SECTOR-BY-SECTOR APPROACHES

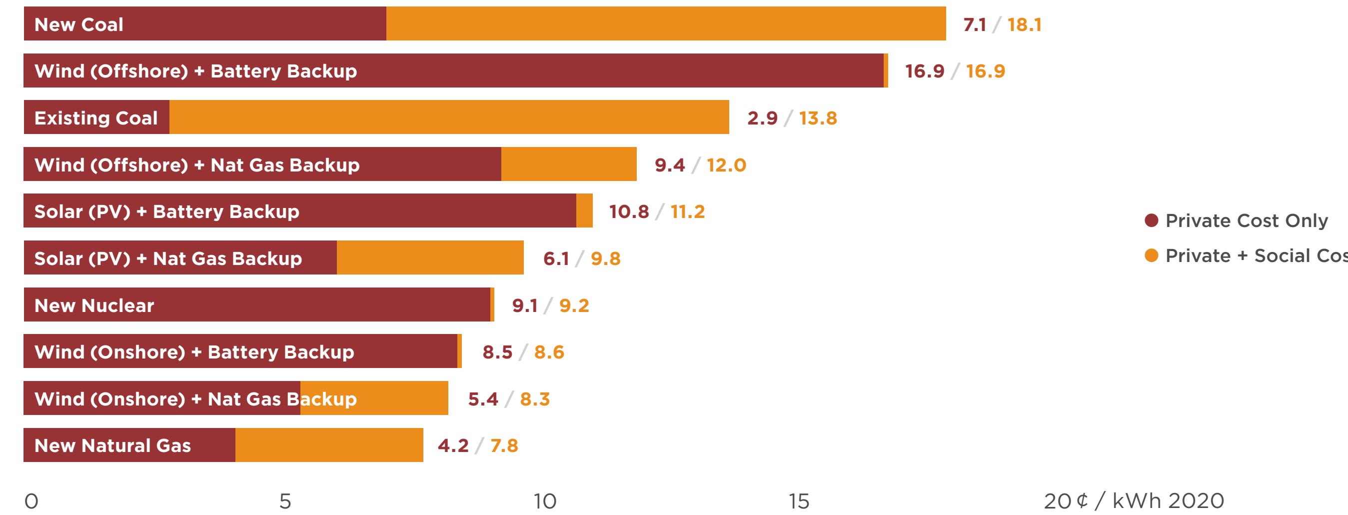
Fueling Technology Deployment with a Clean Electricity Standard

Michael Greenstone, *Milton Friedman Distinguished Service Professor in Economics; Director, EPIC; Director, Becker Friedman Institute*
Ishan Nath, *Postdoctoral Scholar, EPIC*

Low carbon technologies face an uneven playing field in the United States due to competition from fossil fuel sources that do not pay for the costs that their emissions impose on society. At present, carbon-free sources account for a minority of U.S. electricity production and do not appear on track to become the primary source of American electricity in the coming decades under current policy, despite the urgent need to reduce emissions and confront climate change. While the direct costs of renewable sources of power, such as wind and solar, have fallen dramatically in recent years, their continued growth remains uncertain due to the challenges of integrating them with the grid, particularly those arising from extensive transmission requirements and intermittent production.

FIGURE 1 - CHAPTER IN A CHART

Levelized Cost of Electricity by Source



Note: Unable to quantify non-greenhouse gas costs of nuclear energy.

Source: EPIC analysis.

In the absence of a carbon price that forces fossil fuel generators to pay the full social costs of their production, a Clean Electricity Standard (CES) is a possible policy mechanism to drive deployment of existing clean energy technologies and create predictable market demand that encourages innovation. While such a policy has not yet been implemented in any jurisdiction in the United States, many states have implemented a somewhat related policy, Renewable Portfolio Standards (RPS), with a mixed record of success. A federal CES could build upon the lessons of these state-level programs and achieve the greatest environmental benefit at the lowest cost by making the standard geographically flexible and technology-neutral, linking the policy to carbon reduction programs in other sectors, and pairing the national mandate with complementary policies that facilitate grid integration and directly support technological innovation.

Heart of the Problem

Low carbon technologies account for a minority of U.S. electricity production and appear on track to grow only modestly under existing policy. As shown in Figure 2, less than 38 percent of U.S. electricity came from carbon-free sources in 2019.[1] More than half this total (20 percent) came from nuclear power plants, with hydropower, wind, and solar electricity accounting for only 7 percent, 7 percent, and 2 percent respectively.

Various projections suggest that these patterns may continue in the long run, inhibiting the urgent task of reducing CO_2 emissions to avoid the most serious consequences of climate change. For example, Figure 2 shows the U.S. Energy Information Administration (EIA) reference scenario for the coming decades, which suggests that the share of carbon-free electricity will remain under 50 percent by 2030, and climb to only 53 percent by 2050. While the EIA scenarios are not firm predictions, the balance of forecasts from other industry analysts suggests a similar outlook.[2] Thus, despite rapid renewable growth in recent years, low-carbon power sources risk plateauing under current policy as fossil fuels continue to provide a large share of future U.S. power generation.

