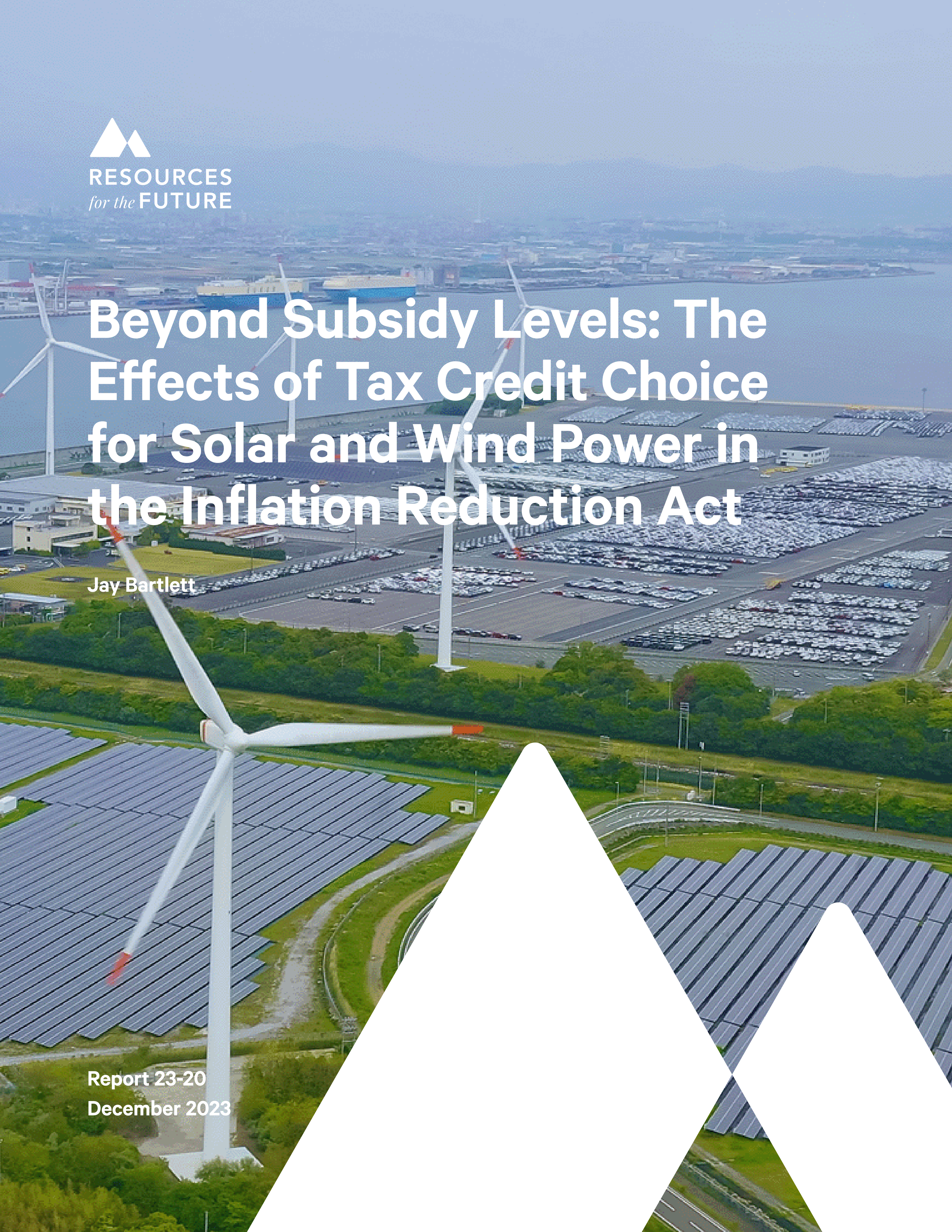

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Beyond Subsidy Levels: The Effects of Tax Credit Choice for Solar and Wind Power in the Inflation Reduction Act

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Abstract

Within the Inflation Reduction Act (IRA), corporate tax credits are the largest source of clean energy funding, so understanding how these credits function is important to market participants and policymakers. In this report, I focus on the IRA's authorization for both utility-scale solar and wind projects to choose between the investment tax credit (ITC) and production tax credit (PTC). After reviewing the history of the ITC and PTC, including the changes made by the IRA, I consider how the three primary owners of utility-scale solar and wind projects—project sponsors, tax equity investors, and regulated utilities—will decide between incentives. I find that the PTC, in most cases, will be strongly preferred by regulated utilities and project sponsors, but the latter's preference must be weighed against the interests of tax equity investors, which may favor the ITC. Next, I assess how the ITC and PTC may distort project decisions, with the ITC leading to higher-cost electricity and the PTC leading to lower-value electricity. Because the PTC is likely to be the incentive chosen by most utility-scale solar and onshore wind projects, I discuss technology and policy options to raise the value of electricity from PTC projects.

