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THE NEXT GENERATION OF FEDERAL CLEAN ELECTRICITY TAX CREDITS

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The federal tax incentive for wind energy expires at the end of 2019, and the incentive for solar energy will begin phasing out in 2020. Over multiple decades, these policies have succeeded in promoting the development and deployment of wind and solar technology, which today are rapidly gaining market share in the US electricity sector.

But it would be a mistake to declare "mission accomplished" and assume no successor policies are needed. After all, well over half of US electricity is still produced by fossil fuels that release climate-warming carbon dioxide and toxic local air pollutants into the atmosphere. It would also be a mistake to simply extend today's incentives indefinitely into the future. These policies have ballooned in cost and are ill suited to spur innovation that would improve upon the existing set of technology options for reducing US carbon emissions.

Federal policy makers should design a new generation of tax incentives as one element of a national plan to decarbonize the US electricity sector almost entirely by midcentury—an integral step in decarbonizing the overall economy to combat climate change. In recent months, lawmakers on both sides of the aisle have proposed new tax credits for a wide range of clean electricity technologies through proposals such as Democratic Senator Ron Wyden's Clean Energy for America Act and Republican Congressman Tom Reed's Energy Sector Innovation Credit Act.

Importantly, tax incentives are no silver bullet. Even carefully designed tax incentives will have drawbacks; for example, tax incentives are inherently less efficient than direct federal spending at transmitting incentives to the private sector. Moreover, it is unlikely that the country can achieve deep and sustained reductions in emissions without foundational policies such as a price on carbon or a national clean energy standard.[1]

Yet such policies may not be politically feasible in the immediate future. In the meantime, a well-designed set of tax incentives offers a promising avenue for near-term federal policy action that serves as a bridge toward a more comprehensive suite of decarbonization policies. Clean energy tax incentives have proven bipartisan appeal, having been enacted by wide margins in Congress multiple times in recent decades. Such incentives can expand the set of commercially viable clean electricity technology options for decarbonizing the US electricity system—and those around the world. Policy makers should tailor tax incentives to support emerging technologies that can solve pressing challenges, such as how to make the power sector more flexible to accommodate the rise of cheap but intermittent renewable energy. Such a strategy can also build political momentum for comprehensive climate policies, such as a carbon price, that can efficiently spur the deployment of clean energy technologies at great scale.

When devising this next generation of clean electricity tax incentives, federal policy makers should follow three design principles:

1. **Tailor tax incentives to critical applications.** Decarbonizing the power sector will require commercializing an array of technologies to perform a range of functions, most notably to provide enhanced flexibility to the power system to accommodate the rise of cheap but intermittent renewable energy. Such functions likely include capturing and storing carbon emissions; generating power that is both clean and dispatchable; transmitting electricity over long distances; storing energy for long durations; and orchestrating an increasingly complex electricity system. Policy makers can harness market competition to support the most promising technologies for each different function by designing tax incentive schemes tailored for each application.

2. **Coordinate tax incentives with support for clean energy research, development, and demonstration (RD&D).** Government support for RD&D can bring a range of novel clean energy technologies to a stage of maturity at which tax incentives can then foster their commercial scale-up and deployment. Policy makers should ensure that for each of the critical power sector applications that tax incentives seek to push forward, there is well-designed and well-funded RD&D support to fill the innovation pipeline with promising technologies.

3. **Ramp down support for technologies as they mature, while minimizing policy uncertainty.** Tax incentives are an expensive policy instrument with which to deploy mature clean energy technologies; the return on taxpayer investment is highest when tax incentives support the creation of new technology options that would not survive in the market without initial support for their commercialization. Policy makers should ensure that the eligibility of a particular technology for tax incentives declines as that technology is increasingly adopted in the marketplace. At the same time, they should avoid capricious policy changes that can chill the climate for private investment in clean energy technologies. Indeed, prior tax incentives for clean energy technologies have been hobbled by periodic bouts of uncertainty over whether the incentives would be renewed. To avoid this, Congress should pass a long-term tax incentive package that sets clear guidelines for the timeline and funding level of the program.

