Investing in Renewable Energy: Reconciling Regional Policy With Renewable Energy Growth

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Abstract—*To address the effects of climate change, it is imperative for economies to proactively invest in, and deploy, low carbon energy technologies to meet current energy demands. To this effect, several states in the U.S. have implemented policies to incentivize the growth of renewable energy technologies. One of these policies is the renewable portfolio standards (RPS), which mandates that a certain percentage of the total electricity sales of utilities be sourced from renewable energy sources. This paper examines the effectiveness of these policies in driving the growth of specific renewable technologies across different regional transmission organizations (RTOs). It evaluates the adoption of renewable energy technologies across these RTOs to provide insights on the varying successes of these policies. The paper develops a ranking system for the correlations between the strength of RPS and renewable energy capacity growth across the RTOs. Two central observations emerge. First, despite the presence of positive correlations between RPS and renewable energy capacity additions, the capacity growth of renewable energy is not monotonic in time as technological differences characterize regional attributes. Second, the technology returns on RPS mandates are location-specific.*

Managerial Relevance Statement*. The value proposition of this paper is the information it provides to energy technology managers that are constantly faced with tough decisions on what technologies to invest in and where to invest in such technologies. The benefits to be derived from such investments and their enhancement of societal welfare are useful to policymakers in the crafting of these instruments. Thus, understanding the effectiveness of strategies to enhance renewable energy adoption will help to reinforce our knowledge about what works and where. While several policy pronouncements have catalyzed the growth of renewable energy technologies, the capacity increase of these technologies has not been uniformly distributed. This stems from the disparities in energy technology investments because of the conundrum that technology managers, developers and investors face. This ambivalence of investment outcomes impacts the intent to embrace renewable energy. Of relevance to the practice of engineering management, this paper suggests the following: (i) there is a very strong support for the growth of wind technology across all the regions especially where there is abundance of the resource. For example, the ERCOT region is fertile for wind growth; (ii) solar photovoltaic technology has not seen as much growth as wind despite the provision of alternative markets for solar credits. However, there are strong indications that the policy enacted in regions including CAISO, ISONE and some non-RTO states in the north-west will provide investors and technology developers with more incentives for solar technology investments; (iii) It is counterintuitive, but significant, for technology developers and managers to know that investing in renewable energy technology is not always a function of the strength of the policies in the*

regions. Specifically, developers will do well to consider non-RTO states, or states without such mandates, for their technology investments; (iv) For investors considering where the policies have been effective, then considerations should be given to regions including PJM, ERCOT, and MISO.

Key words: Renewable energy, policy, renewable portfolio standards, investment, technology management, utility, regional transmission organizations, capacity

I INTRODUCTION

IT is well-documented that the social price of carbon emissions from fossil fuel combustion for energy production and other anthropogenic activities is considerable. This price results from environmental degradation that has direct implications on public health and the resultant effects of climate change. Incidences such as the rising frequency of floods, increasing loss of biodiversity, and the overall extreme variability in weather patterns have escalated. Unfortunately, carbon prices do not include the real costs. The ratification of the Paris Climate Agreement at the 21st Conference of parties [1] in 2015 further highlighted the urgency to address this problem. One of the most powerful tools to achieve this large-scale emission reduction is putting an appropriate mechanism in place to adequately price carbon. Another alternative is to enhance the development of renewable energy technologies in environments where there is limited political wherewithal to directly price carbon.

In this paper, we: (i) evaluate the effectiveness of a prominent policy, the renewable portfolio standards (RPS), at enhancing the growth of renewable energy technologies in the U.S.; and (ii) reconcile the performance of the RPS at promoting the growth of renewable energy across different regional transmission organizations (RTOs) or independent system operators (ISOs)—see the Appendix for a listing and definition of all the acronyms. RPS policies state that a minimum amount of the total energy generated by utilities should come from renewable sources (such as solar, wind, biomass and geothermal).

