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A not-too-modest proposal for a zero-emission U.S. transmission grid: Inter-regional planning, siting, funding & grid enhancing technologies will be key

ABSTRACT

Decisionmakers confront initiatives to upgrade the electric power grid in ways that might enable the U.S. to meet its Paris Accord commitment to hold global warming to no more than 1.5 degrees Celsius above pre-industrial levels. To achieve that imperative, those decisionmakers need to commit to inter-regional buildout of the high-voltage electric power grid and more efficient use of the existing grid through deployment of grid enhancing technologies. The authors detail how that can be done and how regulatory obstacles can be overcome.

Pending before U.S. legislators and administrators are electric transmission grid initiatives that could enable the U.S. to achieve its Paris Accord commitment to prevent global warming more than 1.5 degrees Celsius above pre-industrial levels. Climatologists and energy experts agree the Nation's power and transportation sectors must replace fossil-fuel-fired power (coal, fuel oil, natural gas, gasoline, and diesel) with electricity generated from zero-emission sources (hydro, wind, solar, and nuclear).[1] Most of these scientists also agree that this imperative can be achieved only if and when the Balkanized and aging U.S. electric transmission grid is upgraded—upgraded from what the American Society of Civil Engineers assigned a C-minus in a 2020 report card and former Energy Secretary Bill Richardson charitably characterized as "third world."[2]

What are these initiatives? One is the Infrastructure Investment and Jobs Act (IIJA),[3] which promotes and removes obstacles to long-lead time investments in National Interest Electric Transmission Corridors (NIETC) that will site new high-voltage direct-current transmission lines connecting regions rich in zero-emission resources such as wind and solar with demand centers (load) that often are distant. Another is the Department of Energy's (DOE) recently announced Better Grid Initiative[4] that charts a plan to fund and realize NIETCs and grid enhancing technologies (GET). A third is the bill introduced by Rep. Kathy Castor (D-FL), chair of the Select Committee on the Climate Crisis H.R. 4027, the Efficient Grid Interconnection Act of 2021 (EG21).[5] That legislation would depart from historical utility practice of operating the transmission grid as a mostly static asset; a practice that usually underutilizes most components of the transmission grid (although it can also contribute to constraint overloads in some circumstances). Instead,

[1] *See* Avi Zevin, et al., *Building a New Grid Without New Legislation: A Path to Revitalizing Federal Transmission Authorities*, 48 Ecology L. Q. 169, 176–82 (2021); Stacy Noblet, et al., Beneficial electrification: Lessons from leading utilities (2021) (reviewing electrification program experience at three utilities), available at www://icf.com/work/energy; Paul L. Joskow, *Transmission Capacity Expansion Is Needed to Decarbonize the Electricity Sector Efficiently*, 4 Joule 1, 1–2 (2019); Alexandra B. Klass, *Transmission, Distribution, and Storage Grid Integration*, in Legal Pathways to Deep Decarbonization in the United States 527, 529–31 (Michael B. Gerard & John Dembeck eds., 2019).

[2] *See* Dept. of Energy, *Building a Better Grid Initiative to Upgrade and Expand the Nation's Electric Transmission Grid to Support Resilience, Reliability, and Decarbonization*, Notice of Intent, 87__ Fed. Reg. 2769__ (Jan. 11, 2022) [hereinafter cited as *Better Grid Initiative*] (studies documenting that 70% of the Nation's grid is over 25 years old); American Society of Civil Engineers, *A Comprehensive Assessment of America's Infrastructure* (2020), available at https://infrastructurereportcard.org/wp-content/uplads/2020/12/National IRC 2021-report.pdf. PBS Frontline, Interview Bill Richardson (April 10, 2001). *See generally* Alexandra B. Klass, *et al.*, *Interstate Transmission Challenges for Renewable Energy: A Federalism Mismatch*, 65 Vanderbilt L. Rev. 1802, 1814-15 (2019) [hereinafter *Mismatch*] (summarizing evolution of federal jurisdiction over siting transmission).

[3] Infrastructure Investment and Jobs Act, Pub. Law No. 117–58, (2021) [hereinafter cited as IIJA].

