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Rethinking government subsidies for renewable electricity generation resources

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ABSTRACT

U.S. renewable electricity resource subsidization program design relies on production-based payments that lower electric energy market prices, often below zero, contrary to the objective of increasing market prices when correcting for an environmental externality. An alternative pricing approach, capacity-based subsidy payments, would substantially reduce the likelihood of negative electric market prices. A more thoughtful examination of the impact of subsidization program design on wholesale power markets is long overdue.

1. Background and summary

The construction of renewable electricity generation resources in the U.S. has increased significantly over the last several years in response to incentives created by federal and state subsidies (Barbose, 2016). These subsidy programs take several forms, including production tax credits (PTCs), investment tax credits (ITCs), and renewable portfolio standards (RPS). Proponents of subsidies for renewable resources typically justify these programs by pointing to, among other things, the fact that renewable generation has zero air pollutant and greenhouse gas emissions (as compared to traditional fossil-fuel generation) and that their lower marginal costs will lead to lower electricity prices for consumers. However, these subsidy programs typically appear designed primarily to provide financial support to an evolving industry and to bring investment to local economies, while limiting utility ratepayer financial impacts. Importantly, the details of how subsidy payments under these programs are made have important implications for the functioning of wholesale electricity markets. In many cases, subsidy payment structures can lead to perverse wholesale electricity pricing that has nothing to do with alleviating pollution or ensuring that consumers have access to reliable, yet inexpensive, electricity.

Government subsidy programs to support the development of renewable generation assets will continue and the supply of these assets is expected to grow substantially over the coming decade. In addition, recent programs have been developed to establish zero-emission credits for nuclear resources whose value is based on the avoided cost of carbon dioxide emissions not otherwise captured in electricity prices. This is an opportune time to reexamine how government subsidy programs are structured and whether their design can be improved. From a public policy perspective, the focus of these subsidy programs should be on achieving societal benefits while minimizing unnecessary distortions to the functioning of wholesale power markets. For example, to the extent that the societal benefit of a renewable resource arises from displacing fossil fuel generation (i.e., reducing its dispatch) and thereby reducing carbon emissions, the subsidy to the renewable resource should be based, in part, on the social cost of the carbon emission that would be incurred in its absence. Although accurately estimating the carbon emissions that are displaced may be complex, analytical methods for doing so are readily available.

However, it is important that these subsidies to renewable generation resources not adulterate the incentives these resources face to provide power in wholesale markets at marginal cost. Subsidies that are paid on the basis of how much electricity a generation resource has produced can readily lead to perverse bidding behavior that undermines the functioning of wholesale power markets. Alternatives, such as capacity-based payment mechanisms, avoid distorting the incentives that generation resources face while still encouraging their construction and operation. These capacity-based payment mechanisms would allow governments to continue to direct the market towards a particular resource mixture while fostering a well-functioning wholesale power market. By placing greater attention on how subsidy payments are made, policymakers and regulators can ensure that investments in new renewable generation resources will continue and complement the functioning of wholesale power markets, rather than undermine it.

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2. The economics of existing subsidy programs

Very little social welfare cost-benefit analysis lies behind federal and state RPS programs designed to subsidize renewable electricity resources. Instead, it is typically the case that when state RPS policies are approved they focus on consideration of the cost impacts on retail electricity consumers.[1] For example, it has been recently reported that all states with RPS have cost containment mechanism associated with RPS policies and seek to minimize the impact on consumer costs so it is no more than a small percentage of the monthly bill (Heeter et al., 2014). Moreover, there are several states where meeting the RPS is often found to be a least-cost resource planning approach as the avoided cost of adding a new fossil-fuel-fired resource is greater than the cost of a renewable resource (including the PTC and ITC as appropriate). Importantly the majority of the state analyses of the costs of RPS policies are not evaluating the incremental cost of subsidizing renewable resources and comparing the costs to the benefits (Heeter et al., 2014).

Instead, a recent joint National Renewable Energy Laboratory/Lawrence Berkeley National Laboratory (NREL/LBNL) report finds that state policymakers analyze RPS costs in much greater detail when compared analyses of the benefits that may be attributable to RPS (Heeter et al., 2014). Only a small number of states have estimated the benefits of a RPS policy. In particular, this NREL report examines nine states where there was an effort to carry out some analysis of RPS policy costs and benefits. Depending upon state, these studies sought to estimate the benefits of RPS policies based on avoided air pollutant emissions and health-related benefits, increased local economic investment benefits, and wholesale market price reductions associated with introducing practically zero-marginal-cost renewable resources.