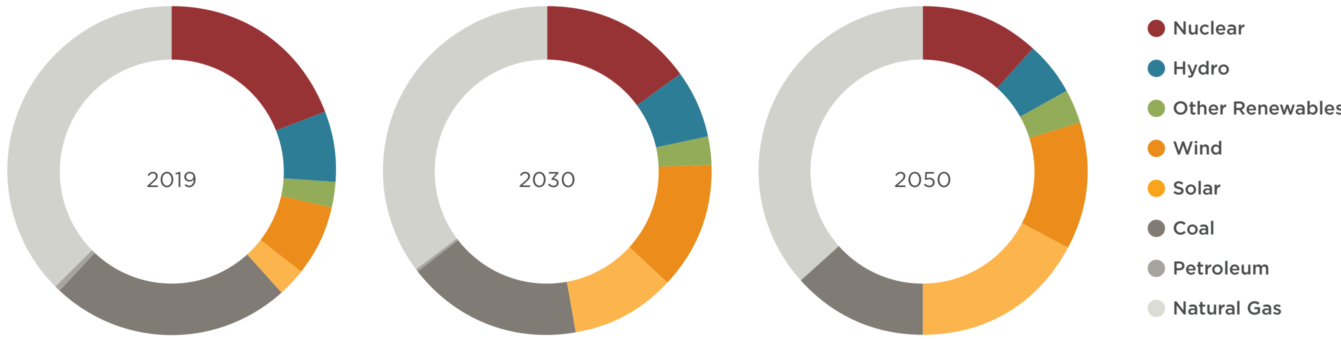
Clean energy sources face an uphill climb in electricity markets for a number of reasons, starting with competition from cheap fossil fuels. For example, the levelized costs of electricity (or LCOE, the total value of lifetime capital,

1 For the purposes of this calculation, the other renewables listed by the EIA, including biomass and geothermal, are assumed to be carbon-free.

2 International Energy Agency, *World Energy*; BP plc, *Energy Outook*; Bloomberg New Energy Finance, *New Energy Outlook 2020*. The International Energy Agency and British Petroleum's Energy Outlooks contain similar projections for renewable generation shares in the U.S. and the world, respectively. The Bloomberg New Energy Finance's New Energy Outlook is more optimistic about global growth in renewables.

FIGURE 2

Global Energy Mix by Source



Source: EIA Projections.

operations, and fuel costs divided by expected power produced) from existing coal fired power plants is 3.1 cents per kilowatt hour (kWh). The LCOE for a new combined cycle natural gas power plant is 4.6 cents per kWh.

Critically, however, these market costs do not account for the harm that pollution inflicts on others. External damages from greenhouse gas emissions and air pollution add more than 10 cents per kWh to the market cost of coal power and about 3.5 cents for natural gas (see Figure 1). The implicit subsidy fossil fuels receive from operating in a policy environment that does not reflect the true price of their emissions helps them out-compete cleaner energy sources, even when this may not be best for society. (For more information on how best to incorporate these costs, see "Updating the United States Government's Social Cost of Carbon," page 20.)

Until the full costs of fossil fuels are reflected in their price, renewable energy will be competing on an uneven playing field. To be sure, these technologies have made enormous progress toward reducing costs in recent years, but key obstacles continue to inhibit their widespread adoption. By one measure, the direct costs of producing electricity have fallen by nearly 86 percent for solar photovoltaic (PV) and 49 percent for wind since 2009, nearing parity with coal and natural gas.[3] However, the indirect costs of integrating these intermittent resources into the grid remains an unresolved challenge. Solar and wind electricity have capacity factors (average power generated divided by maximum possible supply over the course of a year) of about 25 percent and 35 percent, respectively, compared with about 85 percent for a natural gas combined cycle plant, creating a perpetual need to back them up with more stable sources of supply.[4]

The need for backup power adds considerably to the full cost of renewables. According to Lazard, power from natural gas "peaker" plants that can ramp production up and down on short notice is 18 cents per kWh, adding considerably to the full cost of wind and solar.[5] In addition, some grid operators in the United States have started making substantial "capacity payments" to fossil fuel electricity generators—paying them not for producing electricity but rather to keep idle capacity available to protect against unpredictable supply shortages from renewable facilities.[6] While quantifying the precise costs of intermittency remains challenging, Figure 1 displays estimates of the LCOEs of providing a steady supply of power by combining wind and solar with natural gas or battery backups, illustrating the magnitude of the challenge that continues to face renewable sources.

Elevated transmission costs also play an important role in impeding the growth of renewable energy. Because the ideal geography for wind and solar power installations is frequently far away from cities, and because those installations require substantial physical space, the costs of bringing their power to market exceed those of fossil fuels.

3 EPIC calculations using data from the U.S. Energy Information Administration, *Annual Energy Outlook 2009*; U.S. Energy Information Administration, *Annual Energy Outlook 2020*.