In the absence of any federal government backed policy in this regard, RPS mandates have been implemented by twenty-nine states, Washington D.C and three U.S territories [2]. While electricity generators and RPS policies designed to drive the growth of renewable energy are located within geographical state lines, the electrical grid system spans multiple states. RTOs are therefore tasked with managing and coordinating the multi-state electric grid system. A total of seven RTOs exist in the U.S and are responsible for managing about two-thirds of the country's annual electricity demand [3].

The RPS is one of many policies including cap-and-trade, carbon taxes and emission trading schemes that have been proposed and debated over the past three decades. While these policies are primarily aimed at carbon mitigation and renewable energy development, the RPS appears to have an increasing profile across the U.S., and also seems to stimulate both energy and non-energy firms' approach at investing in renewable energy capacity. In fact, for many non-energy firms, their environmental stewardship due to their embrace of renewable energy has improved giving them more leverage on their claims for corporate social responsibility.

This paper is motivated by the mixed outcomes on the relative strengths and successes of the RPS policies on renewable energy technology adoption. In 2017, renewable energy technologies accounted for 17% of the total electricity generated in the U.S, while nuclear and fossil fuel technologies accounted for 20% and 63%, respectively. Amongst the renewable sources, the highest proportion of the total electricity generated was by hydroelectric power at 7.5%. Emerging technologies such as wind and solar accounted for 6.3% and 1.3%, respectively [4]. Researchers have identified adoption of renewable energy technology across the U.S because of technology push and demand pull factors created by energy policies [5], [6]. There have been mixed results on the effectiveness of certain policies like RPS in driving the growth of renewable energy across the U.S. [7]–[9]. The impact of transmission investments in facilitating the growth of renewable energy has also been evaluated [10].

Our investigation is based on evaluating the correlations between the strength of RPS policy targets and the growth of specific renewable energy technologies measured by capacity additions across the US. This approach helps to identify the relative metrics of RPS as a policy intervention and demonstrates how this policy tool has led to the growth of renewable energy technologies. In the process, this paper provides an important guidance for decision makers at the firm level to determine what technologies are most suitable for investment or adoption given the prevailing policies in their jurisdictions. This understanding will also be instructive for how the markets for energy generation will be influenced [11].

Understanding the effectiveness of renewable energy adoption strategies will help to reinforce our knowledge about what works and where, and, in the process, reduce some perceived policy uncertainties. Thus, this paper examines the impact of RPS across different RTOs and offers a ranking of the RPS policy across the RTOs. These outcomes illustrate the evolution of energy technology portfolios in response to policies and reconciles the actual changes in the market place with theoretical prescriptions.

II Methodology

This paper employs publicly available generator-level data on operating solar and wind generators across the U.S. The data was obtained from the Energy Information Administration (EIA-860) database from 2006 through 2015. The renewable energy generators are aggregated by RTOs over time. Data on the actual RPS targets and achievements by states over the same time period was obtained from the U.S. renewable portfolio standards database of the Lawrence Berkeley National Laboratory (LBNL). First, a time series evaluation of the growth of solar and wind technologies alongside the strength of RPS policy mandates across each RTO was developed. Second, the correlation between renewable energy capacity growth and the strength of the RPS policy for each RTO was calculated. The percentage RPS target for each participating state was obtained by dividing the nominal RPS requirements in megawatt hours (MWh) by the total retail electricity sales in MWh for that state. The target does not include any multipliers, alternative compliance payments or waivers.

III Discussion

Figure 1 shows the growth of emerging renewable energy technologies, specifically wind and solar, across the RTOs. The growth of these technologies, in terms of capacity additions, are represented with a bar chart superimposed on the regions or states covered by each RTO in the U.S. Above each bar chart is a line graph representing the average RPS target set by the collection of states in the RTO over the period. The map highlights the increase in the capacity of renewable energy generation over the years across each RTO region.

