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The environmental and cost implications of solar energy preferences in Renewable Portfolio Standards

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HIGHLIGHTS

- A unit commitment and economic dispatch model is used to assess Renewable Portfolio Standard expansion.
- The impact of solar carve-outs and multipliers on costs and benefits of Renewable Portfolio Standards are analyzed.
- Solar carve-outs increase costs and have minimal impact on emissions.
- The solar multiplier decreases total renewable energy expansion.
- The multiplier decreases the emissions reduction potential of the Renewable Portfolio Standard.

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ABSTRACT

Many state-level Renewable Portfolio Standards (RPS) include preferences for solar generation, with goals of increasing the generation diversity, reducing solar costs, and encouraging local solar industries. Depending on their policy design, these preferences can impact the RPS program costs and emissions reduction. This study evaluates the impact of these policies on costs and emissions, coupling an economic dispatch model with optimized renewable site selection. Three policy designs of an increased RPS in Michigan are investigated: (1) 20% Solar Carve-Out, (2) 5% Distributed Generation Solar Carve-Out, and (3) 3 × Solar Multiplier. The 20% Solar Carve-Out scenario was found to increase RPS costs 28%, while the 5% Distributed Generation Solar Carve-Out increased costs by 34%. Both of these solar preferences had minimal impact on total emissions. The 3 × Solar Multiplier decreases total RPS program costs by 39%, but adds less than half of the total renewable generation of the other cases, significantly increasing emissions of CO_2, NO_x, and SO_2 relative to an RPS without the solar credit multiplier. Sensitivity analysis of the installed cost of solar and the natural gas price finds small changes in the results of the Carve-Out cases, with a larger impact on the 3 × Solar Multiplier.

1. Introduction

1.1. Motivation

Renewable Portfolio Standards (RPS) are a common policy tool used by states to encourage the development of renewable energy generation. While each state's RPS varies in design and scope, most require that electric utilities meet a percentage of their demand with eligible renewable energy by a target year, with interim goals along the way. As of May 2014, 29 states have some form of a binding RPS in place (Heeter et al., 2014).

A variety of motivations exist for implementing a RPS. Many see it as a tool to reduce emissions from the power sector, which, in 2012, accounted for about 38% of the CO_2 emissions (U.S. Environmental Protection Agency 2014a), 70% of SO_2, and 13% NO_x emissions (U.S. Environmental Protection Agency, 2014b) in the United States. Increasing local energy generation and manufacturing can be another reason for implementing a RPS, although these tend not to be a driving force to implement a RPS as found by Lyon and Yin (2010).

Beyond the target goals for renewable energy generation, there exist variations in RPS program designs. Eligibility requirements for renewable energy technologies can vary, including or excluding generation based vintage, size, and, for biomass generation, the fuel feedstock (Heeter et al., 2014). Many policies incentivize specific technologies, such as the 14 states that offer incentives or

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Nomenclature

β	above market cost ($)
$C_{PPA,i}$	installed cost, fixed O&M, taxes, and fuel costs for project i ($/MWh)
$C_{e,i}$	estimated average energy market revenue for project i ($/MWh)
$C_{cap,i}$	capacity value for project i ($/MWh)
C_{NE}	value of firm capacity ($/kW-yr)
$Cap_{max,i}$	max installed capacity for project i
CF_i	capacity factor of project i (%)
E_t	market energy price at time t ($/MWh)
φ	incremental renewable generation required by RPS (MWh)
γ_i	percentage of installed capacity that receives capacity credit for project i
P_i	annual generation from project i, (MWh)
$P_{i,t}$	generation at time t for project i (MWh)
P_{ns}	set of non-solar projects
P_{Us}	set of utility scale solar projects
P_{DGs}	set of distributed scale solar projects
ω_{Us+DGs}	percentage of incremental renewable generation that must come from solar projects (%)
ω_{DGs}	percentage of incremental renewable generation that must come from DG solar projects (%)

mandate contributions from solar within their RPS (NC Clean Energy Technology Center, 2014).