4 U.S. Energy Information Administration, *Annual Energy Outlook 2020*.

5 Lazard, *Lazard's Levelized Cost of Energy*.

6 U.S. Government Accountability Office, "Electricity Markets"; Bushnell, Flagg, and Mansur, "Capacity markets."

A review by the Lawrence Berkeley National Laboratory found that excess transmission costs add about 1.5 cents per kWh to the LCOE of wind generation.[7] A separate analysis by the Edison Electric Institute, an electricity industry group, highlighted that nearly 65 percent of a representative sample of U.S. transmission investments over a ten-year period were primarily directed toward integrating renewables, suggesting that these sources account for a disproportionate share of transmission costs.[8] Because the additional costs of transmission and grid integration are not included in traditional comparisons across energy sources, the progress of carbon-free power risks stalling even as the costs of solar panels and wind turbines continue to decline.

While some clean energy technologies have improved greatly in recent years, others have not, and the pace of innovation lags behind what is necessary to mitigate the most serious consequences of climate change. The costs of lithium ion batteries, which could facilitate the integration of variable renewable production by storing electricity to align supply and demand, have fallen, but remain prohibitively high for utility-scale use. Many experts believe that even the minimum technologically feasible cost of lithium ion batteries would be several times too high to be useful for large-scale grid integration, and alternative technologies remain far from broad commercialization.[9]

Incorporating carbon capture and sequestration (CCS) into fossil fuel plants is another potential pathway toward reliable low carbon power, but the United States still does not have a single operational CCS plant generating electricity and capturing CO_2 emissions. (The Petra Nova plant in Texas completed a three-year demonstration project that began in 2016, but was placed in reserve shutdown status as of May 2020.)[10] Only one such CCS plant, the Boundary Dam plant in Canada, exists anywhere in the world.[11]

In sum, low carbon power sources comprise less than 40 percent of current U.S. electricity generation and do not appear on track to drive the reductions in carbon emissions needed to mitigate climate change. The Biden administration must act decisively to enable the transition toward a cleaner U.S. grid and develop the clean energy technologies of the future.

Two broad categories of policy levers exist to promote these goals: direct investment in research and development (R&D) of new technologies, and market signals that will encourage the private sector to innovate on its own. The federal government, through the Department of Energy (DOE) and other agencies, is already active in funding research and development in energy technologies, though it can and should do more. A national Clean Electricity Standard, meanwhile, is an important pathway to establishing market signals. By credibly signaling to investors and firms that there will be market demand for innovations in cheaper, more reliable clean energy technologies, policy can put in place the profit motive to drive investment.

How We Got Here

A Clean Electricity Standard would require carbon-free or low carbon sources to supply a given proportion of electricity generation. To date, no jurisdiction in the United States has implemented such a standard that includes the full range of carbon-free technologies.

Some informative parallels can be drawn, however, from the most-similar existing policies: state-level Renewable Portfolio Standards (RPS), which have been implemented by 30 states and the District of Columbia over the past three decades. These policies mandate that a certain proportion of electricity in a state be generated by sources designated as renewable. Electricity producers that demonstrate generation from a qualifying source receive a certification called a Renewable Energy Credit (REC) for each unit of electricity produced. Electricity retailers must then purchase RECs equal to the required proportion of their sales to achieve compliance. If at the end of the compliance period (typically each year), they have not purchased enough RECs to meet the required standard, they must pay a fine called an "Alternative Compliance Payment" for each unit they fall short.[12]

7 Mills, Ryan, and Kevin, "The Cost of Transmission."

8 Edison Electric Institute, *Transmission Projects*.

9 Pontin, "To Combat Climate Change."

10 NRG Energy Inc, "Petra Nova."

11 Folger, *Carbon capture and sequestration*.

12 In vertically integrated non-restructured states retailers may also use RECs generated by their own renewable generating units. Alternative Compliance Payment fines are typically large – on the order of $50 per MWh.

Renewable energy from variable sources like wind and solar needs to be backed up to ensure the lights stay on whatever the weather.

Because RECs are tradable across technologies, and to some extent across jurisdictions, this approach allows market forces to select the lowest cost sources and locations for renewable production. Electricity suppliers trying to minimize their cost of compliance will purchase the lowest price RECs available for sale, driving competition amongst generators, technologies, and regions to offer the lowest prices.

The technologies covered by existing RPS policies vary across states, but often exclude a number of carbon-free electricity sources that do not meet the criteria to be considered "renewable." While all states include wind and solar, for example, many do not include hydropower or geothermal. No states included nuclear or carbon capture and sequestration (CCS) in their original RPS programs. To date, only Ohio has added nuclear and only four states (Massachusetts, Michigan, Ohio, and Utah) have added CCS to their list of eligible sources.[13]

In addition, many states do not establish a level playing field among included technologies. In some cases, regulators set higher standards for particular technologies, essentially mandating a larger market share for popular technologies. Thirteen states, for example, have specific mandates for the proportion of the RPS that must be met using solar generation. Many others use REC multipliers to assign more than one unit of credit for each unit of power from favored technologies or producers. For example, Delaware gives extra REC credits to plants that use components manufactured in Delaware.[14] While these technology-specific mandates arise for a variety of state-specific reasons, one common justification is the belief that certain technologies offer greater opportunities to benefit from learning-by-doing. Each of these additional restrictions and exclusions, however, serves to distort the market away from the lowest cost allocation of technologies and raise the cost of complying with the policy.