Of these nine state studies, only six estimate potential carbon dioxide emission reductions resulting from the RPS.[2] Notably, considerably more effort is undertaken in these six studies to analyze local economic investment benefits and estimate potential reductions in wholesale market prices resulting from the additional of zero marginal cost renewable resources. For example, Table 1 compiles benefits estimates from these six states' studies. Table 1 shows that only three of the six studies placed a value on the benefits of avoiding carbon emissions. Of particular interest is the variation in the estimated avoided emissions of carbon dioxide per megawatt-hour of electricity production. The geographic location of renewable resources substantially affects the expected carbon dioxide emission benefits with the Northeast and New York estimating lower values than the Midwest, and with no value estimated by states in the Mid-Atlantic. Surprisingly, as of 2014, the benefit of reducing carbon dioxide emissions has only been estimated and reported on a limited basis for the 29 states with RPS (Heeter et al., 2014).[3]

Table 1 also shows that state studies of potential benefits associated with RPS focus more on estimating the local economic impact associated with the addition of renewable resources and the potential wholesale power market price reductions. A comparison of the findings shown in Table 1 demonstrates that the substantial source of estimated benefits arising from the subsidization of renewable resources is local economic impacts and wholesale power market price suppression.

Because subsidization in favor of preferred renewable power resources affects wholesale power market pricing, it is important to estimate the benefits of subsidization using a defensible analytical framework. Of those analyses conducted by states to assess RPS benefits, the majority undervalue the benefits due to carbon reduction, and account for benefits that are based on estimates of isolated impacts on a state's local economy and wholesale power price suppression.[4] These latter benefits are not appropriately counted when using an analytical framework that evaluates the change in overall social welfare.[5] Not surprisingly these benefits focus on individual state economic impacts associated with supporting investment in one particular state and do not account for economic interactions with other states. Moreover, while some states see wholesale price suppression as a benefit of renewable resource additions, it is not a direct measure of increase in social welfare. Instead, holding consumer demand constant as is typical in these analyses, it is a transfer of wealth from producers to consumers.[6] However, one of the most important benefits to consumers of subsidizing low-carbon-emitting resources is avoiding the future costs to society of carbon emissions (and other avoided air pollutants). Given that these resources are typically cited as important for reducing future greenhouse gas emissions, it clearly makes sense to evaluate their cost-effectiveness based on the benefits that they provide to society.

More recent analysis focused on estimating the benefits of RPS policies reinforces the importance of focusing on the avoided costs associated with reduction of pollution from fossil-fuel electric generation units. For example, a 2016 NREL/LBNL report seeks to supplement the results of the various state level studies shown in Table 1 in an effort to provide a nationwide estimate of benefits attributable to RPS policies (Wiser et al., 2016). In this recent study the emphasis is appropriately on the societal benefits that result from a reduction in greenhouse gas and other air pollutants, as well as reduced use and reliance on water.[7] And while the report evaluates other financial impacts of RPS policies, it correctly notes that environmental benefits are those expected to accrue to society and increase welfare (Wiser et al., 2016).

In addition, the measurement of the social welfare impact of policy proposals that increase renewable resource penetration was also the subject of comprehensive studies of the cost-effectiveness of different policies for reducing carbon dioxide emissions. For example, Resources for the Future and the National Energy Policy Institute (RFF/NEPI) conducted a detailed analysis of the welfare impact of various policies to reduce carbon dioxide emissions (Krupnick et al., 2010). Although the RFF/NEPI report compared the welfare costs of different policies to reduce carbon dioxide emissions, it evaluated a how a federal RPS policy would compare to other policies and expressed the findings using a consistent analytical framework which does not consider localized economic impacts as a source of increased welfare.

Finally, an analysis of the impact on dynamic efficiency is often overlooked when evaluating the impact of these subsidy policies on social welfare. The implementation of these policies results in the levy of an implicit tax on unsubsidized zero- emission resources due to costs that are no longer recovered from power markets as a result of reduced prices. However, analysis of dynamic efficiency can show that alleged price reduction benefits are likely to be lost, in part, due

[1] The focus herein is on state subsidization programs. For federal subsidization programs, the stated objectives are to provide financial support to new technologies and create jobs (U.S. Public Law 111-5 2009).

[2] The other three states' studies examined local economic investment impacts and/or wholesale power market price reductions.

[3] There are a number of independent studies that estimate renewable resource benefits, including carbon dioxide emissions reduction estimates, which are often developed in association with regulatory proceedings evaluating resource siting and/or power sales contract approvals. However, these studies rarely focus on an analysis of change in social welfare.

