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Designing Renewable Electricity Policies to Reduce Emissions

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RESOURCES FOR THE FUTURE

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Abstract

A variety of renewable electricity policies to promote investment in wind, solar, and other types of renewable generators exist across the United States. The federal renewable energy investment tax credit, the federal renewable energy production tax credit, and state renewable portfolio standards are among the most notable. Whether the benefits of promoting new technology and reducing pollution emissions from the power sector justify these policies' costs has been the subject of considerable debate. We argue in this paper that the debate is misguided because it does not consider two important interactions between renewable electricity generators and the rest of the power system. First, the value of electricity from a renewable generators depends on the generation and investment it displaces. Second, a large increase in renewable generation can reduce electricity prices, increasing consumption and emissions from fossil generators, and offsetting some of the environmental benefits of the policies. Two policy conclusions follow. First, existing renewable electricity policies can be redesigned to promote investment in the highest-value generators, which can greatly reduce the cost of achieving a given emissions reduction. Second, subsidies financed out of general tax revenue reduce emissions less than subsidies financed by charges to electricity consumers.

Key Words: renewable portfolio standard, production tax credit, investment tax credit, feed-in tariff, clean energy standard, cost-effectiveness, intermittency, wind energy, solar energy

JEL Classification Numbers: Q40, Q54, L94

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Designing Renewable Electricity Policies to Reduce Emissions

Harrison Fell, Joshua Linn, and Clayton Munnings*

Introduction

In the United States, federal, state, and local governments have adopted many renewable electricity (RE) policies, including production subsidies such as the federal production tax credit (PTC) and renewables requirements such as renewable portfolio standards. Currently, many of these policies enjoy quite a lot of public support, but their future is highly uncertain. The PTC for wind generators expires at the end of 2012, and the debate over the federal deficit has sharpened lawmakers' focus on whether this tax credit is worth extending. In addition, over the next several years, state renewable portfolio standards (RPSs) will increase in stringency, and it is unclear how public support will evolve if electricity prices subsequently increase. In fact, interest groups have already begun organizing opposition to the state RPSs, focusing on their negative effects on electricity consumers.

Given the abundance of RE policies and the ongoing debate, we pose two related questions: Do the benefits outweigh the costs for any RE policies? And if so, of the many RE policies, which is best?

First, we need to define what we mean by "best." In the absence of a national carbon price—either a carbon emissions cap or tax—a central objective of RE policies is to reduce carbon emissions at the lowest cost to the public, which includes not only the cost of the renewables technologies, but also other costs of providing electric power. We focus on cost-effectiveness, which is the cost of the policy to electricity consumers and producers per avoided carbon emissions. Before proceeding, we note that RE policies have other objectives beyond reducing carbon emissions. Public support for these policies derives from factors such as promoting innovation, learning-by-doing and creating jobs. But while it is possible to count the number of jobs associated with these technologies, it is difficult to determine how effective these policies are at encouraging innovation in new technology and creating jobs as opposed to simply shifting jobs from one sector to another (Weinstein et al. 2010; Weinstein and Partridge 2011;

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Brown et al. 2012). Because of these difficulties, and to keep the scope of this paper manageable, we focus on emissions.

Much of the discussion about RE technologies focuses on their costs compared with those of conventional technologies, such as coal-fired generators. Advocates and opponents of RE technologies argue over whether they are “cost-competitive,” meaning that they provide a kilowatt-hour (kWh) of electricity at lower cost than other generators. Synthesizing recent research on renewables (Joskow 2011a, 2011b; Fell and Linn 2012), we argue that the focus on cost-competitiveness is too simple to answer our questions. Instead, we adopt a system perspective that assesses how renewables interact with the rest of the power system. We explain how the cost-effectiveness of RE policies depends on two key factors: whether the policies cause investment in the most socially valuable RE generators and whether they cause electricity prices to go up or down.

Not all renewable generators have the same value to society. The value includes the cost of the RE generator itself, which is what the standard analysis focuses on. But value also includes the avoided costs of constructing and operating other generators, as well as the avoided emissions from those generators. We show that the value varies across RE technologies and also across locations and time for a given technology. As we explain, some renewable electricity policies are better than others at encouraging investment in the most valuable generators.

Furthermore, some policies cause electricity prices to go up, whereas others cause prices to go down. Of particular relevance to the current debate over the federal PTC is the fact that policies using tax revenue to subsidize renewables decrease electricity prices. The more prices go down (or the less they go up), the more electricity gets consumed. Greater consumption negates some emissions reductions by leading to less displacement of fossil fuel generators. Therefore, the more policies make prices go down, the less effective they are at reducing emissions.

After illustrating the incentives created by different policies, we report some recent modeling results that demonstrate the importance of value and electricity prices. We find large differences in the cost-effectiveness across policies. The greatest cause of these differences is the effect on electricity prices: policies that subsidize renewables lead to lower prices, greater consumption, and greater emissions. For example, to achieve the same emissions reduction, a hypothetical RPS costs one-third less than a hypothetical subsidy that is modeled after the PTC. Furthermore, policies that promote the most valuable generators are much more cost-effective than policies that do not.

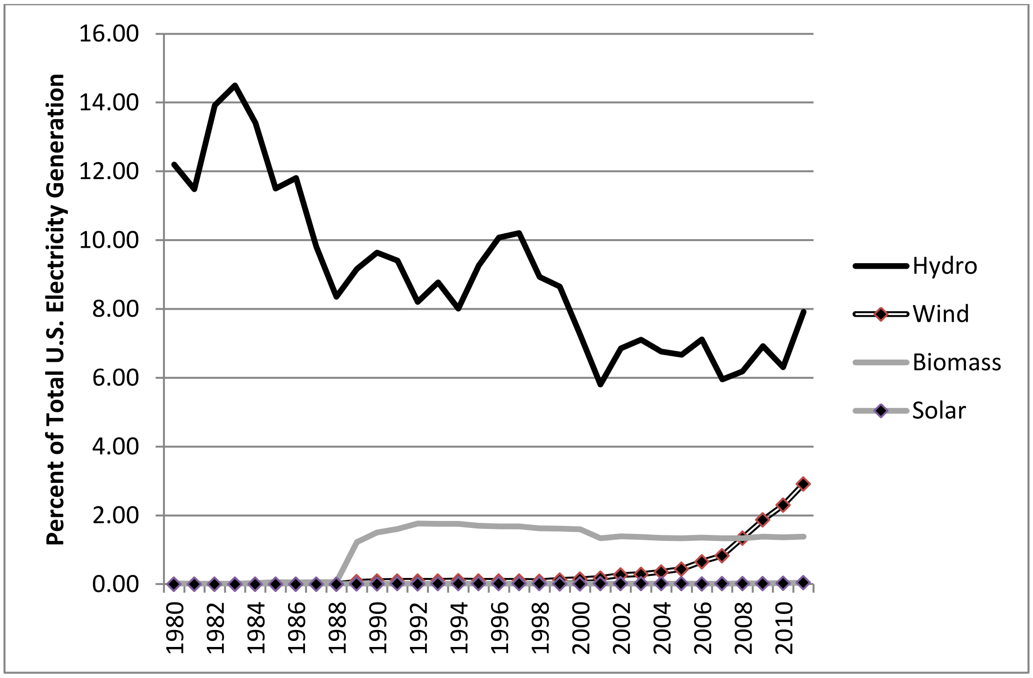
Besides demonstrating the importance of value instead of costs, the analysis points to four conclusions, from which four policy recommendations follow directly:

1. Subsidies that are financed out of tax revenue, such as the investment tax credit or the production tax credit, result in greater electricity consumption → these policies would reduce emissions more if they were financed by charges to electricity consumers instead.
2. Regardless of financing sources, production subsidies are preferred to investment subsidies.
3. The simplest feed-in tariffs (FITs), which do not vary over time or by technology, promote the lowest-cost generators, which may not be the most valuable generators → FITs could achieve much better cost-effectiveness if they were designed to incentivize the most valuable generators.
4. Renewable electricity policies do not incentivize investments with the greatest value to society → policies that more directly target emissions, such as a clean electricity standard or a carbon price, do so and are more cost-effective.

Renewable Electricity in the United States

Overall, RE generation in the United States is a small but increasing part of total generation. In 2011, RE accounted for a record 13.2 percent of total electricity generation. Figure 1 shows the contribution toward total power generation in the United States of several renewable technologies: hydroelectric, wind, solar, and biomass. The figure shows that hydro is the largest contributor, but that hydro generation has remained relatively flat for a decade. On the other hand, wind has been growing rapidly, as has solar, although from a much lower level, which makes the increase imperceptible in the figure.

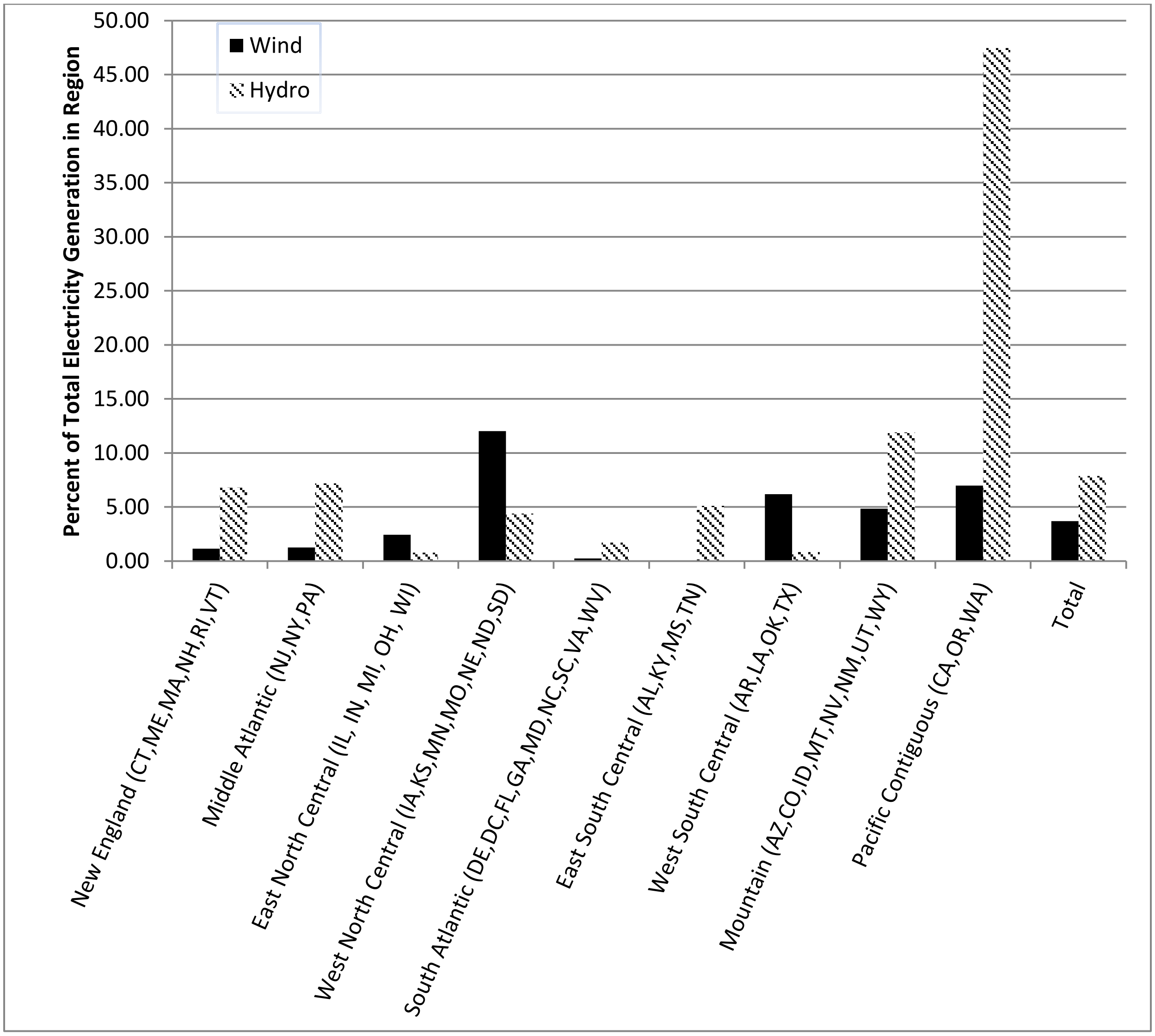
Figure 1. Electricity Generation in the United States, 1980–2011



Source: EIA 2012e.

The previous figure provides a picture of the roles of renewables at the national level, and the next figure illustrates the existence of wide regional variation in renewable electricity generation. Focusing on wind and hydro, the bars in Figure 2 show the generation of both technologies by region.

