HOW RENEWABLE PORTFOLIO STANDARDS ALTER RESIDENTIAL ELECTRICITY PRICES IN THE UNITED STATES

A THESIS

Presented to

The Faculty of the Department of Economics and Business

The Colorado College

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Arts

By

Robert Gardner

December 2019

HOW RENEWABLE PORTFOLIO STANDARDS ALTER RESIDENTIAL ELECTRICITY PRICES IN THE UNITED STATES

Robert Gardner

December 2019

Mathematical Economics

Abstract

Renewable energy policies help drive states in the US toward cleaner energy technologies. Renewable Portfolio Standards (RPS) is one policy which mandates states to produce a certain percentage of their electricity mix from renewable energy sources. This paper looks at how these policies alter residential electricity prices in the United States. This paper hypothesizes that, due to falling costs of renewable energy technologies, residential electricity costs will not increase due to RPS mandates. This main hypothesis is not supported by previous literature, and this paper also concludes that RPS mandates increase residential electricity prices in states which implement them. This paper differs from previous literature by showing a much lower percentage increase in electricity prices due to RPS mandates and thus provides insight into how renewable energy policies affect the people which live in places where the policies are enacted.

KEYWORDS: (energy, renewable energy sources)
JEL CODES: (Q28, Q42)

ON MY HONOR, I HAVE NEITHER GIVEN NOR RECEIVED UNAUTHORIZED AID ON THIS THESIS

Signature

TABLE OF CONTENTS

Section I

INTRODUCTION

Global climate change is one of the most difficult challenges that we face as human-kind. There are many large contributors to our planet's changing climate, but the greatest contributor is Carbon Dioxide emissions created by the burning of fossil fuels to provide energy (EPA, 2019). Renewable Portfolio Standards (RPS) are one of the main policies driving the United States toward cleaner, renewable energy. RPS aim to increase the amount of renewable energy being produced and sold in a state by requiring utilities within their jurisdiction to sell a certain percentage of renewable energy as a share of their total energy mix (DSIRE, 2019). These policies are also meant to lead to long-term decreases in the cost of electricity. While these policies are effective in increasing the amount of renewable energy projects being installed, there are questions as to whether or not they lead to decreases in electricity costs for their consumers. In order to promote renewable energy technologies, they must be cost-competitive not only for utilities, but also for consumers. Lower energy costs would aid wide-spread public support for the transition to cleaner energy.

Renewable Portfolio Standards (RPS) and the Energy Market

Since the mid-1800s, coal energy provided much of the energy in the United States' fuel mix (EIA, 2011). Coal emerged in the 19th Century as a key driver of electricity production. This new, cheap energy helped the United States become a world power throughout the industrial revolution. However, burning coal to produce energy releases Carbon Dioxide into the Earth's atmosphere, which contributes to global climate change. As our electrical needs continue to grow, coal's viability as a long-term option for electricity diminishes. Although coal remains one of the United States' largest contributors to the energy market, it is becoming less cost competitive with renewable energy and natural gas. The U.S. Energy Information Administration (EIA) predicts that by 2050 the percentage of the United States' electricity generation from coal will drop from 28% to 17%. During the same time period, the EIA predicts the percentage of the United States' fuel mix that comes from renewable energy to increase from 18% to 31%, with the majority being solar energy (EIA, 2019). From 2007 to 2016, the capital expenditures (CAPEX) of residential solar energy, which are the expenditures required to achieve commercial operation in a year, decreased from above $9,000 per kilowatt (kW) to below $4,000/kW (NREL, 2018). Solar photovoltaic (PV) modules are 80% cheaper now than they were in 2009 (IRENA, 2018). This huge decrease in installation cost provides greater financial incentives for developers.

While cost is a large driver in the increased installation of renewable energy, different states continue to enact policies to increase reliance on renewable energy and decrease reliance on fossil fuels. Previous literature concluded that the most effective policy which drives renewable energy installations is the Renewable Portfolio Standard (RPS). Like many of the renewable energy policies in the United States, California was the first state to design a detailed RPS in 1995 (Wiser et al., 2007). However, Iowa was the first state to enact a similar concept in 1983 when they required their two investor-owned utilities (IOU) to produce a certain number of megawatts (MW) from renewable energy sources (DSIRE, 2019). California later implemented the first percentage-based policy in 2002, this policy led to design specifications which prompted other states to begin constructing similar policies. According to the Database of State Incentives for Renewables and Efficiency (DSIRE), as of October 2019, 30 states and the District of Columbia subscribe to some kind of RPS policy[1].

Much of the controversy around RPS policies stems from the idea that these policies, due to the expensive transition away from fossil fuel sources, will drive up electricity costs for residential consumers. Many groups researched the relationship between RPS and Electricity Rates, yet the literature finds no solid consensus (Wang, 2014; Maguire and Munasib, 2016). Many proponents of renewable energy production claim that the RPS will lead to long term decreases in electricity cost (Mai et al., 2016; NREL, 2018). On the other hand, claims exist that RPS mandates lead to increases in electricity costs for all of their constituents (Wang, 2014; Tra, 2016).