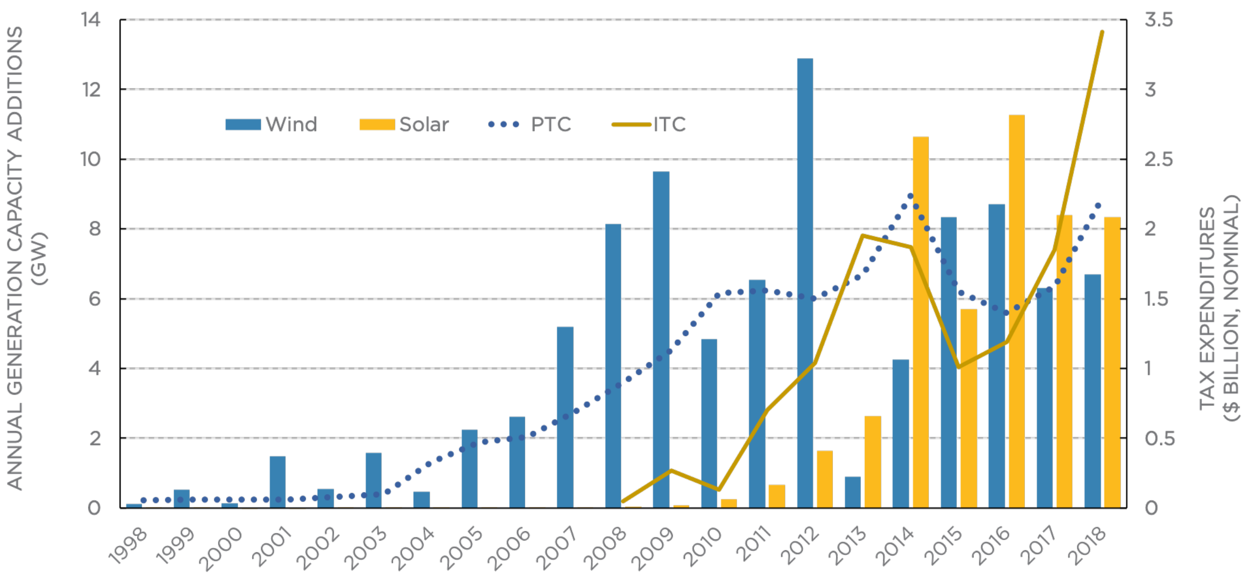
Assessing the Two Most Notable Clean Electricity Tax Incentives: The Production and Investment Tax Credits

The United States has used federal tax incentives to support clean energy for nearly a half century. Amid the oil crises in the 1970s during the Carter administration, Congress passed tax credits to support a range of clean energy technologies to reduce dependence on oil and gas. Although these credits were rolled back sharply under President Reagan in the 1980s, subsequent decades saw substantial increases in tax incentives for clean energy generation and energy conservation.[2]

The two most notable tax incentives for clean electricity technologies have primarily supported the deployment of wind and solar energy. First passed by Congress in 1992 with bipartisan support, the renewable electricity production tax credit (PTC) provided an incentive for every unit of electricity generated by wind power facilities and some other eligible generators such as biomass and geothermal plants. And in 2005, Congress enacted an investment tax credit (ITC)—also with bipartisan support—that provided an incentive valued at 30 percent of investments in solar power facilities and other eligible generators such as fuel cells.

The future of clean energy tax incentives has frequently been clouded by uncertainty. In particular, the PTC has either expired or nearly expired—and then been renewed—several times in recent decades, causing booms and busts in wind project construction (figure 1). In 2015, as both incentives neared expiration, Congress agreed on a bipartisan basis to extend the incentives but also to begin phasing them out. Beginning in 2017, the PTC began to fall in value and will entirely expire by the end of 2019. The ITC will phase out between 2020 and 2022, although a lower ITC of 10 percent will remain for some projects.

Figure 1: Annual wind/solar capacity additions (bars, left axis) and expenditures on PTC/ITC (lines, right axis)



The PTC and ITC have succeeded at accelerating the deployment of solar and wind power. That does not mean that the rise of solar and wind is entirely attributable to tax incentives. Various other policy drivers have supported renewable energy; for example, an increasing number of states have enacted renewable or clean electricity standards that have boosted solar and wind energy. And the falling costs of solar and wind have sped their growth (some, but not nearly all, of those cost declines are attributable to increased deployment resulting from tax incentives). Still, even controlling for other causes, various studies have concluded that the PTC and ITC have substantially contributed to the growth of wind and solar.[3,4] In part thanks to these incentives, installed wind capacity grew from under 20 GW in 2007 to nearly 100 GW in 2018,[5] while solar capacity grew from virtually zero to over 60 GW over the same period.[6,7] Combined, solar and wind generated about 8 percent of US electricity in 2018, up from 0.8 percent in 2007.[8]

Although they have spurred the deployment of solar and wind energy, ITC and PTC policies have not resulted in substantial deployment of various other technologies—aside from solar and wind—that Congress included as eligible for an ITC or PTC. For example, even though since 2005 new nuclear reactors have been eligible for a PTC of 1.8 cents per kilowatt-hour, no nuclear reactor has yet been built that qualifies for the incentive. The deployment of other technologies was stunted in part by a lapse in the ITC between 2016 and 2018, when the ITC was only extended for solar power but not for geothermal or fuel cell facilities.