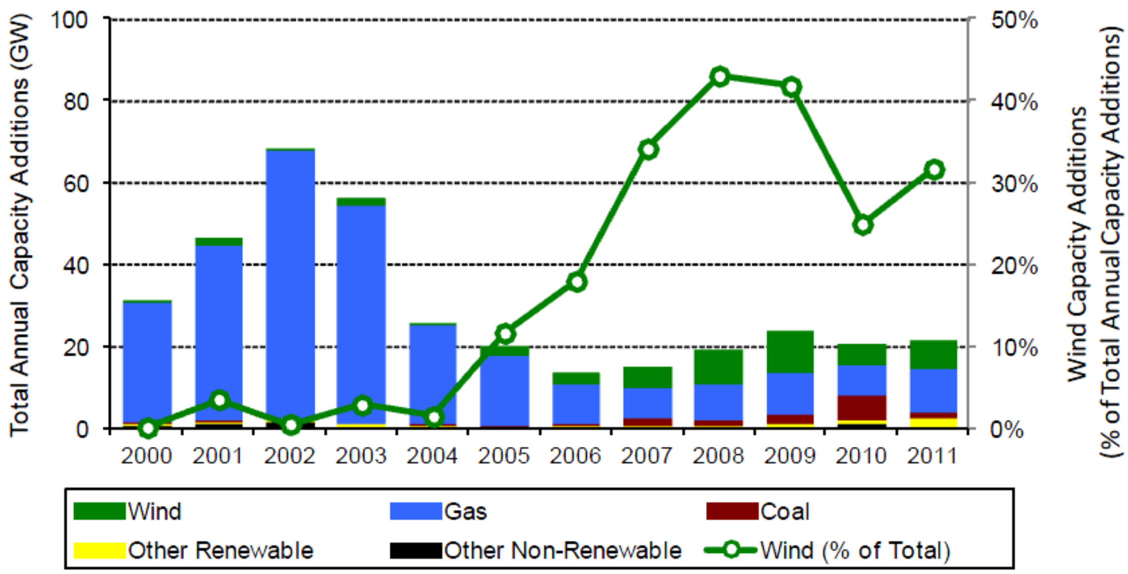
Figure 2. Wind and Hydro Generation in the United States, 2011



Source: EIA 2012a.

Wind and natural gas have accounted for nearly all new capacity investment in the power sector over the past 10 years. Each year since the mid-2000s, annual wind investments have been between 5-10 gigawatts (GW) of capacity. Natural gas is the only technology with greater investment, as Figure 3 shows. Solar investment has been increasing rapidly but has been at much lower levels—compared to wind investment of nearly 50 GW from 2000-2010, total solar investment has been nearly 3 GW (Wiser and Bolinger 2012; Ardani and Margolis 2011).

Figure 3. Capacity Additions to the U.S. Electricity Grid



Source: Wiser and Bolinger (2012)

Natural gas has been the main technology competing with renewables for new investment, and many current forecasts suggest that this pattern will continue (EIA 2012d; Burtraw et al. 2012). Over the past five years, natural gas prices have dropped dramatically, from a high of $10.79/thousand cubic feet in late 2008 to a low of $1.89/thousand cubic feet in 2012 (EIA 2012c). This decrease has clearly had a large effect on the use of gas and coal in the short run, and on investment in gas, wind, and other technologies in the long run. A considerable amount of current research is focused on analyzing just how big these effects are (e.g., Burtraw et al. 2012). More generally, a discussion of the drivers of recent wind and natural gas investment and generation is beyond the scope of the paper, as they aren't directly relevant to our analysis of the workings of, and trade-offs across, RE policies. We merely conclude this section by reiterating that renewables have become increasingly important in the U.S. power system, particularly in certain regions of the country. Our focus in the remainder of this paper is on the cost-effectiveness of policies designed to further increase the share of electricity from renewables and reduce carbon dioxide emissions.

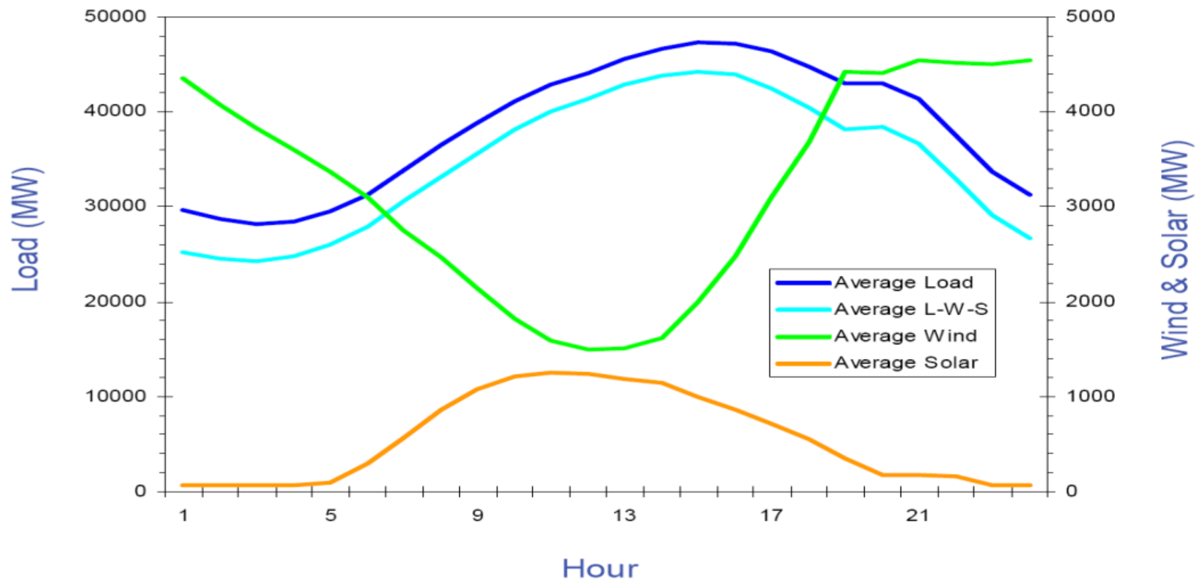
Why Aren't All Renewable Generators Equally Valuable?

Before we discuss the RE policies, we need to explain a bit about the economics of RE generators. A widespread public perception is that, because they each generate electricity without emitting any pollution, renewable generators are all equally valuable. Therefore, the focus turns to the costs of renewables compared with those of other technologies.

There are two problems with this point of view. First, just because generators have the same emissions does not mean they have equal environmental value. What matters is the avoided emissions—that is, the emissions that would have occurred in the absence of the renewable generation. To see why avoided emissions vary regionally, compare a hypothetical increase in RE generation in two states: California and Indiana. Natural gas–fired generators supply about half of California's generation. Furthermore, natural gas–fired generators are often at the margin, which means that they increase or decrease supply in response to expected demand or supply fluctuations. On the other hand, coal-fired generators account for about 90 percent of electricity generated in Indiana, and these coal generators often respond to expected demand or supply fluctuations (EIA 2012b). Therefore, renewable generation in Indiana is much more likely to displace coal than it is in California. Because coal emits so much more carbon and other pollutants than other technologies, the environmental value is greater in coal-intensive regions than in other regions (Cullen 2011, Novan 2011, and Kaffine et al. forthcoming).