For policy makers, the benefits of solar development include encouraging resource diversification among the renewables built to comply with the RPS and the potential to develop a local solar industry (Gaul and Carley, 2012). Even though the installed cost of solar has decreased dramatically over the last decade, it is often not the lowest cost renewable option, accounting for little of the generation used to comply with RPS in the U.S. (Wiser et al., 2011). In an ideal market, RPS mandates are met with the least cost technology; any policy variation incentivizing a more costly technology, such as solar, are methods for the RPS to indirectly subsidize the costly technology (Buckman, 2011). Solar incentives within an RPS fall into two main categories: carve-outs and multipliers. A solar carve-out requires a certain percentage of the overall RPS be met with solar generation. New Mexico, for example, mandates 20% of the renewable generation required by the RPS come from solar generation (Heeter et al., 2014). A solar multiplier gives additional credit toward RPS compliance for every unit of energy generated from solar. Michigan has a 3 × multiplier for solar, allowing every megawatt-hour of solar to count as three megawatt-hours towards RPS compliance (Quackenbush et al., 2014).

Some RPS policies provide incentives or mandates for distributed generation (DG) or customer-sited systems, with limitations on the size of the generators. While DG incentives are not typically limited to solar, it is expected that solar will be the primary benefactor (Gaul and Carley, 2012). DG incentives take the form of both carve-outs and multipliers: Massachusetts requires 456 GWh of customer-sited solar PV, while Washington gives a 2 × multiplier for DG (Wiser et al., 2011).

Technology-specific multipliers and carve-outs can impact the costs and emissions reduction potential of the RPS. Carve-outs may add binding constraints to compliance if the required technology displaces more cost effective options. On the other hand, credit multipliers may cause renewable generation to be less than the required amount in the RPS, as incentive credits that do not represent actual generation can be used towards compliance.

1.2. Objectives

This study presents an approach to quantifying the impacts of RPS solar policy preferences on the resulting generation mix, emissions, and program costs. A solar energy multiplier, a solar energy carve-out, and a residential distributed generation solar carve-out are all compared to a “pure” RPS without technology incentives or mandates. These policy designs are chosen for analysis because they are historically the most common methods used to incentivize solar development within a RPS. Rebates, feed-in tariffs, and other policies can effectively incentivize solar development, but are outside the scope of this analysis. Renewable energy projects are chosen to minimize the cost of RPS compliance subject to any constraints imposed by the solar preference. A unit commitment and economic dispatch (UCED) model is used to measure the impacts on the power system from the introduction of new, typically variable, renewables.

The economic benefits, including the offset production costs of conventional generation and displaced capacity requirements, can be compared to the costs of building the renewables projects to determine the net cost of the RPS to rate payers within the state/region. The environmental benefits arise from the reduction in the emissions from the combustion of fossil fuels, such as CO_2, NO_x, and SO_2.

Output from variable generation (VG) such as wind and solar can change rapidly in short time scales due to changes in wind speed, cloud cover, or time of day. Conventional generation (e.g., natural gas and coal plants) has been used to balance that variability in real time. Energy storage is considered a promising option for VG integration, but recent studies have suggested insufficient economic benefits for widespread deployment under current conditions (Denholm et al., 2013; Arbabzadeh et al., 2015). In this study, the penetration of renewables and the associated need for load following and ancillary services is most cost effectively met using conventional generation.

This methodology of assessing the environmental and cost impacts of solar preferences in a RPS is tested on future potential designs for Michigan's RPS. Currently Michigan has a 10% by 2015 RPS, which is expected to be met (Quackenbush et al., 2014). The results of this study demonstrate the value and applicability of this method to assess the impact of RPS policy design on costs and emissions. While the quantitative results will vary by region, the methods proposed by this study could be applied to any state.

Several studies have employed economic and power systems models to analyze the impacts of RPS policies. Johnson (2014) uses an analysis of renewable generation price elasticity to calculate the cost of carbon emissions reductions in the U.S. Northeast through RPS policies. Considine and Manderson (2014) develop an econometric forecast to determine the impact of California’s RPS on cost and emissions, in the light of efficiency efforts and varying natural gas prices. National Renewable Energy Laboratory (NREL) and Lawrence Berkeley National Laboratory (LBNL) measured the retrospective costs and benefits of existing RPS policies throughout the U.S. (Heeter et al., 2014).

Other analyses of RPS include robust power systems representations to understand the generator responses to the introduction of renewable generation. Multiple studies (Sullivan et al., 2009; Bird et al., 2011; Palmer et al., 2011) deploy the Regional Energy Deployment System (ReEDS) model, a capacity and