A closer examination reveals that the technologies have grown at different rates across the different regions. For example, solar technology has grown significantly in the CAISO region with a total capacity addition of 7668.2 MW representing 608 additional generators. The PJM region follows closely with an addition of 525 solar generators amounting to a capacity addition of 2150 MW across the region. The least capacity

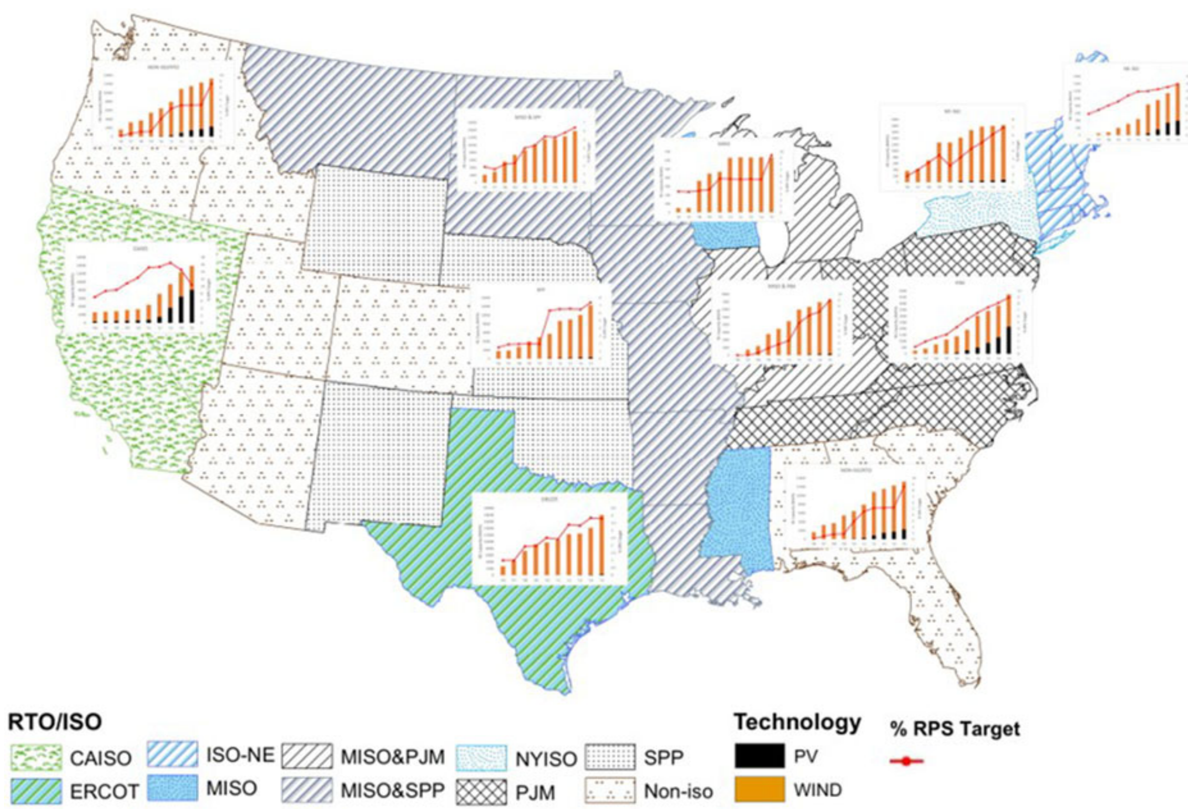

Figure 1. Renewable energy technology and RPS target growth across RTOs.

growth in solar technology of 28.5 MW was observed in the states covered by MISO and SPP. In terms of wind energy, ERCOT (The Electricity Reliability Council of Texas) had the largest Wind capacity additions of 14,925 MW from 112 additional Wind energy generators. Also, the regions covered by MISO and SPP experienced a capacity increase of 11,683 MW from the addition of 127 Wind generators through the period. The least growth in wind energy technology was seen in the NE-ISO and NY-ISO regions with capacity additions of 987.5 MW and 1381 MW respectively.