Contents

1. Introduction

To achieve a substantial decrease in US greenhouse gas emissions, one of the many objectives of the Inflation Reduction Act (IRA), it relies primarily on subsidies for clean energy technologies (Bergman et al. 2023). Among its various subsidies to support clean energy investments, including grants, loans, and personal and corporate income tax credits, the IRA depends most heavily on tax credits for corporations. When Congress passed the IRA, corporate tax credits had been estimated to account for most of the nearly $400 billion in clean energy funding (Badlam et al. 2022). Furthermore, because tax credits are mainly uncapped and researchers anticipate faster growth of clean energy technologies, subsequent estimates for IRA clean energy funding have been two or three times that amount, with corporate tax credits responsible for most of the increase (Credit Suisse 2022; Goldman Sachs 2023). Given their significance, understanding how corporate tax credits support clean energy investments is important to both market participants and policymakers.

The massive amount of corporate tax credit funding in the IRA comes primarily from increasing the values and durations of clean energy tax credits and expanding their eligibility to new technologies (EPA 2023). Additionally, the IRA gives project owners new options for both tax credit structures and utilization. While less conspicuous than the former provisions, allowing clean energy projects to choose their preferred tax credit structures and methods of utilization can have significant effects on capacity growth, technology choice, geographic distribution, power generation decisions, and the supply of investment capital.

With respect to utilization, the IRA allows certain projects—those with tax-exempt owners or using certain technologies—to receive direct payments and permits all clean energy projects to transfer their tax credits. In a subsequent report, I will examine projects' decisions of whether to transfer tax credits and how the option of transferability is likely to affect investment supply and the deployment of clean energy projects.

In this report, I focus on the newly established option for both wind and utility-scale solar projects to choose between the two incentive structures, the investment tax credit (ITC) and the production tax credit (PTC). Although the American Recovery and Reinvestment Act of 2009 (ARRA) established incentive choice for wind projects (Bolinger et al. 2009), it has not previously been available to solar.[1] Note that I limit my analysis within solar to utility-scale projects (Bolinger et al. 2023), which generally have different costs, revenues, ownership structures, and policy incentives than distributed solar projects.

1 ARRA allowed wind projects to choose among the PTC, ITC, and a cash grant in lieu of the ITC for projects placed in service between 2009 and 2012. Solar projects were able to choose between the ITC and the cash grant but could not elect to receive the PTC.

In Section 2, I review the history and respective functions of investment- and production-based tax credits and then assess the provisions in the IRA relevant to the ITC and PTC. In Section 3, I examine the choice between the ITC and PTC from the perspectives of three types of owners—project sponsors, tax equity investors, and regulated utilities—and evaluate the probable implications given their preferences. Finally, in Section 4, I consider how investment- and production-based incentives can distort project decisions, causing inefficiencies in the outcomes of the ITC and PTC. Section 5 concludes.

2. Background on the ITC and PTC

2.1. History of the ITC and PTC

US federal incentives for renewable energy technologies have existed for the past 45 years and have taken the form of either the ITC, a tax credit based on capital cost, or the PTC, a credit based on the amount of electricity produced. The business ITC (Internal Revenue Code [IRC] Section 48) was established in 1978, but it was not until the Energy Policy Act of 2005—which increased the solar ITC from 10 percent to 30 percent—that the credit initiated rapid growth of US solar capacity (SEIA 2023). Although technologies other than solar have been eligible for the ITC, including offshore wind after 2016, solar projects received nearly all ITC funding before the IRA (Sherlock 2021). Separately, a personal renewable energy tax credit (IRC Section 25) applies to residential solar, which is outside the scope of this report.

The PTC (IRC Section 45) was established by the Energy Policy Act of 1992 at a rate of 1.5 cents per kWh for 10 years after a facility is placed in service (Sherlock 2020). It is adjusted annually for inflation using the GDP implicit price deflator, giving the PTC a statutory rate of 2.75 cents per kWh in 2023 (DOE 2023a). As with solar and the ITC, onshore wind has received the majority of PTC funding, with the remainder going to geothermal, biomass, and other qualifying power-generation technologies. Compared with the 30 percent ITC after 2005, the establishment of a generous PTC in 1992—along with the greater maturity of wind technology—enabled US wind capacity to develop ahead of solar power (American Clean Power 2023). However, the PTC has experienced more lapses in eligibility and short-term extensions than the ITC, which has created significant fluctuations in annual wind installations (Frazier et al. 2019).

Before the IRA, both the wind PTC and solar ITC had been scheduled to step down over time, albeit with different timelines and magnitudes. The Consolidated Appropriations Act of 2016 set the PTC to decline to 80 percent of its statutory rate for wind projects starting construction in 2017 (equal to 2.2 cents per kWh in 2023$), 60 percent in 2018, and 40 percent in 2019 (Mormann 2016). The PTC would have expired in 2020, but COVID relief legislation in December 2020 restored the PTC to 60 percent of its statutory rate in 2020 and 2021, with a planned expiration in 2022 (McGuireWoods 2022). Likewise, the Consolidated Appropriations Act of 2016 set the solar ITC to decline from a 30 percent investment credit to 26 percent for projects starting construction in 2020, 22 percent in 2021, and 10 percent thereafter. The December 2020 COVID relief legislation extended the timetable of the solar ITC by two years, providing a credit of 26 percent in 2021 and 2022, 22 percent in 2023, and 10 percent thereafter (Pickerel 2020).

