regulators, generators, and advocacy groups.[20] The planning process varies by region, but generally involves economic and grid stability modeling and identifying key inputs that affect the adequacy of the transmission system.[21] Once a plan exists, the ISO/RTO is able to evaluate proposed transmission projects and to determine whether the projects are beneficial based on the ISO/RTO's established criteria. If a project is approved, it is eligible for cost recovery using the ISO/RTO's methodology.[22]

But existing cost recovery mechanisms are often themselves barriers to construction of new transmission. Cost recovery methodologies employed by the ISO/RTOs are governed by FERC Order 2003[23] and Order 1000,[24] with the common practice being for a developer of a large renewable generation facility to petition to gain access to specific transmission lines, usually located near the facility. In some cases, these lines will need to be upgraded or new lines built along the existing corridors. New facilities connecting to the grid are then usually responsible for funding most of any needed transmission upgrades. This system, often referred to as "beneficiary pays,"[25] aims to fund new or upgraded transmission by making the entities that benefit pay in proportion to the benefits derived from the new transmission. In many cases this concentrates costs on the new power generators that trigger the need for transmission upgrades, even though new transmission may benefit more than just the potential new generators and their customers. However, the major challenge is neither FERC nor the courts have issued rules on how to determine who the beneficiaries might be. The absence of clarity on questions of cost allocation inhibits investors on new transmission. This issue will either be decided through lengthy litigation or though regulatory actions at the federal level. In either case, this issue is likely to slow the pace of transmission improvement at exactly the time that those investments should be accelerating.

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19 Eto, J.H., 2017. "Planning Electric Transmission Lines: A Review of Recent Regional Transmission Plans." Lawrence Berkeley National Lab. (LBNL), Berkeley, CA, United States. https://doi.org/10.2172/1351315.

20 Caspary, J. "Electric Transmission 101: Markets, ISO/RTOs and Grid Planning/Operations." Southwest Power Pool. Last retrieved December 3, 2021 from https://www.eesi.org/files/070913_Jay_Caspary.pdf.

21 ICF International, 2016. "Comparison of Transmission Reliability Planning Studies of ISO/RTOs in the U.S." https://nescoe.com/resource-center/t-planning-comparison-feb2016/.

22 Caspary.

23 Federal Energy Regulatory Commission, 2003. "Order No. 2003 - Standardization of Generator Interconnection Agreements and Procedures." 68 Fed. Reg. 49854. https://www.ferc.gov/industries-data/electric/electric-transmission/generator-interconnection/final-rules-establishing.

24 Federal Energy Regulatory Commission, 2011. "Order No. 1000 - Transmission Planning and Cost Allocation by Transmission Owning and Operating Public Utilities." 76 Fed. Reg. 49842. https://www.ferc.gov/electric-transmission/order-no-1000-transmission-planning-and-cost-allocation.

25 Hogan, W.W., 2018. "A Primer on Transmission Benefits and Cost Allocation." *Economics of Energy & Environmental Policy,* 7(1), 25–46. Retrieved from: https://www.jstor.org/stable/10.2307/27030612.

The other problem with existing transmission planning is the focus on upgrades that are linked to the location of new generation. Instead, it may be more cost effective to assess the needs of the whole network. For example, instead of upgrading specific lines, the better answer may be to upgrade the grid by adding several smaller lines in other parts of the system, thus increasing the capacity of the entire network as opposed to a particular corridor. It is important to remember that electricity does not follow a linear path, but rather flows throughout the system in response to resistance. This conclusion was recently illustrated by a team from the engineering department at Tufts University in assessing the transmission improvements needed to transmit the power from wind developments off the coasts of New England and the Mid-Atlantic states to load centers in the two regions.[26] Transmission planning and cost allocation processes focused on nearby upgrades for individual projects can also inhibit construction of interregional transmission projects that enable the cost effective interconnection of multiple new generation facilities dispersed over a broader region.[27]

FERC Order 1000 also requires that the regional transmission planning process consider state, federal and local laws and regulations.[28] Through this requirement, the process can consider state or federal decarbonization goals. However, the main focus of the ISO/RTOs and regional transmission associations is to ensure system stability at the lowest cost. Of the seven ISO/RTO bylaws (or other relevant governance documents for transmission planning), only PJM has included environmental issues in transmission planning.[29] Furthermore, FERC explicitly states in Order 1000 that, "In requiring the consideration of transmission needs driven by Public Policy Requirements, the Commission is not mandating fulfillment of those requirements," rather that these policies be considered in terms of how they might affect transmission.[30] The responsibility for low-carbon transmission planning is thus passed from the states to entities that are proscribed from considering it as a core concern.