The Study

In this study, data from the U.S. Energy Information Administration (EIA) is utilized to show trends in residential electricity cost and compare those trends with RPS policy information from DSIRE. The fact that only 30 states and the District of Columbia have RPS allows for the remaining states, who lack the standard, to act as a control group. This study accounts for the resource productivity in each of the states in the study and uses a Fixed Effects regression model to find the correlation between RPS policies and residential electricity rates.

[1] These States Include: Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Vermont, Washington, Wisconsin.

This study is driven by one main hypothesis:

> *Hypothesis 1:* Due to the falling costs of renewable energy installation, the Renewable Portfolio Standard does not lead to increases in residential electricity costs in the United States.

The remainder of this section discusses relevant literature on RPS policies. Section II explains relevant theory and how it influences this study. Section III introduces the relevant data as it applies to the hypothesis. Section IV applies the data and the theory to the hypothesis; this section includes the results of the process. Section V discusses the results, conclusions, implications, and the next steps future studies should take.

Literature Review

A wide consensus does not exist on the relationship between RPS policies and electricity rates for residential consumers. The purpose of the study is to see how increased renewable energy development changes electricity rates. In order for this purpose to be met, a few different aspects of renewable energy policy must be observed. The first is if RPS emerges as the most useful renewable energy policy to look at in the United States. The second, if RPS actually leads to increased renewable energy. Once these questions are answered, the previous literature on the specific question this study seeks to answer are walked through, and why this study differs from previous work shall be discussed.

RPS vs. Feed-in Tariffs (FIT)

When studying how renewable energy generation and different policies effect residential energy consumers, there are a few different policies that previous studies analyzed. The main two policies used currently throughout the world are the Feed-in Tariff (FIT) and the RPS (Yamamoto, 2018). The FIT is a price-based approach, while the RPS is a quantity-based approach (Choi et al., 2018). The FIT offers producers of renewable energy long-term contracts which guarantee the energy they produce is bought (EIA, 2013). This provides investors and producers of energy market stability and financial security (Sawin, 2004). Instead of requiring utilities and consumers to purchase specific sources of energy at a specific price, RPS policies mandate the percentage of renewable energy to be purchased by utilities, regardless of which type of source they come from (Lipp, 2007). This ensures that the most cost-efficient form of renewable energy is purchased, which tends to favor the established technologies and the most mature companies.

Both policies yield substantial results in terms of renewable energy development, however there is no consensus on which policy is most economically efficient. For instance, Dong (2012) conducted a study which looked at the relative effectiveness of FIT and RPS in 53 countries. The study argued that FIT put more renewable energy in the ground, however RPS provided better short-term incentives for developers. A few other studies argued that, in Europe and South Korea, FIT policies were more cost-effective and created more renewable energy (Butler et al., 2008, Sovacool, 2010, Kilinc-Ata, 2016). However, studies which focused on the United States argue that RPS is a more effective policy (de Mello Santana, 2016; Choi et al. 2018). In previous studies on FIT, actors other than investors were left out of the model, which Schmalensee (2012) accounted for, and found that RPS had a better price effect on consumers than FIT. In the United States, both policies are used, however a much larger percentage of states subscribe to RPS, not FIT (Cory et al., 2009).

RPS Leading to Increases in Renewable Energy Installation

In order for this study to be significant, RPS policies must lead to an increase in renewable energy generation in the states which adopt them. If it did not, then there would be no correlation between RPS policy adoption and electricity price change because the fuel mix, which affects the price of electricity most, would not change (EIA, 2019). RPS policies must first be shown to increase the amount of renewable energy power installations in a state, and various studies proved this (Wiser & Langniss, 2003;

Menz and Vachon, 2006; Carley, 2009; Yin and Power, 2010). These studies used different methods to reach their conclusions, some used case-studies (Wiser and Langniss, 2003; Gan et. al, 2007) and others used econometric methods (Menz and Vachon, 2006; Carley, 2009; Yin and Powers, 2010).

The case-study approaches (Wiser and Langniss, 2003; Gan et al., 2007) showed significant increases in renewable energy development due to RPS. In Texas, RPS policies, led to the development of more than double the benchmark that the RPS set in 2001 (Langniss and Wiser, 2003). Their paper argued that a well-designed RPS policy, like the one in Texas, can promote large scale renewable energy development. Other states, which adopted policies after Texas, structured their policies and benchmarks similarly to Texas. The case-study approach works well when looking at individual states, but on a national-scale econometric measurements give broader conclusions about how RPS mandates increase renewable energy development.

More qualitative and econometric measuring studies (Menz and Vachon, 2006; Carley, 2009; Yin and Powers, 2010) yielded similar results. Menz and Vachon, 2006, used an Ordinary Least Squares (OLS) model to study how different state-wide policies affect wind capacity, with RPS being one of the independent variables in their model. The study found that wind power development increases as the number of years the state implements the RPS increases. Carley (2009) expanded on the previous findings by using a state fixed-effects model to look at how RPS affects renewable energy generation. The study found that states which have operational RPS policies have higher rates of total renewable energy installations than states which do not, however they did not find that RPS policies affect the percentage of a state's fuel mix which is renewable energy. Yin and Powers (2010) furthered the previous literature by introducing the cumulative number of years which a state has had RPS policies into their model. They found that RPS policies led to a significant positive impact on the amount of renewable energy generation as the amount of years which the RPS is implemented increases in the United States.