The installed capacity analysis illustrates that as of 2015, the CAISO and PJM regions had the highest total solar installed capacity across the RTOs with capacities of 8,027 MW and 2,150 MW respectively. For wind capacities, the regions of ERCOT, MISO and SPP had the largest capacities of 17,662 MW, 13,785 MW, and 11,966 MW, respectively.

The Non-ISO/RTO regions that are responsible for a collective 40% of the U.S. electricity supply [12], had a total of 2268 MW solar installed capacity and 10994 MW of wind installed capacity. Therefore, on the one hand, the data analysis reveals that most of the utilities that invested in many of these new plants have little or no capacity in fossil-based technologies in their energy generation mix. On the other hand, this can be perceived as reinforcing the notion that utilities with a greater investment in fossil technologies have largely not invested significantly in renewable energy.

We also find that utilities with investments spread across different RTOs are more likely to invest in the technologies that have grown more rapidly in specific RTO regions. For instance, as of 2017, Southern Power Company had a total of 2,340 MW installed solar capacity and no wind technology in the CAISO region, while it had a total of 1,470 MW of wind energy with only a 380 MW of solar energy installed capacity in the ERCOT region. Similarly, the PJM region had an installed solar energy capacity of 63 MW with no wind energy capacity. In contrast, SPP had 600 MW wind energy installed capacity compared to 83 MW total solar energy installed capacity. The map in Figure 1 also shows that the average RPS target set by the states in each RTO has increased alongside the number of renewable energy generators. This increase signals a strong correlation between the growth of these technologies and the energy policies set by the states.

Figure 2 shows a ranking of the correlations between the capacity growth of renewable energy and the RPS targets across all the RTO regions. A strong positive correlation persists across the RTOs. The strength of the rankings increases from 1 to 10, with 1 being the lowest rank representing the least correlation and 10 being the highest rank representing the highest correlation. For example, for solar

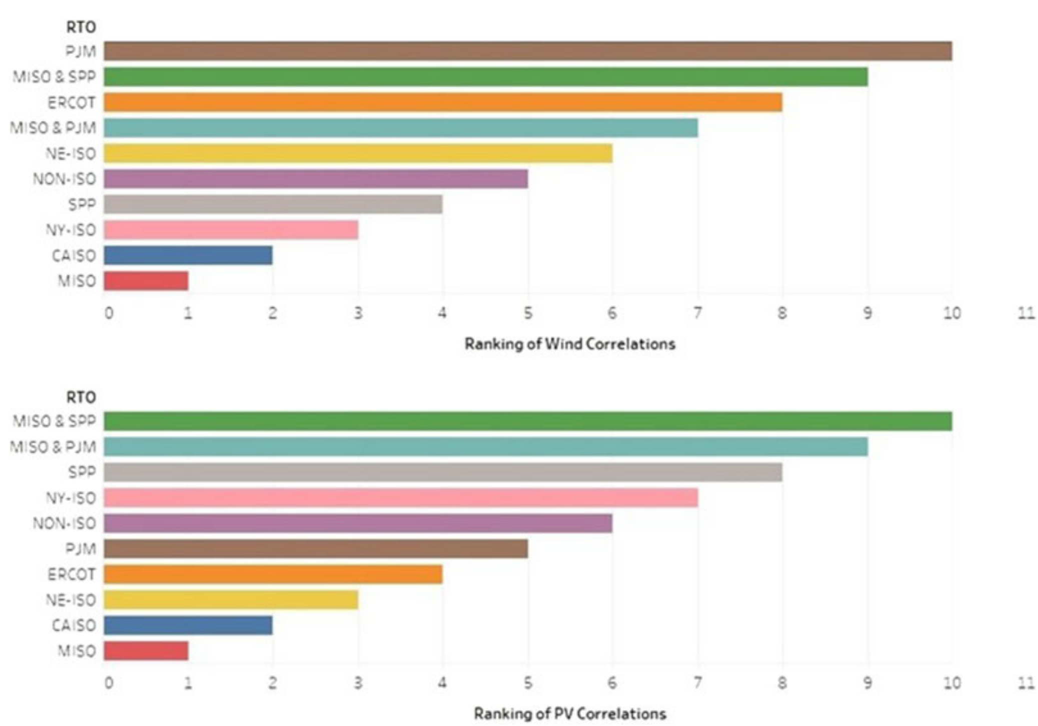

Figure 2. Rankings of correlations between renewable energy growth and RPS policy targets across RTOs.