Second, there is a lack of coordination between transmission planning regions magnified by an absence of clear guidance from FERC to both the ISO/RTOs and the state regulators. Although FERC Order 1000 aimed to improve interregional transmission planning, such improvements have

26 Smith, K., S. Lenney, O. Marsden, B. Kates-Garnick, A. Stankovic, E.M. Hines, 2021. "Offshore Wind Transmission and Grid Interconnection across U.S. Northeast Markets." Offshore Power Research and Education Collaborative, OSPRE-2021-01. Power Systems and Markets Research Group, Tufts University. https://createsolutions.tufts.edu/wp-content/uploads/2021/08/OSW-Transmission-and-Grid-NE.pdf.

27 Pfeifenberger, J.P., 2021. "A Call for More Pro-Active, Multi-Value Transmission Planning." Energy Systems Integration Group. https://www.esig.energy/a-call-for-more-pro-active-multi-value-transmission-planning/.

28 Federal Energy Regulatory Commission, 2011.

29 PJM Interconnection, LLC, 2011. "Amended and Restated Operating Agreement of PJM Interconnection, L.L.C." https://www.pjm.com/directory/merged-tariffs/oa.pdf.

30 Federal Energy Regulatory Commission, 2011.

been slow to materialize, held back in no small part by cost allocation challenges, siting difficulties, and the lack of mechanisms to facilitate interregional planning for interstate transmission.[31]

The range of actors responsible for transmission reflects the heterogeneity in the U.S. electricity sector. Overall, there is a significant gap between the ISO/RTOs' 2030 regional plans and the Biden administration's goal of having a carbon emissions free electricity system by 2035. Among the ISO/RTOs, PJM is the most proactive in planning for a net-zero electricity system, with proposals to update the transmission planning process to include renewables and zero-carbon electricity.[32] That being said, even for the most proactive ISO/RTOs, there is a heavy focus and assumed high reliance on distributed energy resources, storage, and other in-state or in-region resources instead of a focus on a large build-out of transmission infrastructure.[33] In almost all cases, there is very little specificity on how the system might achieve these high levels of storage or distributive systems. As a result, interregional long distance transmission lines, envisioned as a critical component of many net-zero pathways analyses,[34] gets little attention. A lack of focus on interregional transmission is likely to greatly increase the cost of electricity in a net-zero electricity system; a recent study found that, for a renewables-heavy electricity system, interregional transmission expansion could reduce the system average cost of electricity by 46% compared to a state-by-state approach.[35]

The Siting Challenge

A final obstacle to rapidly building a low carbon grid system is the existing collection of federal, state, and local siting and permitting regulations. These regulations have provided measurable environmental and social benefits, but they also have been a disincentive to investment in the energy sector and may seriously impede the country's ability to meet its ambitious emission-reduction goals. Although transmission planning is in the hands of the ISO/RTOs, responsibility for approving and permitting new transmission lines is generally at the state and local level. New lines must undergo extensive environmental reviews, require multiple permits, and often overcome

31 Lyons, C., and Greg Litra, 2020. "Informing the Transmission Discussion-A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States."ScottMadden, Inc. https://www.scottmadden.com/content/uploads/2020/01/ScottMadden_WIRES_Informing-the-Transmission-Discussion_2020_0115.pdf.

32 PJM Interconnection, LLC, 2021. "2020 Regional Transmission Expansion Plan." https://www.pjm.com/-/media/library/reports-notices/2020-rtep/2020-rtep-book-1.ashx.

33 E.g.: Hibbard, P.J., C. Wu, H. Krovetz, T. Farrell, and J. Landry, 2020. "Climate Change Impact and Resilience Study – Phase II: An Assessment of Climate Change Impacts on Power System Reliability in New York State." The Analysis Group. https://www.nyiso.com/documents/20142/16884550/NYISO-Climate-Impact-Study-Phase-2-Report.pdf/e9214fd4-9c52-036d-b92b-15f282e686e6.