2.2. Comparison of the ITC and PTC

Notwithstanding the differences in their subsidy amounts (on a present-value basis), financing considerations, and regulatory factors discussed in Section 3, the ITC and PTC for utility-scale solar and wind appear to function similarly. Capital costs, inclusive of equipment and installation costs, account for 88 and 83 percent of levelized costs for utility-scale solar and wind, respectively, and the remaining costs are fixed operating and maintenance (O&M) expenses (Lazard 2023). Unlike hydrogen, for example, solar and wind have zero marginal production costs, so choosing either the ITC or PTC would not seem to skew production decisions, at least not with respect to costs.[2]

However, the ITC and PTC do have some important differences, even for solar and wind projects, which have no variable costs and simple cost structures. First, solar and wind projects make decisions affecting their three principal inputs to levelized cost: capital cost, O&M cost, and capacity factor (the ratio of a project's actual electricity generation to its annual theoretical maximum). The ITC causes projects to be less sensitive to capital costs (which are subsidized), and thus projects may choose inefficient cost structures. Second, along with the factors of generation costs, solar and wind projects consider the compensation for the power they produce, which would include the PTC for projects under that incentive. The PTC, based on the quantity rather than value of generation, causes projects to be less sensitive to generation value. In Section 4, I discuss ways in which the ITC may lead to higher-cost electricity and the PTC may lead to lower-value electricity.

2.3. How the IRA Has Changed the ITC and PTC

To assess the choice between the ITC and PTC that the IRA has made possible, it is necessary to review the other changes made by the IRA to these two incentives. First, the IRA restored the ITC and PTC to their full statutory amounts—30 percent and 2.75 cents per kWh (in 2023$), respectively—for projects placed in service in 2022. Second, the credits will remain at those levels for projects that commence construction by the end of 2032 (if not later), as long as they meet the requisite standards for prevailing

2 Electrolytic hydrogen production entails marginal costs from the power consumed. If producers face variable power prices, projects with an ITC may choose to produce less often than projects with a PTC because they have lower capital costs to recoup. For further discussion of why the ITC is inefficient for hydrogen, see House Select Committee on the Climate Crisis (2020, 252).

wages and apprenticeships.[3] Third, the IRA established several bonus credits to enhance the value of the ITC or PTC (DOE 2023a).

For utility-scale solar and wind power, two of these bonus credits are significant. The IRA offers 10 percent bonus credits each for meeting domestic content requirements and for locating in an energy community (Watson 2022). These bonus credits are stackable, so a project eligible for both credits will receive an increase of 20 percentage points to their ITC or PTC. However, the bonus credits have proportionately greater effects on the ITC than on the PTC. For the PTC, the increase is multiplicative, with each bonus credit adding 10 percent of the PTC value, equal to 0.275 cents per kWh (in 2023$). For the ITC, the increase is additive, so a project qualifying for one bonus credit will receive a 40 percent ITC, a 33 percent increase in value, and a project qualifying for both credits will receive a 50 percent ITC, a 67 percent increase in value.

3. Perspectives and Implications of the Choice between the ITC and PTC

The impacts of the choice between the ITC and PTC will be largely determined by three types of owners: project sponsors, tax equity investors, and regulated utilities. Utility-scale solar and wind projects have been predominantly owned by independent power producers (IPPs), which operate throughout the United States and sell their electricity to utilities, power marketers, or large corporate customers or into wholesale power markets. IPP ownership has accounted for approximately 80 percent of utility-scale solar and wind capacity installed since 2010 (Feldman et al. 2020). In regulated markets, utilities may own generation assets, selling the power to their customers. Project ownership by investor-owned utilities (IOUs) has accounted for nearly the entire remaining 20 percent of installed utility-scale solar and wind capacity.

Within IPP-owned projects, there are two types of equity providers: project sponsors and tax equity investors (Feldman and Schwabe 2018). The IPP is typically the project sponsor, but to efficiently use the tax credits and deductions, the project also includes a tax equity investor (typically a large financial organization). The most common structure is known as a partnership flip because project ownership flips between the project sponsor and tax equity investor to appropriately allocate the tax benefits.
For IOU-owned projects, the utility is typically the sole owner but is subject to the constraints of state regulators and various federal and state requirements. Given that these three types of owners have different incentives and constraints, the following three subsections consider their perspectives on the choice between the ITC and PTC and the implications of their probable selections.

3 The ITC and PTC will phase out for projects that start construction after 2032 or the year that US power sector greenhouse gas emissions have declined by 75 percent from 2022 levels, whichever is later.

3.1. Project Sponsors

Putting aside the interests of tax equity investors, which are considered in Section 3.2, the project sponsor will choose the tax credit that provides the greater present value. Whether a 30 percent ITC is worth more than a 10-year PTC of 2.75 cents per kWh (annually adjusted for inflation) depends primarily on three project factors: capital cost, capacity factor, and discount rate. First, a higher capital cost increases the benefit of the ITC. Offshore wind projects, which have per-kW capital costs three or more times higher than utility-scale solar or onshore wind projects (EIA 2023a), may thus receive greater benefit from the ITC. Second, a greater capacity factor increases the amount of electricity produced and consequently the value of the PTC. Utility-scale solar and wind projects in sunny or windy areas, respectively, such as the US Southwest or the Great Plains, would likely find the PTC more attractive. Third, the present value of the 10-year PTC is sensitive to the discount rate. The increased cost of project capital over the past two years, caused by higher interest rates and greater competition for tax equity (Feldman et al. 2023), has raised the discount rate and thereby lowered the present value of the PTC. Beyond the full statutory rates of the ITC and PTC, the IRA offers bonus credits for domestic content usage and energy community locations, and as discussed in Section 2.3, these credits are proportionately more valuable under the ITC.

