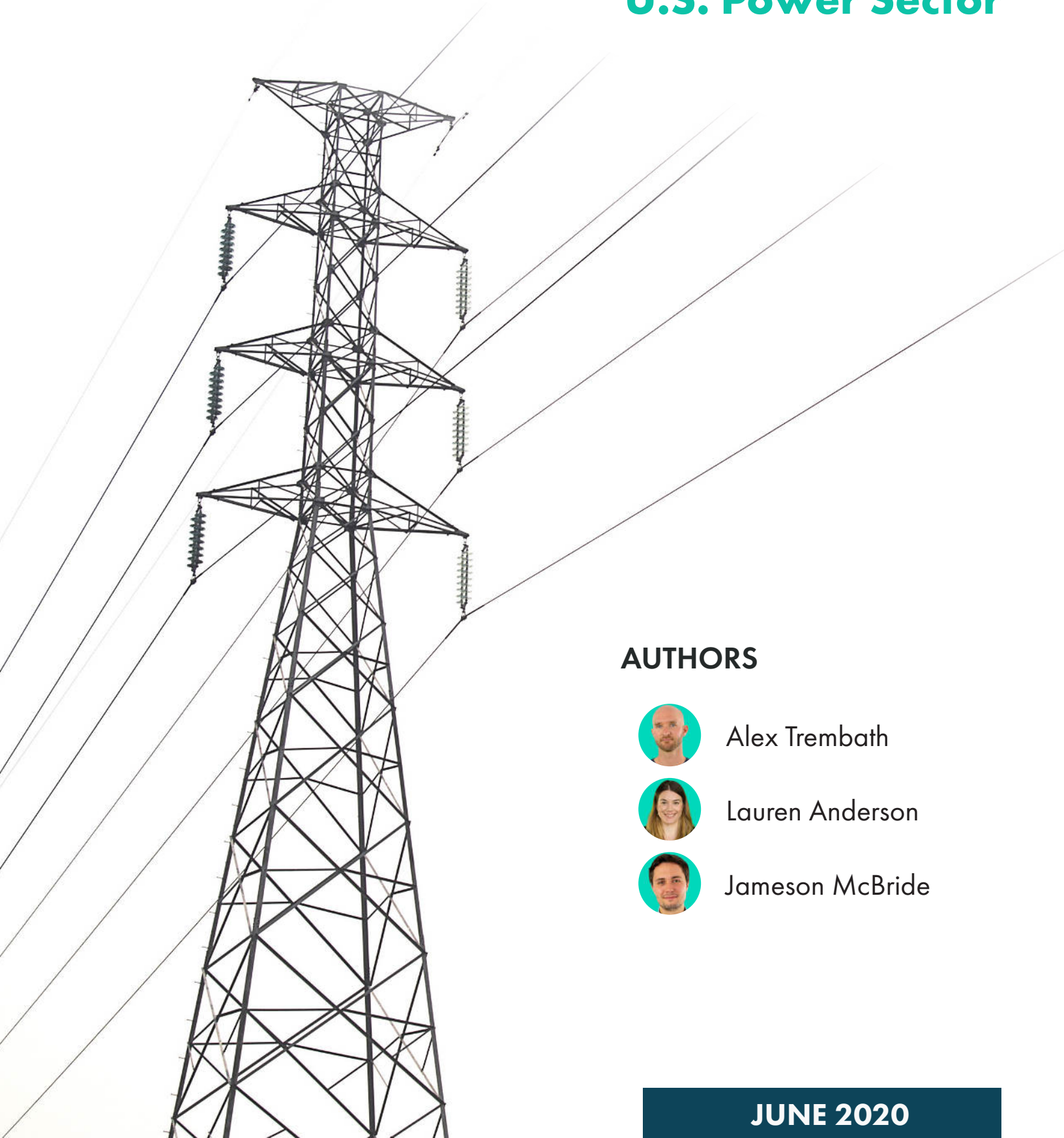
BREAKTHROUGH INSTITUTE

Reforming Federal Policy to Support Innovation and Clean Energy in the U.S. Power Sector



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EXECUTIVE SUMMARY

Solar and onshore wind technologies have become increasingly competitive with conventional electric generation technologies in the United States. The progress to date has been driven largely by federal deployment subsidies. But while these two technologies have reached relative maturity, experts agree that current-generation solar and wind are insufficient for the task of fully decarbonizing electric power grids. Filling the remaining gaps will require reforms to federal energy technology policy, including but not limited to deployment policy.

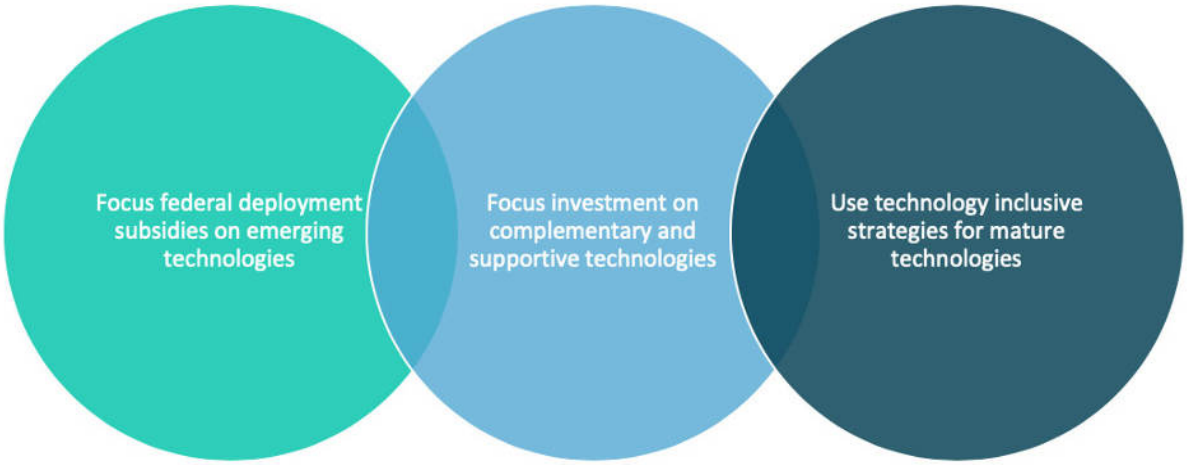
Following a decade of shifts in the US power sector — including the growth of solar and wind, the coal-to-gas transition, and the electrification of sectors like light-duty transport — the next few years present an inflection point in the evolution of the American electric system. Barriers to deep decarbonization of the power sector remain, including lack of sufficient transmission, energy storage, and firm clean generation. Action now to address these barriers will enable faster, cheaper decarbonization in the future.