technology, the highest positive correlations were observed in the regions covered by MISO, SPP, and PJM while for wind energy, the highest correlations occurred in PJM, MISO, and SPP.

Figure 3 shows a box and whisker plot of the RPS policy targets across the different RTOs over the years. This figure indicates the CAISO region having the largest average RPS policy targets over the period. The top regions with the highest RPS target over the years are CAISO, NE-ISO and MISO while the least growth in terms of RPS targets are seen in the regions covered by ERCOT, MISO & PJM and the NON-ISO/RTO states.

In Figure 2, CAISO is ranked second in terms of the strength of the correlations between the growth of these technologies and the actual increases in RPS policy targets across the regions. However, Figure 3 shows that the CAISO region has the highest policy targets in the period considered. Another contrast is seen in the ERCOT region where the actual RPS policy mandate strength is the least, but have recorded modest growth in renewable capacity. In analyzing how the strengthening of the policy mandates have led to actual growth in renewable energy technology, a high correlation rank of 8 for wind energy technology is observed for ERCOT. Conversely, Figure 3 shows that the MISO region with a relatively strong RPS policy mandate appears to have the least rank (1) in terms of correlation between the policy mandate and the actual growth of wind energy technology. In a similar vein, the NE-ISO region with the second highest RPS mandate is ranked third in its correlation between the RPS mandate and the growth of solar technology.

The inconsistency in the policy strength and the ranking of correlations between renewable energy technology growth and policy strength across different RTO regions strongly indicates the absence of a *cause and effect* relationship between the RPS policy targets set across states and the actual increases in the renewable energy technology adoptions across the different RTOs.

Figure 4 highlights a summary of RPS policy strengths and their correlations with capacity growth across all regions. The vertical axis shows increasing correlation between policy strengths and wind energy capacity growth while the horizontal axis shows increasing correlations between policy strengths and PV capacity growth across the RTOs. The strength of the policy mandate across regions is represented by the size of each bubble. While some stronger policy mandates have displayed weaker correlations in comparison to others, as in the cases of CAISO and ERCOT, other weaker policy mandates have shown stronger correlations as in the MISO & SPP region states.

Despite the evidence from the data of a strong positive relationship between the growth of renewable technologies and RPS policies, research suggests that these policies are not necessarily a catalyst to the growth of emerging renewable energy technologies, specifically wind energy and solar technologies. In this respect, RPS policy mandates may not be currently considered as a major causal agent in the growth of renewable energy technology across different regions in the U.S. Other studies have found