[4] The importance of recognizing that wholesale electric energy price suppression is not itself a measure of benefits of subsidization has been explained previously. See, for example, Felder, 2011.

[5] A modeling framework that examines the benefits to society of a particular renewable resource development policy on power markets should focus on measuring the change in power system production costs resulting from the policy as this change represents a measurement of those resources that are saved by society due to the addition of zero marginal cost resources. To the extent that the analysis of a proposed policy accounts for price elasticity of demand associated with a given shift in the supply curve due to the addition of renewable resources, there will be an increase in efficiency that must also be estimated.

[6] A standard societal cost- benefit analysis appropriately nets out transfers of economic rents and surplus between producers and consumers which result from changes in wholesale power market prices associated with a renewable resource policy.

[7] Note that the study relies on a mixture of methodologies to estimate the potential benefits resulting from the addition of renewable resources in the year 2013.

Table 1
Estimated Benefits of State RPS Policies.
Source: Adapted from Heeter et al., 2014; Tables 11–13 and references therein.

State	Avoided Emissions Benefits		Regional Economic Benefits		Wholesale Market Price Suppression	
	Estimated Benefit	Estimated CO_2 Reductions	Estimated Benefit/Impact	Benefits $/MWh of RE	Estimated Benefit (annual except where noted)	Benefit ($/MWh)
CT	N/A	0.39–0.53 tons/MWh	− to + Gross State Product Impact-2020	N/A	N/A	N/A
OH	N/A	.17 − 0.5%	N/A	N/A	N/A	$0.05–$0.17/MWh
ME	$13 million	0.57 tons/MWh	$1140 million[a]	$24/MWh[a]	$4.5 million	$0.375/MWh
DE	$980-$2200 million[2]	30%[b]	N/A	N/A	N/A	N/A
IL	$75 million	0.79 tons/MWh[c]	$3003 million[d]	$14/MWh[d]	$177 million	$1.3/MWh
NY	N/A	0.43 tons/MWh	$1252 million[e]	$13/MWh	$455 million[f]	1% decline
MI	N/A	N/A	$159.8 million[g]	N/A	N/A	2% decline
OR[h]	N/A	N/A	N/A	N/A	N/A	N/A
MA	N/A	N/A	N/A	N/A	~ $34 million[i]	~ $.5/MWh

[a] The values are estimated for expenditures made during the construction period. In addition, Maine has estimated annual benefits of $7.3 million ($4/MWh of RE) during each year of resource operation.
[b] Estimated human health benefits of avoided emissions for Delaware over the 2013–2022 time period reported in $2010 dollars. Carbon Dioxide reduction reported for electric generation units located in Delmarva Power and Light transmission zone.
[c] Estimated based on 6.9 million MWh of renewable energy needed to meet the 2011 RPS requirements.
[d] Illinois benefits estimates reported in $2012. Calculations per MWh are estimated assuming a 30% capacity factor and for the construction benefits, spread over generation for a 25-year project life.
[e] New York estimates are in $2012. Estimated benefits represent the present value of direct investments associated with New York State renewable resources over the life time of the renewable resource. New York also estimated a cumulative impact on gross state product of $921 million ($9/MWh RE).
[f] Present value calculation reported in $2012 and calculated over life time of the renewable resource.
[g] Estimated over construction period based on four operational wind farms in Michigan.
[h] Oregon estimated jobs resulting from renewable energy projects using a survey.
[i] Annual estimate based on Massachusetts Department of Public Utilities (DPU), Docket No. D.P.U. 10–54, Revised Response to Record Request of the DPU, RR-DPU-NG-4, October 5, 2010.

to an offsetting increase in capacity prices that will occur in regions where independent system operators/regional transmission organizations (ISOs/RTOs) rely on centralized capacity markets through an increase in offers and administrative pricing schedules resulting from reduced energy market margins. Alternatively, social welfare can be adversely impacted in regions without centralized capacity markets as longer-term resource addition plans are skewed away from otherwise dynamically efficient outcomes that identify more efficient production resources that appear uneconomic as a result of subsidization of other resource choices.