The second misconception in the standard view is that all renewable generation has the same market value. The market value of generation will be determined, in part, by the demand for electricity during the period when the generation occurs. However, unlike fossil-fuel generators that can choose when they produce, the intermittency of solar and wind resources prohibits wind and solar generation units from dispatching power whenever they want. Therefore, the market value of the wind and solar generation depends on how correlated wind and solar resources are with the load curve. Figure 4 gives the average electricity demand throughout the day, or load curve, for California. The pattern of low demand in late-night hours and high demand in the mid to late afternoon is typical in the United States. Electricity prices tend to follow demand, increasing during the day and decreasing at night. As can be seen in Figure 4, solar is positively correlated with the load curve, while wind is inversely correlated with the load curve. Thus, solar generation tends to have a higher market value, though lower environmental value, than wind generation. The generators with the greatest value to society have the highest combined market and environmental values. We next turn to the history of the major RE policies in the United States and a discussion of how they affect investment.

Figure 4. Average Net Electricity Demand and Solar and Wind Generation



Notes: Values are for California in 2003
Source: NERC 2009

A History and Analysis of Renewable Electricity Policies

This section introduces each of the major types of renewable electricity policies: a production subsidy such as the production tax credit (PTC), an investment subsidy such as the investment tax credit (ITC), a feed-in tariff (FIT), and a renewable portfolio standard (RPS). We do not include other important subsidies such as depreciation allowances, but similar principles could be used to compare those policies. We include a brief history of each policy, a discussion of its future, and an analysis of the incentives it creates for investment in generation capacity. We compare the cost-effectiveness of the RE policies on a theoretical basis and consider simplified versions of the policies to draw sharp conclusions that are likely to hold in the real world.

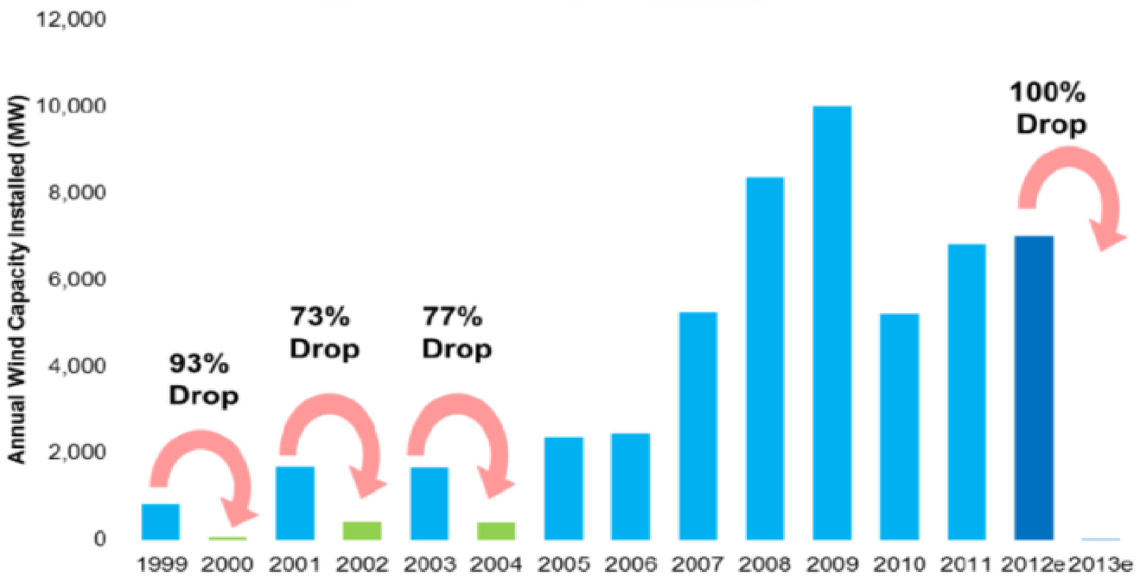
Renewable Energy Production Tax Credit (PTC)

A Brief History of the PTC

The Energy Policy Act of 1992 established the PTC, and the American Jobs Creation Act of 2004 expanded the list of technologies eligible for the PTC (Sherlock 2011). For the first 10 years a renewable generator operates, the PTC provides a corporate tax credit for each kilowatt-hour of renewable energy produced. The subsidy is indexed to inflation and currently equals 2.2 cents per kilowatt-hour for wind, geothermal, and closed-loop biomass production, and 1.1 cents per kilowatt-hour for landfill gas, trash, hydropower, and open-loop biomass production (Sherlock and Brown 2011). Notably, solar does not qualify for the PTC. To date, wind power projects have claimed over two-thirds of the total subsidy value ($10.6 billion) issued under the PTC (Sherlock 2011; Jenkins et al. 2012).

Most likely, the PTC has had a large effect on wind investment. Figure 5 provides some evidence for this, showing observed annual wind investment in the United States to 2011 and projected annual wind investment thereafter. The PTC has expired three times, in 2000, 2002, and 2004, only to be renewed the subsequent year. Each time the PTC expired, wind investment dropped precipitously, only to recover when the PTC was renewed. This provides suggestive evidence of the link between the PTC and total wind investment, which some recent research has confirmed (Lu et al. 2011; Hitaj 2012).

Figure 5. Expirations of the Production Tax Credit and Annual Installed Wind Capacity



Notes: 2012 and 2013 are projections. As noted in the text, many other 2013 projections are higher than depicted in the figure.
Source: AWEA 2011

Future of the PTC

The PTC is set to expire at the end of 2012 for wind and 2013 for other technologies. What is at stake for the wind industry? If the PTC expires, projects placed in service on or after January 1, 2013, are not eligible for the PTC. If recent history is a guide, an expiration could mean a very large drop in wind investment. However, many analysts expect that even if the PTC is expanded, wind investment is unlikely to return to recent levels. For example, market analysts from Bloomberg Energy Finance predict that a three-year extension of the PTC would increase wind investment in 2012–2015 from roughly 4 GW per year to 7 GW per year. Even at the higher end of this projection, investment would be below peaks in 2008 and 2009 and well below the manufacturing capacity of nearly 14 GW in the United States (Brown 2012).