Still, the primary reason that tax incentives have failed to stimulate large-scale deployment of diverse clean energy technologies is not that the tax incentives were short lived or erratic. Rather, it is that the tax incentives were ill suited to help stimulate nonincremental innovation to expand the set of viable technology options for commercial scale-up. The PTC and ITC successfully lowered the cost and enabled scale deployment of technology options that had already achieved a threshold level of maturity. For example, three-blade, horizontal-axis wind turbines had already been developed in the years preceding the PTC, so tax incentives were able to scale up—and incrementally improve—wind energy. Yet one study found that tax incentives for wind power actually coincided with a decline in highly innovative patents for wind technology and concluded that other policies, such as government funding for research, development, and demonstration, are better suited to generating new technology options.[9]

As the deployment of solar and wind power has risen, so too has the cost of the PTC and ITC. In 2018 alone, they cost the US federal government an estimated $2.2 billion and $3.4 billion, respectively (figure 1).[10] Compared with an alternative policy such as a price on carbon, federal spending on tax credits has been inefficient at stimulating the displacement of emissions from fossil fuels. One study estimates the carbon abatement cost of these policies—that is, the cost to the federal government in lost tax revenue to reduce US carbon emissions by one metric ton—at roughly $250/ton.[11,12] Moreover, tax incentives are an especially inefficient way to deliver subsidies to renewable energy because of the difficulty in monetizing tax credits, which nullifies part of the subsidy. For example, for a solar project to benefit from the ITC, a project developer needs to identify a financing partner from among a limited pool of tax equity sponsors; as a result, a typical cost of tax equity capital is twice that of debt capital.[13]

One might object that such *static* estimates of cost-effectiveness undersell the *dynamic* cost-effectiveness of tax incentives. By increasing the scale of production and deployment of a clean energy technology, tax incentives can lead to lower costs of that technology, and therefore enable more cost-effective decarbonization in the future, particularly once a policy like a carbon price is implemented. For example, both solar and wind power have fallen in cost, partly as a result of firms "learning by doing" as well as harnessing economies of scale as they produce and deploy more solar panels and wind turbines. Yet this benefit of tax incentives is far more meaningful in the early stages of a technology's commercial scale-up.

Both the solar and wind manufacturing industries are now multibillion-dollar global industries that will continue to increase in scale irrespective of the ITC or PTC. Downstream from manufacturing, firms have already harvested substantial cost savings through their experience with deploying over a hundred gigawatts of solar and wind capacity, so tax subsidies have a diminishing marginal effect on cost reduction. If the tax credits are no longer leading to meaningful improvements in the cost or performance of wind and solar energy technologies, they are not making future decarbonization efforts cheaper and easier. In other words, the static and dynamic cost-effectiveness of tax incentives for clean energy technologies converge as those technologies mature.[14]

The lesson is that tax incentives give the "biggest bang for buck" when they support initial commercial scale-up. It therefore makes sense to allow the current tax credits for solar and wind energy to expire. They will leave behind important lessons for how to design the next generation of incentives to be maximally cost-effective in fostering a diverse range of commercially viable clean energy technology options.

The Need for Successor Policies

The United States is very far away from the vision set forth by the Obama administration to almost entirely decarbonize the US power sector by 2050 by relying on zero-carbon sources to supply over 90 percent of the electricity mix. Meeting that target was an integral element of the Obama administration's plan to reduce overall US greenhouse gas emissions by at least 80 percent by midcentury.[15] Although President Trump intends to withdraw the United States from the Paris Agreement on climate change, the United States should still aim to meet its midcentury decarbonization goal.

In 2017, emissions from the US power sector stood at 1.7 billion metric tons of CO_2.[16] Decarbonizing the electricity system will require the sector's emissions to fall by more than 50 million metric tons per year between now and midcentury. Yet the Rhodium Group projects that under current policies, emissions are expected to fall just 16 million metric tons per year through 2030.[17] And the US Energy Information Administration expects only 19 GW of new zero-carbon electricity generation capacity (almost entirely wind and solar power) to be deployed in the United States in 2019, which is roughly half the pace required for deep decarbonization by midcentury.[18]

Much more is needed than just a faster pace of deployment of wind and solar power. A decarbonized electric power system will ideally include five elements:

- Cheap and abundant renewable energy that reduces the need for fossil-fueled electric generation. Building on the momentum of the wind and solar power boom, the United States should harness those sources to generate a significant portion of US electricity by midcentury. Relying heavily on intermittent electricity generation will require a much more flexible electricity power system.
- Electricity generators that can produce zero-carbon, dispatchable power to compensate for intermittent renewable energy and reliably supply demand for long durations and throughout the year. Potential options for such "firm low-carbon

resources" include nuclear reactors, hydroelectric plants with high-capacity reservoirs, geothermal plants, and coal- and natural gas–fueled plants equipped with carbon capture and storage (CCS).[19]