3. Subsidy payments should be based on the marginal benefit to society from reduced emissions of carbon dioxide[8]

Assuming that a primary objective of subsidization programs for zero-emission resources is to avoid the harm that would be caused by otherwise higher emissions of carbon dioxide that result from reliance on more carbon-intensive resources, it is theoretically appropriate to base the payment of a subsidy on the avoided cost to society of carbon dioxide emissions.[9] In this instance an acceptable estimate of the societal marginal benefit of avoided carbon emissions would be the avoided marginal cost of carbon emissions measured based on the estimated social cost of carbon emissions.[10]

However, the policies implemented by the U.S. federal government and states do not typically seek to estimate what the subsidy level should be in order to correct for the failure to internalize the externality.[11] Instead, as explained above, zero-emission RPS production quantities are primarily based on percentage of retail sales with cost caps where applicable. There is little evidence beyond the recent decisions of New York and Illinois to subsidize nuclear units based on the estimated social cost of carbon to demonstrate that the subsidy design is linked to its societal benefits (NY PSC 2016 and Illinois SB 2814 2016). Because there is no direct linkage of the subsidy level to the social cost of carbon, or any other externality that would support the payment of a subsidy (e.g., a positive externality), analysis of the extent to which the subsidy increases social welfare is incomplete.

Recent literature has started to evaluate and report the estimated social welfare change associated with the adoption of different renewable resource subsidization programs using primarily stylized electricity market models (Andor and Voss 2016; Pahle et al., 2016; Green and Léautier 2015; Rosnes 2014). These recent analyses focus on countries in the EU where reliance on feed-in tariffs (production-based subsidies that guarantee prices for renewable energy or guarantee a premium payment on top of the market price of electricity) to subsidize renewable resources has been widespread. In these analyses the efficiency of capacity based subsidies (investment support payments independent of resource production) is evaluated against that of production-based subsidies. The literature reports the estimated change in social welfare resulting from the theoretical application of these different subsidization policies.

Although there is some variation in the findings of these recent analyses, there is a notable concern that production based subsidies have been pursued without a clear understanding of the tradeoffs when compared to capacity-based subsidization policy. For example, analyses find that production-subsidy-induced negative prices reduce the social welfare benefits of subsidization policies (Rosnes, 2014 and Green and Léautier, 2015).[12] These analyses reveal the importance of carefully

[8] It is equally important to consider societal benefits associated with other pollutants whose external costs are not otherwise internalized. The focus herein is on carbon dioxide emissions, which garners the most attention as an external cost that should be internalized.

[9] The logic for adopting, as a second-best solution, the subsidization of renewable resources based on avoided pollutant emissions has been identified and summarized previously (Andor et al., 2016).

[10] It is important to note that proper measurement of the marginal avoided cost of carbon emissions requires reliance on appropriate modeling techniques that capture the operational structure of the power markets (Rudkevich and Ruiz, 2012) and an acceptable estimate of the social cost of carbon (e.g., IAWG, 2016).

[11] There are ex post analyses that seek to demonstrate that the benefits of estimated PTC reduced emissions of carbon dioxide and other air pollutants are greater than the PTC's costs. See, for example, Siler-Evans et al. (2013).

[12] A recent analysis also suggests increased incidence of negative prices may favor a feed-in tariff in the long run, ignoring existing generation resources and assuming significant penetration of renewable resources and adoption of real-time pricing by consumers (Pahle et al., 2016).

evaluating subsidy options' impact on power market prices as power system operations must be able to capture renewable resource output variation and subsidy program design features will have a significant impact on renewable resource operational decisions.

Moreover, although it is often suggested that there is an externality associated with potential learning-by-doing gains difficult for investors to capture (and which may be overcome through subsidization policy), analysis to date indicates that such gains are small when compared against internalizing the cost of the externality. For example, the U.S. National Academy of Sciences (NAS) reports that the spillover effects measured by an estimated learning-by-doing premium are small for renewable resources and greater emphasis on setting a price on carbon is much more important (NAS, 2016). Moreover, the NAS concludes that upstream transformational research and development is a more suitable policy objective than broad subsidies for existing green technologies. The implication of these findings calls into question whether current renewable resource subsidization policy promises to result in long-lived resource technologies that increase social welfare.

The failure to analyze the value of the subsidies based upon estimated societal benefits creates a hodgepodge of U.S. renewable resource subsidization programs that cannot demonstrably claim that an increase in social welfare results from the subsidization program. Instead, these programs primarily redistribute income among producers and consumers, and often favor a particular state's resources at the expense of another state's or geographic region's resources. Moreover, because market prices are influenced by these subsidization programs, an important objective when evaluating subsidy design should be to minimize unintended inefficiencies introduced in wholesale markets, as opposed to relying on these same price reductions as a validation of subsidization program benefits.

4. The design of subsidy programs should focus on minimizing distortions to wholesale power markets

4.1. Market distortions from subsidy programs

Ideally, the application of a subsidy to encourage the development of resources that reduce carbon emissions should align as closely as possible to the objective that would be achieved by assessing a Pigouvian tax that corrects for negative externalities (Baumol and Oates, 1988). If the goal is to reduce emissions of carbon dioxide, then the subsidy should compensate all zero- or low-emission resource owners for the social benefits that their resources provide to society. However, current subsidization policies readily introduce several market place distortions that would be avoided through the imposition of a carefully designed tax.