[4] *Better Grid Initiative*, 87 Fed Reg. 2771-72.

[5] H.R. 4027, Efficient Grid Interconnection Act of 2021, 117th Congress 2021–2022 (June 22, 2021), available at https://www.congress.gov/117th-congress/house-bill/4027/text?r = 1&s = 1.

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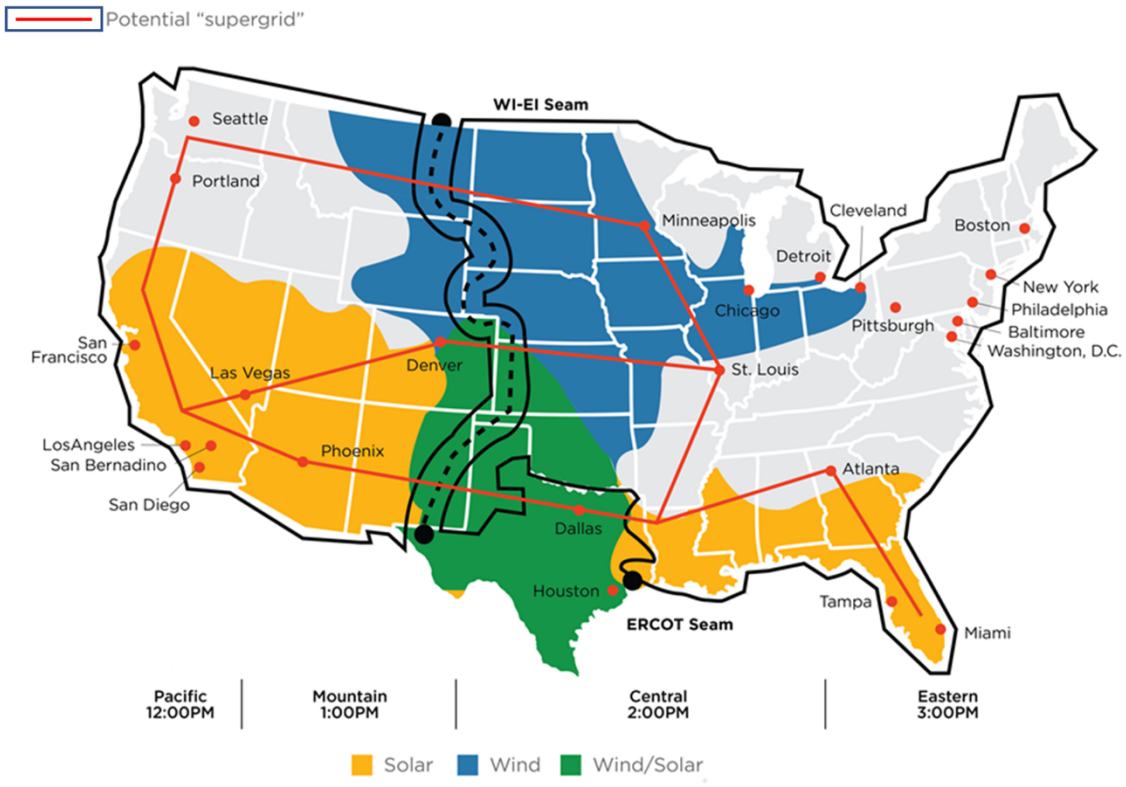
EG21 would direct the Federal Energy Regulatory Commission (FERC) to (1) prohibit the cost allocation practice called "participant funding" that saddles developers of new generation or storage with all or a disproportionate share of the cost of interconnecting their projects to the grid and (2) require transmission owners and operators to consider deploying shorter lead-time and relatively lower-cost GETs that dynamically operate the transmission grid when that is the most efficient (although not always most profitable) way to prevent curtailment of generation, especially from a renewable generator or storage facility.

Independent of DOE's Better Grid Initiative and EG21, in an Advance Notice of Proposed Rulemaking (ANOPR) FERC already is proposing to accelerate inter-regional transmission planning and is exploring new ways to allocate transmission costs in ways that eliminate free-rider outcomes and lessen the burden on developers seeking to interconnect zero-emission generation or storage.[6] But prompt progress on DOE's Better Grid Initiative and enactment of EG21's legislative directives likely would hasten adoption and implementation of FERC's ANOPR and reduce the likelihood of court challenges.