IN THIS PAPER, WE:

1) Recommend principles for how the federal government can best deploy clean electricity technologies, and
2) Recommend policy options supporting the continued growth of the renewable and clean energy industries during and after the COVID-19 pandemic.

PRINCIPLES FOR FEDERAL INVESTMENT IN CLEAN ENERGY DEPLOYMENT AND POWER SECTOR DECARBONIZATION

1. **FOCUS DEPLOYMENT SUBSIDIES ON EMERGING TECHNOLOGY:** Shift federal subsidies from cost-competitive technologies (e.g. onshore wind and solar) to emerging technologies (e.g. offshore wind, advanced nuclear, enhanced geothermal, carbon removal, and energy storage).
2. **FOCUS INVESTMENT ON COMPLEMENTARY AND SUPPORTIVE TECHNOLOGIES:** Ensure funding adequately supports complementary technologies, such as transmission, firm generation, and energy storage.
3. **USE TECHNOLOGICALLY INCLUSIVE STRATEGIES FOR MATURE TECHNOLOGIES:** Policies for broad-based clean energy deployment and decarbonization, such as a clean electricity standard (CES), should be technologically inclusive.



RECOMMENDATIONS FOR CLEAN ENERGY DEPLOYMENT AND INNOVATION POLICY

TEMPORARY DEPLOYMENT SUPPORT

- Delay the sunsetting of the wind and solar tax credits until the end of calendar year 2022 to allow adequate recovery time from the COVID-19 pandemic and recession.
- Make all federal clean energy tax credits fully refundable for projects that begin before the end of calendar year 2022.
- After 2022, extend federal clean energy deployment incentives through the end of calendar year 2030, removing eligibility for solar and onshore wind projects.
- Impose a 250 MW per-reactor cap on the existing nuclear production tax credit to ensure federal deployment support benefits a new generation of smaller, advanced nuclear reactor technologies. Lift the existing 6000 MW cap on the credit availability.
- Extend the section 45Q tax credit for carbon removal through the end of calendar year 2030, and allow project developers to receive a cash payment in lieu of the credit if their project begins before the end of calendar year 2022.

TRANSMISSION EXPANSION AND INCREASED GRID INTERCONNECTION

- Invest in new grid infrastructure to better connect the Western and Eastern Interconnections.
- Dedicate federal funding for transmission expansion and upgrades in the Power Marketing Administrations (PMAs).
- Establish a tax credit for the construction of regionally significant transmission projects.
- Reform and strengthen federal backstop siting authority for projects in transmission corridors.
- Alleviate regulatory burdens on transmission construction projects.

SMART PLANNING FOR LARGE-SCALE INFRASTRUCTURE PROJECTS

- Support deployment of wind and solar on federal lands by identifying priority areas for development in a manner that minimizes environmental impacts.
- Develop a federal plan for strategic national transmission expansion.

ENERGY STORAGE

- Develop a dedicated investment tax credit for grid-scale energy storage projects to facilitate deployment.
- Increase funding for research, development and demonstration (RD&D) of long-duration grid-scale storage systems.

INTRODUCTION

Wind and solar technologies have become increasingly competitive with conventional electricity generation in the United States over the past decade. This progress, propelled largely by federal subsidies for deployment, echoes the government-driven technological success seen in light-water nuclear reactors, hydraulic fracturing, LED lighting, and other energy technologies. Before the economic downturn triggered by the COVID-19 pandemic, policymakers were faced with the questions of how much more growth to expect from solar and wind, and how policies should shift to reflect this new period of technological maturity.

As of this writing in Spring 2020, the pandemic has depressed economic activity around the world. Now is certainly not the time — in the midst of a severe economic downturn that has seen over 600,000 jobs lost in the clean energy industry — to eliminate subsidies for renewable energy technologies. But perpetual volumetric subsidies do not sustain healthy electricity systems or technology industries either. With an eye toward post-COVID stimulus and long-term shifts in electric power generation and infrastructure, the federal government should consider reforming the existing clean energy subsidy regime to prioritize innovation, minimize system costs, and promote a balanced clean generation portfolio.