First, by reducing wholesale power market prices subsidization programs will tend to increase consumer electricity demand (all else equal), as opposed to the reduction in demand that would result if the externality were internalized through a tax. Moreover, the majority of those zero-emission resources that are subsidized have low, or nearly zero, variable operating and maintenance costs, and the subsidies for many of these zero-emission resources are paid based on production quantity (except for the more recent ITC). The use of a production-based subsidy that accrues to already nearly zero-cost resources puts downward pressure on wholesale market prices. Whereas consumers should face increased prices when correcting for the impact of the negative externality on markets, they instead face reduced prices, which will increase power demand over the long run.

The allocation of the subsidies' costs does not correct for the reduction in wholesale market prices realized by consumers. Although the costs of the subsidization programs are passed through to these same power consumers, the costs are typically recovered as additional charges on utility bills that do not vary coincidentally with resource production. Thus, in wholesale hourly power markets prices decline affecting many consumers' marginal demand while the costs of the subsidization policy are assessed as an increase in consumers' average total costs.[13] Moreover, the costs consumers incur to subsidize the zero-emission resources are lower than would otherwise be incurred if a tax were imposed on all generation resources that emit carbon dioxide. Because the dominant marginal fuel source in many U.S. power markets is carbon-based fossil fuel (gas/coal), the imposition of a tax increases wholesale electricity prices in most hours (again pushing consumer consumption downward over time). However, a subsidy paid to only a subset of generation resources (typically zero-emission resources) will be less costly to consumers than paying a tax that internalizes the cost of the externality (assuming the tax revenue is not returned to consumers) in kind.[14] Thus, consumers face subsidization costs over a small number of resources that is spread across all consumer consumption resulting in lower per unit cost than would result if a tax were applied to all fossil fuel resources.

Second, in the instance where a subsidy is paid to some but not all sellers in the market, the subsidized resources will realize lower average total costs (and likely marginal costs, too, depending upon the subsidy design) and crowd out existing marginal suppliers and other would-be new entrants. However, the market impact over the short run and the long run will be different. In the short run the subsidization of existing and zero-emission assets will suppress electric energy prices driving down margins for non-subsidized resources. Absent new entry, short-run prices decline and the marginal non-subsidized resources will be likely to eventually shut down unless the resource is sufficiently low-cost (and may do so similar to what would happen if a tax was imposed as opposed to a subsidy). Over the longer term, to the extent that the subsidization of existing and new zero-emission resources supports the addition of new generation capacity and delays the addition of new, more efficient resources, these potential new unsubsidized market place sellers are also harmed by the subsidy.

In contrast, if the negative externality associated with carbon emissions were captured in wholesale power markets, it would increase wholesale power prices, all else equal, and make higher-carbon-emitting resources less competitive than lower-carbon-emitting resources. In particular, the impact of a tax on producer marginal costs will align production costs more closely with marginal social cost. First, prices will rise during those times when relatively higher-carbon-emitting resources are the marginal source of electricity supply, providing an accurate price signal to low-emission resources of when their supply is most valuable. Second, the imposition of a tax can be expected to eliminate the incentive for low- emission resources to offer supply at negative prices, which will result in a more efficient mixture of resources being committed day-to-day to meet consumer demand. Market prices would rise and consumer and producer responses would be efficient responses to the market prices that internalize the externality. Ideally the amount of supply from zero-emission resources would be driven by market prices, assuming that there was no longer a perceived need for financial support via investment subsidies or production tax credits.

However, the application of a carbon tax on a regional or statewide basis is complex. Assessment of a tax will lead to "reshuffling" where high emission resources located outside the geographic region affected by the tax will substitute supply for in-region resources whose costs are increased. Moreover, the disposition of the revenue collected under a tax regime can diminish the effectiveness that the tax would otherwise have in reducing demand. A tax clearly aligns the costs faced by producers with the social cost of their production, but absent uniform application across a broad geographic region with careful attention

[13] By assessing the subsidy costs on an average total cost basis any variation in customer rates that otherwise occurs based on time of use, or time of year (e.g., seasonally), that would affect customer consumption decisions at the margin is foregone.

[14] This fact is surely recognized by politicians and regulators when putting in place subsidization programs that do not offset costs borne by consumers. See also McKibbin and Wilcoxen (2002).

paid to the impacts of redistribution of the collections, an efficient tax for internalizing the externality is difficult to design.