34 E.g., Larson et al., 2020.

35 Brown, P. R., and A. Botterud, 2021. "The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System." *Joule,* 5(1), 115–134. https://doi.org/10.1016/j.joule.2020.11.013.

opposition from local stakeholders, which can delay projects and raise costs.[36] Often these lines must be approved by several states and multiple local jurisdictions.[37] Due to these requirements at different levels of government, new high voltage transmission lines can frequently take more than a decade to complete the planning, siting, and construction stages.[38] For example, the 732-mile TransWest Express high voltage transmission line filed its first permit application in 2007, but did not receive all of the approvals until 2020.[39] The Environmental Impact Statement alone took eight years to complete.[40] This particular project is scheduled to be online in 2026 or 19 years after it was first proposed.[41]

The building of new transmission lines can be politically controversial in the jurisdictions through which interstate lines cross as they move power from the point of generation to the point of use. This phenomenon was most recently demonstrated in the 2021 referendum in Maine, where 59% of voters rejected the proposed New England Clean Energy Connect transmission line, which would transport power from Quebec to southern New England.[42] One common reason for opposition, as was the case with New England Clean Energy Connect, is the concern about the impacts of transmission on local ecosystems.[43] Another main cause of opposition is concern about the impacts of new transmission on property values. Studies generally suggest the effects of transmission on property values are small,[44] although the actual size is heavily dependent on location.[45] Case studies have suggested that early engagement with stakeholders such as landowners can help mitigate

36 Eto, J., 2016. "Building Electric Transmission Lines: A Review of Recent Transmission Projects." Lawrence Berkeley National Laboratory. LBNL- 1006330. Berkeley, CA, United States. https://emp.lbl.gov/publications/building-electric-transmission-lines.

37 Staff of the Federal Energy Regulatory Commission, 2020. "Report on the Barriers and Opportunities for High Voltage Transmission." https://www.congress.gov/116/meeting/house/111020/documents/HHRG-116-II06-20200922-SD003.pdf.

38 Ibid.

39 TransWest Express, LLC. "TransWest Express – Schedule and Timeline." Last retrieved December 6, 2021, from http://www.transwestexpress.net/about/timeline.shtml.

40 Ibid.

41 Ibid.

42 Reuters, November 3, 2021. "Maine voters reject Quebec hydropower transmission line." *Reuters.* Retrieved from https://www.reuters.com/world/americas/maine-voters-reject-quebec-hydropower-transmission-line-2021-11-03/.

43 Natural Resources Council of Maine, 2021. "CMP Corridor: A Bad Deal For Maine." https://www.nrcm.org/wp-content/uploads/2021/09/cmp-corridor-facts.pdf.

44 Anderson, O.C., J. Williamson, and A. Wohl, 2017. "The Effect of High-Voltage Overhead Transmission Lines on Property Values: A Review of the Literature Since 2010." *Appraisal Journal*, 85(3). Retrieved Jan 14, 2022, from https://wcc.efs.iowa.gov/cs/idcplg?IdcService=GET_FILE&dDocName=1740301&allowInterrupt=1&noSaveAs=1&RevisionSelectionMethod=LatestReleased; Tatos, T., J.M. Glick, and T.A.L. Tai, 2016. "Property Value Impacts from Transmission Lines, Subtransmission Lines, and Substations." *The Appraisal Journal,* 84(3), 205. Retrieved Jan 14, 2022 from https://www.researchgate.net/profile/Ted-Tatos/publication/338686140_Property_Value_Impacts_from_Transmission_Lines_Subtransmission_Lines_and_Substations/links/5e24abb192851cafc39312b1/Property-Value-Impacts-from-Transmission-Lines-Subtransmission-Lines-and-Substations.pdf.

45 Wyman, D., and C. Mothorpe, 2020. "The Pricing of Power Lines: A Geospatial Approach to Measuring Residential Property Values." *Journal of Real Estate Research.* Retrieved from https://www.tandfonline.com/doi/abs/10.1080/10835547.2018.12091490.

opposition, but even in those instances, cost and time overruns remain the rule not the exception.[46] Local opposition to new transmission can occasionally be reduced by burying the lines rather than using overhead transmission,[47] although this method can increase construction costs by 5-10 fold.[48] Increased or continuous financial compensation to affected landowners could similarly reduce local opposition to new transmission, but would also raise the costs of new lines and again is no guarantee of reduced local opposition.[49]