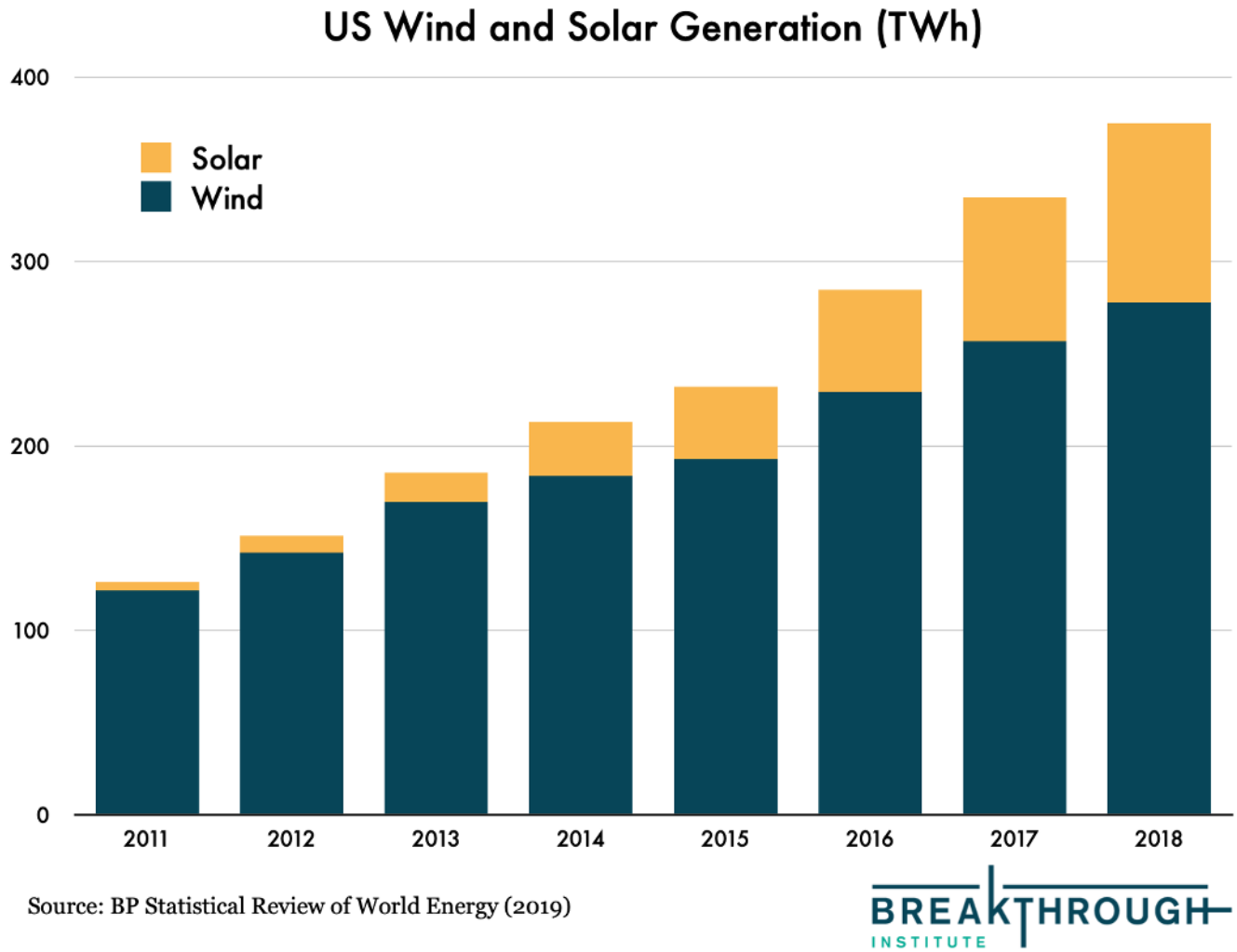
Following a decade of shifts in the US power sector — including the growth of solar and wind, the ongoing coal-to-gas transition, and the increasing electrification of sectors like light-duty transport — the next few years present an inflection point in the evolution of the American electricity system. The recent cost declines of wind and solar technologies, combined with the green shoots of advanced nuclear, carbon removal, enhanced geothermal, and offshore wind industries, create opportunities to reform American energy policy and capitalize effective post-COVID stimulus investment. Along with upgrades to America's transmission infrastructure and research into advanced energy technologies like long-duration storage, the next few years of power sector investments could pay dividends for decades.

The principles and policy recommendations included in this brief would ensure that the US electricity system continues to decarbonize, that affordability and scalability of generation technologies remain priorities, and that future innovations in generation technologies and infrastructure can be accelerated.