How the PTC Works

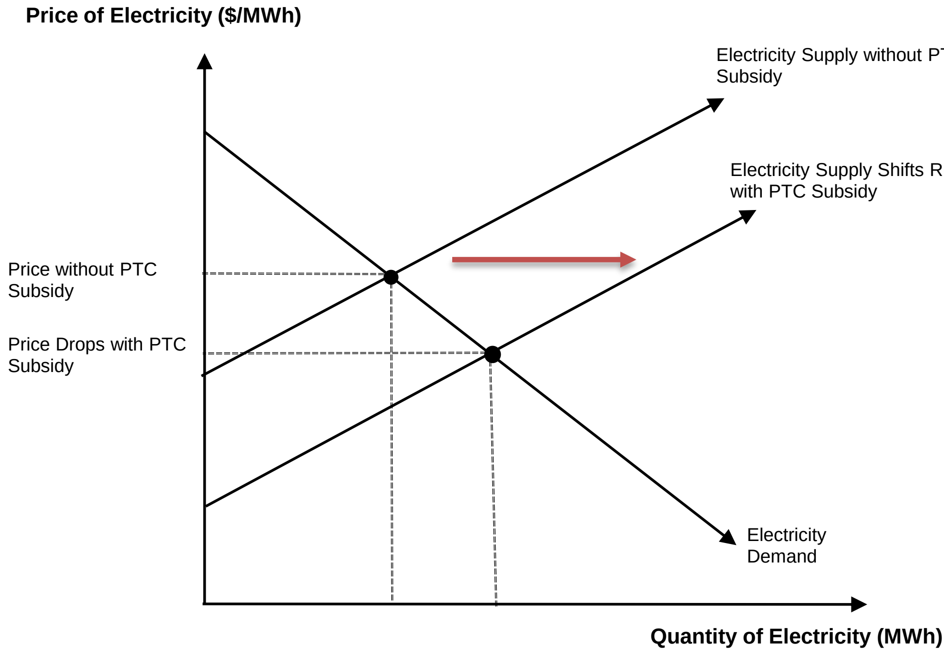
The PTC increases the revenue accruing to a RE generator at the expense of taxpayers. We show that because the PTC is a subsidy to new generators, it decreases electricity prices.

Consider the effects of the PTC on the decisions made by a hypothetical investor in a new wind project. The PTC provides a fixed subsidy per megawatt-hour (MWh) of generation. The subsidy is added to whatever market revenue the generator can earn. As discussed earlier, two renewable generators can have the same cost but different market value if the correlation of their generation with demand differs; the more positive the correlation, the higher the value.

Because the PTC is the same for any generator of the same technology, the investor chooses the project with the highest market value. However, the investor ignores the environmental value (the avoided emissions) because there is no advantage in choosing a project that reduces emissions more than another.

Figure 6 shows a simple representation of an electricity market, where electricity demand slopes down because consumers reduce consumption when prices are high. The supply curve slopes up because some generators have lower operating (i.e., marginal) costs than others. (The diagram does not account for intermittency but makes the same point as the analysis in Fell and Linn 2012, which does). The PTC causes an increase in generation capacity in the system, which causes the supply curve to shift right in Figure 6. Consequently, electricity prices decrease.

Figure 6. Electricity Market with a Production Tax Credit for Renewables



Renewable Energy Investment Tax Credit and Cash Grant

A Brief History and Future of the ITC and Cash Grant

To reduce U.S. consumption of oil and natural gas, Congress created the ITC by passing the Energy Tax Act of 1978. Since 1978, the ITC has been modified numerous times (CRS 2006; Sherlock 2012), but currently, the ITC provides a 30 percent income tax credit for investments in solar, fuel cells, and small wind systems and a 10 percent credit for investments in geothermal systems, micro-turbines, and combined heat and power. The credit is received at the time of investment. Notably, large wind systems do not qualify for the ITC. To date, nearly $3.5 billion in subsidies have been issued under the ITC—with the majority ($1.9 billion) of the subsidy accruing in the 1980s. The fiscal cost of the ITC from 2000 to 2010 was much less than that of the PTC, $1.6 billion compared with $10.5 billion (Sherlock 2011; Jenkins et al. 2012). Looking forward, owners of solar generators are expected to claim nearly all of the credit associated with the ITC from 2011 to 2015. Moreover, a permanent 10 percent ITC will remain for solar after the 30 percent rate expires in 2013 (Sherlock 2012).

Because many RE firms were too small to be able to claim the full tax credit, they often formed partnerships with other organizations that could claim the tax credit. The American

Recovery and Reinvestment Act of 2009 established the Section 1603 grant program in response to a perceived difficulty in forming such partnerships during the financial crisis (Sherlock and Brown 2011). Section 1603 allowed certain renewable energy project owners to claim a onetime cash grant in lieu of the ITC or PTC. Wind and solar projects claimed 84 percent and 8 percent, respectively, of the $12 billion worth of subsidies (Sherlock and Brown 2011; Jenkins et al. 2012). Section 1603 expired at the end of 2011, and thus only projects that were (a) placed in service before the end of 2011 or (b) under construction before the end of 2011 and meet a specified deadline for being placed in service are eligible for the cash grant (Sherlock and Brown 2011). Overall, Section 1603 significantly improved financing for renewable energy projects.

How the ITC Works

At the simplest level, the ITC provides incentives that are similar to those of the PTC. The ITC provides a subsidy to renewable generators, resulting in an increase in investment and a decrease in electricity prices. However, because the ITC reduces the cost of constructing the generator rather than providing a production subsidy, there are two important differences between the ITC and PTC, both of which make the ITC inferior to the PTC. [1] The first is that the amount of the subsidy increases with the capital intensity of the project. Whereas the PTC leads investors to choose projects with the highest market value, the ITC skews investment toward more capital-intensive projects, which may not necessarily be the most valuable projects. Second, because the ITC subsidizes investment rather than generation, it could cause investment in generators that are unreliable and produce little electricity. This is important for untested technologies, which receive a substantial share of the value of the ITC.

Feed-In Tariffs

Recent History and Future of FITs and How They Work

FITs are more popular in Europe than they are in the United States, but eight states have FITs: Indiana, California, Louisiana, Hawaii, Oregon, Vermont, New York, and Florida (REN21 2011; DSIRE 2012a, 2012c). A FIT offers a specified subsidy for each unit of renewable generation. Sometimes the FIT is offered in addition to the market price, in which case it is very similar to the production subsidies described above. Other times the FIT is offered in place of the market price. In the simplest case, the FIT is a flat rate that does not vary over time or across

[1] As we discuss in the introduction, this paper focuses on the effectiveness of policies at reducing emissions. The ITC could be better than the PTC at correcting capital market failures.

technologies, but sometimes a FIT provides a time-varying or technology-specific rate. For example, Indiana's FIT offers a unique premium for wind, solar, biomass, and hydroelectric facilities; this is also the case in Germany's system, which is perhaps the most prominent national system (DSIRE 2012b). The FIT can be financed out of general tax revenue or by charges to ratepayers.

FITs subsidize renewable electricity generation. Consider a simple FIT system that offers the same rate to all technologies and at all times. Investors choose projects with the lowest cost. In other words, when choosing a project, investors do not consider the value of the electricity to consumers. Consequently, the FIT does not cause investment in the RE generators with the highest market value, but instead results in investment in those with the lowest cost. Because the cost of solar generators is usually higher than that of wind generators, offering a single FIT for all technologies would not lead to any solar investment.