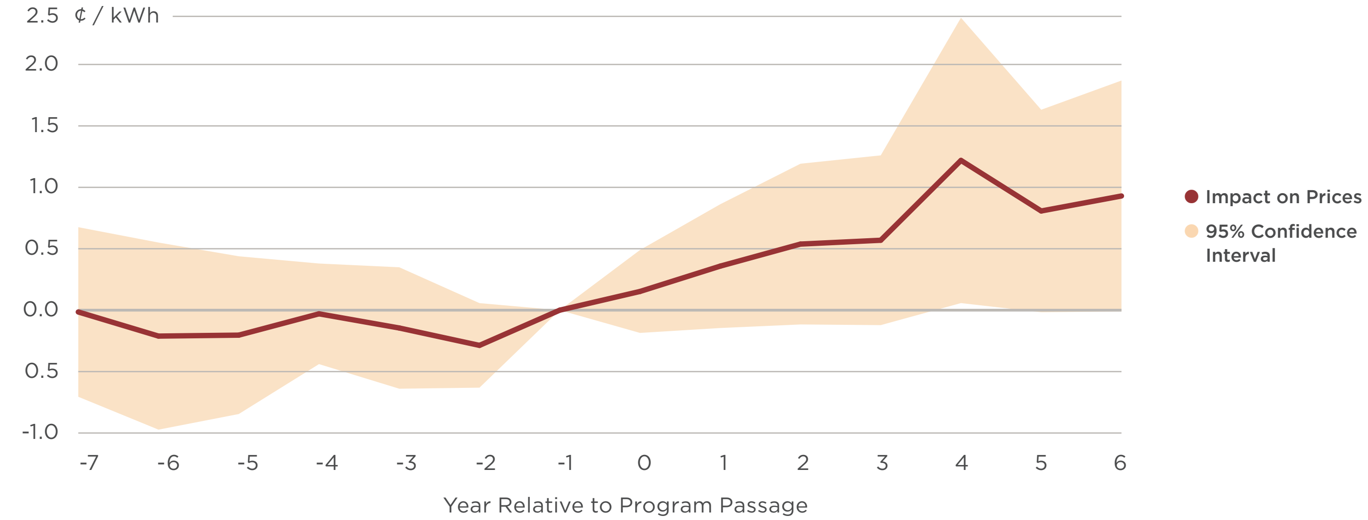
Existing state-level RPS policies allow for a limited degree of trade across regions. Electricity retailers can purchase RECs from out-of-state generators within a geographic region to comply with their state's requirement. Some REC regions cover broad geographic regions—for example, the M-RETS tracking system covers states from the upper Midwest to the South, stretching from North Dakota to Arkansas—allowing producers to comply with policies while locating where renewable resources are abundant and low-cost. Other RPS programs, however, such as those in Michigan, Nevada, North Carolina, and Texas, restrict REC regions to their home state, and some states, such as Illinois and Ohio, require special permission from regulators to approve out-of-state REC purchases.[15] Such restrictions raise costs by narrowing the available range of options for producers to comply with clean energy mandates.

Not only do existing RPS policies limit technologies and markets in ways that could raise costs, they have also generally resulted in only modest increases in the share of renewables in a given state. Though the headline numbers for renewable generation in the early years of RPS mandates appeared substantial, many of the requirements could be met by preexisting capacity. One study found that seven years after the adoption of RPS policies, renewables were required to raise their market share by only 2.2 percentage points of total generation, and twelve years after by only 5.0 percentage points.[16]

In the coming years, however, many RPS mandates are set to rise considerably. For example, the New Jersey and New York standards will cover 50 percent of all generation by 2030, Vermont will require 75 percent renewables by 2032, and California will go to a full 100 percent by 2045. Evaluating the likely effects of such demanding targets requires extrapolating both far into the future and far outside the range of existing experience with clean energy generation. It remains to be seen whether they can achieve those results at a bearable economic price.

FIGURE 3

Impact of RPS on Retail Electricity Prices



Source: Greenstone and Nath, (2019).

The balance of evidence indicates that existing RPS policies have not been a cost-effective method to reduce emissions. While one study that measured only the direct costs of new renewable generation found that RPS raised costs to consumers by about 2 percent, other research has shown that the full cost of RPS policies was significantly higher.[17] Two studies that account more broadly for such indirect costs, including the transmission and integration of renewables into the grid, find that RPS raised prices substantially—in the range of 11-17 percent in years seven through twelve after the policy was passed.[18] This research finds that RPS policies also reduced carbon emissions appreciably, but that the cost per ton reduced was higher than other policies that more directly target emissions reductions.