- Grid-scale electricity storage to supply electricity during periods of scarce renewable supply. Options for energy storage include lithium-ion batteries for short-duration applications as well as flow batteries, pumped hydro facilities, and more speculative technologies for longer-duration applications.[20]
- A nationwide network of high-voltage, direct-current transmission lines that would enable the US grid to tolerate a higher percentage of intermittent renewable energy. Such a network would connect areas of high renewable supply with major demand centers across the country, mitigate intermittency by encompassing multiple weather patterns and time zones, and reduce the need for expensive reserves.[21]
- A digitally enabled ("smart") transmission and distribution grid capable of orchestrating an increasingly complex system as well as harnessing flexible electric demand to meet intermittent renewable supply. Examples of demand flexibility include controllable appliances or industrial loads and smart-charging electric vehicles.[22]

Cost-effectively decarbonizing the electricity system will require new technology options to be developed and commercially scaled up. Relying only on commercially available and mature technologies would make decarbonization unnecessarily expensive. For example, firms that have tried to build new nuclear reactors in recent years have been set back by rising costs and project delays; advanced nuclear reactor technologies will be needed for a US nuclear renaissance. Similarly, new technology options for long-duration energy storage are urgently needed, and their value will become much more apparent as the increasing penetration of intermittent renewable energy leads to seasonal variation in electricity supply. The list of critical innovations for power sector decarbonization continues, spanning from advanced power converters to reduce the cost of long-distance transmission lines to digital innovations that enhance demand flexibility.

The United States should adopt a comprehensive policy framework to develop these technology options and set them on a path to commercial scale and cost reductions.

This is not to imply that no progress has been made. In 2018, the federal government expanded a tax credit known as 45Q that would incentivize carbon capture and storage projects. This is a promising start and addresses an important technological need. Yet in isolation, this policy will have a limited impact on the overall challenge of deep decarbonization.[23]

As the existing suite of clean electricity tax incentives expire, federal policy makers should design successor tax incentive policies. For all the demerits of tax incentives, such as their inefficient transmittal of subsidies, they have been the preferred policy tool by Congress in part because tax incentives are fiscally "scored" more favorably than direct expenditures. Indeed, at present, tax credits may be one of the few politically viable routes to bipartisan energy and climate policy progress.

More ambitious and comprehensive policies, such as a nationwide carbon price or clean electricity standard, would struggle to gain passage in today's political climate. Such policies would greatly improve the feasibility of deep decarbonization by driving the deployment of low-carbon technologies at scale. In the meantime, by increasing the set of commercially viable technology options, a next generation of tax incentives can set the table in anticipation of a more comprehensive and ambitious suite of climate policies.

Three Design Principles for the Next Generation of Clean Electricity Tax Incentives

When devising successor policies to the expiring suite of tax credits, federal policy makers should follow three design principles:

1. **Tailor tax incentives to critical applications**

Deep decarbonization will require many different clean electricity technologies that perform a range of disparate functions. Therefore, tax incentives should aim to foster promising technology options for each distinct function. Historically, Congress has explicitly named specific technologies—such as solar, wind, geothermal, or nuclear generators—as eligible for tax incentives. In theory, Congress might succeed at fostering the right technology options for deep decarbonization by enacting new, technology-specific tax incentives.

But there are good reasons to doubt that doing so would be the most prudent approach. First, federal policy makers will struggle to identify all technologies that will be needed for cost-effective deep decarbonization. They may choose too few technologies, too many technologies, or the wrong technologies, resulting in insufficient innovation or inefficient federal expenditures. Recall that the "sweet spot" of tax incentive efficacy is encouraging the scale-up of commercially immature technology options. It is unrealistic to expect policy makers to accurately forecast which of these immature options will ultimately thrive in the marketplace, attract private capital, fall in cost, and improve in performance. Moreover, prespecifying eligible technologies risks leaving out promising alternatives that later emerge or sparking uncertainty over whether a closely related technology is eligible. Finally, providing technology-specific tax incentives is liable to create vocal political constituencies from each eligible industry, hampering policy makers' ability to ramp down incentives after they achieve their aim of fostering initial commercial scale-up.

A better approach than technology-specific tax incentives—and one endorsed by Bill Gates–backed Breakthrough Energy, among others—is to harness market competition to select the most compelling technology options.[24] Policy makers should guide this market competition by creating different categories of tax incentives that are each tailored to a particular function that will need to be performed in a deeply decarbonized power system. The five functions described earlier are a reasonable starting point for designing the next generation of tax incentives. For example, Congress might create a tax incentive for the deployment of technologies that can provide dispatchable, zero-carbon power to complement intermittent renewable energy. Any electricity generation technology would be eligible to claim the tax incentive provided it met certain performance thresholds. Setting these thresholds—for example, a particular rate at which a zero-carbon generator can increase or decrease its power output or a percentage of the year that the generator is available to generate power—will require careful study. Therefore, after designating different tax incentives to meet each critical function of a deeply decarbonized power sector, Congress might opt to delegate the specifications of exact performance standards to an executive agency such as the US Department of Energy.