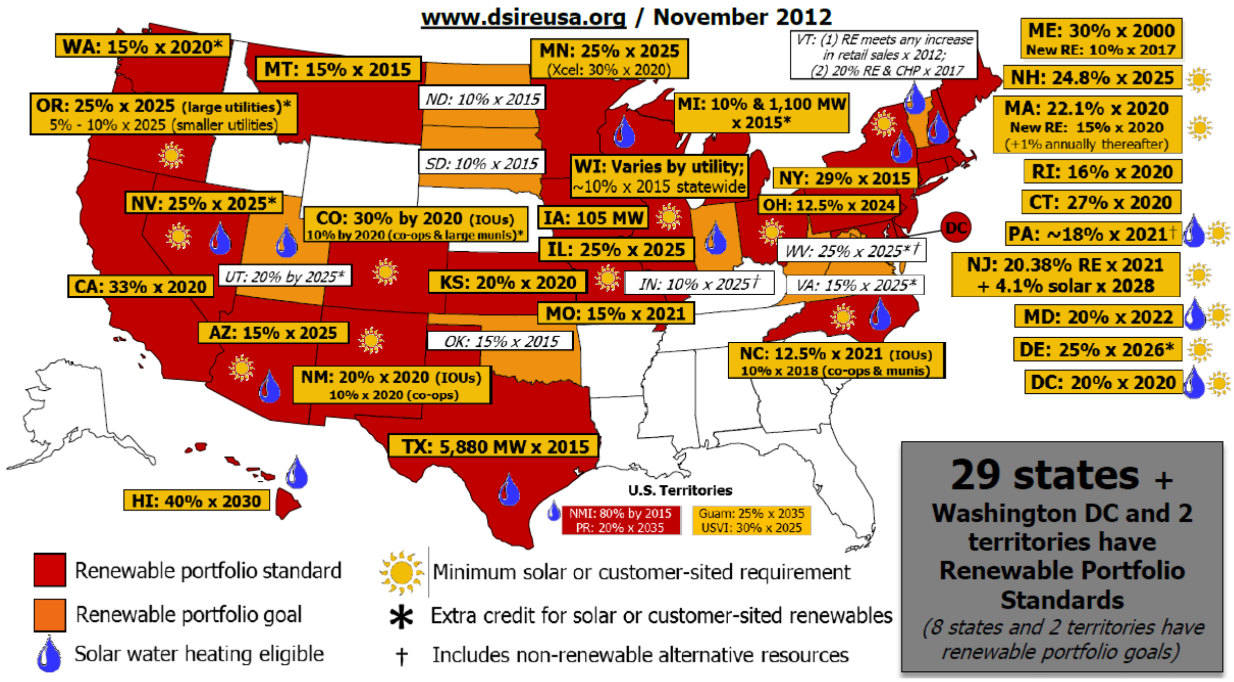
It is important to note that only the simplest FIT, which offers a fixed price instead of the market price, favors the lowest-cost generators. A FIT could be designed to favor generators with the highest market value, such as by offering a fixed rate on top of the market price of electricity.

Renewable Portfolio Standards (RPS)

A Brief History

Most RPSs require that RE generators account for a specified fraction of total electricity. Iowa first passed the first RPS in 1983. As Figure 7 shows, 29 states plus Washington, D.C., currently have RPS programs, which typically qualify wind, solar, biomass, and geothermal as eligible sources of renewable electricity (several other states have targets that are not backed up by penalties for noncompliance). In total, RPSs apply to over half of U.S. electricity load (Wiser and Barbose 2011). Each RPS is unique, differing in the overall target, which technologies are eligible, whether the program is linked to those of other states, and other factors.

Figure 7. State Renewable Portfolio Standards



Source: DSIRE 2012d

Most RPS's use renewable energy certificates (RECs), one of which is issued for each MWh of renewable electricity produced. The RPS requires electricity retailers to purchase a number of RECs equal to the product of the specified fraction and the amount of electricity it sells. For example, with a 20 percent RPS, a retailer that sells 100,000 MWh of electricity must purchase 20,000 RECs. In this way, an RPS establishes a market for RECs in which the price of a REC is in units of dollars per MWh.

How have state RPSs affected investment? Wiser and Barbose (2011) estimate that RPSs caused 27 GW of new capacity, with 91.8 percent of this capacity attributed to wind projects. More careful statistical analysis paints a more complicated picture, with authors finding statistically positive, neutral, and even negative correlations between RPSs and renewable energy investment (Shrimali et al. 2012). These neutral or negative correlations are not surprising, because many state RPSs are currently nonbinding.

Future of RPSs

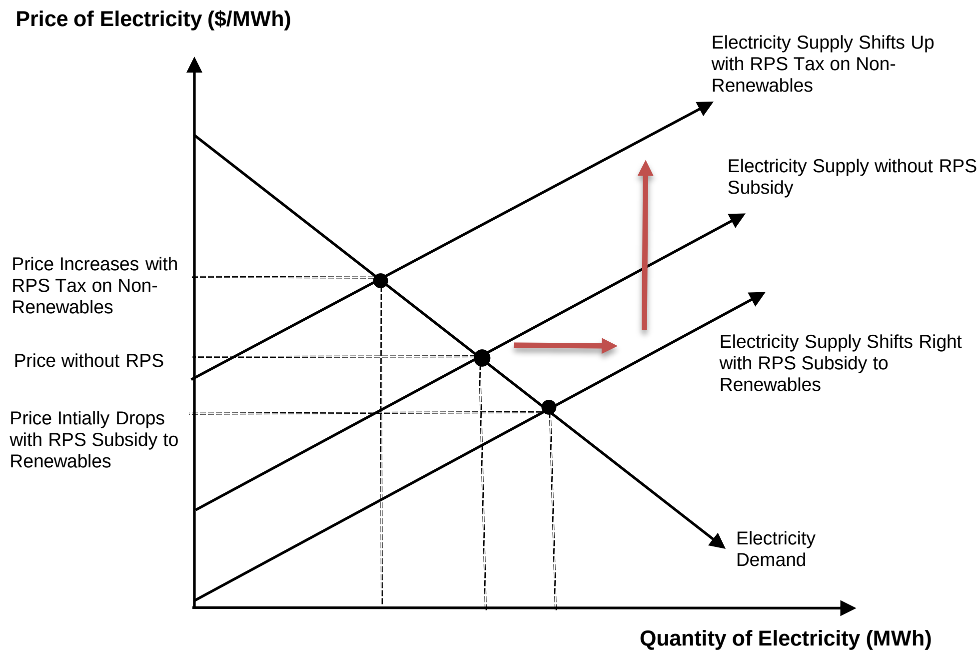
The stringency of many RPSs will increase dramatically over the next 5 to 10 years. For example, California requires that one-third of electricity generation come from renewables by 2020, whereas current levels are around 20 percent. Although these policies enjoy widespread public support now, will they continue to do so if increasingly stringent requirements lead to higher electricity prices or other problems?