Using these findings to project the effects of a long-term national Clean Electricity Standard is challenging. The specific details of a potential national policy matter a great deal, and could differ substantially from existing state-level mandates. Years of future technological innovation could reduce the costs of compliance far below what states are presently experiencing. On the other hand, aggressive targets well outside the range of today's state-level mandates could cause costs to consumers to increase dramatically if broad reliance on intermittent power sources places unexpected or unmanageable strains on the grid.

If the Biden administration decides to pursue a Clean Electricity Standard, drawing on the lessons from state RPS programs can help guide the process of designing policy to promote low-carbon technology deployment and innovation at the lowest possible cost.

Policy Recommendations

The objective of effective U.S. climate policy is to achieve major reductions in emissions while minimizing the economic burden placed on American firms and consumers. Implementing a national market price on carbon emissions is the most efficient method to achieve this goal (see "Put a Price on It: The How and Why of Pricing Carbon," page 50). In the event that political constraints make such an approach unavailable to the Biden administration, however, a national Clean

13 Jacobs and Craig, "Legal Pathways"; National Governors Association, *Policy Update*. Jacobs and Craig provide information about including CCS. National Governors Association provide information about Ohio's RPS including nuclear. Four other states—Connecticut, Illinois, New Jersey, and New York—issue Zero Emissions Credits (ZECs) to nuclear power plants, but these credits are not tradable with RECs and thus operate as a subsidy outside of the RPS policy. Illinois has a separate carveout requiring electric utilities to procure at least 5 percent of their total energy supply from coal plants that sequester 50 to 90 percent of their carbon emissions.

14 Lips, *Credit Multipliers*.

15 PJM Environmental Information Services, "Illinois."

16 Greenstone and Nath, "Do Renewable Portfolio Standards."

17 Barbose, "U.S. renewable portfolio standards"; Gowrisankaran, Reynolds, and Samano, "Intermittency and the value of renewable energy."

18 Upton Jr and Snyder, "Funding renewable energy"; Greenstone and Nath, "Do Renewable Portfolio Standards."

Electricity Standard is a viable alternative to harness market forces, incentivize firms to innovate, and reduce U.S. emissions substantially over time. The following are principles and proposals that the Biden administration and Congress could use to develop such a policy.

PRINCIPLE

Allow the broadest possible range of technologies and geography to qualify for compliance.

Existing state-level RPS policies have been expensive to consumers, in part because they place undue restrictions on the type and location of clean electricity generation included in the policy. A national CES policy could reduce costs by allowing electricity retailers to purchase credits from low-carbon generators across a broad range of technologies and without geographic restrictions. This means including options that have been largely excluded from state-level programs, such as nuclear energy and carbon capture and sequestration. It also means allowing credits generated by those companies to be traded in an integrated national market, reducing barriers that prevent low-carbon producers from locating in the most advantageous possible places and thereby reducing overall costs.

Credits earned under a national CES program could be referred to as Clean Energy Credits (CECs) instead of Renewable Energy Credits (RECs) to be consistent with this broader definition of allowable technologies.

PROPOSAL

Specify clear standards for certifying new technologies to promote innovation.

Achieving the emissions reductions necessary to prevent dangerous levels of climate change is an immense challenge that will unfold over a period of decades. Thus, it is critical not to limit the bounds of policy to technologies that exist today, but instead to create a flexible legal framework that can incorporate the innovations of scientists and entrepreneurs tomorrow. Any policy that certifies only a static list of technologies for compliance will exclude inventors working on technologies that might not commercialize until 2030, 2040, or 2050—technologies that could radically transform the market.

To avoid this restriction on future innovation, a national Clean Electricity Standard could articulate clear standards, including emissions benchmark measurements and broader public health and safety certifications, to qualify as an approved low-carbon source of power. While an initial list of approved power sources must be specified in the law, regulators at the Department of Energy could be empowered to apply the standards outlined in the law to decide whether other technologies or power sources merit additional inclusion. These regulators would be charged with certifying new technologies for inclusion in the decades to come, as well as with periodically reviewing approved technologies to ensure they are delivering as designed (for example, whether carbon capture and sequestration technologies are successfully preventing carbon emissions).

PROPOSAL

Set up a centralized exchange for CEC trading to promote transparency and efficiency.

Realizing the full efficiency benefits of a technology-neutral and geographically inclusive national CES will require a transparent and efficient market on which CECs can be traded. Retailers purchasing CECs must be able to easily observe the range of available offers from clean electricity generators in order to purchase the lowest-cost option, and producers must have access to a national pool of potential buyers. Establishing a centralized exchange through FERC where generators can post CEC bid prices and retailers can choose which credits to purchase will ensure price transparency, facilitate monitoring of trade and compliance, and ensure that the aggregate costs of the policy are minimized.