Thus, state and federal policies rely on poorly designed, distortionary subsidies with no, or limited, linkage to correcting for the impact of a negative externality. In practice, aligning the subsidy based on the objective of improving social welfare has not been a prominent consideration when designing subsidies, given that RPS programs target particular resource types and rely on a mixture of federal production and investment credits, state renewable energy credits, and long-term fixed price contracts to support renewable resource development. Moreover, where active discussions are underway regarding rapidly increased growth in renewable resource supply (New England and New York), the regulatory framework is expected to rely primarily on offering long-term fixed-price contracts via competitive solicitations as the basis for supporting new renewable resource supply additions (NEPOOL, 2017; NYPSC, 2016). To the extent that growth in RPS program obligations results in continued incentives for renewable resources to be offered into wholesale markets at prices driven artificially low by subsidy design, wholesale power market prices will be pushed downward and consumer and producer decision-making will be distorted away from efficient outcomes.

4.2. Limiting the market distortions

The impending growth of the obligations under RPS programs to support renewable resource investment calls for more detailed analysis of the wholesale market impact of these subsidization programs. Subsidization program design should consider the expected impacts on wholesale markets and include design features to minimize those impacts that are inconsistent with correcting for a negative externality. RPS programs which base subsidy payment on hourly resource production level incentivize seller behavior that is unlikely to improve social welfare. In particular, the federal PTC, state RPS programs (and their reliance in part on renewable energy credit (REC) payments), and long-term fixed energy price contracts collectively incentivize zero-emission resource bidding behavior that will continue to push electric energy market prices below zero (see, e.g., U.S. EIA, 2014). However, there are actions that can be taken at the state and federal level to minimize adverse wholesale market impacts.

A reasonable objective to achieve when defining a zero-emission resource subsidization program is to ensure that subsidized resources do not have an incentive to offer supply to the wholesale markets at lower than realized short-run marginal costs (i.e., actual incurred marginal operation and maintenance costs). Eliminating the incentive for subsidized resources to make negative-priced bids in the wholesale markets will reduce negative market clearing prices driven solely by subsidization programs. Growing incidence of negative electricity prices is clearly inconsistent with the objective of eliminating a negative externality; preventing negative prices is a reasonable policy objective.

First, there are RPS program implementation frameworks that can be adopted to prevent and/or minimize unintended distortionary effects. Many key subsidization program design features are implemented via the terms and conditions of long-term contracts typically relied upon by renewable resource developers to facilitate access to investment capital to support resource construction costs. Although there can be a number of variations for power sale agreement (PSA) structures, the key economic terms and conditions are the price and quantity commitments made by the buyer and seller under a PSA. To date, in many cases PSA prices are set to provide compensation per megawatt-hour of energy delivered and include an estimated annual production quantity. Pricing can vary for production above and below specified annual production targets, and it is often the case that there will be price reductions in the event a resource's production falls below a minimum quantity.

The interaction of type of PSA structure used, and the impact on seller wholesale market bidding behavior, is becoming increasingly relevant as the penetration of low-cost renewable resources increases. For example, ISO-NE recently provided taxonomy of different types of PSAs and their expected impact on wholesale energy markets (ISO-NE, 2017). The ISO-NE analysis identified two commonly used PSA structures—fixed and minimum per MWh price guarantees—and explained that, under these contract structures, resource owners are incentivized to bid below observed marginal costs because sales prices are guaranteed. Although guaranteed energy sales prices are desirable for sellers and can facilitate project financing, ISO-NE found that these two contract structures have the highest distortionary impact on the wholesale electricity market. In contrast, ISO-NE identified two alternative contract structures—fixed price adder (possibly based on marginal societal cost of carbon) and minimum delivery with shortfall payment—as alternatives that would have less distortionary impact on the wholesale power market. To minimize the incentives created by PSA structures tightly linked to production quantity, alternative payment mechanisms can be adopted.[15]

In particular, PSA structures that compensate facilities for meeting pre-defined availability targets can provide adequate incentives for a resource to perform favorably, and maximize production, while limiting incentives that would otherwise incentivize market offering strategies that reward below actual marginal cost offers. For example, it is already common for PSAs to include detailed estimates of expected resource availability (i.e., forecast monthly hourly production which is often evaluated in conjunction with associated requests for proposals used to procure renewable resources).[16] A contract payment structure could take the form of a monthly capacity payment based on the expected average seasonal hourly availability (measured in MW) of the resource. Historical meteorological data can be used to estimate expected seasonal availability, and a minimum average hourly seasonal production level (measured on a three-year rolling average) can be conservatively defined based on the probability that minimum average seasonal hourly output will be greater than a value that historically would be expected to be exceeded 65–75% of the time (dependent upon facility hourly output statistical distribution).