How a Typical RPS Works

An RPS is more complicated than a production or investment subsidy. From the perspective of an investor in a renewable generator, a typical RPS provides a flat subsidy—determined implicitly by the market price of a REC—to renewable electricity producers. The credit price represents a subsidy to the renewable generator, because for each MWh, the investor receives the credit price. For this investor, therefore, the RPS creates similar incentives to the production subsidy. Like the production subsidy, the RPS causes firms to invest in RE generators with the highest market value. Also as with the production subsidy, the investor ignores the environmental value of the generator.

However, the RPS also affects the decisions of the electricity retailer. Consider a retailer that is initially exactly in compliance with the RPS, meaning that it is purchasing precisely the fraction of renewable electricity the policy requires. Suppose electricity demand increases and the retailer needs to purchase more electricity. If the retailer decides to purchase one MWh of fossil fuel generation, it must also purchase a fraction of a credit to remain in compliance with the RPS. The RPS creates an implicit tax on fossil fuel generation by raising the cost of purchasing electricity from fossil fuel generators (Fischer 2010). The implicit tax represents an important difference between the RPS and subsidies. As Figure 8 shows, the supply curve shifts out and up rather than just out as with the subsidy. The outward shift arises from the subsidy to renewables, and the upward shift from the tax on non-renewables. Whether electricity prices increase or decrease is ambiguous and depends on a variety of factors, including the slopes of the supply and demand curves.

Figure 8. Electricity Market with a Renewable Portfolio Standard



A production subsidy and an RPS both result in investment in generators with the greatest market value. The production subsidy causes electricity prices to decrease by more than the RPS and therefore causes electricity consumption and emissions to be higher. Because investment is the same and emissions are lower with the RPS, the RPS is more cost-effective than the production subsidy. Above, we argued that an investment subsidy is inferior to a production subsidy. How does a FIT compare with these policies?

In theory, it is ambiguous whether a FIT is more cost-effective than a production subsidy and an RPS. On the one hand, the FIT encourages low-cost technologies rather than high-value technologies as with the RPS or production subsidy. This difference favors the RPS and production subsidy, as can be seen with a simple example of an RPS and FIT. As an extreme example, suppose the price of electricity at night is zero and the wind blows only at night. Further, suppose that the price of electricity is positive only during the day. The FIT would encourage wind investment that has no value, whereas the RPS would encourage solar investment that does have a positive value.

In this simple example, the RPS is more cost-effective than the FIT. However, a second consideration is that the environmental value of the low-cost generator may be very large. Suppose instead that coal produces electricity at night and the price is positive. The wind at night displaces coal, whereas the solar during the day displaces hydro. It is possible, in that case, for the FIT to be more cost-effective than the RPS. The general rule of thumb is that when market value is similar across renewable generators but environmental value varies a lot, and low-cost generators have high environmental value, the FIT is better than the RPS; otherwise, the RPS is better. Likewise, it is ambiguous whether the FIT is more cost-effective than the production subsidy.

Summary

In this section, we have provided a history of RE policies and discussed the incentives created by each of them. We have shown that RPSs are more cost-effective than a production subsidy such as the PTC, which is more cost-effective than an investment subsidy such as the ITC. Whether a FIT is more cost-effective than an RPS or production subsidy is ambiguous and requires economic modeling, which is what we turn to next. Table 1 summarizes the current status of, and incentives created by, RE policies in the United States.

Table 1. Summary of Key State and Federal U.S. RE Policies

RE policy	Description	Coverage	Type of RE generator favored	Effect on electricity prices	Costs to taxpayers?
Investment Tax Credit (ITC)	Flat tax credit (subsidy) based on investment cost	Federal	High market value, high investment cost	Lowers (unless financed by charge to consumers)	Yes
Production Tax Credit (PTC)	Flat tax credit (subsidy) based on production of RE	Federal	High market value	Lowers (unless financed by charge to consumers)	Yes
Feed-in Tariff (FIT)	Pays RE generators a premium to produce	8 states	Lowest cost within technology category (assuming FIT doesn't vary over time)	Lowers (unless financed by charge to consumers)	Depends on design of FIT
Renewable Portfolio Standard (RPS)	Mandates a quantity or capacity of RE	29 states	Highest market value	Ambiguous	No

Comparing the Cost-Effectiveness of Different Renewable Electricity Policies

This section transitions from economic theory to economic modeling. We describe a simple investment model and present results from a simulation of Texas's electricity grid that estimate differences in cost-effectiveness among RE policies. Fell and Linn (2012) provide details of the model and results.

Overview of Our Model

We used a model of an electricity market in which firms invest in generation capacity and generators produce electricity to meet demand over a 23-year period, from 2008 to 2030. We calibrate the model to the Electric Reliability Council of Texas (ERCOT) power system because ERCOT is a competitive electricity market, publishes large amounts of data, and includes the largest installed wind capacity in the United Sates. We account for the intermittency of wind and solar electricity by estimating hourly generation for hypothetical generators. Combining these estimates with hourly electricity demand and pricing data from ERCOT allows us to characterize the market value of RE generators. Furthermore, emissions rate data from ERCOT allow us to characterize the environmental value of RE generators. Finally, we account for heterogeneity among wind generators by classifying two types of generators: "high" wind generators are more positively correlated with electricity demand, whereas "low" wind generators are more negatively correlated. The high-correlation generators have higher market value. The model's main output is an estimate of the cost-effectiveness of hypothetical RE policies. The model accounts for intermittency, heterogeneity in market and environmental value across RE generators, and the composition of the electricity grid.

Because our objective is to provide a clear comparison among alternative RE policies, we make a number of simplifications. First, the hypothetical RE policies we consider are an abstraction from RE policies implemented in the real world. Whereas we impose one RE policy at a time in our model, real-world firms often face numerous RE policies. For example, RE generators in California are affected by an RPS, FIT, PTC, and ITC—not just one of these policies. Second, our model does not include two aspects of the electricity market: ramping costs and transmission congestion. Fossil fuel generators incur significant costs in shutting down and starting up again and in changing production rapidly. We refer to such costs collectively as ramping costs, which we do not model; in practice, because we consider scenarios in which renewables account for less than 10 percent of total generation, failing to model ramping costs probably does not greatly affect our numerical results. Third, our model is deterministic, meaning there is no uncertainty in electricity demand, electricity production, or prices (including electricity, RECs, and fuel prices). These abstractions reduce modeling complexity and allow for a more crisp comparison of the cost-effectiveness among RE policies. We have compared the model results with actual outcomes, and we find fairly close agreement between the two, which suggests that these simplifying assumptions probably do not affect our main conclusions.