The IRA has allowed sponsors of utility-scale solar and wind projects to choose the tax credit that is more generous, given the features of their projects. Therefore, even without increasing the level of the ITC or PTC—although the IRA has done this as well by restoring the credits to their full statutory rates and establishing bonus credits—credit choice has made both the ITC and PTC more beneficial energy incentives. However, it is the ability to choose the PTC that is likely to be more consequential to the deployment of clean power. For utility-scale solar and onshore wind projects with low capital costs or high capacity factors, the PTC is significantly more generous (Lazard 2023). Consequently, the choice of the PTC by sponsors of utility-scale solar projects is likely to be a key factor in the overall growth of clean power.

3.2. Tax Equity Investors

The project sponsor may prefer whichever tax credit has the greater present value, but the sponsor is reliant on the tax equity investor to efficiently monetize the credit. While tax equity investors may benefit from a credit with greater present value, they have other concerns that affect their preference for the ITC or PTC. The interests of tax equity investors are particularly important given their critical role in growing clean power capacity. With the increased incentives in the IRA, the demand for tax equity is expected to grow from approximately $20 billion in 2021 and 2022 to $50 billion by 2025 (Burton 2023). Furthermore, a significant portion of this incremental demand must come from new entrants, as the current pool of financiers has limited capacity for increased investment. In a subsequent report, I will assess how transferability of credits could ease financing constraints; here, I consider the effects of the tax credit structure on the attractiveness of tax equity investments.

Although the PTC will typically be more valuable to a utility-scale solar or onshore wind project, the ITC provides advantages for the tax equity investor, particularly for new entrants. First, the investment commitment is shorter, with the primary tax benefits—the tax credits and accelerated depreciation deductions—realized within 5 years for projects choosing the ITC versus 10 years for projects choosing the PTC. Moreover, the ITC returns a substantial amount of capital in the first year. For providers of tax equity, a distinct benefit of shorter investments is that the investor needs fewer years of predictable future tax liabilities. Second, as the ITC is based on a project's capital cost, it entails less investment risk than the PTC, which depends on electricity generation over a 10-year period. Power generation is affected by the energy resource (e.g., wind speeds or solar irradiance), equipment performance, and curtailment risk, so a change in any one of these factors will affect the value of the PTC. In addition to bearing greater risk, PTC investors must have the ability and willingness to do more due diligence than ITC investors.

For sophisticated tax equity investors with predictable future tax liabilities, these advantages are less significant, and the PTC may even be their preferred structure. The downside of the ITC returning capital quickly is that the tax equity investor must then make a new investment to offset its subsequent tax liability. Because each investment entails a transaction cost, the aggregate transaction costs of ITC project investments may cause investors to favor the PTC, with its 10-year stream of tax credits. Additionally, solar power has a more consistent energy resource and less equipment vulnerabilities than wind power, so investment risks under the PTC are less significant for solar projects.

The ITC and PTC options each provide a mechanism for expanding the supply of tax equity. The ITC, with its favorable structure for tax equity investors who are less sophisticated or have less predictable tax liabilities, has the potential to expand the investor pool in the long term. Nonfinancial corporate entities are the most probable new entrants. While they have yet to provide a substantial fraction of tax equity, the greater demand for tax equity could increase rates of return to the point where they are sufficiently attractive investments. Moreover, in extending the ITC and PTC at their full levels for at least 10 years, the IRA has provided firms with a long time frame in which to develop the capabilities to evaluate tax equity opportunities and make investments. The PTC, with its higher present values for utility-scale solar power in sunny locations, is likely to be the choice of many solar projects that would have taken the ITC had the PTC option not been established. In switching from the 1-year ITC to the 10-year PTC, these utility-scale solar projects will consume less tax liability in the early years, increasing the near-term supply of tax equity investment and thus its availability for other projects.

3.3. Regulated Utilities

In regulated markets, IOUs are allowed to own generation assets, but federal law has limited the appeal of IOUs to own ITC-eligible technologies. Tax normalization rules have required that the value of the ITC be spread over the operating life of the asset (Feldman et al. 2020), potentially exceeding 30 years for solar projects. Therefore, normalization diminishes the present value of the ITC to IOUs and increases the cost of electricity generated. Some IOUs have successfully formed joint ventures with tax equity investors, which the Internal Revenue Service has determined do not trigger normalization requirements (Cooper and Tingle 2019). However, this structure entails additional development time, risk, and cost, and most IOUs have not used the method (Blank and Richardson 2020).

Rather than own ITC-eligible assets, IOUs could sign a power purchase agreement (PPA) with an IPP, which is not subject to normalization requirements and thus can achieve a significantly lower generation cost. However, procuring power through PPAs presents two disadvantages to the IOU. First, whereas an IOU earns a rate of return on the assets it owns, this is not the case for a PPA. Second, as a long-term contract to buy power, the PPA is considered a liability on the IOU's balance sheet, which may negatively affect its credit rating. These factors make a PPA an undesirable option for IOUs despite its considerable cost benefit to ratepayers.