Previous Studies on RPS's Effect on Electricity Prices

Numerous studies analyzed how different renewable energy policies affect electricity costs. Relatively few econometric studies looked specifically at RPS and its effect on electricity costs. These studies concluded, almost unanimously, that RPS cause electricity rates for residential consumers to increase (Wang, 2014; Tra, 2016; Morey and Kirsch, 2013; Kydes, 2007; Upton and Snyder, 2017). However, one study showed the opposite (Maguire and Munasib, 2016).

Early on, studies focused on the possibility of a national RPS and how that would affect electricity prices. One of the first studies of how RPS mandates affect electricity rates came when Kydes (2007) studied the effects of a national 20% RPS. The study used the National Energy Modeling System (NEMA). Kydes concluded that the average electricity cost would increase by 3% from a national 20% RPS. The study predicted that the power generation industry's costs would almost double by 2020 due to the RPS. This provided the earliest idea that RPS would alter electricity rates.

The studies which showed RPS mandates increase electricity costs are numerous. Morey and Kirsch (2013) looked at how the restructuring of energy markets, along with the introduction of RPS policies in some states, affected electricity costs. Their study used a panel dataset from 1990 to 2011. Their model was an ordinary least squares (OLS) regression where retail electricity price was their dependent variable. Their independent variables included if states restructured their energy market, divesture of generation assets, coal and gas prices, and whether or not the state had an RPS mandate. Their findings showed states which restructured their energy markets by giving retail access only had their electricity prices increase if the state also had an RPS mandate. This gave an early example that RPS mandates would increase electricity costs in some circumstances. This discovery was reinforced by different models and authors. Wang (2014) used a difference-in-difference (DD) estimator with panel data from 1990 to 2011. This study was the first to introduce temperature into the model and concluded that temperature can significantly affect electricity prices. The study used three different adaptations of RPS: when the RPS was enacted, when the RPS became binding, and when the RPS became effective. Wang found that the binding year was when RPS began to significantly effect electricity costs. The study showed a positive correlation between RPS's binding year and electricity costs in those states. This idea continued to be analyzed from different perspectives. Tra (2016) looked at different utilities and how their prices were affected by RPS mandates. Tra (2016) used a DD estimator to look at how electric utilities that were mandated by RPS policies differed from utilities which were not. The study used data from 1990 to 2012. The model controlled for state population, population density, and the average price of coal and natural gas. The study found, on average, utilities that were mandated by an RPS charged higher rates than those which were not. The most recent study which evaluated this relationship was Upton and Snyder (2017). Similarly, they used panel data from 1990 to 2012. Unlike previous studies, they looked at four dependent variables: renewable energy generation, average electricity price, carbon dioxide emissions, and electricity demand. Similar to previous studies, they used a DD estimation, but they made new ground when they included each state's solar and wind resource potential. The study found that electricity prices in states with RPS policies have increased by $0.86/kWh on average, a 10.9% increase. These studies all found, through different methods, that RPS mandates increase electricity prices.

On the other hand, only one study showed that RPS mandates did not significantly alter electricity costs. Maguire and Munasib (2016) looked at a smaller sample size and focused their study only on Texas. They used the synthetic control method (SCM), where Texas was the state exposed to the intervention, while similar states without an RPS were used as the group without the intervention. The study found no statistically significant results that showed that Texas's RPS increased electricity costs for residential customers. A limitation of all of these studies was their time period. Since 2012, the final year of data used in each study, there has been a substantial decrease in the cost of renewable energy installation, and not accounting for this trend could lead to large issues when attempting to explain electricity price increases.

Renewable Energy's Recent Cost Competitiveness

In the past, much of the argument against renewable energy based itself in the expensive nature of the technology. However, over the past few years, due to better technology and infrastructure, renewable energy technology costs decreased drastically. These drops made renewable energy more cost-efficient than coal and cost-competitive with natural gas and oil, which are the three largest energy sources in the United States

(EIA, 2019). This trend is expected to continue into 2020, when 75% of new on-shore wind sites and 80% of new utility-scale solar sites will provide cheaper electricity than the cheapest new coal-fired, oil or natural gas option (IRENA, 2018).

Every year, Lazard, the world's largest independent investment bank, releases a report on the levelized cost of energy (LCOE). The report compares different types of energy production and how expensive they are to produce. Their 2018 report showed the cost of utility-scale coal generation to be $102 per megawatt hour (MWh) in 2011. In the same year solar energy sat at $125/MWh and wind energy was $72/MWh (Lazard, 2018). This was the first year that wind energy was cheaper than coal. In 2018, coal prices have stayed at $102/MWh, while solar prices and wind prices have both dropped to $43/MWh and $42/MWh, respectively (Lazard, 2018). Lazard's (2018) LCOE accounts for all subsidies made by the federal government towards both fossil fuels and renewable energy. It is important to note the vast differences in subsidies for both types of energy sources. The federal government, in 2016, spent a total of $6.682 billion on renewable energy subsidies, while they spent only $489 million on non-renewable energy source subsidies (EIA, 2019).