The Energy Policy Act of 2005 attempted to fix some of these siting issues by giving FERC the authority to approve transmission in areas designated by the Department of Energy (DOE) as needing high voltage transmission lines.[50] However, subsequent court cases found that FERC did not have the authority to reverse state decisions and that the designation by the DOE of areas requiring high voltage transmission was done improperly.[51] The recently enacted Infrastructure Investment and Jobs Act attempts to restore backstop siting authority for FERC by allowing it to overrule state or local opposition.[52] FERC's backstop authority remains limited to projects on private lands within DOE designated "National Interest Corridors," but such corridors can now be designated based on transmission needs for unlocking renewable energy sources rather than just based on alleviating system congestion. At the moment, DOE has yet to designate any such areas and the previous two such designations were overturned by court rulings.[53]

The Biden administration has also proposed siting of new transmission lines along highways, relying on existing rights of way,[54] thus opening alternative regulatory pathways. Unfortunately, there

46 Eto, 2016.

47 Iaconangelo, D., August 27, 2021. "Northeast Transmission Fight Shows Biden's Renewable Dilemma." *E&E News.* Retrieved from https://www.eenews.net/articles/northeast-transmission-fight-shows-bidens-renewable-dilemma/.

48 Hall, K., 2013. "Out of Sight, Out of Mind 2012: An Updated Study on the Undergrounding of Overhead Power Lines." Hall Energy Consulting, Inc. and Edison Electric Institute. Washington, DC, United States. https://www.eei.org/issuesandpolicy/electricreliability/undergrounding/Documents/UndergroundReport.pdf.

49 Kite, A., April 21, 2021. "Grain Belt Transmission Line Forges Ahead Amid Landowner, Lawmaker Pushback." Flatland, Public Television 19, Inc. Last retrieved December 6, 2021, from https://www.flatlandkc.org/news-issues/grain-belt-transmission-line-forges-ahead-amid-landowner-lawmaker-pushback/

50 109th Congress of the United States, "H.R.6 - Energy Policy Act of 2005." https://www.congress.gov/bill/109th-congress/house-bill/6.

51 Bracewell LPP, 2011. "Divided Court Disconnects DOE Transmission Corridors." *Energy Legal Blog.* https://www.energylegalblog.com/blog/2011/02/08/divided-court-disconnects-doe-transmission-corridors.

52 Shkuta, B., M. Brooks, S. Hug, R. Marsh, and C. McCarthy, 2021. "Electricity Transmission Provisions in the Bipartisan Infrastructure Bill." *National Law Review,* Volume XI, Number 322. Last retrieved November 22, 2021, from https://www.natlawreview.com/article/electricity-transmission-provisions-bipartisan-infrastructure-bill.

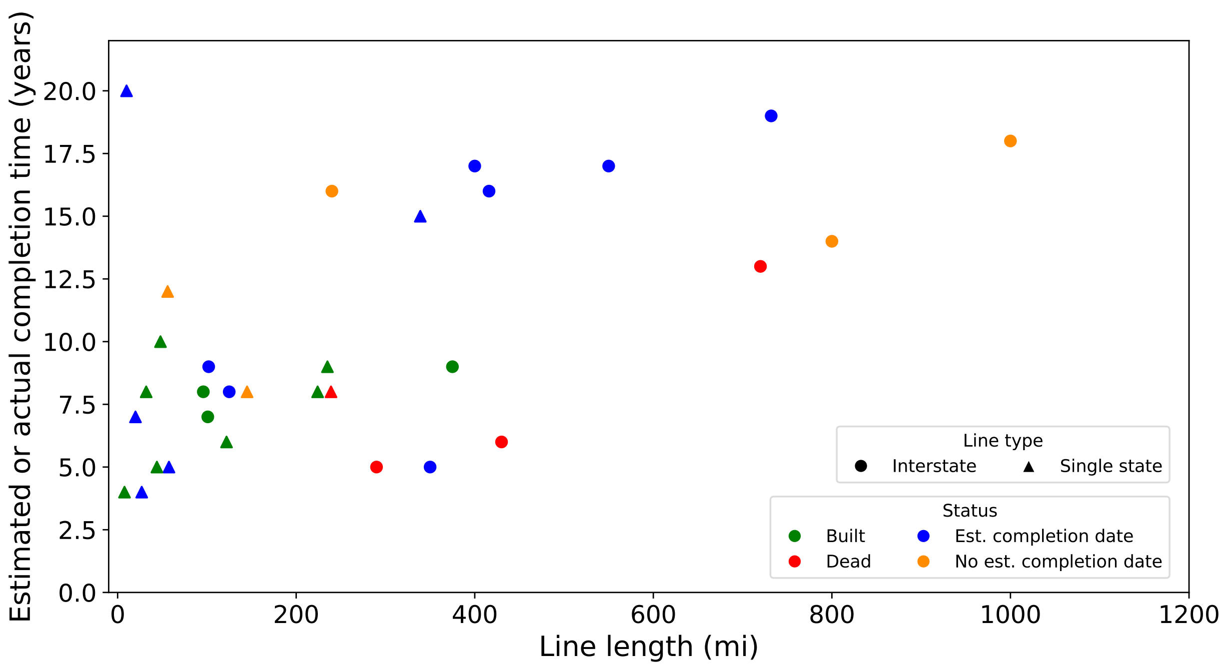
53 Bracewell LLP, 2011; Shkuta et al., 2021.

