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The costs and value of renewable portfolio standards in meeting decarbonization goals

David Young *, John Bistline

Electric Power Research Institute, 3420 Hillview Ave, Palo Alto, CA 94304, United States

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ABSTRACT

Renewable portfolio standards are common policy instruments deployed in many U.S. states and other countries. Arguably the primary driver for these standards is their use as a tool to reduce carbon dioxide (CO_2) emissions from the electric sector. The cost-effectiveness of this mitigation approach relative to other policies is hotly disputed. In this paper, we use the US-REGEN model to evaluate the costs and CO_2 emissions reductions of existing and potential renewable portfolio standards in the United States, and to compare these mandate-based policies to the least-cost resource portfolio that achieves equivalent CO_2 reductions. We find that, in most cases, renewable portfolio standards are approximately twice as costly as the equivalent least-cost portfolio for achieving CO_2 reductions, although the ratio can be much higher for standards with lower abatement. Furthermore, the effectiveness of renewable portfolio standards at reducing CO_2 emissions depends strongly on future natural gas prices. Technology-neutral instruments to achieve CO_2 reductions usually replace existing coal generation with the cheapest alternative, given natural gas and CO_2 prices. A mandate for renewables is higher cost both because renewable generation may not be the cheapest alternative to coal generation, and because adding renewable capacity often displaces non-coal generation on the margin when there is no CO_2 price.

1. Introduction

A renewable portfolio standard (RPS) is a common policy instrument deployed in many U.S. states and other countries. In the United States alone, renewable portfolio standards exist in 29 states (DSIRE, 2017), requiring renewable deployment from 5 to 100% of load by 2045. Multiple drivers are cited as motivating these standards, including job creation, market creation through ensuring a known demand for renewable generating technologies, energy security, and renewable cost reductions through learning by doing and increased efficiencies of supply at scale. But arguably the primary driver for renewable portfolio standards, especially for recent, higher standards such as those in California and New York (both 50% by 2030), or Hawaii (100% by 2045), is their use as a tool to reduce carbon dioxide (CO_2) emissions from the electric sector, by substituting existing fossil generation with zero-CO_2 emitting renewable generation.

The cost-effectiveness of using renewable portfolio standards relative to other policies to reduce CO_2 emissions is hotly disputed (Fischer and Newell, 2008). A large-scale, cross-model study of technology-neutral CO_2 caps in the U.S. electric sector found that the least-cost generation mix included a variety of technologies, including nuclear and carbon-capture-equipped technologies, as well as renewable technologies (Clarke et al., 2014; Fawcett et al., 2014). A more recent strand of the literature aims to show that high renewable penetration levels are technically possible, but these studies typically make investment assumptions before the fact without considering whether it would be economic to actually deploy such levels (e.g., Jacobson et al., 2015). Economists generally agree that command-and-control regulations (e.g., technology-specific mandates or performance standards) entail efficiency losses relative to their market-based, technology-neutral counterparts (Schmalensee, 2012). However, given political economy headwinds to first-best policies for achieving environmental objectives and other perceived market failures (e.g., innovation-related externalities), it is important to quantify potential trade-offs associated with second-best policies and to understand how uncertainties about technologies, markets, and policy provisions can alter their attractiveness. Some studies provide retrospective or prospective analysis of benefits and costs of renewable mandates (e.g., Millstein et al., 2017; Mai et al., 2016), but few studies comprehensively compare prospective impacts of renewable portfolio standards against other policy instruments.

In this paper, we use the U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) energy-economic model to directly analyse

* Corresponding author.
E-mail addresses: dyoung@epri.com, (D. Young), jbistline@epri.com. (J. Bistline).

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the cost-effectiveness of renewable portfolio standards for meeting a carbon target in the U.S. electric sector. We consider two contexts: one where the renewable portfolio standard is the only policy restricting CO_2 emissions, and one where a renewable portfolio standard is considered as a precursor to a future carbon constraint. The latter is motivated by the use of renewable portfolio standards by states as a form of 'early action' on climate change, as a precursor to a future U.S. wide carbon policy which, it is assumed, will occur later in the time horizon. There are many pathways by which a renewable portfolio standard can help meet future carbon targets, including building political coalitions (Peterson and Rose, 2006; Meckling et al., 2015), advancing technological progress (Bertram et al., 2015), improving economies of scale for low-emitting technologies, lowering the future costs of renewables by advancing technological development, or simply avoiding future sunk costs of retiring fossil-fired capacity by favouring low-emitting generation capacity today. Such pathways cannot be assessed in the inter-temporal optimization model used in this analysis; however, the mere presence of a future climate policy should improve the cost-effectiveness of deploying a renewable portfolio standard today, and we assess this value. Finally, while our focus in these experiments is strictly on the cost-effectiveness of a renewable policy standard in meeting a carbon policy goal, we can infer, through the difference in costs between an RPS policy and a least-cost portfolio, the perceived costs and value of the other drivers of renewable portfolio standards.