While the price of renewable energies, in the past seven years, decreased to make them cheaper than coal powered energy, natural gas and oil are still cost competitive with solar and wind energy. The costs of renewable energy vary based on their resource productivity. In other words, a good wind resource in a specific area will lower wind costs to around $0.03-$0.04 per kilowatt hour (kWh) (IRENA, 2018). However, in a place with little wind the cost will increase. The same goes for solar energy. So, currently, renewable energy is not cheaper in every state than natural gas and oil, so they are cost competitive (Lazard, 2018). RPS policies, as stated above, cause the utilities in a state to sell a certain percentage of renewable energy to their consumers. This study hypothesizes that this decrease in the cost further up in the supply chain will not translate to higher electricity costs for residential electricity users.

Section II

Theory

RPS policies have an ambiguous effect on electricity prices (Tra, 2016). The idea that the policies cause electricity price increases stems from the consensus that most existing electricity generation capacity comes from non-renewable sources, and so switching to renewable sources would impose extra costs on utilities, causing them to charge higher rates in the short run (Tra, 2016). The cost of electricity for consumers is most dependent on the utility's generation cost (EIA, 2018). Therefore, after utilities switch to renewable sources, their prices should be dependent on the cost of generation of renewable energy. According to Fisher (2010), the price effect of RPS mandates depends on the relative elasticities of renewable energy and non-renewable energy resources. Under RPS mandates, producers of excess renewable energy receive a subsidy payment from the purchases of the energy they produce, while producers of nonrenewable energy have to pay a tax for the renewable energy they buy in order to meet the percentage requirement set by the RPS. Fisher (2010) illustrates that, unless supply curves for nonrenewable and renewable energy are perfectly elastic, the tax puts upward pressure on prices while the subsidy puts downward pressure on prices. Therefore, the main assumption of Fisher's (2010) study is that these elasticities are not perfectly elastic, and thus RPS policies' effect on electricity price is ambiguous.

Different renewable policies effect renewable energy development. The two main policies which drive renewable energy development around the world are FIT and RPS

(Yamamoto, 2018). Due to the larger group of states with RPS policies, and the effectiveness of the policy in the United states, this study looks at RPS's effect on residential utility rates rather than FIT.

Base Model

This study adds to the work from Wang (2014) who used a difference-in-difference (DD) estimator to see how RPS mandates affected residential electricity prices. Wang's (2014) study used the states which never adopted RPS mandates as the untreated group, while the states who adopted the mandate were the treatment group. Wang's (2014) model includes many important variables which effect electricity costs which emerged from previous literature. According to the U.S. Energy Information Administration, extreme temperatures, whether they be hot or cold, increases demand for electricity. This increase in demand causes residential prices to increase. To account for this potential change in price, Wang introduced the average July and January temperatures from each state from 1990-2011 (EIA, 2018; Wang, 2014).

Wang identifies issues such as electricity price shocks which vary across states due to other influences besides policy, and to account for this, state fixed effects are included in the model. To account for national level economic ebbs and flows, for instance the three recessions which occurred during the period from 1990 to 2018, Wang includes yearly fixed effects. Electricity market deregulation is included in the model as market deregulation may have a significant effect on residential electricity prices (Klitgaard & Reddy, 2000; He et al., 2016). Wang also introduces census divisions as a vector of indicator variables.

Wang used the following basic regression model:

$$logP_{st} = \alpha RPS_{st} + \theta Deregulation_{st} + \tau_1 Time_t + \tau_2 Time_t^2 + \tau_3 Time_t * Division_i$$
$$+ \tau_4 Time_t^2 * Division_i + \delta_1 Jantemperature_{st} + \delta_2 Jultemperature_{st}$$
$$+ \varphi Year_t + \eta State_s + \mu_{st}$$

Where P_{st} is the real residential electricity cost in cents per kilowatt hour (kwh) for state *s* in year *t,* as predicted by state-level data of:

- $\boldsymbol{RPS_{st}}$**,** representing the presence of RPS mandates,
- $\boldsymbol{Deregulation_{st}}$**,** representing the presence of deregulation of energy markets where 0 indicates no deregulation in state *s* for year *t* and 1 if deregulation is present,
- $\boldsymbol{Time_t}$, representing the time trend dummy indicator for year *t*,
- $\boldsymbol{Division_i}$**,** representing a vector of indicator variables for the 9 census divisions where *i* ranges from 2 to 9 to avoid collinearity,
- $\boldsymbol{Jantemperature_{st}}$, representing the average January temperature in state *s* during year *t*,
- $\boldsymbol{Jultemperature_{st}}$, representing the average July temperature in state *s* during year *t*,
- $\boldsymbol{Year_t}$**,** representing the year fixed effect in year *t,*
- $\boldsymbol{State_s}$**,** representing the state fixed effect in state *s,*
- $\boldsymbol{\mu_{st}}$, representing the error term for the model.