Advancing inter-regional electric transmission corridors

A Princeton University study illustrated that significant sources of renewable zero-emission electricity generation—offshore and mid-western wind and southwestern solar—are not adequately connected to major markets where electricity is consumed, with few exceptions, largely in the Nation's coastal urban areas.[7] [i] The following map prepared for DOE's National Renewable Energy Laboratory illustrates this:



Source: Aaron Bloom, Design 3, Interconnections Seams Study, presentation to TransGrid-X 2030 Symposium, NREL (2018), pg. 45, https://iastate.app.box.com/s/vfgn9nikl1rz7r8x0vaoauzpm2210t35

Congress in the Energy Policy Act of 2005 acknowledged and sought to address this disconnect. It enacted provisions to empower the DOE and FERC to interconnect electricity markets with regions rich in zero-emission energy resources. Those provisions directed DOE every three years to investigate where the grid is constrained, congested, or otherwise inadequate and to designate those areas as NIETCs. FERC, in turn, was empowered to authorize construction of transmission lines in NIETCs and grant the power of eminent domain to acquire rights of way. But that 2005 initiative came to naught. Federal appellate courts, one in the west and one in the east, blocked implementation. One ruled that DOE's corridor designation process failed to include adequate

[6] Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection, Advance Notice of Proposed Rulemaking, 86 Fed. Reg. 40266 (July 27, 2021) [hereinafter cited as *ANOPR*].

[7] *See* Princeton University Adlington Center for Energy + Environment, Net-Zero America: Potential Pathways, Infrastructure, and Impacts, (Final Rept. Oct. 29, 2021). See also David Roberts, A National US power grid would make electricity cheaper and cleaner (June 20, 2020) available at https://www.vox.com/energy-and-environment/2020/6/20/21293952/renewable-energy-power-national-grid-transmission-microgrids (cataloguing studies advocating integrating regional interconnections into a national macro grid).

consultation with affected states;[8] the other ruled FERC could not override a state's decision to deny construction and eminent domain authority.[9] Plaintiffs in both court cases were motivated by what Professor Richard Pierce accurately characterized as predictable "not-in-my-backyard"—better known as NIMBY—concerns.[10] But obstacles erected in both court decisions now are addressed and presumably surmounted in the IIJA, which explicitly eliminates from the 2005 Act state veto power over FERC's authority to approve construction of new transmission lines and confer eminent domain authority within NIETCs.[11] With this expanded authority, and NIMBY opposition cabined, DOE and FERC can and should proceed expeditiously with new constraint/congestion studies, state consultations, and corridor designations and construction authorizations of projects connecting zero-emission generation and storage to major electricity markets.

How will these NIETC transmission lines be financed? IIJA creates a Transmission Facilitation Program and authorizes the Treasury Department to loan to DOE $2.5 billion to fund eligible transmission projects under the program, plus $10 million for DOE to administer the program.[12] While inadequate to the task projected to require in excess of $2 trillion, this might be sufficient seed money to attract utility and other sources of private capital investment.

Fair and consistent funding and cost allocation

Determining who pays for he HVDC transmission to connect zero-emission resources to load is often a contentious issue. This issue of cost allocation arises most acutely when one state or region absorbs the siting burden but does not directly benefit as a consumer of the electricty transmitted or associated environmental benefits.[13]

Developers of new generation or storage apply to transmission operators – independent regional operators (ISO or RTO) – or owners to interconnect their projects to the grid so they can deliver power either directly to a consumer or to a local distribution utility that, in turn, will deliver the power to its franchise customers. The cost of interconnection broadly can be thought of in two parts: On the one hand, there is the cost of the "tie" or "radial" connection that runs between the generator or storage facility and the high-voltage grid; on the other hand, there are upgrades to the network that benefit the broader universe of electricity consumers who take power off of that grid.