PRINCIPLES FOR FEDERAL INVESTMENT IN CLEAN ENERGY DEPLOYMENT AND POWER SECTOR DECARBONIZATION

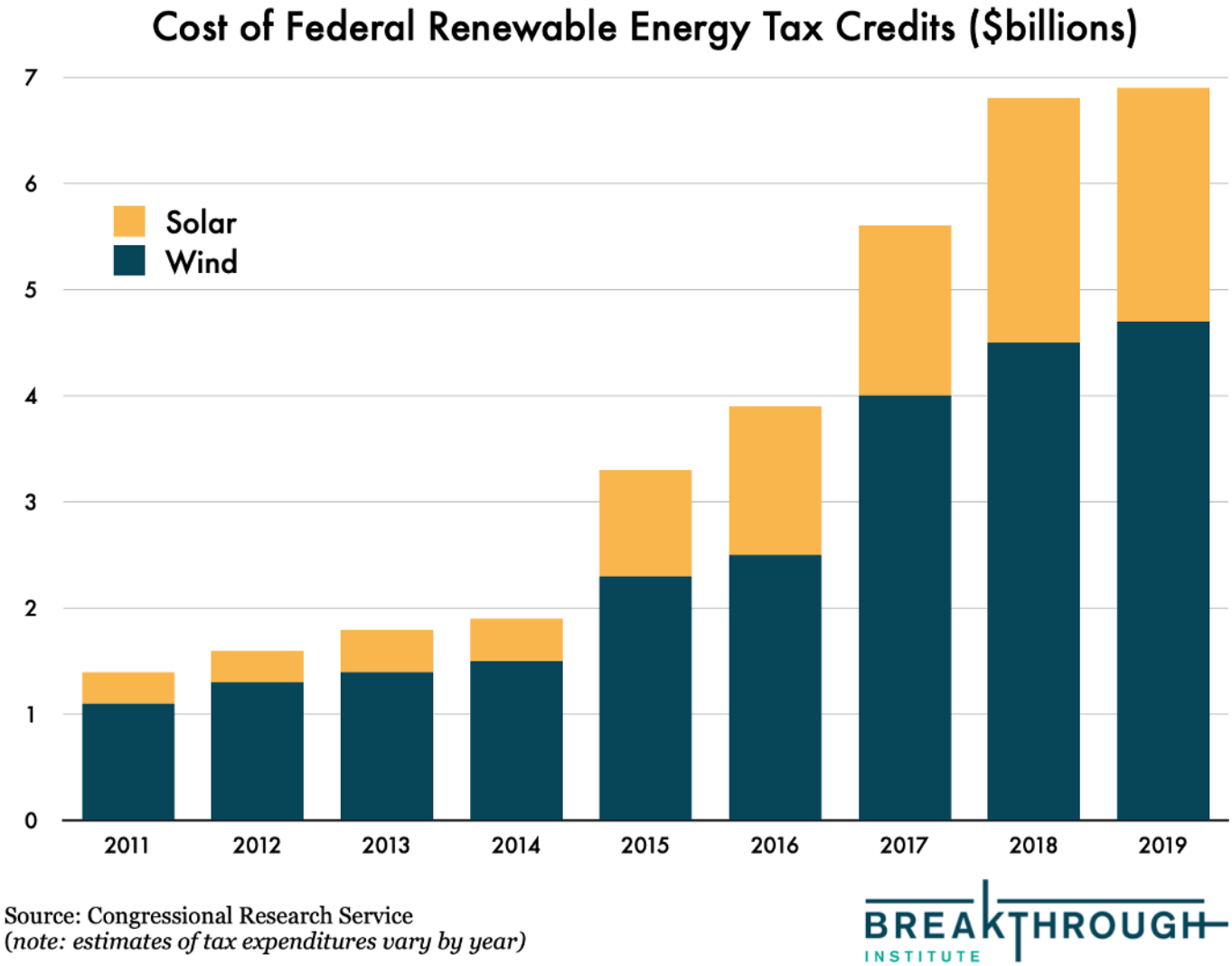
FOCUS FEDERAL DEPLOYMENT SUBSIDIES ON EMERGING TECHNOLOGIES

The primary federal subsidy benefiting the wind industry, the Production Tax Credit (PTC), was first enacted in 1992. Solar's main deployment incentive, the Investment Tax Credit (ITC), was created in 2005. These policies, combined with state-level standards, have complemented sustained RD&D support and resulted in substantial cost declines and innovation since their inception, enabling wind capacity to hit 100 GW and solar to hit 77 GW of installed capacity at the end of 2019. Wind and solar now provide over 8 percent of US electricity generation, up from less than 2 percent a decade ago.



Despite falling costs and widespread claims of subsidy independence, much of the environmental advocacy and cleantech communities continue to lobby for the extension of these federal tax credits. But a permanent extension would be a permanent misallocation of federal technology deployment support. Subsidies like the ITC and the PTC are best used as early-stage efforts to align RD&D initiatives and market formation, to drive cost declines and technological learning and, crucially, to usher in a new phase of subsidy independence — not as permanent commercial incentives nor as efforts to internalize the social cost of carbon emissions.

Environmental economists have long criticized deployment subsidies as inefficient and expensive decarbonization policies. Studies show that internalizing the social cost of carbon via technology-neutral policies like carbon prices or clean energy standards are much more affordable on a cost per-carbon basis.[1] Subsidies should not be a replacement for policies addressing the economy-wide externality of carbon pollution. Instead, subsidies are best used to induce technological learning and drive down costs for new and emerging technologies.[2] But once those cost reductions are achieved and widespread deployment mounts, as has occurred with wind and solar, the inefficiencies of subsidies become progressively costlier, further burdening both taxpayers and the tax equity markets that developers rely on to capitalize these credits. In 2019, federal expenditures on the wind PTC were $4.8 billion and solar ITC expenditures were $2.2 billion. Wind, solar, and other renewable energy technologies now account for the bulk of energy-related tax expenditures.[3]



The factors limiting renewable energy growth are no longer simply high prices for solar and wind. Instead, the barriers lie primarily in overcoming the variable nature of wind and solar generation. Analysts have worried for decades about the challenges encountered by an electricity system dominated by variable renewable energy (VRE) when the sun doesn't shine and the wind doesn't blow. And while these "lulls" in renewable resources do happen and entail added costs,[4] a more pressing challenge in the long term may be an excess of solar and wind resources.

Solar panels and wind turbines, dependent as they are on the availability of the sun and the wind, tend to have relatively low capacity factors. As the penetration of VRE on a grid approaches the nominal annual capacity factor of those technologies, their contribution to electricity load will swing regularly between zero and 100 percent. At that point, any added wind and solar capacity enters the market at least partially redundant. This "capacity factor threshold" can be considered a rule of thumb for the market limitations to solar and wind.[5]

But the challenge for VRE technologies is even more significant than that. Solar and wind plants are near-zero marginal price resources. Because they have no fuel costs and low operating costs, when they sell electricity into the system, they drive the wholesale cost of electricity toward zero. Under current market conditions, this results in a situation where more solar and wind on a grid can discourage further deployment of solar and wind resources. This effect can be expected to hamper the economics of wind and solar plants up to, at, and beyond the "capacity factor threshold."

Several scholars have observed that this value deflation effect is in a "race" against ongoing cost improvements in solar and wind technologies. A 2020 analysis by researchers at the Rochester Institute of Technology concluded that, even with projected component cost declines, "subsidy requirements to ensure profitability could increase over time," and that the "integration of significant amounts of wind or solar necessitates new grid technologies."[6]

Policymakers can confront these challenges, to the benefit of the renewables and broader clean energy industries, by investing strategically in complementary and supportive technologies — namely transmission, energy storage, and firm generation.

FOCUS INVESTMENT ON COMPLEMENTARY AND SUPPORTIVE TECHNOLOGIES

As VRE technologies reach higher penetrations across the grid, the marginal value of adding more wind and solar declines as a result of flexibility limitations.[7] To overcome these limitations, policymakers must ensure the availability of complementary technologies like transmission, energy storage, and clean firm generation.

Projects that benefit from excellent natural solar and wind resources might prove uneconomic thanks to transmission constraints. And the regional variability of solar and wind resources can be substantially mitigated by high-voltage, long-distance transmission.