Empirical Model

This study uses the following basic regression:

$$logP_{st} = \alpha YRPS_{st} + \theta Deregulation_{st} + \delta_1 Jantemperature_s + \delta_2 Jultemperature_s + \rho Sun_s + \omega Wind_s + \varphi Year_t + \eta State_s + \mu_{st}$$

Where P_{st} is the real residential electricity cost in cents per kilowatt hour (kwh) for state *s* in year *t* as predicted by state-level data of:

- $\boldsymbol{YRPS_{st}}$**,** representing the number of years an RPS mandate has been in place in state *s* in year *t*,
- $\boldsymbol{Deregulation_{st}}$**,** representing the presence of deregulation of energy markets where 0 indicates no deregulation in state *s* for year *t* and 1 if deregulation is present,
- $\boldsymbol{Jantemperature_s}$, representing the average January temperature in each state,
- $\boldsymbol{Jultemperature_s}$**,** representing the average July temperature in each state,
- $\boldsymbol{Sun_s}$**,** representing the average number of sunny days in state *s,*
- $\boldsymbol{Wind_s}$**,** representing the average wind speed in state *s,*
- $\boldsymbol{Year_t}$**,** representing the yearly dummy variables*,*
- $\boldsymbol{State_s}$, representing the state dummy variables,
- $\boldsymbol{\mu_{st}}$**,** representing the error term for the model.

Modifications

For this study, two variables are added to better represent the independent variables that could affect real electricity price. The average number of sunny days per year is included by state to measure each state's solar resource. As a state's solar resource increases, the amount of energy produced from the same number of solar panels also increases (NREL, 2018). Therefore, a state with a higher solar resource would have more energy produced for the same cost, making the generation cost for the utility decrease, and electricity price decrease. For this study, the average number of sunny days per year are assumed to accurately represent each state's solar resource. Also included in the study is a proxy for each state's wind power resource. The average wind speed in miles per hour (mph) in the capitol of each state is included. For this study, we assume that the capital of each state accurately represents the entire state's average wind speed. We also assume that average wind speed is an accurate measure of a state's wind resource.

This study leaves out census division dummy variables. Wang (2014) included these dummy variables to measure the geographic differences between states which could account for changes in electricity cost. This study improves on this by using state dummy variables. We assume that state geographic differences are captured by the state dummy variables, and region wide geographic differences are insignificant. Due to unavailable data, the prices of coal, natural gas, oil, and different renewable energy technologies are left out of the study. Similarly, to previous studies, we assume that these costs will be captured in the time and state dummy variables, similarly to previous studies (Wang, 2014; Tra, 2016). These studies argued that the electricity price shocks and changes in generation costs are assumed to be accounted for in the state and year fixed effects variables.

All previous studies included RPS as a dummy variable, assuming that the number of years the RPS is in place does not affect electricity prices. However, Tra

(2016), argues that the main source of increased cost for utilities comes from the electricity generation switch that occurs when utilities change from non-renewable technologies to renewable technologies. This study includes the number of years that RPS mandates were in place, rather than a binary variable for whether an RPS mandate was in place in a given year in a given state. This is based on the assumption outlined by Tra (2016), once utilities make the switch from non-renewable energy technologies to renewable energy technologies their cost to produce will eventually stabilize and potentially decrease.

Previous studies which used the Difference-in-Difference estimator to study RPS relied on the estimator's main assumption: that trends in the control states accurately approximate what would happen in the treatment states in the absence of the treatment over the same time period. These studies left out important state by state variations which affected electricity prices. This study argues that a Fixed Effects regression model, better shows the effect of RPS mandates on electricity rates as it includes important independent variables, like temperature variations, and solar and wind resource, which have effects on residential electricity prices.

This section outlines this study's model, which builds on the model used by Wang (2014). This study modifies the previous study by adding variables to make it better fit the data. The first modification is the inclusion of more up to date data, which will provide a timelier look at electricity price increases. The second modification is the inclusion of the number of years an RPS mandate is effective. The third is the addition of solar and wind resource.

Section III

Data

This section outlines the data used in this study. It outlines the key aspects of the dataset, and any advantages or limitations present in the data used. It will also outline the model used in the study and any advantages or limitations within the model. This study uses data from the U.S. Energy Information Administration (EIA), the National Oceanic and Atmospheric Administration (NOAA), and the Database of State Incentives for Renewables & Efficiency (DSIRE). The model used in this study seeks to better explain residential electricity price changes by using variables which previous models excluded.

Dataset and Exclusions

This study uses panel data from 1990 to 2018 which includes residential electricity price, average state temperatures in July and January, solar and wind resource, and other energy market policies and deregulations. All variables present in the study come from previous literature on electricity price increases and RPS mandates. All data comes from publicly available data sources.

To be included in this study, each state must have similar transmission infrastructure opportunities as all other states, there must be power lines attached to the same grid as other states. Also, in order to test the effect of RPS mandates, the mandate must begin during the time period from 1990 to 2018. In response to these parameters, and similarly to Wang (2014), three states are excluded. Due to their location and their different independent interconnection grids, Alaska and Hawaii are left out of the study.