Who pays for each has been a function of FERC's Order 2003[14] or exceptions FERC has allowed to it. As a consequence of exceptions, some transmission operators and owners foist the cost of both ties/radials and network upgrades entirely onto the generation or storage developer, providing certain credits or capacity payments back to the developer. Others pursue a combination that sees the developer finance the tie, and the operator fund network upgrades. Or there is the case of mid-Atlantic regional operator PJM Interconnection LLC and its transmission owners. Several years ago, they opted for "participant funding," foisting all costs onto the generation or storage developer. More recently realizing how much new renewable generation and storage is being developed and would seek interconnection, PJM and its transmission owners reversed course; they are now asking FERC to allow the transmission owners to pay for the whole kit-and-kaboodle and earn a regulated return on that investment.

In its pending ANOPR, FERC is proposing to standardize interconnection cost allocation rules on which developers and investors can rely and plan around.[15] EG21 would direct FERC to rationalize the prevailing and often uneconomical allocation of interconnection costs. It would require FERC to promulgate regulations prohibiting "participant funding." Instead, consistent with FERC's longstanding beneficiary-pays principle, EG21 would require that costs be spread among those who directly transmit on the network upgrades or demonstrably benefit from those upgrades in the form of enhanced reliability and reduced emissions of greenhouse gases and other pollutants. If informed by solid data on who benefits, then this approach should expand access to the electric grid by allocating tie costs to the interconnection customer while spreading the costs of network upgrades broadly among reliability and environmental beneficiaries.

Financing merchant transmission developments

Confronting different financing and cost responsibility challenges are merchant transmission projects – transmission lines developed by new entrants, independent of system operators or incumbent transmission owners. Developers of these projects shoulder the costs and liabilities of project design and development; they therefore should control financing and influence cost allocation. But this obvious conclusion is being tested.

On point is the proposed SOO Green merchant HVDC transmission line that will connect existing and proposed wind generation in the plains states within the Midwest Independent System Operator (MISO) to load centers mostly in PJM, including Chicago. The merchant SOO Green developer has borne the costs of designing and developing this underground inter-regional transmission line. But not to be cut out of the action, MISO and its transmission owners are currently asking FERC to amend MISO's transmission tariff to grant the incumbent MISO transmission owners a unilateral option euphemistically called a "self-fund option" that would allow them to swoop into a fully designed and developed merchant project, preempt the developer, and choose to finance construction of SOO Green and earn a regulated return on that investment.[16] The MISO transmission owners would own this "self-fund option" even though the "self" at issue is *SOO Green*, not MISO or its incumbent transmission owners who didn't develop and design the idea. Worse, MISO transmission owners could exercise this "option" even when SOO Green could obtain capital to finance construction of its project at a rate lower than the rate the transmission owners would be willing to offer or could even obtain. The SOO Green developer estimates that the MISO tariff amendment would increase the cost of its project by over $30 million.[17]

DOE's Better Grid Initiative promises to overcome some of the

[8] Cal. Wilderness Coalition v. DOE, 631F.3d1072, 1086–95 (9th Cir. 2011).

[9] Piedmont Env't' Council v. FERC, 558F.3d 304, 313–15 (4th Cir. 2009), cert. denied, Edison Elec. Inst. v. Piedmont Env't Council, 558 U.S. 1147 (2010). See also Mismatch, 65 Vanderbilt L. Rev. at 1819 (tracking evolution of jurisdiction over transmission siting).

[10] Richard J. Pierce, Jr., The Need to Change Jurisdiction Over the U.S. Electric Grid, The Regulatory Review at 3–4 (Nov. 8, 2021), available at https://www.theregreview.org/2021/11/08/pierce-need-to-change-jurisdiction-us-electric grid/. Professor Pierce acknowledges the obvious that high-voltage transmission lines can be an eyesore, but a necessary one if catastrophic climate change is to be averted.

[11] IIJA § 40105 (amending 16U.S.C. §824p(b) (2021)).

[12] Id. at § 40106(b)(2), (3); see Better Grid Initiative, 87 Fed. Reg. 2771

[13] Mismatch, 65 Vanderbilt L. Rev. at 1870-73 ("cost allocation can be particularly contentious for multi-state transmission projects").