With ITC-eligible projects less attractive in regulated markets—IOU ownership being more expensive to ratepayers and PPAs being unappealing to IOUs—eliminating normalization requirements had been a legislative priority of the utility industry (Howland 2022). The IRA did indeed exempt IOUs from normalization rules for the new ITC for stand-alone energy storage but left normalization rules for the solar ITC unchanged (O'Neill et al. 2022). However, in allowing utility-scale solar projects to elect the PTC, which is not subject to normalization, the IRA offers IOUs an incentive that is not diminished by tax rules. The choice of incentive structure under the IRA removes a disincentive to adding utility-scale solar capacity in regulated markets, which should lead to further growth of solar energy in those areas.

4. Economic Distortions Created by the ITC and PTC

The previous section considered the perspectives on incentive structure of project owners—sponsors, tax equity investors, and IOUs—and their effects on technology choice, capacity growth, and investment supply. In this section, the focus is on incentive efficiency, how the structures of the ITC and PTC can distort the choices of utility-scale solar and wind projects. Consequently, these incentive structures can affect the cost and value of the electricity produced by projects under the ITC and PTC.

4.1. The ITC May Raise the Total Cost of Electricity Production

In subsidizing only the capital cost of the project, the ITC can lead to inefficiencies in how solar and wind projects weigh their capital costs against their capacity factors and O&M costs. Therefore, the ITC has the potential to increase total levelized costs, inclusive of the unsubsidized costs to the project and subsidized costs to the government (EIA 2023b). While unsubsidized projects would choose a higher cost structure to produce sufficiently higher-priced power, the ITC can lead to higher total levelized costs in the absence of higher power prices. Cost distortions from the ITC for utility-scale solar and wind projects could arise from spending either excessively on capital costs or inadequately on O&M costs.

First, projects could make technology or geographic choices that involve excessive capital costs to achieve a higher capacity factor than would be justified without an investment-based incentive. For example, a solar project might include tracking or choose a higher inverter loading ratio (Bolinger et al. 2023), and a hybrid generation-storage project might choose a larger battery system. Similarly, a solar project with an ITC might be more reluctant to select lower-cost modules with a higher degradation rate—and thus a lower capacity factor over time—as is the case with perovskite solar cells (DOE 2023b). With respect to geography, wind or solar projects could choose higher-cost locations that are windier or sunnier to attain a higher capacity factor.

Second, projects could spend less-than-optimal amounts on equipment maintenance because the ITC reduces their effective capital costs. A recent study of wind projects—which were able to choose between investment- and production-based incentives from 2009 to 2012—finds that wind projects with an investment subsidy generate 10 percent less electricity than they would have with a production subsidy (Aldy et al. 2023). Two-thirds of this reduction is likely attributable to wind turbines that received an investment subsidy being less available to generate power, a consequence of reduced spending on equipment maintenance and repairs.

Within the context of the IRA, the magnitude of cost distortions from the ITC may be modest. The capital costs for onshore wind and solar have declined substantially since 2009 (Lazard 2023), diminishing the value of the ITC relative to the PTC and thus the probability of onshore wind or solar projects choosing the ITC. Additionally, solar projects have less equipment risk than wind projects, so reduced power generation from diminished availability is likely to be less significant for solar projects under the ITC. However, two caveats are important. First, offshore wind has both high capital costs, making these projects likely to choose the ITC, and high equipment risk, increasing the availability effect from underspending on maintenance. Second, cost distortions from the ITC are limited both by the constraints to shifting costs toward subsidized expenditures and by the unsubsidized proportion of capital costs. Increasing the ITC percentage—as the IRA bonus credits do—reduces the unsubsidized proportion and thereby raises the potential for cost distortions.

4.2. The PTC May Lower the Value of Electricity Production

Because the PTC subsidizes the quantity of power generation irrespective of its price, the PTC may incentivize lower value electricity. Whereas the ITC may lead to higher total levelized costs, the PTC may lead to decreased generation revenue, also known as levelized avoided costs (EIA 2023b). Note that this is the private value of electricity—from the energy, capacity, and ancillary services it provides (Bartlett 2019)—and is the primary focus of this report. The social value of electricity would also depend on the emissions profile of the power generation displaced, which I will discuss later. The PTC can lower the private value of electricity production by distorting project choices of when to generate and where to locate.

Solar and wind power have zero marginal costs of generation, so projects without a PTC will choose to produce whenever the prevailing electricity price is positive. The PTC changes this calculation. With a PTC, projects find it profitable to generate power even when electricity prices are negative, if the price is greater than $(\text{-PTC})/((1\text{-tax rate}))$. Negative pricing for wind power has been prevalent, whereas solar projects under the ITC have been more likely to curtail generation when electricity prices fall markedly below zero (Seel et al. 2021). The aforementioned wind study found that negative prices likely explain one-third of the generation difference between projects with production incentives versus investment incentives (Aldy et al. 2023). Utility-scale solar projects choosing the PTC should cause more negatively priced electricity. However, energy storage exploits negative prices, so the addition of battery capacity will mitigate the effect of utility-scale solar projects choosing the PTC. Indeed, the increased demand—along with reduced cost and new ITC for energy storage—has led to a surge in battery capacity, often installed with solar projects (EIA 2023c).