For decades, federal studies have called for the construction of a network of long-distance, high-voltage transmission lines that span all American time zones. As far back as 1952, a Bureau of Reclamation report called for a "super transmission system."[8] Today, lack of transmission (and the resultant grid congestion) are already limiting renewable energy development. In 2019, wind developers withdrew their project proposals from the Midcontinent Independent System Operator's (MISO) interconnection, citing insufficient transmission. According to the Clean Energy Alliance, out of the 5,000 MW of proposed wind and solar projects that were being analyzed for connection to MISO's western region, all but 250 MW had been withdrawn by the end of 2019.[9]

Even with sufficient transmission infrastructure, seasonal variation in generation will pose serious challenges for balancing supply and demand of electricity and, most acutely, for the profitability of a given VRE plant. Hourly and multi-day storage can help flatten these imbalances over short periods of time. But VRE-heavy grids will tend to "overgenerate" significantly at certain times of year while under-generating in others. Existing technologies, with the exception of pumped-hydroelectric capacity, are unable to economically store this excess generation in one season for consumption in another.[10]

The declining marginal value of wind and solar increases the need for less variable generation technologies. Such "firm" or "dispatchable" technologies can, depending on the exact mix of the grid, either compensate for the variability of a wind-and-solar-heavy generation portfolio or form the base of a diverse generation mix.

Over the past several years, a growing scholarly consensus has pointed to the virtues of such a diverse mix of resources, and in particular the value of firm, dispatchable, or "flexible base" resources like geothermal, nuclear, and fossil fuels with carbon capture. As a 2017 review of the relevant literature concluded, "...there is strong agreement in the literature that a diversified mix of low-CO_2 generation resources offers the best chance of affordably achieving deep decarbonization."[11]

A more effective long-term strategy must address the relative lack of sufficient long-distance transmission infrastructure, long-duration electricity storage solutions, and of firm, dispatchable low-carbon generation technologies.

USE TECHNOLOGICALLY INCLUSIVE STRATEGIES FOR MATURE TECHNOLOGIES

Making clean energy cheap unlocks significant potential to accelerate deep decarbonization. As policymakers consider climate mitigation options, they should emphasize affordability and technological inclusivity.

Extending technology-specific subsidies indefinitely is inefficient, as the effective cost per ton of carbon reduced from these subsidies increases over time. However, there are other options for broader decarbonization policies that properly value clean energy generation for its ability to mitigate climate change and air pollution.

As RD&D and smart deployment policy drive down the cost of clean energy technologies, they also drive down the cost of broad-based decarbonization policies like carbon pricing and clean energy standards. It is essential that such mitigation policies be designed in a technologically-inclusive way in order to minimize costs, as the relative values of different technologies will change substantially with expanded deployment.

RECOMMENDATIONS FOR CLEAN ENERGY DEPLOYMENT AND INNOVATION POLICY

While the first half of this paper addresses key principles for how the federal government can best deploy renewable energy and decarbonize the power sector, the second half recommends policy options supporting the continued growth of the renewables and broader clean industry during and after the COVID-19 pandemic. The long-term sustainability of the renewable energy industry is at risk, and before policy makers can turn to renewable energy policy reform, they must first address the crisis at hand.

The need to reform federal clean energy policy to accelerate deep decarbonization has become increasingly pressing. While the economic crisis caused by the COVID-19 pandemic has made the challenges facing clean energy industries more acute, efforts to rescue and stimulate the American economy may provide opportunities to significantly improve federal clean energy investment policies.

TEMPORARY DEPLOYMENT SUPPORT

- Delay the sunsetting of the wind and solar tax credits until the end of calendar year 2022 to allow adequate recovery time from the COVID-19 pandemic and recession.
- Make all federal clean energy tax credits fully refundable for projects that begin before the end of calendar year 2022.
- After 2022, extend federal clean energy deployment support through the end of calendar year 2030, removing eligibility for solar and onshore wind projects.
- Impose a 250 MW per-reactor cap on the existing nuclear production tax credit to ensure federal deployment support benefits a new generation of smaller, advanced nuclear technologies. Lift the existing 6000 MW cap on the credit.

- Extend the section 45Q tax credit for carbon removal through the end of calendar year 2030, and allow project developers to receive a cash payment in lieu of the credit if their project begins before the end of calendar year 2022.

The federal government spends over $10 billion on energy-related subsidies every year, the bulk of which is directed at renewable energy projects, particularly solar and onshore wind.[12] These subsidies are most effective when used as a temporary tool in technology innovation policy, not as stand alone decarbonization policy.[13] Limited federal deployment resources — and the limited availability of tax equity — should be directed at earlier-stage technologies, including offshore wind, enhanced geothermal, advanced nuclear, and carbon removal.

Congress should fully extend the federal renewable production and investment tax credits until the end of 2022. After that, the ITC and PTC should be extended through 2030, but solar and onshore wind projects should no longer be eligible. (Geothermal, offshore wind, and other clean energy technologies would retain their eligibility.) Congress should also consider further reforms to federal deployment policy, such as those proposed in the Energy Sector Innovation Credit Act of 2019 (HR. 5523) and the Clean Energy for America Act (S. 1288). That legislation would create deployment incentives that automatically ramp down as the technology gains a foothold in the market.[14]

While federal energy deployment policy should prioritize more nascent technologies in the long term, the ongoing COVID pandemic justifies continued deployment support for the solar and wind industries over the next couple years. Despite strong growth in recent years, the current economic downturn threatens renewables' continued progress. Clean energy employment has already suffered, with more than 600,000 clean energy jobs lost in March and April alone.[15]

The economic crisis threatens wind and solar developers in particular because they rely on tax equity partners — large financial institutions with large tax liabilities — to take advantage of the credits and finance projects. In a recession, tax equity markets dry up, which can kill planned development projects. The 2009 stimulus included a provision to make the wind and solar tax credits directly refundable as cash payments, known as the 1603 Program.[16] This program should be temporarily restored during the crisis, and the sunsetting of the wind and solar tax credits should be paused until the end of 2022 to ensure market stability and protect American jobs.