Iowa is also left out of the study as their RPS mandate was established in 1983, excluding it from the scope of this study due to the unavailable earlier data. Unlike Wang (2014), this study includes the District of Columbia, as it meets all of the parameters of the study, and data is readily available. Therefore, there are 47 states and Washington D.C. included. With 29 years of data, and 48 different states, total observations in this study equals 1392.

Dependent Variable

The dependent variable in this study is the real residential electricity price with 2015 as the base year. Residential electricity prices for each state come from the U.S. Energy Information Administration's (EIA) electricity data browser, with 2018 being the most recent year that data was published. This price is measured in cents per kilowatt hour (kwh) of electricity. To account for inflation the prices in the data set are converted from nominal prices to real prices using the U.S. GDP deflator with 2015 as the base year. In the model, the natural log of real price is taken to see the percentage change in price due to changes in the independent variables.

- **real_price:** the real price of residential electricity measured in cents/kwh with 2015 as the base year.

Independent Variables

The key variable under consideration is the RPS mandate. Information on different state's RPS mandates come from the DSIRE database from October of 2019. This database shows when RPS mandates were adopted, and also how severe the mandates were for each state. January and July average state temperatures come from the

National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information data base. Yearly average temperatures in both months are calculated using data from 1990 to 2018. For each state there are 29 observations, which are averaged to find one temperature for each month in each state. The average annual number of sunny days and average wind speed for each state comes from the NOAA National Climactic Data Center. A sunny day is defined as a day when clouds cover less than 30 percent of the sky during daylight hours. Wind speed is measured in miles per hour (mph). Also, energy market deregulation is included in this study. This is a binary variable which looks at whether or not a state's energy market is undergoing deregulation during a specific year.

- **yrps:** the amount of years an RPS policy has been enacted in a specific state, 0 if no policy is enacted.
- **jan_temp:** the average January temperature in 1990 to 2018 in a specific state measured in degrees Fahrenheit (F).
- **july_temp:** the average July temperature in 1990 to 2018 in a specific state measured in degrees Fahrenheit (F).
- **sun:** the average annual amount of days in a specific state's capital where clouds cover less than 30% of the sky during daylight hours.
- **wind:** the average annual wind speed in a specific state's capital measured in miles per hour (mph).
- **dereg:** A binary variable which equals 1 or 0 depending on if energy market deregulation practices were in place during a specific year in a specific state.

Summary Statistics

The summary statistics for the dependent variables and all independent variables which are not binary are displayed in table 1, below:

TABLE 1

SUMMARY STATISTICS

Variable	Definition	Mean	Standard Deviation	Minimum	Maximum
real_price	Residential Real Price of Electricity (cents/kWh)	12.22	3.094	7.06	22.46
yrps	Years of RPS	2.817	5.144	0	28
jan_temp	January Temperature (F)	31.417	10.579	10.4	58.4
july_temp	July Temperature (F)	73.919	5.199	65.5	82.7
sun	Sunny Days	106.458	30.787	58	203
wind	Average Wind Speed (mph)	17.431	2.918	12.91	31.44

Source: Author's calculations.

Advantages and Limitations

The first key advantage when it comes to the data in this study, is the number of observations in the dataset. For instance, Wang (2014), had 987 total observations and only had data up to 2011. This increase in observations by 405 should give a more accurate and up to date assessment of RPS mandates' impact on electricity prices. Another advantage of this study is the use of the number of years that an RPS mandate was in place. Using a binary variable for RPS would not measure the effect which increased years of RPS have on a state. The inclusion of years that RPS mandates were in place measures how states which had time to change to more efficient renewable generating systems could affect their prices. Another key advantage of this study is the inclusion of measures of solar and wind resource. Previous studies did not mention the potential for omitted variable bias, but this study hypothesizes that both solar resource and wind resource will be significant variables which affect electricity price.

A key limitation of this data is that both the number of sunny days and the average wind speed are measured in each state's capital. This is especially a limitation in large states like California, where the climate can change from one side of the state to the other. This could impact the study in significant ways due to different geological differences within states. The only way to improve this would be to collect all of the data from every town and village and city in each state and average them out. NOAA does not have weather stations in every state, and therefore this would be impossible. The state fixed effects should help mitigate this limitation. Another potential limitation with the data used, is that there is no measurement by DSIRE on how severe each state's RPS policies are. The different RPS policies all have different percentage requirements with different years, so the binary RPS variable could not measure how the severity of the policy effects prices. The number of years of a RPS mandate is included in this study to try and account for these differences.

This section outlines the data used in this study and their sources. This study uses data from the U.S. Energy Information Administration (EIA), the National Oceanic and Atmospheric Administration (NOAA), and the Database of State Incentives for Renewables & Efficiency (DSIRE). This study has some key advantages and limitations, but it seeks to better explain RPS mandates and their relation to residential electricity prices by using recent data and important variables which previous studies excluded.

Section IV

Results

This section outlines the results of the Fixed Effects regression analysis of RPS mandates and their effect on residential electricity prices. This section discusses the two models used and their results. Overall, the models give a good picture of different effects of RPS mandates on residential electricity prices. Although the main hypothesis is not supported, the model shows that many components are statistically significant.