PROPOSAL

Allow CECs to be traded with credits issued for compliance under EPA's Light-Duty Vehicle GHG Standards.

Given that the electricity sector accounts for only 27 percent of U.S. emissions, a Clean Electricity Standard will be just one element of U.S. climate policy. By harmonizing carbon-trading regimes across multiple sectors, policymakers can increase the total percentage of emissions being addressed in a single system. This approach can also reduce total costs to the economy, as companies will buy the cheapest emissions credits

Hydropower is one of the most common renewable energy sources in the United States but is not always included in RPS policies.

available and thereby direct investment toward the lowest-cost forms of carbon abatement, regardless of sector.

Under existing state level policies, RECs certify that a unit of electricity was produced with zero emissions. Similarly, the Environmental Protection Agency (EPA) administers a system for vehicle manufacturers to acquire and trade credits for compliance with tailpipe greenhouse gas (GHG) emissions standards (see " Four Proposals to Improve the Design of Fuel Economy Standards," page 122). Making permits tradable across the two programs—EPA's tailpipe GHG program and the national CES—would allow emissions reductions to be achieved wherever costs were lowest between the two sectors.

One difficulty with allowing permits to be traded across regimes is the difference in units, since CECs are measured in units of electricity generated rather than GHG emissions. To resolve this discrepancy, regulators could assign each CEC a value for the emissions it abates. Specifically, they could multiply the amount of electricity a generator produces by the average emissions intensity of traditional generation sources displaced by the CES in the state of production. For example, if average the emissions intensity from non-CES sources is one metric ton per MWh, then each MWh of CEC would be worth one metric ton of CO_2 when traded for a permit in the tailpipe emissions market.[19]

PROPOSAL

Award CECs for carbon reductions that do not involve electricity generation.

Vehicles are just one of many sectors that could be integrated with a Clean Electricity Standard. Policymakers could also empower regulators to issue credits for other provable methods of reducing emissions outside of the electricity sector. For example, technologies that successfully demonstrate the ability to capture and durably sequester carbon could be eligible for CECs. These may include direct air capture, agricultural processes that increase soil absorption of carbon, forest expansion, and carbon mineralization.[20] This certification process could be administered by DOE in consultation with relevant scientific experts from the EPA.

As above, the amount of CEC credits to be awarded can be determined by measuring the existing emissions intensity from traditional electricity sources. If the emissions intensity of those sources is one metric ton per MWh, DOE would award one metric ton of carbon removal with one MWh worth of CEC credits.

PROPOSAL

Empower FERC to site interstate transmission lines in "National Interest Electric Transmission Corridors" to improve integration of renewables.

Renewable energy relies heavily on the availability of extensive transmission infrastructure to bring electricity from areas with abundant sun or wind resources (such as the desert Southwest or the southern plains) to cities, where demand is high. Obtaining regulatory approval for long distance, interstate transmission lines, however, remains virtually impossible due to a

19 Greenstone, Sunstein, and Ori, "Fuel Economy 2.0."

20 Mulligan et al., "Six Ways to Remove Carbon Pollution."

FURTHER READING

Clean Electricity Standard

Do Renewable Portfolio Standards Deliver?

Social Science Research Network

State-level renewable electricity mandates increase electricity prices by as much as 17 percent over twelve years, making the cost of reducing carbon emissions with these policies likely more expensive than current estimates of the direct benefits of emissions reductions.

fragmented regulatory approval process. Siting interstate transmission lines requires obtaining approval from each state and local regulatory authority with jurisdiction over the proposed path, and can often take many years and/or fail to gain approval as unanimous agreement is very difficult to attain.[21]

The Energy Policy Act of 2005 established the authority for FERC to establish "National Interest Electric Transmission Corridors" (NIETC), in which the federal government can take over responsibility for siting transmission lines deemed to be critically important, but to date this power has not been used. The Biden administration can take two concrete steps to maximize the value of this tool. First, the law currently places tight limits on when such corridors can be established, limiting their use to locations experiencing persistent grid congestion due to insufficient transmission capacity. As part of legislation that establishes a CES or other energy policy, the Biden administration could pursue a minor update to the statutory definition of "national interest" to include connecting renewable energy to population centers. Given that facilitating the integration of low-cost carbon free power to mitigate climate change clearly constitutes a national interest, this adjustment would be within the spirit of the original legislation.

Second, initial efforts to establish these national interest corridors were stalled by surmountable legal barriers. Specifically, a district court ruled in 2009 that Congress had not made it explicit that FERC had the authority to override siting permits that were denied, rather than simply delayed, by local authorities.[22] Without the power to oversee the full siting process, it has not proved feasible for FERC to establish even a single NIETC in the fifteen years since the legislation was passed.[23] The Biden administration can work with Congress to amend the statute and clarify FERC's authority to take full control over the siting process in regions designated for a NIETC.

21 Thornley, "Regulatory Barriers." Provides examples of projects that were delayed, and also as one source for the policy proposals that follow in the next paragraph.