[14] *Standardization of Generator Interconnection Agrmts. & Procs.*, Order No. 2003, 104 FERC ¶ 61,103 (2003), order on reh'g, Order No. 2003-A, 106 FERC ¶ 61,220 (2004), *order on reh'g*, Order No. 2003-B, 109 FERC ¶ 61,287 (2004), *order on reh'g*, Order No. 2003-C, 11FERC ¶ 61,401 (2005), *aff'd sub nom. Nat'l Ass'n, of Regul. Util. Comm'rs*, 475 F.3d 1277 (D.C. Cir. 2007), *cert. Denied*, 552 U.S. 1230 (2008).

[15] *See* ANOPR, 86 Fed. Reg. at PP 123–130.

[16] Midwest Independent System Operator, Inc., Filing of Revisions to Tariff Attachment GGG and Related Tariff Provisions, FERC Docket ER22–477–000 (Nov. 24, 2021).

[17] Protest of SOO Green HVDC Link Projectco, LLC, Midcontinent Independent System Operator, Inc., at 2, 9, FERC Docket No. ER22–477–000 (Dec. 20, 2021); see also Ethan Howland, *MISO Proposal to Let Utilities Profit from Upgrades for HVDC Lines Sparks Debate at FERC* (Dec. 22,2021) (detailing the MISO proposed amendment and protests of it).

challenges to financing merchant transmission. It authorizes DOE to serve as an anchor customer for a project like SOO Green, buying from the developer up to 50% of planned capacity for a term of 40 years.[18] Once the developer secures long-term financing, DOE could then market its share of the capacity and recoup some or all of its investment.

Grid enhancing technologies

GETs available today can increase dramatically the operational transfer capability of the existing transmission grid to deliver least-cost electric generation, especially from intermittent wind and solar sources.[19] The IIJA provides DOE with $3 billion in matching grants for the deployment of these technologies.[20]

Dynamic (not static, seasonal, or ambient) line ratings

Understanding what the *existing* grid can transfer across congested areas is prerequisite to deploying GETs effectively. Transfer capability is a function of facility ratings, including line ratings. The most accurate line ratings are dynamic line ratings (DLR). DLR is a GET that helps transmission operators and owners determine the prevailing limits of overhead transmission lines in response to ambient conditions – temperature, wind speed, solar irradiance – the positioning of electrical conductors, and the tension and angle of sag of critical transmission spans. Other things being equal, the colder the transmission line, the greater its transfer capability. According to a 2019 DOE report to Congress, "the benefit of DLR is the cost savings associated with utilizing *existing* equipment to carry more power, allowing greater utilization of low-cost resources while offering a potential low-cost alternative to spending millions of dollars on economic [as opposed to reliability] transmission upgrades."[21]

Historical practice has assigned static or seasonal line ratings (SLR). This is conservative. It usually leads to underutilization (although it can also contribute to overloads in some circumstances). SLR has been compared to setting speed limits based on snowy road conditions. According to several studies, DLR can increase operating facility ratings above SLR by as much as 20–40% during many hours, reducing unnecessary curtailments commensurately.[22]

In its recent Order No. 881 rulemaking FERC directed all transmission providers to abandon SLR in favor of ambient-adjusted ratings (AAR).[23] AAR adjusts line rating in response to some of the same ambient conditions factored into DLR but suffers from some of the same defects of SLR in that AAR often starts from some of the same overly conservative base-line assumptions. FERC nevertheless is continuing to move in the right direction, having opened a notice of inquiry proceeding to take public comments on requiring the use of DLR.[24]

Advanced power-flow control

This GET comes in two forms. The more expensive is a phase angle regulator. Less expensive and scalable is a flexible alternating current transmission system. Where power can flow over multiple paths, these GET controls are capable of adjusting the impedance of transmission lines to direct power away from lines that would otherwise become overloaded. Doing so allows the system operator, *without curtailing or redispatching generation or storage*, to make better use of all existing transmission lines under its control and defer or abandon much more costly investments in parallel circuits or other transmission hardware.[25]