This study's main focus is on RPS mandates and their effect on electricity prices. The main hypothesis of this study is that RPS mandates, with recent falls in costs, would not lead to increases in residential electricity prices. The coefficients for RPS mandates, as dummy variables and as number of years, are expected to not be statistically significant. This would indicate that RPS mandates do not cause residential electricity prices to increase, and their effect would be negligible.

Second, the coefficient for average January temperature is expected to be statistically significant and negative. The coefficient for average July temperature is expected to be statistically significant and positive. These would indicate that as January temperature increases, electricity prices decrease. This would also indicate that as July temperature increases, electricity prices also increase. This would be consistent with costs of heating and cooling homes in the coldest and warmest months of the year.

No hypothesis is made on how solar resource or wind resource will affect electricity prices. These effects are left out of previous literature and there is no consensus on how increased solar resource or wind resource could affect electricity prices. Typically, increased resource would lead to increased installed capacity of renewable energy, and therefore would also change with cost competition of renewable energy. This study makes no hypothesis on how energy market deregulation affects electricity prices. Previous literature (Taber, 2006; Dormandy et al., 2018) reached no broad consensus, therefore no hypothesis is made.

Two models are outlined in this section, both observing RPS mandates as the key variable. The first model looks at RPS mandates as a binary variable, to see whether or not the establishment of an RPS in itself has an effect on residential electricity prices. The second model substituted the number of years an RPS mandate is in place to see if states which had time to change to renewable energy experienced a change throughout time. Using fixed effects and other key variables, these models shows the role that RPS mandates play in altering residential electricity prices. This study expands on previous literature by using recent data and including variables which previous studies left out. These changes provide a more accurate model of RPS mandates and how they alter electricity prices.

Regression Analysis

Econometric tests of model 1 and model 2 revealed that residuals were distributed normally, and that autocorrelation was not present. A skewness and kurtosis test revealed that the Chi^2 value in model 1 was 4.39, below the threshold level of 7, and therefore normality of error terms is present.[2] The same test was conducted in model 2 and yielded

[2] See Figures 6.1 and 6.2 in Appendix A for Normality Histograms and Plots.

a Chi^2 value of 4.34, which is also below the threshold level of 7. This meets a key assumption of Fixed Effects regression analysis and proves that significance tests are valid for the model. However, a Breusch-Pagan / Cook-Weisburg test, in both models, revealed that heteroskedasticity was present.[3] To correct for this, robust standard errors were included in both models. Multicollinearity was present in only two of the variables: average July and January temperatures.[4] This is expected as a given state's climate will affect both July and January temperatures, and the two should be related.

[3] See Figure 6.3 and 6.4 in Appendix A for Breusch-Pagan / Cook-Weisburg test results.
[4] See Appendix C for full multicollinearity matrix

TABLE 2

RESULTS FOR IMPACT ON RESIDENTIAL ELECTRICITY PRICES

VARIABLE	Model 1	Model 2
yrps		0.0018**
		(2.15)
rps	0.0241***	
	(3.20)	
dereg	-0.0135	-0.0137
	(-1.35)	(-1.31)
sun	0.0009***	0.0013***
	(3.85)	(5.33)
wind	0.0038*	0.0038*
	(1.74)	(1.75)
jan_temp	-0.0086***	-0.0008
	(-14.38)	(-1.18)
july_temp	.02527***	0.0167***
	(11.71)	(7.88)
Constant	0.7164***	1.0112***
	(4.68)	(6.72)
Observations	1,392	1,392
R-Squared	0.9022	0.9019

T-stats in parenthesis
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's calculations

Model 1

The high R-squared value shows that the variables included in Model 1 explain about 90.22% of the variance in residential electricity prices in the United States. All variables, except one, are statistically significant with 90% confidence and four variables are statistically significant with 99% confidence. Although almost all variables are statistically significant, some of the coefficient signs do not align with hypotheses made earlier in the section. These hypotheses found their base in previous literature and common energy market knowledge.

Results matching hypotheses. There are only two variables in Model 1 that are statistically significant and consistently show the change outlined in the hypotheses: January and July average temperature. Average January temperature is negatively correlated with residential electricity price. For every Fahrenheit degree increase in average January temperature, residential electricity prices will decrease by 0.86%. As temperature in the coldest months increases, it causes less energy to heat the home, and utility bills and prices should reflect that change. Average July temperature is positively correlated with residential electricity prices. For every Fahrenheit degree increase in average July temperature, residential electricity prices will increase by 2.5%. As summer temperatures increase, it costs more to cool the home. These coefficients are fairly large, and this model shows that they play a key role in residential electricity price.

Results not matching hypotheses. The main variable which this study looks at is rps. and although the results of the regression show RPS mandates to be significant, the coefficient sign is positive, indicating that RPS mandates are positively correlated with residential electricity prices. This regression shows that, over the time period from 1990 to 2018, states with RPS mandates have residential electricity prices that are approximately 2.4% higher than those states without the mandates. This coefficient is sufficiently large to state that RPS, as a binary variable, has a significant effect on electricity prices. This increase may result due to a potential lag in the shifting of lowering costs to residential customers. Renewable energy technologies are cheaper than ever before, however, this cost may not be translated to customers as it takes many years to get renewable energy projects up and running.