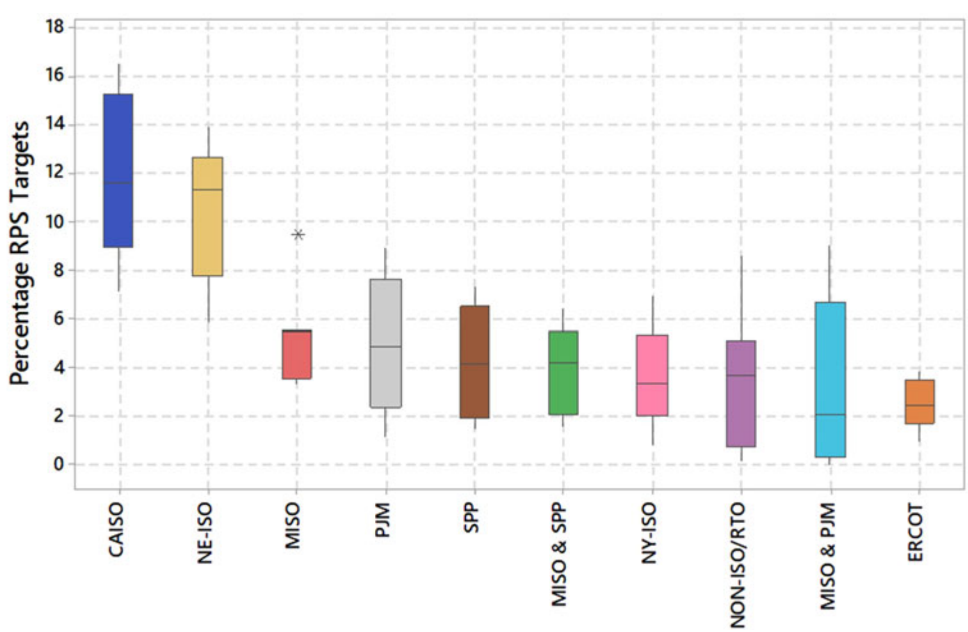

Figure 3. RPS targets across RTOs.

that social and political factors surrounding the contexts in which the policies are deployed such as democratic leadership and type of utility ownership are policy effectiveness determinants [8]. Others have attributed the ineffectiveness in RPS policies to inappropriately laid out policy structures, inadequate control and enforcement mechanisms by states and the inability of the renewable energy deployment to meet up with the rising electricity demand growth across markets [13]. Furthermore, another concern is the reliability of intermittent renewable energy supplies [14].

Another energy policy which could *potentially* weaken the effectiveness of RPS policy mandates in stimulating the growth of renewable energy investment are renewable energy certificates (RECs). RECs are issued when one megawatt of electricity has been generated from an eligible renewable energy source. A majority of states allow electric utilities to purchase RECs in order to fulfill RPS policy mandates. While some states may not allow in state and out of state REC trading to meet RPS mandates, others allow a combination of the two with varying levels of incentives attached. However, to a great extent, this alternative gives utilities an alternative option in meeting the policy mandates without actually investing in renewable energy capacity growth. This option inadvertently hampers the effectiveness of certain state RPS mandates in stimulating renewable energy technology development.

RPS policies tend to vary in structure and design across different states [15]. This variation contributes to variances in their effectiveness in stimulating renewable energy growth across different states. For instance, an ambitious but poorly designed policy mandate could be less effective compared to a moderately ambitious target that is better enforced with more attractive incentives for compliance [16].

In this regard, policy coverage among utilities and how individual policies address existing renewable energy capacity are important dimensions which distinguish RPS policies and determine their comparative effectiveness [13].

IV Conclusion

Several states have introduced RPS targets to encourage the growth and development of renewable energy technologies. The results show that the adoption of these renewable energy technologies like solar and wind energy have indeed grown over the years across different states in the U.S. While the growth of solar energy was more rapid in the states covered by CAISO and PJM RTOs, its growth was less rapid in states covered by MISO and SPP and NY-ISO. Wind energy growth was greatest in regions covered by ERCOT, MISO and SPP; and least in the regions covered by NE-ISO, NY-ISO and PJM. The results also suggest that electric utilities are willing to invest in those particular renewable technologies that seem to have experienced more growth. Though renewable energy resource availability is an obvious factor that has encouraged the development of particular renewable energy technologies in certain regions, it is unlikely that this availability has any considerable impact on the actual growth of these technologies.