Topology optimization

As a software-only GET that relies entirely on existing grid components, topology optimization is the most economical GET, costing between $10 and $100 per switching cycle.[26] A recent study by the MISO Independent Market Monitor found that a single optimization reconfiguration would have resulted in congestion cost savings of over $37 million during the summer of 2021.[27]

Similar to advanced power-flow control, topology optimization enables re-routing of power flows away from fully loaded transmission lines by opening and closing circuit breakers on the existing transmission grid. Topology optimization has aptly been analogized to the Waze GPS application many drivers use to navigate; this is a software technology that automatically finds reconfigurations that direct power flows around congested grid elements just as Waze directs drivers away from traffic jams and hazards. The ability to switch circuits in this fashion already exists on most transmission assets. However, most transmission operators lack the software to identify and implement alternatives to do so most effectively.

Topology optimization empowers operators to optimize transmission grid configurations in response to ever changing system conditions, including maintenance, forced transmission and generation outages, and variations in wind, solar, and demand patterns. According to several studies, topology optimization can increase operating transfer capability on binding constraints by as much as 40%, reducing unnecessary wind curtailments and market congestion management costs commensurately.[28]

Regulatory disincentives to deploying GETs

Why are currently available GETs not more widely deployed? The answer can be found in the incentives embedded in traditional utility rate regulation.

Incumbent utilities (both investor- and publicly owned) operate or own most of the interconnected U.S. grid. They do so either directly or through ISOs or RTOs. In most of the eastern interconnection and California, these utilities in recent years have sold to affiliates or third parties much of their generating assets (save for nuclear and some qualifying facilities), leaving on their books only the transmission grid. Traditional regulation rewards them through cost-based rates that earn a return on or of the equity plus debt they have on their books invested in the transmission grid – that is their rate base. In this regulatory structure, the more you spend, the more you grow your rate base, and the more money you make. Your incentive is not to find least-cost solutions

[18] Better Grid Initiative, 87 Fed. Reg. 2771-72.

[19] T. Bruce Tsuchida, Stephanie Ross, and Adam Bigelow, *Unlocking the Queue with Grid-Enhancing Technologies, Case Study of the Southwest Power Pool* (Final Rept. Feb. 1, 2021) (and authorities cited) [hereinafter cited as *Unlocking*].

[20] Better Grid Initiative, 87 Fed. Reg. 2772.

[21] Dept. of Energy, *Dynamic Line Rating-Rept. to Congress*, at 24 (June 2019).

[22] *See, e.g.*, International Renewable Energy Agency, Dynamic Line Rating-Innovation Landscape Brief (2020) (compiling DLR results from implementations around the world).

[23] Managing Transmission Line Ratings, Order No. 881, 177 FERC ¶ 61,179 at PP 4–6, 83–103 (2021) (amending 18 C.F.R. § 35.28).

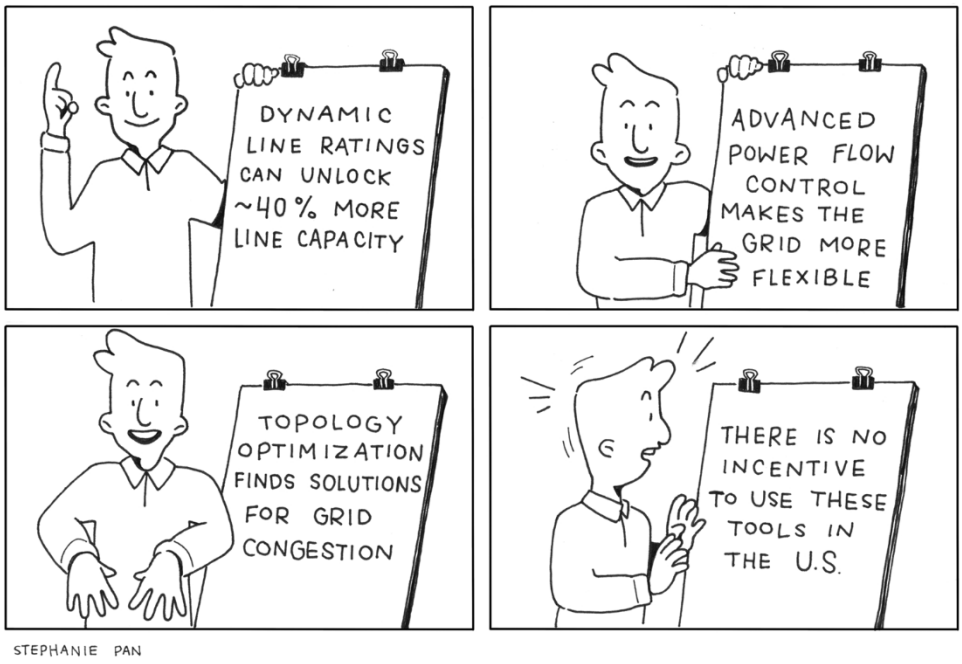
[24] Implementation of Dynamic line Ratings, 178 FERC ¶ 61,110 (2022).