The model does account for recent policy and market developments. Importantly, the model includes recent projections for future natural gas prices and a proposed rule from the U.S. Environmental Protection Agency that effectively requires carbon capture and sequestration from new coal-fired power plants. The next section turns to the results of our simulation of hypothetical RE policies.

Results

In our simulation, we calibrate each hypothetical RE policy to achieve a 7.7 percent reduction in aggregate emissions. Therefore, comparing cost-effectiveness is equivalent to comparing costs to electricity producers and consumers. We compare an RPS, FIT, and PTC; in the model the ITC is an equivalent to an RPS, but as we discussed above, in the real world the ITC is likely to be inferior. We simulate a 10 percent RPS that credits all renewables equally, a $72/MWh PTC, and a $111/MWh FIT that replaces the market price of electricity and credits all renewables equally. Table 2 reports the main results.

Under the no policy case, there is no new investment in coal because of low projected prices for natural gas. Low projected natural gas prices also result in equilibrium electricity prices that preclude investment in wind investment.

Consistent with our theoretical analysis, the PTC is the least cost-effective RE policy, reducing emissions at a cost to electricity producers and consumers of $66.58 per ton. The PTC causes the highest overall levels (12.66 GW) of total investment in high and low-correlation wind generators. It also causes the highest levels of investment in wind generators highly correlated with electricity demand, confirming our previous observation that the PTC causes investment in RE generators with the highest market value. Equilibrium electricity prices are lowest ($60.03/MWh) under the PTC. While the RPS increases electricity prices relative to the no policy case, the PTC actually subsidizes electricity consumption. The subsequent increase in emissions is the main reason why the PTC is the least cost-effective RE policy.

The FIT costs 20 percent less than the PTC. Recall that it is theoretically ambiguous whether the FIT is more cost-effective. The PTC causes investment in the RE generators with highest market value, but if these generators have lower environmental value, the FIT could be more cost-effective. We observe that the PTC does cause more investment in the high-correlation wind generators, which have a high market value. The bottom of the table shows that on balance, the second effect (greater environmental value for the FIT) outweighs the first effect (greater market value for the PTC), and thus the FIT is more cost-effective than the PTC. Like the PTC, the FIT also decreases electricity prices.

The cost of the RPS is about one-third lower than that of the PTC and about 17 percent lower than that of the FIT. Comparing the RPS and the PTC demonstrates the importance of the price effects. Both policies cause investment in the RE generators with the highest market value. As a result, the share of high-correlation wind investment in total wind investment is similar for the two policies. However, the RPS puts more upward pressure on electricity prices, and consequently the RPS outperforms the PTC.

We have also modeled polices that, rather than promoting RE generators, focus more directly on reducing emissions: a carbon dioxide emissions price (i.e., an emissions cap or tax) and a clean electricity standard (CES). A CES is an extension of an RPS that credits generators based on their emissions rates rather than on whether they are RE technologies. Several recent proposals for a national CES have been put forth, including in the U.S. Senate. In our model, these policies rank highly because they allow for more flexibility in compliance. Because these policies increase generation costs according to emissions rates, they result in more fuel switching—such as from coal to natural gas generation—which provides a significant amount of low-cost emissions reductions that the RE policies do not encourage. Ultimately, a carbon price is the most cost-effective because, in addition to fuel switching incentives, it results in the highest electricity prices and reduces electricity demand. Compared with the RPS, a carbon price and CES reduce emissions at 23 and 38 percent of the cost.

Table 2. Summary of Results from Model Simulation of Hypothetical RE Policies

	No policy	RPS	FIT	PTC
Panel A: Investment (GW) and Average Wholesale Electricity Price ($/MWh)				
Coal	0	0	0	0
Natural gas	5.95	1.11	1.45	1.22
Wind (high)	0	6.37	6.30	7.26
Wind (low)	0	4.00	6.30	5.40
Wholesale electricity price	63.22	67.52	60.62	60.03
Panel B: Emissions, Costs to Electricity Producers and Consumers, and Cost-Effectiveness				
Emissions (billions of tons of CO_2)	4.01	3.70	3.70	3.70
Costs to electricity producers and consumers (billions of dollars)	499.02	485.36	482.46	478.57
Cost-effectiveness (dollars per ton of avoided CO_2)	n/a	44.47	53.64	66.58

Recommendations for Policymakers

Given the immediate issue of whether to allow the PTC to expire, we offer two recommendations. First, the PTC could be replaced by other policies that are much more cost-effective, particularly a carbon price or CES. Second, if the PTC is to be extended, it should be financed by a per-kWh charge to electricity consumers instead of by federal taxpayers. Properly financing the subsidy would decrease or even eliminate the downward pressure on electricity prices and improve the cost-effectiveness of the PTC. Our analysis does not imply that allowing the PTC to expire without replacing it with another RE policy is optimal; rather, we focus on which policy is best for achieving a target emissions reduction. Also, we do not consider the effectiveness of these policies at promoting innovation or learning-by-doing.[2]

The more long-run issue is the increasing stringency of state RPSs. Again, we have two recommendations. First, replacing the RPS with a carbon price or CES would greatly improve cost-effectiveness. Second, states should adjust RPSs to account for the environmental value of renewable generators. Accounting for environmental value would reduce investments in generators that have high market value but do not displace many emissions.

We conclude by expanding on the recommendations from the Introduction.

1. Subsidies that are financed out of tax revenue, such as the investment tax credit or the production tax credit, cause greater electricity consumption, which erodes the cost-effectiveness of these policies. Adjustments that increase electricity prices improve the cost-effectiveness of these policies. For example, financing these subsidies by charges to electricity consumers instead of by revenue from federal taxpayers would improve cost-effectiveness.
2. Regardless of financing sources, production subsidies are preferred to investment subsidies. This is because investment subsidies favor capital-intensive generators and generators that might not produce much electricity.
3. The simplest feed-in tariffs, which do not vary over time or by technology, promote the lowest cost rather than the most valuable generators. FITs could achieve much better cost-effectiveness if they were designed to account for market and environmental value.
4. An RPS or production subsidy (such as the PTC) provides the greatest incentive to invest in generators with the highest market value but not necessarily those with the greatest environmental value. Policies that more directly target emissions, such as a clean electricity standard or a carbon price, can account for both market and environmental value.

[2] Further, note that we focus on the effects of the policies on electricity producers and consumers, holding fixed prices in other markets. Many studies, such as Goulder et al. (1999), allow for price changes in other markets, but typically they do not compare renewable electricity policies with one another.

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