It is important, however, to recognize the limits of market competition in identifying and fostering the best technology options for deep decarbonization. In response to tax incentives that are technology-neutral (though application-specific), the market may prematurely converge on one technology option that achieves an early commercial lead and then harnesses tax incentives to reduce its costs through economies of scale and learning by doing. This dominant technology option might actually be an inferior technology to other potential options that, despite their higher initial costs, might have steeper learning curves or superior performance. In that case, such premature "technology lock-in"—a well-documented economic phenomenon—might preclude the most compelling technology options from achieving commercial viability. For example, a tax incentive for long-duration energy storage might initially benefit flow battery designs that have already achieved commercial deployment and can readily use the tax incentive to scale up further. But other technology options that are much less mature—such as liquid metal batteries or even more speculative battery chemistries—may struggle to obtain the initial private capital needed to begin scaling up and take advantage of the tax incentive. As the early movers, which will tend to be more mature technologies, continue scaling up, they will raise the barrier to entry to more immature technologies that might be even lower in cost at scale but may never get the chance to prove themselves.[25]

There are three ways to combat undesirable technology lock-in. First, federal policy makers should set a high bar for the performance standards of their application-specific tax incentives, to reduce the risk that the incentives will help an inadequate technology lock out technologies that can better perform the functions urgently needed for cost-effective grid decarbonization. Second, even though policy makers should not make tax incentives technology-specific, they should ensure that other policies—such as funding for research, development, and demonstration—explicitly support a diversity of technologies. Cultivating a pipeline of promising but immature technology options that can then compete to win tax incentives and achieve initial commercial scale will make it less likely that tax incentives will only benefit mature technologies. And third, policy makers should design tax incentives to ramp down as eligible technologies achieve scale and commercial maturity. These latter two strategies are discussed in greater detail below.

2. **Coordinate tax incentives with support for clean energy research, development, and demonstration**

Tax incentives are known as "demand-pull" policies. By lowering the cost of eligible technologies, they stimulate additional demand that pulls technologies into the market. Demand-pull can take technologies that have already attained a certain threshold of maturity and support their initial commercial scale-up. However, on their own they are insufficient to create new technology options.

"Technology-push" policies, such as funding for research, development, and demonstration

(RD&D), push new technologies toward commercial readiness without relying on customer demand to induce private firms to invest in innovation. Together, technology-push and demand-pull policies can create new technology options, demonstrate and commercialize those options, and harvest technology cost reductions through learning and scale effects. Therefore, on top of enacting new tax incentives, policy makers should also bolster technology-push policies.

Fortunately, Congress has already demonstrated its willingness to do so. From 2016 to 2018, the federal government increased funding for clean energy RD&D from $6.4 billion to $7.1 billion.[26] The Obama administration committed to an even larger increase—targeting a federal budget of nearly $13 billion by 2021—when it spearheaded the launch of Mission Innovation, through which 22 other countries and the European Union have also committed to doubling their public RD&D budgets.[27]

Still, more RD&D funding is not the only priority. Policy makers should also ensure that there is a close linkage between such funding and the next generation of tax incentives. Tightly coupling the two sets of policies maximizes the chance that technology-push policies will cultivate an assortment of promising technology options for each application-specific tax incentive. This will require substantial reforms. Today, a hodgepodge of federal RD&D funding programs stretches across different agencies and programs; basic research support is often poorly coordinated with applied technology development; and continued funding is rarely conditioned on meeting stringent milestones. There are important exceptions, however, that can serve as examples for modernizing federal RD&D funding. For example, the Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) organizes its funding by functional need and rigorously reviews its portfolio allocation to ensure the highest return on its investments.