22 The case was Piedmont Environmental Council v. FERC, 2009. For analysis, see the following two sources: Klass and Wilson, "Interstate Transmission Challenges"; Sagar, "A Twenty-First Century Lazarus?"

23 The fact that this authority has not been exercised is covered in note 22, but for a more recent source confirming the lack of established NIETCs, refer to Scottmadden Management Consultants, *Informing the Transmission Discussion*.

More generally, establishing an effective approach to federal siting authority for long distance transmission lines can draw on lessons from the siting process for interstate natural gas pipelines. FERC has served as the primary siting authority for natural gas pipelines since passage of the Natural Gas Act of 1938.[24] In the process for siting pipelines, potential builders must acquire approval from FERC affirming that the project constitutes a necessary public objective, which grants the pipeline owner eminent domain authority over the proposed path. Under eminent domain, private property owners along the proposed path for building are entitled to "just compensation" for their losses under the Fifth Amendment.[25] Under the original 2005 law designating FERC's eminent domain authority over NIETCs, such compensation in the case of transmission lines can either be negotiated directly between the property holder and the construction permit holder, or be determined by a federal or state court.[26]

PRINCIPLE

Invest heavily in government research and development of new energy technologies.

There are two ways free markets fall short in the energy sector. First, as described above, a market with unpriced emissions is unfairly tilted against clean technologies because polluting technologies do not have to pay for all the costs they impose on others. A national CES indirectly addresses part of this issue by giving clean technologies credit for zero-emissions production and creating demand to incentivize innovation. However, this still leaves a second market failure that applies to emerging technologies—inventors get only a small portion of the benefits to society they create with their innovations, so the incentive to develop better technologies is below the level that would be best for society.

Thus, even with a national CES encouraging the private sector to develop better clean energy technologies, government support for energy R&D remains critical. U.S. investment in energy R&D has fallen by nearly two-thirds over the past few decades, and currently stands at only about 0.4 percent of GDP—far below the level recommended by most economists.[27] The low carbon technologies essential for meeting U.S. climate goals make up a minority of electricity production and face major obstacles to further growth. Major investments to enable future breakthroughs of carbon-free electricity production and grid integration technologies such as advanced batteries are necessary to make ambitious CES targets achievable. The Biden administration could drive progress in this area by substantially raising funding to the Department of Energy and its Advanced Research Projects Agency (ARPA-E) to support all stages of this innovation process, from basic science to demonstration and commercialization. A number of other analysts and researchers have provided detailed recommendations and specific proposals to execute these objectives.[28]

Closing Argument

Low carbon technologies play a relatively minor role in current U.S. electricity production, and continue to face significant challenges to substantial growth in the coming decades. A national Clean Electricity Standard would level the playing field between clean and dirty sources, mandate decarbonization of the power sector, and encourage innovation in clean energy technologies, though it has the disadvantage of being less efficient than policies that price carbon directly. While CES policies with broad technology inclusion remain largely untested in the United States, the mixed track record of somewhat related state-level Renewable Portfolio Standards offers policymakers some experience to draw on. If the Biden administration chooses to implement a national CES policy, policymakers could maximize the benefits of this approach by making the standard flexible and technology neutral, linking it to carbon reduction policies in other sectors, and pairing it with complementary policies that facilitate grid integration and directly support technological innovation.

24 Klass and Wilson, "Interstate Transmission Challenges"; Klass, "The Electric Grid."

25 Brandeis and Supreme Court of the United States, "U.S. Reports."

26 Department of Energy, "National Electric Transmission Congestion."

27 OECD/IEA (2020), "RD&D Budgets per GDP."

28 Sivaram et al., *Energizing America*; Shak and Krishnaswami, *Transforming the U.S. Department of Energy*; Hart and Kearney, "ARPA-E: Versatile Catalyst."

REFERENCES

Barbose, Galen. *US renewables portfolio standards: 2018 annual status report*. Lawrence Berkeley National Lab, 2018.

Bloomberg New Energy Finance. *New Energy Outlook 2020*. 2020

BP plc. *Energy Outlook 2020 edition*. 2020.

Brandeis, Louis Dembitz, and Supreme Court of the United States. "U.S. Reports: Lynch v.United States, 292 U.S. 571 (1934)." *Insurance Law 292* (1933).

Bushnell, James, Michaela Flagg, and Erin Mansur. "Capacity markets at a crossroads." *Energy Institute at Hass Working Paper* 278 (2017).

Department of Energy. "National Electric Transmission Congestion Report." *Federal Register* 72, no. 193 (2007).

Edison Electric Institute. *Transmission Projects: At A Glance*. Washington, DC: Edison Electric Institute, 2012.

Folger, Peter. *Carbon capture and sequestration (CCS) in the United States*. Congressional Research Service, 2018.

Gowrisankaran, Gautam, Stanley S. Reynolds, and Mario Samano. "Intermittency and the value of renewable energy." *Journal of Political Economy* 124, no. 4 (2016): 1187-1234.