[25] For illustration, see Smartwires Reimagine the Grid, *Unlock System Wide Power Transfers* (Case Study 2019), available at https://smartwires.com/wp-content/uploads/dim_uploads/2019/05/NewCaseStudy-SystemTransfer.pdf

[26] *Unlocking* at 21.

[27] David Patton, MISO IMM Quarterly Report: Summer 2021, MISO MC of the Board of Directors (Sept. 2021), available at https://cdn.misoenergy.org/20210914%20Markets%20Committee%20of%20the%20BOD%20Item%2006%20IMM%20Quarterly%20Report588017.pdf, slides 8 and 27.

[28] *See, e.g.,* Pablo A. Ruiz and Xiaoguang Li, Transmission Topology Optimization to Efficiently Mitigate Congestion & Overloads: Case Studies and a Path Toward Implementation, FERC *Tech Conf. on Increasing Market Efficiency through Improved Software*, Docket AD10–12–012, June 2021, available at https://www.ferc.gov/media/w1-ruiz, slide 15



such as GETs; often it's just the opposite.

That probably explains why GETs have not been adopted more widely and presents a challenge to energy planners and regulators who should accelerate GETs deployment. EG21 proposes to reorient traditional regulatory incentives of transmission system operators and owners toward GETs and away from more costly investments.

EG21 reform of processing GETs requests

The process EG21 proposes for deploying GETs is comprehensive, fair, and sensible. It would require FERC to promulgate regulations empowering the interconnection customer seeking to minimize curtailments from its electric generation or storage to request one or more GETs, require system operators (RTOs, ISOs or transmission coordinators) to consult with the customer and affected transmission owners on deployment options for the requested GETs, and allow the customer to appeal to FERC any denial of the requested GETs. Subject to any further right of appeal, deployment, if any, would be at the customer's expense except possibly in instances where FERC's beneficiary-pays principle comes into play.

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To keep the U.S. within reach of its Paris Accord commitment to 1.5 degrees Celsius, the electric grid initiatives and regulatory changes described here should be implemented with all due speed. Since building transmission takes more investment and substantially more time than developing new sources of zero-emission generation and storage or deploying GETs, DOE and FERC in tandem promptly should advance NIETC designations and authorize siting and construction of HVDC transmission. In turn DOE should aggressively pursue its Better Grid Initiative, and Congress should enact EG21 or comparable legislation to ensure that electricity deliveries from zero-emission generation and storage using the existing grid can be optimized through regional planning, equitable cost allocation, and the strategic deployment of GETs. And FERC should promptly (1) finalize its ANOPR, mandating comprehensive, regional transmission planning and approaches to cost allocation that recognize the broad benefits of nearly all network upgrades for generation and storage interconnections and merchant transmission and (2) require much more extensive use of DLR, power flow control, and topology optimization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr. Tabors is President of Tabors Caramanis Rudkevich a consulting engineering economic firm that provides economic and regulatory advice to a range of entities in the electric power sector. He is also Executive Vice President and a founder of NewGrid, a software as a service company that has developed and licenses transmission topology optimization software and services.

Mr. Watkiss is a member of the District of Columbia, New York, and Energy Bar Associations, with over 40-years of experience in energy and environmental law. He is a Senior Advisor to Tabors Caramanis Rudkevich.

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