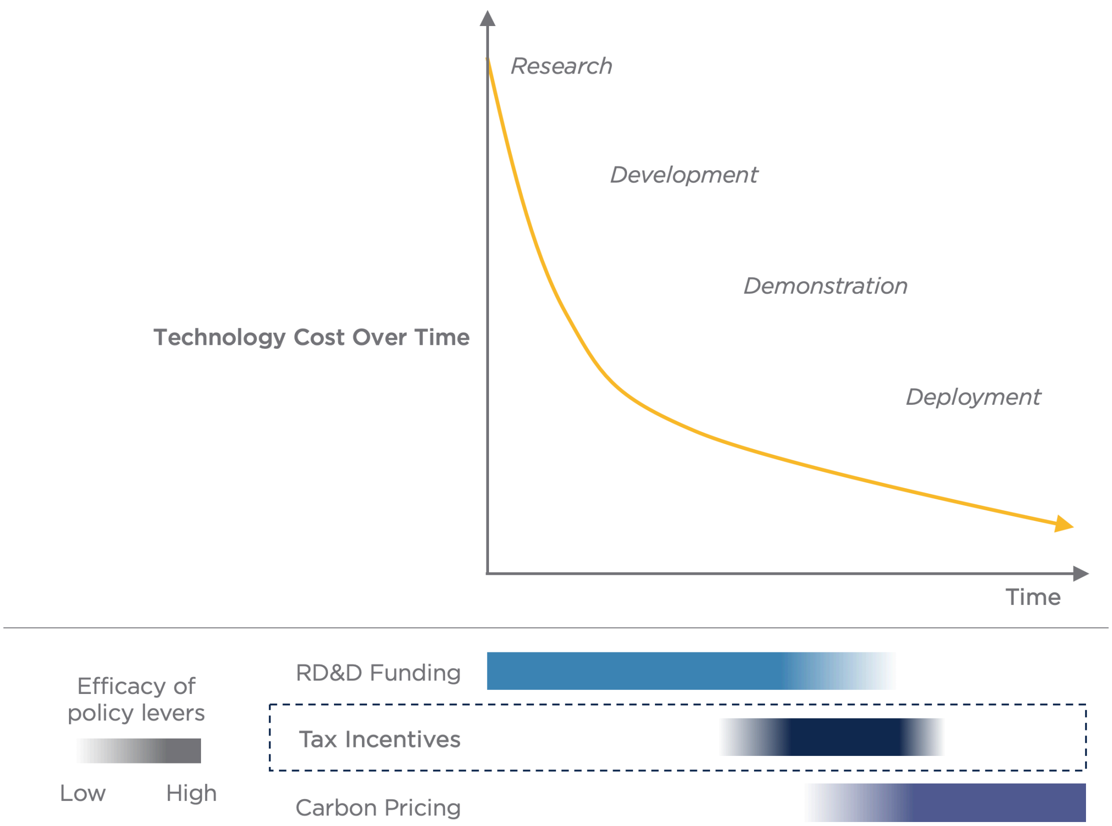
Along with enacting new tax incentives, policy makers should invest in tailored technology-push policies. For example, they should pair a tax incentive for long-duration storage with RD&D funding that can produce new storage technology options. Funding bodies including the Department of Energy and the National Science Foundation should develop a highly coordinated program of basic research and applied technology development with the end goal of producing commercially viable storage technologies. The Department of Energy should also establish an interdisciplinary research center that coordinates scientific institutions around the world developing diverse long-duration storage technologies. The department recently renewed funding for one such "innovation hub" for energy storage at Argonne National Laboratory, but the unique challenges of long-duration storage justify an additional dedicated research hub. Finally, in addition to supporting research and development, the federal government should also provide funding for first-of-a-kind field demonstration projects—perhaps in the form of loan guarantees—in order to reduce the barriers that new storage technologies face when raising private capital. By supporting the full spectrum of RD&D into long-duration storage options, policy makers will maximize the chance that tax incentives can then help the best technologies achieve initial commercial scale.

Unlike the tax incentives, federal RD&D funding should not be exclusively application specific and technology neutral. RD&D funding decisions should certainly be informed by end-use applications, but policy makers should also ensure that they fund a diverse range of technologies through technology-specific support. Cultivating such a diverse set of technology options will increase the robustness of the innovation pipeline, thus avoiding premature technology lock-in.[28] So, for example, it may be prudent to dedicate funding for advanced nuclear RD&D, even if other electricity generation technologies could also perform a similar function of producing zero-carbon, dispatchable power in a deeply decarbonized power system. Nevertheless, it is not the case that every technology is worthy of RD&D funding. Policy makers should constantly evaluate the potential for any technology to contribute to deep and cost-effective decarbonization before beginning or continuing initiatives to fund that technology.

The perils of failing to closely coordinate technology-push and demand-pull policies are exemplified by the failure of the federal Renewable Fuels Standard to promote the production of advanced biofuels. Originally enacted in 2005, the policy set mandates for oil companies to purchase biofuels and included a mandate for advanced biofuels that rose over time. When Congress sharpened the mandates in 2007, it intended to encourage the production of advanced biofuels such as cellulosic biofuels that did not displace cropland and were better for the environment than corn ethanol. Yet production of advanced biofuels has been anemic over the last decade; in 2018, just one-third of the statutorily mandated volume of advanced biofuels was produced (and most of that produced volume was in the form of biodiesel, rather than more advanced alternatives).[29] An important reason for the mandate's underperformance—despite a generous demand-pull policy—is underinvestment in technology-push support. Without strong and sustained funding for RD&D in advanced biofuels, private industry has struggled to develop technology options that are then eligible to be commercially scaled up with the help of demand-pull policies.[30]

Figure 2 visually situates tax incentives in the landscape of policy support for innovation and makes it clear why tax incentives alone cannot generate the technology options *and* promote their commercial scale-up. Rather, technology-push policies are needed to create such options and bring them to a level of maturity beyond which the baton can be passed to demand-pull policies. As figure 2 illustrates, carbon pricing is another demand-pull policy, and the efficacy of carbon pricing at deploying commercially available technologies at scale far outstrips that of tax incentives. Therefore, after the baton is passed from RD&D funding to tax incentives, it should once again be transferred to carbon pricing as a technology passes the stage of initial commercial scale-up. Achieving this transfer requires that tax incentives ramp down as technologies mature.