Our analysis suggests that these policies have not necessarily been a driving factor in the growth of renewable energy technologies across states. Several factors which seem to make RPS policy mandates less effective have been discussed. These include poorly

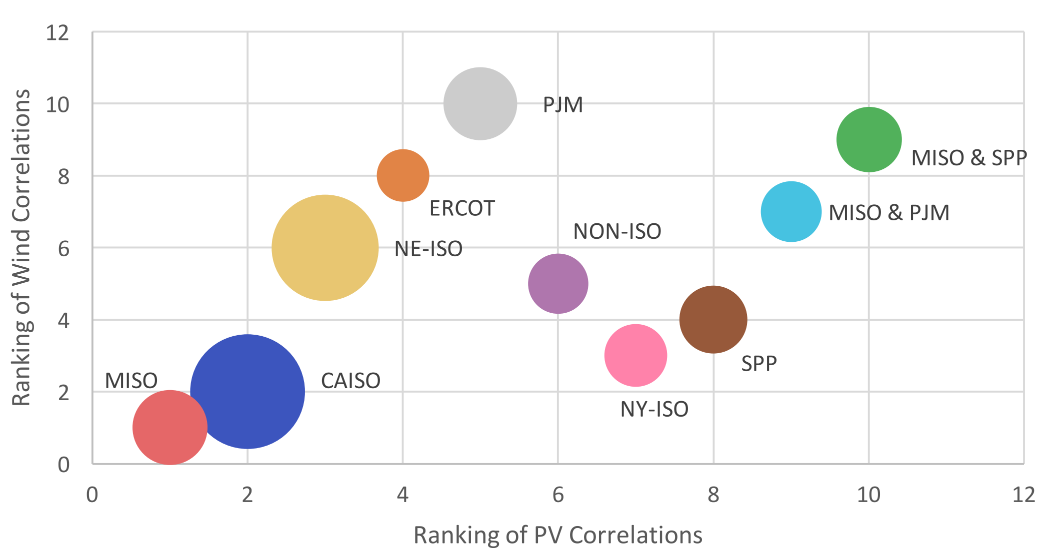

Figure 4. RPS target strength and its correlations with renewable energy capacity growth.

designed policies, variances in the scope, depth, structure and design of the policies, weak enforcement of the policies and the introduction of RECs into the RPS policy design. However, it is expected that the impact of RPS policies would improve as states introduce stricter enforcement policies, integrate stronger structures into the policy design and as competitiveness of emerging renewable energy technologies increases. In addition, these policies can be more effective when combined with carbon pricing policies that discourage electricity generation from conventional fossil sources.

The value proposition of this paper is the information it provides to energy technology managers that are constantly faced with tough decisions on what technologies to invest in and where to invest in such technologies. The benefits to be derived from such investments and their enhancement of societal welfare are useful to policymakers in the crafting of these instruments. Thus, understanding the effectiveness of strategies to enhance renewable energy adoption will help to reinforce our knowledge about what works and where.

TABLE A1. Acronyms and Definitions

ACRONYM	DEFINITION
RTO/ISO	Regional Transmission Organization/Independent System Operator
CAISO	California Independent System Operators
ERCOT	Electricity Reliability Council of Texas
MISO	Midcontinent Independent System Operator
ISO-NE	New England independent System Operator
NY-ISO	New York Independent System Operator
PJM	Pennsylvania-New Jersey-Maryland Interconnection
SPP	Southwest Power Pool
RPS	Renewable Portfolio Standards
REC	Renewable Energy Certificate

TABLE A2. RTO/ISO and States

RTO/ISO	STATES
CAISO	California, Nevada
ERCOT	Texas
MISO	Mississippi, Wisconsin
MISO&PJM	Illinois, Indiana, Kentucky, Michigan
MISO&SPP	Arkansas, Iowa, Louisiana, Minnesota, Missouri, Montana, North Dakota, South Dakota
NE-ISO	Connecticut, Maine, Massachusetts, New Hampshire, Rhode island, Vermont
NON-ISO/RTO	Alabama, Alaska, Arizona, Colorado, Florida, Georgia, Hawaii, Idaho, Oregon, South Carolina, Utah, Washington
NY-ISO	New York
PJM	Delaware, District of Columbia, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia
SPP	Kansas, Nebraska, New Mexico, Oklahoma, Wyoming

APPENDIX

See Tables A1 and A2.

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