Greenstone, Michael, and Ishan Nath. "Do Renewable Portfolio Standards Deliver?" *University of Chicago, Becker Friedman Institute for Economics Working Paper* (2020).

Greenstone, Michael, Cass R. Sunstein, and Sam Ori. "Fuel Economy 2.0." *Harvard Environmental Law Review* 44 (2020): 1.

Hart, David M. and Michael Kearney. "ARPA-E: Versatile Catalyst for U.S. Energy Innovation." Information Technology & Innovation Foundation, November 15, 2017. https://itif.org/publications/2017/11/15/arpa-e-versatile-catalyst-us-energy-innovation

International Energy Agency. *World Energy Outlook 2020*. IEA Publications, October 2020.

Jacobs, Wendy B., and Michael Craig. "Legal pathways to widespread carbon capture and sequestration." *Environmental Law Reporter News & Analysis* 47 (2017): 11022.

Klass, Alexandra B. "The Electric Grid at a Crossroads: A Regional Approach to Siting Transmission Lines." *UC Davis Law Review* 48 (2014): 1895.

Klass, Alexandra B., and Elizabeth J. Wilson. "Interstate transmission challenges for renewable energy: A federalism mismatch." *Vanderbilt Law Review* 5 (2012): 1801.

Lazard. *Lazard's Levelized Cost of Energy Analysis – Version 12.0*. November 2018. https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf

Lips, Brian. *Credit Multipliers in Renewable Portfolio Standards*. Clean Energy States Alliance, 2018. https://www.cesa.org/wp-content/uploads/RPS-Multipliers.pdf

Mills, Andrew D, Wiser Ryan, and Porter Kevin. "The Cost of Transmission for Wind Energy: A Review of Transmission Planning Studies." *Lawrence Berkeley National Laboratory*(2009).

Mulligan, James, Gretchen Ellison, Katie Levin, and Alex Rudee. "6 Ways to Remove Carbon Pollution from the Sky." World Resources Institute, June 9, 2020. https://www.wri.org/blog/2020/06/6-ways-remove-carbon-pollution-sky.

National Governors Association. *Policy Update: State Policy Support for Nuclear Generation*. April 25, 2019. https://www.nga.org/wp-content/uploads/2019/04/Policy-Update-Nuclear-Energy-April-25-20191.pdf.

NRG Energy Inc. "Petra Nova." Accessed November 2, 2020. https://www.nrg.com/case-studies/petra-nova.html.

OECD/IEA (2020). "RD&D Budgets per GDP." *IEA Energy Technology RD&D Statistics* (database). Accessed November 4, 2020. https://doi.org/10.1787/bb91a63c-en.

PJM Environmental Information Services. "Illinois." Program Information. Accessed November 2, 2020. https://www.pjm-eis.com/program-information/illinois.aspx.

Pontin, Jason. "To Combat Climate Change, We Gotta Get a Better Battery. But How?" *Wired*, September 17, 2019. https://www.wired.com/story/better-battery-renewable-energy-jason-pontin/.

Sagar, Santosh. "A Twenty-First Century Lazarus? The Demise and Possible Rebirth of FERC Backstop Siting Authority." *Ecology Law Quarterly* 37, no.2 (2010): 693-699.

Scottmadden Management Consultants. *Informing the Transmission Discussion: A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States*. January 2020. https://www.scottmadden.com/content/uploads/2020/01/ScottMadden_WIRES_Informing-the-Transmission-Discussion_6-Challenges-Policy-Implications_2020_0115.pdf

Shak, Tarak and Arjun Krishnaswami. *Transforming the U.S. Department of Energy in Response to the Climate Crisis*. National Resource Defense Council, November 2019. https://www.nrdc.org/sites/default/files/transforming-doe-response-climate-crisis-report.pdf

Sivaram, Varun, Colin Cunliff, David Hart Julio Friedmann, and David Sundalow. *Energizing America: A Roadmap to Launch a National Energy Innovation Mission*. Columbia University SIPA Center for Global Energy Policy, 2020. https://www.energypolicy.columbia.edu/sites/default/files/file-uploads/EnergizingAmerica_FINAL_DIGITAL.pdf

Thornley, Drew. "Regulatory Barriers to a National Electricity Grid." *Manhattan Institute for Policy Research, Energy Policy and the Environmental Report* 6 (2010).

Upton Jr, Gregory B., and Brian F. Snyder. "Funding renewable energy: An analysis of renewable portfolio standards." *Energy Economics* 66 (2017): 205-216.

U.S. Energy Information Administration. *Annual Energy Outlook 2009*. Washington, DC: 2009.

———. *Annual Energy Outlook 2020*. Washington, DC: 2020.

U.S. Government Accountability Office. "Electricity Markets: Four Regions Use CapacityMarkets to Help Ensure Adequate Resources, but FERC Has Not Fully Assessed TheirPerformance." December 7, 2017. https://www.gao.gov/products/GAO-18-131