Unlike the solar and onshore wind industries, other clean energy industries have struggled to deploy a steady stream of projects. Major nuclear and carbon capture projects — such as the AP-1000 nuclear reactors under construction at Georgia's Vogtle power plant and the Kemper coal-gasification facility in Mississippi — have suffered from cost overruns and engineering and project management failures.[17,18] New technologies and new business models will be required to get the most bang for the federal government's deployment buck. And there are signs of progress. The Petra Nova project at the Parish coal-fired power plant in Texas, which started capturing carbon in January 2017, was finished on time and under budget. A new generation of advanced nuclear startups has shown early engineering promise and several companies have commercial agreements with utilities to start building reactors within the next few years.[19]

Policymakers should design deployment subsidies to accelerate technological learning and cost reductions in these industries instead of subsidizing a few one-off projects. In the case of nuclear power, Congress should lift the aggregate 6000-megawatt cap on eligible projects, while imposing a per-reactor eligibility cap of 250 megawatts, which will ensure that deployment supports are spread across multiple reactors and companies and that they benefit a new generation of advanced nuclear reactor technologies. Providing support to many smaller projects rather than a few large ones should accelerate technological learning and cost reductions.[20]

In 2018, Congress created the section 45Q tax credit for carbon removal. To date, the tax credit has benefitted few projects, and questions remain about IRS guidelines for project compliance.[21] The IRS should clarify standards by which businesses can claim the credit[22] and the credit should be extended through 2030 to give the carbon removal industry time to develop and deploy projects.

Like advanced nuclear and carbon capture, other clean energy industries, including offshore wind and enhanced geothermal, remain in their infancy. The billions of dollars in project finance unlocked by federal deployment subsidies would be better spent on these nascent technology sectors than on solar and onshore wind projects, and can help drive learning and cost reductions over time, as they did for solar and wind.

These deployment subsidies should be paired with efficient and effective investment in RD&D for early stage technologies. While dozens of advanced nuclear reactor startups have shown engineering and project management success, none has built an advanced reactor yet. Many carbon removal solutions have yet to be proven at commercial scale. And, enhanced geothermal has the potential to unlock substantial clean energy potential, but requires improved drilling, geologic fracturing, and other advanced technologies to do so.

At their current stage, advanced nuclear, carbon removal, enhanced geothermal, and offshore wind find themselves in a position familiar to the existing solar and onshore wind industries, which continued to benefit from scientific, engineering, and manufacturing improvements even as they were deploying projects at gigawatt scales. Smart deployment policy, paired with other public RD&D resources, can help drive down costs, create thriving industries, and accelerate decarbonization.

TRANSMISSION EXPANSION AND INCREASED GRID INTERCONNECTION

- Invest in "supergrid" infrastructure to better connect the Western and Eastern Interconnections.
- Dedicate federal funding for transmission expansion and upgrades in the Power Marketing Administrations (PMAs).
- Establish a tax credit for the construction of regionally significant transmission projects.
- Reform and strengthen federal backstop siting authority for projects in transmission corridors.
- Alleviate regulatory burdens on transmission projects.

The federal government should make sizable investments in high-voltage, long-distance transmission, which will enable further VRE deployment while benefiting the grid as a whole. An expansion in transmission would enable the integration of large amounts of clean energy on the grid, as it would connect remote areas with high renewable resource potential to demand centers.

A significant federal investment in long-distance electric transmission as part of the COVID-19 stimulus would quickly create a great many jobs across a wide geographic area, and would magnify the benefit of further investment in clean energy development. A study funded by the Department of Energy's Grid Modernization Initiative found that expansion of transmission capacity would have a clear economic benefit, saving at least least $2.50 for every $1 spent.[23] A study by The Brattle Group found that every $1 billion invested in transmission per year supports 13,000 FTE jobs.[24]

A national transmission expansion would require federal investment and coordination, as it would reach across many state and local jurisdictions. A national "supergrid" — connecting the Eastern, Western, and Texas Interconnections — would reduce system costs and regional variability associated with high shares of variable renewables in the generation mix.[25]

Congress has a variety of available mechanisms at its disposal to accelerate the development of transmission. These include:

Designating federal funding for transmission expansion in the Power Marketing Administrations (PMAs). PMAs are federal agencies in the West and Southeast that transmit and sell power from federally-owned electric generators; their transmission lines already serve more than 40 percent of the country.[26] Past efforts to expand and modernize the PMAs have met criticism for risking higher rates.[27] However, designated funds from the federal government could enable the expansion of the PMAs while ensuring rate stability. Expanding transmission infrastructure in PMA territory would enable rapid clean energy expansion in rural states and faster decarbonization of the power supply for demand centers. State governments and utilities should support the development of PMA transmission, as many states and utilities have emissions reductions targets. Finally, an expansion of PMA transmission could help identify best practices for grid modernization, which could then be scaled up outside of the PMA territories.

Establishing a tax credit for the construction of regionally significant transmission projects. Tax credits have been successful in incentivizing the development of new energy sources like wind and solar. However, there is currently no federal tax credit for transmission. While FERC guarantees a rate of return on capital for transmission investment, there are still regionally significant transmission projects that should receive an additional incentive to ensure their construction. These regionally significant projects would help to alleviate grid congestion, create jobs, and stimulate further clean energy development. The Electric Power Infrastructure Improvement Act (S.3107) would establish this tax credit and should be included in the stimulus.[28]

Reforming and strengthening federal backstop siting authority for projects in transmission corridors. Historically, siting and approval decisions about transmission projects were made by states. The Energy Policy Act of 2005 (EPAct) gave federal agencies, DOE and FERC, the authority to make siting decisions for transmission projects in key geographical regions if they have stalled in the state approval process. However, subsequent federal court decisions significantly restrained this authority. Congress should restore this mechanism by rewriting the federal backstop authority in accordance with the court decisions by restricting its scope further and requiring it to be used in concordance with regional transmission organizations.[29]

Alleviating regulatory burdens on transmission projects. Expanding transmission will help accelerate decarbonization, so Congress should except or expedite key transmission projects from environmental regulatory barriers — those with clear potential to enable clean energy deployment and drive emissions reductions. Relevant legislation includes the Interregional Transmission Planning Improvement Act of 2019 (H.R.5511, S.3109).