Seasonal three-year rolling average production below the contractual minimum would be subject to a penalty assessed seasonally and calculated by multiplying the difference between the minimum and realized average hourly production level (when positive) by the weighted average of a geographically relevant real-time hourly hub price (using on- and off-peak weights based on typical resource type for geographic location). Although there would remain a tenuous linkage to observed production, the penalty is sufficiently large to signal to the seller that it is expected to achieve average seasonal output consistent with a level based conservatively upon historical meteorological data. Conditioning payment for capacity on resource availability measured using widely known and accepted generation availability data system statistics can provide a transparent PSA payment structure while ensuring that production results whenever the value of energy is greater than the near zero marginal cost of the resource.

It is equally important that PSAs specify terms that result in sellers making resource market offers based on actual marginal costs, as well. This is especially relevant as renewable resources should be expected to offer to the wholesale markets on an hourly basis and be dispatched by system operators. Of particular importance is the fact that resource output that is pre-scheduled will be assigned a very low negative offer by ISO/RTOs' software. For example, ISO/RTOs routinely convert self-

[15] The need for non- production-based subsidy payment structures has been identified previously (Hogan, 2010).

[16] See, for example, proposed Power Purchase Agreement between Delmarva Power & Light Company and Bluewater Wind Delaware LLC, Dec. 10, 2007 at Section 3.5. See also, Draft, RPS Class I Renewable Generation Unit Power Purchase Agreement, Massachusetts Clean Energy, at Exhibit F, Available at: https://macleanenergy.com/83d/83d- documents/.

scheduled supply to offer prices well below zero (e.g., −$400/MWh in the case of the CAISO).[17] It is imperative that renewable resource supply be offered to the marketplace based on actual short- run marginal costs undistorted by PSA payments. A PSA payment structure can be designed to provide resources sufficient compensation while minimizing incentives for a seller to make negatively priced offers.

However, adoption of a PSA structure that relies on capacity- based availability payments will likely require a revaluation of how the cost of risk will be allocated between buyers and sellers. For example, under many renewable resource PSA structures, buyers often assume PSA product market risk by taking title to energy, capacity, and RECs and then either reselling the products in shorter-term markets or using them to meet customer obligations (at an opportunity cost equal to the foregone market value). This PSA structure reduces risk for the seller by fixing the price paid for energy and provides a strong incentive to the seller to meet annual production targets, including depending upon PSA structure, bidding below actual marginal operating cost (i.e., opportunity-cost-based negative offers). Alternatively, if PSA pricing were based on resource availability to the marketplace, the seller could face market risk, or still pass it on to the buyer (i.e., buyer assumes market price risk), but no longer face a strong incentive to bid below actual operating marginal cost.[18] Moreover, if a seller faces market risk it will be forced to seek out locations where its output is maximized and of most value to the marketplace.[19]

At the same time, it is critical to emphasize that reliance on a competitive solicitation process is important to ensure that renewable resource PSA pricing is minimized and to allow for objective comparison of multiple resource offers. The buyer can specify the contractual terms and conditions as part of a request for proposal process and solicit capacity pricing under different assumed allocations of market risk. The key consideration is to minimize the resource owners' likelihood of making negative-priced offers to the market operator. With the PTC phasing out, and renewable resource costs declining rapidly, there is an opportunity to use an alternative PSA structure and minimize adverse wholesale power market pricing impacts. State subsidization programs can specify PSA payment structure and solicitation processes can minimize costs using analytical frameworks similar to what are already being used.

Second, if production based payments are unavoidable, then PSA terms and conditions should be specified that will not create an incentive for sellers to make negative priced offers. For example, in those instances where resource scheduling and offering responsibilities are not assumed by a buyer under a PSA, a contractual condition should be specified calling for a seller not to be compensated when resource interconnection node prices are less than zero. The impact of this PSA condition will ensure at a minimum that resource sell offers will not be set below zero, and create an incentive for renewable resources to select geographic locations where production can be expected to be deliverable to the marketplace. That is, renewable resource owners will face incentives where they factor into their development considerations the recognition that subsidization policies do not seek to drive wholesale electric energy prices below zero.