Figure 2: The role of tax incentives in the innovation policy landscape



Notes: Top panel: Illustrative, simplified chart of technology costs falling over time as a technology progresses through research, development, demonstration, and commercial deployment stages. Bottom panel: Selected policy levers and the periods when their efficacy is highest. The darkness of a policy's bar corresponds to the level of its efficacy.

3. **Ramp down support for technologies as they mature, while minimizing policy uncertainty.**

Reducing tax incentives to technologies as they mature will control costs and also mitigate technology lock-in. Moreover, ramping down such subsidies could also aid the political feasibility of enacting important policies such as an economy-wide carbon price. If tax incentives benefit firms deploying mature clean energy technologies, those firms may opt to lobby for extensions of their preferred tax incentives and lobby less vigorously for a carbon price, which would much more cost-effectively support the deployment of a range of clean energy technologies.[31] Tax incentives that are focused toward the initial commercial scale-up of emerging technologies will create new technology options and build political momentum for a comprehensive suite of energy and climate policies.

But when enacting the next generation of tax incentives, federal policy makers will know in advance neither which technologies will succeed commercially nor the rate at which those technologies will mature and outgrow the need for initial scale-up incentives. And even as policy makers face uncertainty over future technology trends, the private sector requires some measure of policy certainty in order to make investment bets on emerging clean energy technologies. Policy makers therefore face the difficult challenge of designing tax incentives that are both dynamic, by differentially supporting technologies as they mature, and static, by offering private investors a long-term, stable framework for how those incentives will function.

The most straightforward way for Congress to enact dynamic tax incentives is to task an executive agency, such as the Department of Energy, to periodically review the incentives and ratchet down the support for technologies that have matured. However, this approach may lead to politicization of the review process. The recent rollback of US federal fuel economy standards is an example of how executive agency review can be politicized and create damaging regulatory uncertainty. In 2016, the Obama administration's Environmental Protection Agency and National Highway Traffic Safety Administration conducted a review of federal fuel economy standards and concluded that the standards should continue to escalate to more stringent levels. Two years later, the same agencies under the Trump administration reversed this finding by recalculating the costs and benefits of fuel economy standards and proposed making the standards less stringent. The confusion has hampered private automakers' efforts to plan their future investments in vehicle efficiency technology.[32]

Therefore, it falls to Congress to set clear guidelines, when they enact tax incentives, for how the incentives will ultimately phase out. There is still an important role that executive agencies should play—that of implementing tax incentive legislation through a detailed rulemaking process that, for example, would set the exact performance standards for each application-specific incentive. But once enacted and implemented, the structure of the tax incentives should not vary according to political whims.

As policy makers design the conditions under which tax incentives will phase out, they can draw on the approaches taken by proposed or recently enacted clean energy tax incentive schemes, which include:

- **Market share limits.** A technology becomes ineligible for tax incentives once it achieves some prespecified percentage of a given market. For example, in the Energy Sector Innovation Credit Act proposed by Congressman Tom Reed (R-NY) in 2018, a clean electricity generation technology's eligibility for tax credits depends on the percentage of annual domestic electricity produced by that technology in the previous year. A technology is eligible for the full tax incentive until it achieves a market share of 0.5 percent, beyond which the technology receives a progressively lower tax incentive until it becomes ineligible for the incentive at or beyond a market share of 2 percent.
- **Time limits.** Technology projects are eligible for a particular tax incentive only for a limited number of years. This is the approach that Congress took when it enacted tax credits for carbon capture, utilization, and sequestration technologies in 2018. Under that policy's guidelines, any new fossil-fueled power plant or carbon-producing industrial facility that commences construction before 2024 is eligible for tax credits for up to 12 years thereafter.[33] Similarly, solar project eligibility under the ITC will begin phasing out in 2020.