2. Model

2.1. Overview

We employ the United States Regional Economy, Greenhouse Gas, and Energy (US-REGEN) economic capacity planning model of the electric sector to understand the cost-effectiveness of renewable portfolio standards at reducing CO_2 emissions. US-REGEN is an inter-temporal optimization model of the U.S. economy through 2050 that combines a detailed dispatch and capacity expansion model of the electric sector with a dynamic computable general equilibrium (CGE) model of the rest of the economy. For this analysis, only the electric model is employed, and it is spatially disaggregated into the 48 contiguous states to accurately capture the differing renewable portfolio standards by state.[1] US-REGEN was developed and is maintained by the Electric Power Research Institute (EPRI).

The electric sector model is formulated as a large-scale optimization model with a bottom-up representation of power generation capacity and dispatch across a range of intra-annual load segments. In each time step, the model makes decisions about existing capacity (carry forward, retrofit, or retire) and investments in new capacity both for generation and inter-region transmission, as well as dispatch decisions for installed capacity. A discount rate of 5% is applied but varied in a sensitivity analysis. Individual existing generators in each region are aggregated into larger capacity blocks based on similar operating characteristics. The block is dispatched as a single unit, but the age profile of the underlying individual units is preserved.[2]

Several unique features of the electric sector make the explicit treatment of capacity versus dispatch essential to accurately model decision-making and the impact of new policies. First, the 'shape' or hourly profile of end-use demand and variable resource availability is crucial for appropriately characterizing the operational patterns and profitability (i.e., market value) of different types of capacity. Second, these patterns and hence the value of generating assets are also dependent on the mix of installed capacity in a region (and in neighboring regions). Third, capital investments in generating capacity tend to be long-lived, creating a strong link between dispatch and investment decisions across time periods.

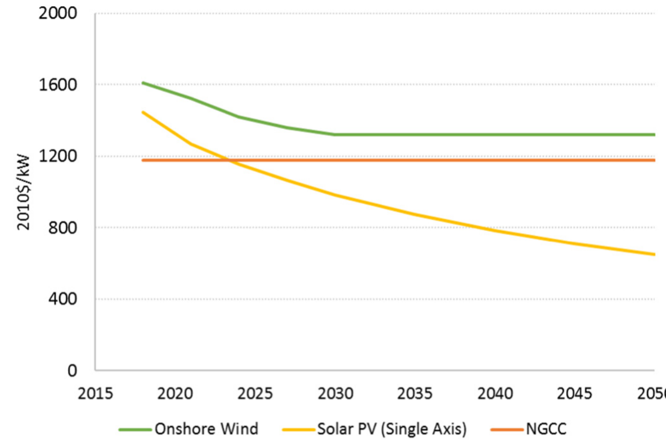

Fig. 1. U.S. average investment cost curves for selected technologies over time in the US-REGEN model.

US-REGEN was built with a detailed representation of wind and solar technologies, with particular emphasis on capturing the intra-annual profile of intermittent generation while retaining the long time horizon needed to evaluate capacity investment decisions (Blanford et al., forthcoming). Wind speed and solar flux data is sourced from NASA's MERRA2 dataset,[3] down to a resolution of a half degree. This resource data is combined with several technology options, notably wind turbines at either 80 m or 100 m hub heights, and solar photovoltaic farms with either fixed tilt, single-axis tracking, or double-axis tracking. In total, US-REGEN can choose between eight on-shore wind classes and fifteen solar PV technology classes for each U.S. state, where a class represents a combination of resource quality and deployed technology. US-REGEN also includes one off-shore wind class and two concentrated solar classes per state, where the resource exists. US-REGEN also represents existing fossil-fired, nuclear, hydro, and geothermal technologies, plus several options for converting or retrofitting existing coal units.

One strength of the US-REGEN model is the selection process for the segments used to approximate the 8760 h for a given year. EPRI has developed an algorithm that, for known wind, solar, and load profiles by state, selects 'representative hours' that aim to capture the co-variation between the three time-series profiles in all states. In particular, the algorithm looks to capture the extremes points, e.g. when load is high, but wind and solar generation are low. After the representative hours are chosen, within a specified tolerance, the hours are weighted to minimize the variation from the true load, wind, and solar profiles by state. The result is 114 segments that approximate that effectively capture the co-variation between load, wind, and solar in all states, while maintaining computational tractability. A detailed analysis and description of this algorithm can be found in Blanford et al. (forthcoming).

Finally, US-REGEN maintains a detailed inventory of the existing fleet, informed by ABB's Energy Velocity dataset. The assumed cost

[1] Note that the scope of modeling precludes net emissions changes (i.e., leakage) and economic impacts in other sectors of the economy. It is prima facie unclear how such omissions may impact model outcomes (Bistline and Rose, 2018).

[2] This formulation implies that, when a unit retires, a block's capacity will fall based on the retiring unit's capacity relative to the aggregate block capacity. This age profile carries over if the units are retrofitted or converted. This formulation keeps the model concise, while retaining the diversity of unit lifetimes in the analysis.

[3] https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/.

[4] Database of State Incentives for Renewables & Efficiency, available online at http://www.dsireusa.org/.

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