SMART PLANNING FOR LARGE-SCALE INFRASTRUCTURE PROJECTS

- Support deployment of wind, solar, and geothermal on federal lands by identifying priority areas for development in a manner that minimizes environmental impacts.
- Develop a federal plan for strategic national transmission expansion.

Large infrastructure projects, such as those that will be needed for wind, solar, and transmission, will require smart upfront planning and siting to help ensure projects are shovel ready. For example, there are key opportunities to expand large-scale wind, solar, and geothermal projects on public lands and such development would benefit from a national plan with clear guidelines for siting these projects. Wind, solar, and geothermal projects on federal lands have contributed $13 billion to the economy since 1996. In 2019, these projects produced over 5,000 megawatts of clean electricity.[30] Smart siting policy and upfront planning could help exempt projects from certain aspects of regulatory review and enable streamlining.

Senators McSally (R-AZ) and Heinrich (D-NM) have introduced the Public Land Renewable Energy Development Act of 2019 (S. 2666), which would identify priority areas for wind, solar and geothermal development on federal lands, while ensuring impacts to wildlands and wildlife are minimized.

Developing a federal plan for national transmission expansion would also help identify important corridors for new infrastructure, and help ensure development moves forward. The plan should build on past studies, like the DOE's Grid Modernization Initiative, to identify potential transmission corridors that unlock clean energy deployment, minimize environmental impacts, and respect existing rights-of-way. Then, transmission projects built in these planned corridors should be exempted from typical regulatory burdens and fast-tracked for construction.

ENERGY STORAGE RD&D INVESTMENT

- Develop a dedicated investment tax credit for grid-scale energy storage projects to facilitate deployment.
- Increase funding for RD&D of long-duration, grid-scale storage systems.

Finally, appropriators should double down on federal RD&D investments in long-duration electricity storage technologies, without which the mounting costs of seasonal variation in VRE generation will continue to rise.

The market for energy storage is expected to grow considerably in the coming years. Recent projections predict U.S. energy storage capacity growing 13-times to 230 GWh by 2025, as investment expands from $18 billion in 2019 to $100 billion in 2025.[31] Significant growth is also expected in global markets, particularly in countries that are pursuing rapid deployment of renewable energy for climate mitigation. Federal investment in storage technologies now would help to unlock domestic US clean energy in the future, while also creating the potential for a fast-growing export industry.

At present, large-scale and long-duration storage technologies are, largely, commercially unavailable, and thus still require sustained federal support. Congress should develop a dedicated investment tax credit for grid-scale energy storage projects to facilitate deployment, in addition to the limited existing tax credit available for storage systems associated with renewables projects.[32] Relevant legislation includes the Energy Storage Tax Incentive and Deployment Act of 2019 (H.R.2096, S.1142).

In addition to tax credits, the federal government should ramp up its funding for RD&D of long-duration grid-scale storage systems. The Better Energy Storage Technology (BEST) Act (S. 1602) would establish a RD&D program for grid-scale energy storage systems, a critical first step in deploying these technologies more broadly in the US. The Senate version of the BEST Act was amended to incorporate language from four additional energy storage bills, and was also included in the comprehensive energy innovation package known as the American Energy Innovation Act.

CONCLUSION

Existing solar and onshore wind technologies are cheap on the margin and benefit from increasingly robust project development and supply chains. They already have and will surely continue to play major roles in the replacement of fossil generation sources and in the decarbonization of electricity systems worldwide.

This is largely the result of federal RD&D and deployment policy. But the policies that have allowed these industries to grow past infancy cannot be expected to support them in perpetuity. The proportional subsidy costs, combined with challenges related to the variability of wind and solar and the storage and transmission constraints, require a new set of supportive policies altogether.

In particular, the same types of incentives that helped make solar and wind cheap can be put to better use now to help drive down the costs of other clean energy technologies, including offshore wind, advanced nuclear, geothermal, carbon removal, and others. Improving and upgrading the nation's transmission infrastructure and electricity storage technologies will play similar roles in accelerating deep decarbonization of the power grid.

ENDNOTES

1 Gillingham, Kenneth, and James H. Stock. "The cost of reducing greenhouse gas emissions." Journal of Economic Perspectives 32.4 (2018): 53-72.

2 Jenkins, Jesse, Mark Muro, Ted Nordhaus, Michael Shellenberger, Letha Tawney, and Alex Trembath. "Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence." The Breakthrough Institute. April 2012. https://thebreakthrough.org/articles/beyond-boom-and-bust-report-overview

3 Congressional Research Service. "The Value of Energy Tax Incentives for Different Types of Energy Resources." Updated March 19, 2019. https://fas.org/sgp/crs/misc/R44852.pdf

4 Olson, Erik, Lauren Anderson, and Jameson McBride. "Assessing Lulls in Variable Renewable Generation." The Breakthrough Institute, March 3, 2020. Accessed April 8, 2020. https://thebreakthrough.org/issues/energy/variable-renewable-generation

5 Trembath, Alex, and Jesse Jenkins. "A Look at Wind and Solar Part Two: Is there an upper limit to intermittent renewables?" The Breakthrough Institute. Accessed May 8, 2020. https://thebreakthrough.org/issues/energy/a-look-at-wind-and-solar-part-2

6 Das, Saptarshi, Eric Hittinger, and Eric Williams. "Learning Is Not Enough: Diminishing Marginal Revenues and Increasing Abatement Costs of Wind and Solar." Renewable Energy 156 (August 1, 2020): 634–44. doi:10.1016/j.renene.2020.03.082.

7 Hirth, Lion. "The Market Value of Variable Renewables." Energy Economics 38 (July 2013): 218–36. doi:10.1016/j.eneco.2013.02.004.