- **Unit limits.** A technology is eligible for tax credits until it reaches a specified unit cap; if each unit under the cap is eligible for the same incentive, then a unit cap is equivalent to a cap on total government expenditures on tax incentives. For example, the tax credit for advanced nuclear energy facilities is available until it is claimed by 6 GW of new reactor generation capacity.[34] Similarly, federal tax incentives for electric vehicles have a unit cap after which they phase out. (The twist is that this cap applies to each manufacturer, so whereas buyers of Tesla and General Motors electric vehicles receive declining incentives now that the two automakers each passed the 200,000-unit limit in 2018, buyers of other electric vehicles still receive the full incentive.) There is empirical evidence that this structure has both sped the commercialization of electric vehicles and also limited federal tax expenditures.[35]

Each of these three approaches has selling points and drawbacks. The first type of phaseout condition—market share limits—enables policy makers to ensure that incentives last long enough for a particular technology to gain a foothold in the market before the incentives ramp down. Yet it is difficult to choose the correct market share threshold. A threshold that is too high may be unnecessarily expensive and support already-mature technologies, whereas a low threshold may fail to bring any technology to initial commercial scale.

Similarly, a longer time limit for tax incentive eligibility risks wasting funds and promoting technology lock-in, whereas a shorter time limit could fail to spur any scale-up at all. But the advantage of a time limit is that it clearly signals the duration of incentive eligibility to private investors, whereas the other two phaseout conditions imply incentive durations that are contingent on technology uptake. Of course, as the history of the PTC demonstrates, time limits can lead to episodic political uncertainty about whether tax incentives will be extended, which can chill the private investment climate.

Finally, unit limits enable policy makers to stipulate in advance how much they are willing to spend on incentives, eliminating the risk of runaway expenses. But again, there is no way to optimally set the unit limits to screen out mature technologies while supporting the initial scale-up of promising technologies.

It is impossible to stipulate in advance the ideal phaseout timeline. This is the price of providing long-term policy certainty, and it is a price worth paying. Irrespective of which of the three options it chooses, Congress should seek to provide long-term and unambiguous guidance to private markets. They should also avoid “cliffs”—in which incentives disappear suddenly—in favor of gradually phasing out incentives.

Unfortunately, even if lawmakers carefully design a phaseout schedule that reduces support for technologies as they mature, their work will not be done yet. After grappling with policy design, they will need political resolve. Indeed, tax incentives that are successfully tailored to supporting emerging technologies will likely support many clean energy technology projects that ultimately fail, exposing the incentives’ proponents to political accusations that the policy is squandering taxpayer money. Such accusations might be true; a poorly designed tax incentive might support far too many avoidable failures. But well-designed incentives will also face similar charges. It will be essential for lawmakers to recognize that some technology projects will likely fail and help the private sector reallocate capital to better projects. By ultimately supporting the commercialization of superior technology options that reduce the overall cost of decarbonization—and phasing out as technologies outgrow the need for subsidies—well-designed tax incentives will save far more money than they lose.

Conclusion

A new generation of federal tax incentives for clean electricity technologies can accelerate the deep decarbonization of the US power sector. Successor policies to expiring tax credits are needed to bring a diverse range of emerging technology options to commercial scale. To maximize the efficacy of such successor policies, policy makers should incorporate the lessons learned from decades of previous tax incentives.

Figure 3 summarizes our view of the five critical elements of a low-cost carbon-free electricity system and the three design principles for the next generation of clean electricity tax incentives. Of course, tax incentives are just one of many important tools that policy makers will need to use to decarbonize the power sector.

Figure 3: Summary of carbon-free power system elements and design principles

Elements of a low-cost carbon-free electricity system
1. Cheap and abundant renewable energy
2. Zero-carbon dispatchable power generators
3. Grid-scale electricity storage
4. Nationwide network of transmission lines
5. Digitally enabled T&D grid

Principles for the next generation of clean electricity tax credits
1. Tailor tax incentives to critical applications
2. Coordinate tax incentives with support for clean energy RD&D
3. Ramp down support for maturing technologies and minimize policy uncertainty

These three design principles are merely a starting point for policy makers in developing tax incentives; they must still make a myriad of decisions to put these principles into practice, from choosing critical applications to setting phaseout conditions. Often, there will be no correct answer because policy makers will need to balance policy goals that are in tension with one another. For example, policy makers may want to subsidize technologies to accelerate their deployment and harvest cost reductions through economies of scale and learning, but they may also want to limit federal expenditures and mitigate premature technology lock-in. No optimal policy can maximally achieve all of these goals. But through a deliberative process in which policy makers deeply understand and grapple with these trade-offs, they will design better policies than if they ignore the reality of competing objectives.

Policy makers should be especially careful not to let the perfect be the enemy of the good. Tax incentives are a fundamentally flawed instrument—for example, because of their inefficient transmittal of subsidies—but they have proven bipartisan appeal. There will be a measure of inefficiency no matter how policy makers structure these incentives. But they should still enact a new generation of tax incentives. Doing so will speed progress toward the urgent goal of deep decarbonization and serve as a bridge to a future suite of comprehensive and effective energy and climate policies.

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The views represented in this commentary represent those of the authors.

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