54 Stephanie Pollack, 2021. "Memorandum: State DOTs Leveraging Alternative Uses of the Highway Right-of-Way Guidance." U.S. Department of Transportation, Federal Highway Administration. https://www.fhwa.dot.gov/real_estate/right-of-way/corridor_management/alternative_uses_guidance.cfm.

are many existing Federal Highway Administration regulations, focusing on safety and aesthetics, that limit the effectiveness of using highway rights of way to speed up transmission siting.[55]

A review of over 30 transmission projects initiated after the 2005 Energy Policy Act found that new transmission takes an average of over 10 years to complete.[56] The quickest line reviewed was sited and built in only four years, while the longest project has been ongoing for over 16 years. Both of these projects are only 10 miles long, demonstrating that shorter lines do not necessary get completed faster. As shown in Figure 2, the reviewed lines have only weak relationship (r^2=0.28) between line length and time to actual or estimated completion. Interstate transmission lines generally take longer to site than lines that remain within a single jurisdiction. Importantly, should current estimates remain unchanged and prove accurate, long distance interstate transmission lines will frequently take 15 years or more to site and construct, which would put the Biden goal of decarbonizing the electricity sector by 2035 out of reach.

Figure 2. Relationship between Transmission Line Length and Completion Time



Review of completion time for 30 high voltage transmission lines that began initial planning and outreach after 2005. Triangles represent lines that are completely within one state, while circles represent transmission lines that pass through two or more states. Green indicates the line has been constructed and is in service, red that the transmission project was abandoned, blue a project that is still ongoing with an estimated completion date, and orange indicates a project that is still ongoing, but an estimated completion date was not available and the year 2025 was used instead. All transmission lines were considered to have started on the date of initial public outreach or permit filing.

55 Reed, L., M. Dworkin, P. Vaishnav, and M. G. Morgan, 2020. "Expanding Transmission Capacity: Examples of Regulatory Paths for Five Alternative Strategies." *The Electricity Journal,* 33(6), 106770. https://doi.org/10.1016/j.tej.2020.106770.

56 A list of the reviewed lines with accompanying data and sources is available at: https://doi.org/10.7910/DVN/MDQ6ME.

Siting challenges vary due to the wide variety of jurisdictions and permit types. The weak relationship between line length and time to completion suggests that having to apply for permits in multiple jurisdictions may not be as much of a factor as the fact that individual permits take a long time to process.

The siting problem is likely to get worse as the number of new transmission projects increases. In the last decade, investment in new regional transmission has been steady or declining,[57] and almost no new interregional transmission has been successfully completed.[58] The current lengthy siting process is thus operating under conditions of little to no growth in the number of permit applications. The probability that this declining scenario will continue is low. In reality, as the number of projects increase so too will the number of permit applications, placing enormous strain on state regulatory agencies. Inadequate regulatory capacity will be a major barrier to the rapid deployment of clean power technologies.

The Way Forward

Connecting to the electric grid has been and will continue to be a primary bottleneck for the buildout of renewable electricity sources. As of 2020, over 750 GW of proposed generation, most of it wind and solar, were waiting for transmission to be built.[59]

FERC is now considering updating the rules for regional and interregional transmission planning.[60] A nationwide grid plan to meet the net-zero goals is needed that includes carbon emissions guidelines for federal agencies and state regulators. As all of these parties have little experience with incorporating decarbonization goals into transmission planning, guidance from the federal government would help frame sub-regional forecasts and provide common criteria on how to balance emission reductions and reliability standards. There is also a need for national grid planning to support a net-zero electricity system, as this type of transmission planning is not occurring at the ISO/RTO level. New cost allocation frameworks are likewise needed for considering the transmission

57 Gramlich, R., and J. Caspary, 2021. “Planning for the Future: FERC’s Opportunity to Spur More Cost-Effective Transmission Infrastructure.” Americans for a Clean Energy Grid. https://cleanenergygrid.org/wp-content/uploads/2021/01/ACEG_Planning-for-the-Future1.pdf.