Third, ISO/RTOs may be able to put in place market rules that prevent subsidized renewable resource owners from making supply offers that adversely impact power market prices. However, the likely success of applying renewable, or zero-emission, resource offering rules is uncertain. Currently the proposed imposition of these types of market rules has been for capacity markets in those regions of the U.S. where ISO/RTOs oversee centralized capacity markets. For example, concerns have been raised in the Northeastern and Mid-Atlantic U.S. regions where market participants have debated the application of capacity market bid mitigation protocols (minimum offer price rules, or MOPRs) for renewable resource offers (FERC, 2014). The intention of the proposed MOPRs is to set an offer-price floor for subsidized renewable resources in annual capacity market auctions. The application of an offer-price floor seeks to address the fact that the majority of these resources benefit from cost reductions due to state and federal subsidization programs. Resource owners receiving these subsidies reduce resource capacity auction offer prices to account for the cost reduction. In addition, it may also be the case that a stated objective of a particular subsidization program is to push down capacity market auction prices, which may be an exercise of buyer market power and of significant concern to the FERC.

Thus far, FERC has adopted the position that relatively small amounts of renewable resources, supported in part by state regulatory policies, should be exempted from the application of MOPRs. In the case of New England, the FERC found that a renewable exemption that was "narrowly tailored" would allow renewable resources with "limited or no incentive and ability to exercise market power to artificially suppress ICAP [installed capacity] market prices (FERC, 2015a)[20]; FERC has also exempted renewable resources in the Mid- Atlantic's PJM Interconnection geographic region from the application of a MOPR, reasoning that these exempted resources are not expected to be brought to market with the intention of exercising buyer market power (FERC, 2013a). Finally, in New York, FERC recently directed the NYISO to propose a renewable resource MOPR exemption in association with an ongoing regulatory proceeding (FERC, 2015b). In response, the NYISO proposed a limitation of 1000 MW of installed renewable resource capacity in a given Class Year.[21]

The suggested imposition of rules to limit the impact of renewable resources on wholesale power markets has not yet been extended to wholesale electric energy markets. Instead, to the contrary, wholesale electric energy markets seek to accommodate negative priced offers as they have allowed for the marketplace to work more efficiently by providing sellers more accurate price signals when there is excess generation supply. For example, FERC approved the California Independent System Operator Corporation's proposal to lower its bid floor in the energy markets from negative $30/MWh to negative $150/MWh, to permit variable energy resources to bid at more negative prices because they "generally receive, in addition to market revenues, production tax credits, renewable energy credits, and contractual energy payments" (FERC, 2013b). To the extent that the negative-priced offers are being driven by production-based subsidies, the marketplace is adapting to the distortionary impact of the subsidization policy. Such adaptation is clearly contrary to the objective of correcting for the impact of a negative externality.

Finally, an alternative or complementary action that can be taken to reduce the distortionary impact of production-based subsidization is the adoption of state policies that seek to offset the impact of lower power prices through programs that concomitantly reduce consumer power demand. An example of such a policy would be one that focuses on reducing consumer demand, all else equal, to offset the otherwise increased demand that results from wholesale power prices being pushed downward due to subsidization policies. The practical application of this type of consumer-focused policy can be difficult given the complexity of trying to match consumer demand reduction to those time

[17] CAISO, Business Practice Manual for Market Operations, Version 51, Revised: February 02, 2017, at 6.6.5 Adjustment of Non- Priced Quantities in IFM.

[18] Regardless of how a contract pricing mechanism is structured, resources eligible for the federal PTC will be incentivized to make negatively priced offers.

[19] It is well understood that renewable resources' displacement of fossil fuel resource production varies substantially depending upon where the resources are located (Siler-Evans et al., 2013).

[20] ISO-NE's renewable resource offer-floor exemption only applies to 200 MW per year, for a cumulative total of 600 MW. ISO-NE will then apply an offer review trigger price which may impact a renewable resource offer depending upon the amount of subsidization received.

[21] New York Public Service Commission, et al. v. New York Independent System Operator, Inc., Filing and Request for Commission Action within Sixty Days, Federal Energy Regulatory Commission Docket No EL15-64-000, et al., April 13, 2016 at 10–13.

periods when it is most consistent with eliminating an externality. Moreover, the intermittency of renewable resources does not result in a consistent match with those periods where consumer demand reductions are likely to be realized.

5. Conclusion

The design of subsidy programs should focus on maximizing societal net benefits. Continued reliance on subsidization programs to support the operation of renewable and other zero-emission resources calls for greater attention to the evaluation of societal benefits associated with the subsidization program. Limiting analysis to parochial impacts and ignoring distortionary impacts creates winners and losers while often ignoring the primary objective, which ought to be improving social welfare. Moreover, the impact of resource subsidization on wholesale power markets has become of heightened concern given the growth in RPS. A renewed focus on an evaluation of the societal costs and benefits of zero-emission resource subsidization is long overdue.

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