8 U.S. Bureau of Reclamation. "A Study of Future Power Transmission for the West," 1952.

9 Tomich, Jeffrey. "TRANSMISSION: Renewables 'hit a Wall' in Saturated Upper Midwest Grid." E&E News, December 12, 2019. Accessed May 11, 2020. https://www.eenews.net/stories/1061787851

10 Brick, Stephen and Samuel Thernstrom. "Renewable and decarbonization: Studies of California, Wisconsin, and Germany." The Electricity Journal. Vol. 29:3 (April 2016): 6-12. https://doi.org/10.1016/j.tej.2016.03.001

11 Jenkins, Jesse D. and Samuel Thernstrom. "Deep Decarbonization of the Electric Power Sector: Insights from Recent Literature." Energy Innovation Reform Project. March 2017. https://www.innovationreform.org/wp-content/uploads/2018/02/EIRP-Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf

12 "The Value of Energy Tax Incentives for Different Types of Energy Resources." Congressional Research Service. March 2019. https://fas.org/sgp/crs/misc/R44852.pdf

13 Jenkins, Jesse, Mark Muro, Ted Nordhaus, Michael Shellenberger, Letha Tawney, and Alex Trembath. "Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence." The Breakthrough Institute. April 2012. https://thebreakthrough.org/articles/beyond-boom-and-bust-report-overview

14 Sivaram, Varun and Noah Kaufman. "The Next Generation of Federal Electricity Tax Credits." Columbia Center on Global Energy Policy. June 3, 2019. https://energypolicy.columbia.edu/research/commentary/next-generation-federal-clean-electricity-tax-credits

15 Los Angeles Times, "Climate change is looming. But America has lost 600,000 clean energy jobs" https://www.latimes.com/environment/story/2020-05-13/half-million-clean-energy-job-losses-amid-coronavirus

16 U.S. Department of the Treasury. 1603 Program: Payments for Specified Energy Property in Lieu of Tax Credits. https://home.treasury.gov/policy-issues/financial-markets-financial-institutions-and-fiscal-service/1603-program-payments-for

17 Lovering, Jessica. "Last Plant Standing." The Breakthrough Institute. September 6, 2017. https://thebreakthrough.org/issues/energy/last-plant-standing

18 Thompson, John. "Two Carbon Capture Projects: A Deeper Look." Clean Air Task Force. July 19, 2017. https://www.catf.us/2017/07/two-carbon-capture-projects/

19 Nordhaus, Ted and Jessica Lovering. "Why Advanced Nuclear Reactors May Be Here Sooner Than Many Imagine." Greentech Media. May 24 2019. https://www.greentechmedia.com/articles/read/why-advanced-nuclear-reactors-may-be-here-sooner-than-many-imagine

20 Lovering, Jessica, Loren King, and Ted Nordhaus. "How to Make Nuclear Innovative: Lessons from Other Advanced Industries." The Breakthrough Institute. March 22, 2017. https://thebreakthrough.org/articles/how-to-make-nuclear-innovative

21 Frazin, Rachel. "Government probe finds companies claiming carbon capture tax credit didn't follow EPA requirements." The Hill. April 30, 2020. https://thehill.com/policy/energy-environment/495526-government-probe-finds-companies-claiming-carbon-capture-tax-credit

22 Ong, Justin. "Carbon Capture Now a Jobs Lifeline Thanks to 45Q Tax Credit." ClearPath. April 9, 2020. https://clearpath.org/our-take/carbon-capture-now-a-jobs-lifeline-thanks-to-45q-credit/

23 Temple, James. "How to Get Wyoming Wind to California, and Cut 80% of U.S. Carbon Emissions." MIT Technology Review, December 28, 2017. Accessed April 8, 2020. https://www.technologyreview.com/2017/12/28/146566/how-to-get-wyoming-wind-to-california-and-cut-80-of-us-carbon-emissions/

24 Pfeifenberger, Johannes, and Delphine Hou. "Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada." The Brattle Group/WIRES, May 2011. https://brattlefiles.blob.core.windows.net/files/8209_employment_and_economic_benefits_of_transmission_infrastructure_investmt_pfeifenberger_hou_may_2011_wires.pdf

25 Olson, Erik, Lauren Anderson, and Jameson McBride. "Assessing Lulls in Variable Renewable Generation." The Breakthrough Institute, March 3, 2020. Accessed April 8, 2020. https://thebreakthrough.org/issues/energy/variable-renewable-generation

26 Jacobs, Jeremy. "Ex-Obama aide, analysts balk at Sanders' grid plan." E&E News Energywire, February 10, 2020. https://www.eenews.net/energywire/stories/1062308261/search?keyword=public+marketing+administrations

27 Northey, Hannah. "DOE: Chu's Grid Guru Came in 'like Gangbusters,' Left Quietly." E&E News Greenwire, December 19, 2013. Accessed April 8, 2020. https://www.eenews.net/stories/1059992057

28 Heinrich, Martin. Electric Power Infrastructure Improvement Act (S.3107). Introduced December 19, 2019. https://www.congress.gov/bill/116th-congress/senate-bill/3107/text

29 "Proposed Reform of Existing Federal Backstop Transmission Siting Authority | Bipartisan Policy Center." Accessed April 9, 2020. https://bipartisanpolicy.org/blog/bpc-electric-grid-initiatives-proposed-reform-existing-fed/

30 Yale University Center for Business and the Environment and the Wilderness Society 2020. https://www.wilderness.org/sites/default/files/media/file/CBEY_WILDERNESS_Renewable%20Energy%20Report_0.pdf

31 Wood Mackenzie. "Global Storage Market to Grow from 12 GWh to 158 GWh by 2024," April 9, 2019. https://www.woodmac.com/press-releases/global-storage-market-to-grow-from-12-gwh-to-158-gwh-by-2024/

32 NREL, "Federal Tax Incentives for Energy Storage Systems." NREL/FS-7A40-70384, January 2018. https://www.nrel.gov/docs/fy18osti/70384.pdf

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