58 Gavan, J.C., and R. Gramlich, 2021. “A New State-Federal Cooperation Agenda for Regional and Interregional Transmission.” *NRRI Insights. National Regulatory Research Institute, Washington, DC, United States.* https://gridprogress.files.wordpress.com/2021/11/a-new-state-federal-cooperation-agenda-for-regional-and-interregional-transmission.pdf.

59 Lawrence Berkeley National Laboratory, May 24, 2021. “New Data Products from Berkeley Lab Summarize Proposed Projects in Interconnection Queues.” https://emp.lbl.gov/news/new-data-products-berkeley-lab-summarize.

60 Federal Energy Regulatory Commission, 2021. “Advance Notice of Proposed Rulemaking: Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection.” https://www.ferc.gov/news-events/news/advance-notice-proposed-rulemaking-building-future-through-electric-regional.

needs of a portfolio of projects at once and using a systemwide lens for evaluating new transmission proposals. At the regional level, the ISO/RTOs and other relevant state regulators should consider amending their bylaws to include reducing carbon emissions as a core goal, in parallel with improving grid reliability and reducing costs. Without adding carbon reductions as a primary objective in transmission planning, integrating renewable energy into the grid is likely to continue to be treated as a complication to be managed, rather than an objective to be proactively promoted.

Speeding up the siting process for new transmission lines is essential to meet the Biden administration's emission reduction goals. Across all jurisdictions—local, state, and federal—it will require a level of coordination and cooperation, consolidation of the permitting processes, and a substantial increase in regulatory capacity.

The recent infrastructure bill restoring FERC's backstop siting authority is a small step in the right direction. FERC can now also use its expanded authority to designate new interstate National Interest Corridors between regions with large renewable resources and population centers. However, whether these reforms materially speed up the siting process will depend on how they are implemented. There are currently no designated National Interest Corridors. Thus, as of the beginning of 2022, FERC has no additional siting authority. DOE is scheduled to complete a new transmission study by 2023.[61] This study will consider the designation of National Interest Corridors, but these will likely end up in litigation unless the agency initiates a major effort to include key stakeholders, including states, tribes, the ISOs, the affected utilities, and major interests. This consultation process will likely take at least two years, but if it can avoid six years of litigation, it will be worth the time.

Utilizing funding from the infrastructure bill, the Biden administration also recently launched the "Building a Better Grid" initiative at DOE.[62] The initiative aims to make progress on many of the obstacles to new transmission identified here, including by undertaking national and long-term transmission planning, coordinating permitting processes among agencies, and promoting early engagement and collaboration on transmission with states, local governments, and other stakeholders. As the initiative proceeds it should make sure to coordinate closely with the ISO/RTOs and FERC, to ensure national level transmission planning and consultation can be integrated into existing transmission planning and cost recovery processes, rather than create conflicts over jurisdiction. The Building a Better Grid initiative also will deploy more than $20 billion in financing tools for building out the electric grid, although only $2.5 billion of this is specifically designated as loans for transmission projects. Given that an estimated $360 billion of investment

61 Shkuta et al., 2021.

62 U.S. Department of Energy, 2022. "DOE Launches New Initiative From President Biden's Bipartisan Infrastructure Law To Modernize National Grid." Last retrieved January 12, 2022 from https://www.energy.gov/articles/doe-launches-new-initiative-president-bidens-bipartisan-infrastructure-law-modernize.

through 2030 is needed to stay on the path towards a net-zero electricity sector by 2050,[63] much more funding is still necessary.

This policy brief has identified some of the major barriers to developing the expanded transmission system needed to meet the goals of the transition to a low carbon electricity system. It has focused more on the challenges than providing prescriptions for meeting those challenges. Important questions for further research include: What is the role of financial incentives? For example, how will a price on carbon affect transmission decisions? To what extent will the present tariff structures serve as an incentive or disincentive to new investment? What is the optimal allocation of responsibility for siting between the federal and state governments? How can the benefits of stakeholder involvement be balanced with the need to rapidly deploy the various components of a decarbonized electric grid? Can we learn from the development of the interstate highway system established 70 years ago? Finally, what are the comparative costs and benefits of decentralized mini-grids as compared with centralized traditional grids?

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63 Larson et al., 2020.

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