Before projects choose when to generate power, they must decide where to locate, a decision that is strongly affected by the PTC. In selecting a site, utility-scale solar and wind projects weigh the costs of generation there against the prospective revenues and subsidies (from the ITC or PTC and renewable energy credits). Unlike the ITC, the PTC's worth varies greatly by location because of the large regional differences in capacity factors. Utility-scale solar projects in the West generate 50 percent more energy than those in the Northeast (Bolinger et al. 2023), and capacity factors for wind projects in the Great Plains can be twice as large as those on the East and West Coasts (Wiser et al. 2023). Without a PTC, projects in low-cost locations (typically the result of high capacity factors) could still be unprofitable if energy and capacity values there were low. Examples could include prospective wind projects in Texas or the Great Plains and utility-scale solar projects in California and the Southwest. The PTC changes this calculation, as it did with negative pricing. A project with a PTC in a high-resource location—if curtailment does not significantly reduce output—may be profitable even with paltry revenues. Lazard (2023) calculates subsidized levelized costs for low-cost wind and utility-scale solar with a PTC to be zero, implying that minimal revenues would be required for project viability and thus skewing projects toward high-resource locations, even where private electricity values are very low.

Notwithstanding my focus on private values, it is important to emphasize that electricity with a low private value may have substantial social value if the power it displaces entails considerable pollution. Even negatively priced wind or solar generation will be socially valuable if the benefit of reduced pollution is greater than the negative power price, as may often be the case (Aldy et al. 2023). While neither the PTC nor the ITC rewards projects based on the pollution they displace, the greater power production of PTC versus ITC projects tends to increase the comparative environmental benefits of the PTC.

A more reasonable critique of the PTC is that its incentive for projects to locate in high-resource locations may come at the expense of projects locating where the value-to-cost ratio is higher (EIA 2023b). Because of the constraints on tax equity supply, the PTC may have a detrimental effect on the installation of projects where their net value would be greater.

With the PTC likely to be the more attractive credit for utility-scale solar and wind projects, it is important to consider how to raise the low private values of electricity that may result from PTC projects. Energy storage—as well as flexible demand—can increase the values of solar and wind power in otherwise low-private-value locations, but energy storage and flexible demand can address only the time-related components of low electricity prices. For example, midday power prices are low in California because of the abundance of solar power, known as the duck curve (EIA 2023d). Battery storage can transfer a portion of that electricity to the evening hours when prices are higher, increasing the value of solar power in California. Moving flexible loads—such as some electric vehicle charging, water heating, and space heating or air-conditioning—to the midday hours would also have this effect.

Energy storage and flexible demand help equalize electricity prices across time, but equalizing electricity prices across space requires sufficient transmission capacity, which has been particularly challenging to increase. Building new transmission lines is significantly more time-consuming than battery projects (Bird and McLaughlin 2023; Rand et al. 2023), and federal policy to broadly address permitting delays in transmission construction has not yet been passed. Although grid-enhancing technologies would increase the capacity of existing transmission lines, current market structures and regulatory rules for transmission owners provide little incentive to implement these technologies (Slaria et al. 2023). By expanding PTC eligibility to utility-scale solar projects, as well as restoring the PTC to its full statutory amount and adding bonus credits, the IRA is likely to induce large amounts of low-private-value electricity, which accelerates the importance of countervailing technologies and policies to support their adoption.

5. Conclusions

The option in the IRA to choose between the ITC and PTC incentives will have significant effects on clean energy deployment, investment supply, and subsidy efficiency. The source of many of these effects is the higher present value of the PTC compared with the ITC for most utility-scale solar and onshore wind, causing a large proportion of utility-scale solar projects to change incentives. The greater generosity of the PTC will make viable a portion of utility-scale solar projects that would not have been viable under the ITC, even with one or two bonus credits (Lazard 2023). Furthermore, in regulated territories, IOUs can now choose the PTC for their solar projects—avoiding normalization, a costly workaround, or a disadvantageous PPA—which should provide a further boost to solar in these areas. The combined result will be additional and widespread growth in solar capacity, increasing overall clean energy deployment.

With respect to investment supply, the effect of utility-scale solar projects choosing the 10-year PTC over the 1-year ITC will be to reduce the consumption of near-future tax liabilities, thereby increasing the supply of tax equity over the short term. Although the near-term growth of tax equity availability comes at the expense of greater tax capacity constraints in later years, the shift from the ITC to the PTC allows time to enlarge the pool of tax equity investors. The continuing option of the ITC, with its shorter duration and lower investment risk, could prove important to attracting new entrants, critical for sufficient expansion of tax equity supply.

Lastly, the election of the PTC among utility-scale solar projects will have effects on subsidy efficiency. For utility-scale solar and onshore wind, cost distortions will diminish as solar projects shift away from the ITC. Value distortions resulting from the PTC will increase—made more intense by the restoration of the PTC to its full statutory rate and the addition of bonus credits. With the PTC unchanged for all projects that commence construction by the end of 2032 (at the earliest), there is the potential for utility-scale solar and wind projects to be driven increasingly by the PTC rather than by market revenues and costs. Mitigating the divergence between PTC-induced generation and optimal additions of power to the grid will require massive increases in energy storage, flexible demand, and transmission capacity, with supportive policies and permitting reforms playing critical roles.

References

Aldy, Joseph, Todd Gerarden, and Richard Sweeney. 2023. "Investment versus Output Subsidies: Implications of Alternative Incentives for Wind Energy." *Journal of the Association of Environmental and Resource Economists* 10 (4): 981–1018.

American Clean Power. 2023. *Clean Power Annual Market Report 2022*. **https://cleanpower.org/resources/clean-power-annual-market-report-2022/**.

Bartlett, Jay. 2019. "The Changing Costs and Values of Electricity Generation Technologies: Measuring Profitability and Evaluating Options for Integrating Renewables." Issue Brief 19-04. Washington, DC: Resources for the Future.

Badlam, Justin, Jared Cox, Adi Kumar, Nehal Mehta, Sara O'Rourke, and Julia Silvis. 2022. *The Inflation Reduction Act: Here's What's in It*. Chicago: McKinsey & Company.

Bergman, Aaron, Alan Krupnick, Joshua Linn, Nafisa Lohawala, Richard G. Newell, Karen Palmer, Daniel Raimi, Nicholas Roy, and Beia Spiller. 2023. "What Have We Learned about the Inflation Reduction Act, One Year after the Law's Passage?" *Common Resources* (blog). August 21. Resources for the Future. **https://www.resources.org/common-resources/what-have-we-learned-about-the-inflation-reduction-act-one-year-after-the-laws-passage/**.

Bird, Lori, and Katrina McLaughlin. 2023. "US Clean Energy Goals Hinge on Faster Permitting." *Insights*, February 9. Washington, DC: World Resources Institute.

Blank, Eric, and D. R. Richardson. 2020. "ITC Tax Normalization Limits Solar Growth and Favors Fossil Fuels." *Utility Dive*, May 14. **https://www.utilitydive.com/news/itc-tax-normalization-limits-solar-growth-and-favors-fossil-fuels/577920/**.

Bolinger, Mark, Joachim Seel, Julie Mulvaney Kemp, Cody Warner, Anjali Katta, and Dana Robson. 2023. "Utility-Scale Solar, 2023 Edition: Empirical Trends in Deployment, Technology, Cost, Performance, PPA Pricing, and Value in the United States." Lawrence Berkeley National Laboratory. **https://doi.org/10.2172/2007458**.

Bolinger, Mark, Ryan Wiser, Karlynn Cory, and Ted James. 2009. "PTC, ITC, or Cash Grant? An Analysis of the Choice Facing Renewable Power Projects in the United States." Lawrence Berkeley National Laboratory. **https://doi.org/10.2172/950222**.

Burton, David. 2023. "The Solar + Wind Finance and Investment Summit Soundbites: The Tax Equity Market and Transferability." *Project Finance* (blog). March 20. Norton Rose Fulbright. **https://www.projectfinance.law/tax-equity-news/2023/march/the-solar-plus-wind-finance-and-investment-summit-soundbites-the-tax-equity-market-and-transferability/**.

Cooper, Heather, and Philip Tingle. 2019. "IRS Issues Private Letter Ruling Allowing Tax Equity Financing with a Regulated Utility Taxpayer." McDermott Will & Emery. December 2. **https://www.mwe.com/insights/irs-issues-private-letter-ruling-allowing-tax-equity-financing-with-a-regulated-utility-taxpayer/**.

Credit Suisse. 2022. "US Inflation Reduction Act: A Catalyst for Climate Action." November 30. **https://www.credit-suisse.com/about-us-news/en/articles/news-and-expertise/us-inflation-reduction-act-a-catalyst-for-climate-action-202211.html**.

DOE (US Department of Energy). 2023a. "Federal Solar Tax Credits for Businesses." Solar Energy Technologies Office. Last updated August 2023. **https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses**.

———. 2023b. "Perovskite Solar Cells." Solar Energy Technologies Office. **https://www.energy.gov/eere/solar/perovskite-solar-cells**.

EIA (US Energy Information Administration). 2023a. *Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2023*. **https://www.eia.gov/outlooks/aeo/assumptions/pdf/elec_cost_perf.pdf**.

———. 2023b. *Levelized Costs of New Generation Resources in the Annual Energy Outlook 2023*. **https://www.eia.gov/outlooks/aeo/electricity_generation/pdf/AEO2023_LCOE_report.pdf**.

———. 2023c. "STEO between the Lines: EIA Expands Publication of Short-Term Forecasts for U.S. Power Plants' Generating Capacity." March 7. **https://www.eia.gov/outlooks/steo/report/BTL/2023/03-capacity/article.php**.

———. 2023d. "Today in Energy: As Solar Capacity Grows, Duck Curves Are Getting Deeper in California." June 21. **https://www.eia.gov/todayinenergy/detail.php?id=56880**.

EPA (US Environmental Protection Agency). 2023. "Summary of Inflation Reduction Act Provisions Related to Renewable Energy." Last updated October 25. **https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy**.

Feldman, David, Mark Bolinger, and Paul Schwabe. 2020. *Current and Future Costs of Renewable Energy Project Finance across Technologies*. National Renewable Energy Laboratory. **https://www.nrel.gov/docs/fy20osti/76881.pdf**.

Feldman, David, Krysta Dummit, Jarett Zuboy, and Robert Margolis. 2023. *Winter 2023 Solar Industry Update*. National Renewable Energy Laboratory. **https://www.nrel.gov/docs/fy23osti/85291.pdf**.

Feldman, David, and Paul Schwabe. 2018. *Terms, Trends, and Insights on PV Project Finance in the United States, 2018*. National Renewable Energy Laboratory. **https://www.nrel.gov/docs/fy19osti/72037.pdf**.

Frazier, A. Will, Cara Marcy, and Wesley Cole. 2019. "Wind and Solar PV Deployment after Tax Credits Expire: A View from the Standard Scenarios and the Annual Energy Outlook." Electricity Journal 32 (8): 106637.

Goldman Sachs. 2023. "The US Is Poised for an Energy Revolution." *Intelligence*, April 17. **https://www.goldmansachs.com/intelligence/pages/the-us-is-poised-for-an-energy-revolution.html**.

House Select Committee on the Climate Crisis. 2020. "Solving the Climate Crisis, Majority Staff Report." June.

Howland, Ethan. 2022. "PNM, AEP Executives, Other Utility Leaders Meet with Biden to Push Clean Energy Tax Measures." *Utility Dive*, February 10. **https://www.utilitydive.com/news/pnm-aep-utility-executives-biden-clean-energy-renewable-tax-credits/618630/**.

Lazard. 2023. *Lazard's Levelized Cost of Energy Analysis—Version 16.0*. **https://www.lazard.com/media/typdgxmm/lazards-lcoeplus-april-2023.pdf**.

McGuireWoods. 2022. "Inflation Reduction Act Extends and Modifies Tax Credits for Wind Projects." August 24. **https://www.mcguirewoods.com/client-resources/alerts/2022/8/inflation-reduction-act-tax-credits-for-wind-projects/**.

Mormann, Felix. 2016. "Fading into the Sunset: Solar and Wind Energy Get Five More Years of Tax Credits with a Phase-down." American Bar Association. May 1. **https://www.americanbar.org/groups/environment_energy_resources/publications/trends/2015-2016/may-june-2016/fading_into_the_sunset/**.

O'Neill, Rob, Eric Rohner, Matt Kaden, Keegan McClure, and Jon Blitman. 2022. "An Overview of Clean Energy Tax Legislation in the Inflation Reduction Act." Moss Adams. August 26. **https://www.mossadams.com/articles/2022/08/inflation-reduction-act-clean-energy-credits**.

Pickerel, Kelly. 2020. "Solar Investment Tax Credit Extended at 26% for Two Additional Years." *Solar Power World*, December 21. **https://www.solarpowerworldonline.com/2020/12/solar-investment-tax-credit-extended-at-26-for-two-additional-years/**.

Rand, Joseph, Rose Strauss, Will Gorman, Joachim Seel, Julie Mulvaney Kemp, Seongeun Jeong, Dana Robson, and Ryan H. Wiser. 2023. *Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2022*. Lawrence Berkeley National Laboratory. **https://emp.lbl.gov/publications/queued-characteristics-power-plants-1**.

Seel, Joachim, Dev Millstein, Andrew Mills, Mark Bolinger, and Ryan Wiser. 2021. "Plentiful Electricity Turns Wholesale Prices Negative." *Advances in Applied Energy* 4: 100073.

SEIA (Solar Energy Industries Association). 2023. "U.S. Solar Market Insight." September 7. **https://www.seia.org/us-solar-market-insigh**t.

Sherlock, Molly. 2020. The Renewable Electricity Production Tax Credit: In Brief. Congressional Research Service Report. **https://sgp.fas.org/crs/misc/R43453.pdf**.

———. 2021. The Energy Credit or Energy Investment Tax Credit (ITC). Congressional Research Service Report. **https://crsreports.congress.gov/product/pdf/IF/IF10479**.

Slaria, Srishti, Molly Robertson, and Karen Palmer. 2023. *Expanding the Possibilities: When and Where Can Grid-Enhancing Technologies, Distributed Energy Resources, and Microgrids Support the Grid of the Future?* Report 23-13. Washington, DC: Resources for the Future.

Watson, Stephen. 2022. *Inflation Reduction Act Provides Major Tax Incentives for Public Power*. Norton Rose Fulbright. **https://www.nortonrosefulbright.com/en-us/knowledge/publications/20e136f1/inflation-reduction-act-provides-major-tax-incentives-for-public-power**.

Wiser, Ryan, Mark Bolinger, Ben Hoen, Dev Millstein, Joe Rand, Galen Barbose, Naïm Darghouth, et al. 2023. *Land-Based Wind Market Report: 2023 Edition*. US Department of Energy, Office of Energy Efficiency and Renewable Energy. **https://www.energy.gov/sites/default/files/2023-08/land-based-wind-market-report-2023-edition.pdf**.