Results for variables with unspecified hypotheses. Two out of the three unspecified variables proved to be statistically significant in Model 1. This model shows that both average sunny days and average wind speed in a state affect electricity price. There is a statistically significant positive correlation at 99% confidence between the number of sunny days in a state and the residential electricity price. However, the coefficient is quite small, this model shows that for each additional sunny day the real price of residential electricity would only increase by 0.09%. Although this percentage seems small, there is still some kind of effect of sunny days on electricity prices. This increase could be due to increased temperature inside the home, causing more electricity to be needed to heat the home in the summer. Although this could have the opposite effect in the winter, this study hypothesizes that the increase in electricity used is net positive. Average wind speed has a statistically significant positive effect on electricity prices at 90% confidence. This lower confidence level illustrates that the relationship between wind speed and electricity prices is not quite as evident as average sunny days. This study hypothesizes that this increase is due to wind damage to transmission lines in the areas. Energy market deregulation is the only variable in Model 1 which does not prove to be statistically significant. This is consistent with previous literature which did not reach a broad consensus on how deregulation affects electricity prices.

Model 2

Model 2 differs from Model 1 only slightly in fit. Model 2 includes the number of years that an RPS policy is in place, along with the other variables from Model 1. Model 2 excludes RPS as a binary variable. This second model explains 90.19% of the variance in residential electricity prices. In the second model, only two variables are statistically significant with 99% confidence: average sunny days and July temperature. Two variables are not statistically significant: average January temperature and deregulation. Average wind speed is statistically significant with 90% confidence. The main variable of interest, years of RPS mandates, is statistically significant with 95% confidence.

Some of the results from Model 2 resemble those from Model 1. The average number of sunny days, in both models, is statistically significant and positively correlated with similar coefficients which outline its relationship with residential electricity prices. The same goes for average wind speed and average July temperature. In both models, energy market deregulation is proved to not be statistically significant to residential electricity prices.

Differences between the two models. One difference between the two models is that average January temperature is no long statistically significant in the second model, which is difficult to explain. This could be due to the collinearity of July temperature and January temperature. The main difference between the two models which jumps out is the lower confidence of the years of RPS mandates versus RPS mandates as a whole. The yrps is only significant with 95% confidence, showing that the relationship is less significant than that of RPS as a whole. The small coefficient on this variable shows that as an RPS policy is in place for one additional year, residential electricity prices would increase by only 0.18%. This change shows that as RPS policies are in place, they may cause electricity prices to increase slightly, but less than previous studies concluded.

Summary

Overall, the two models outlined in this section explain about 90% of the variance in residential electricity prices. The two models differ by one key variable of interest: RPS mandates as a whole, and years that RPS mandates are in place. In the first model, RPS mandates are shown to increase residential electricity rates by approximately 2.4%. However, when looked at on an annual basis, RPS mandates only increase residential electricity prices by 0.18% per year. Taking into consideration the changing technology and cost of renewable energy resources and non-renewable energy resources in the future could change these values. After correcting for several econometric issues, these models provide an accurate snapshot of which variables affect residential electricity prices.

Section V

Conclusions

Humans face one of the greatest challenges ever in global climate change. Different governments and countries work in different ways to combat the crisis, amongst those is the attempt to grow clean energy resources to cut down on harmful fossil fuel emissions. In the United States, the main policy driver of renewable energy development is the RPS. These mandates are a way for states to require their utilities to produce a specific amount of energy that does not come from fossil fuels. A comprehensive look at how the RPS mandate affects constituents where it is mandated is crucial to establishing whether or not these policies could be supported everywhere.

While previous studies looked at the relationship between RPS mandates and electricity prices, none used recent data, and none included some important variables which could alter electricity prices. This paper fills this gap in the literature by using data from 1990 to 2018, and by adding solar and wind resource potential, which proved to significantly affect electricity prices. The central hypothesis of this study is built off of the recent cost-competitive nature of renewable energy technologies and argues that this cost drop would not translate to higher electricity prices. This went against much of the previous literature which argued that RPS mandates increase electricity prices.

This study used publicly available data from various governmental agencies, including the U.S. Energy Information Administration (EIA), the National Oceanic and Atmospheric Administration (NOAA), and the Database of State Incentives for Renewables & Efficiency (DSIRE). This information was used to construct a dataset which included 47 states and the District of Columbia, along with six key variables which affect residential electricity prices.

This study constructed a model based off a similar model by Wang (2014) to see how RPS mandates and other significant variables affect residential electricity rates. Wang's (2014) model lacked key variables along with recent data, and thus, this study improved upon the earlier work in order to paint an up-to-date picture of RPS mandates and their effect on electricity prices. This study improves on previous literature also by establishing significant correlations between residential electricity prices and solar and wind resource. This study provides a comprehensive look at what alters residential electricity rates by explaining above 90% of the variation in prices.

The results from this paper provide broad implications for renewable energy policy moving forward, especially for the future of RPS mandates. This study found that states which implemented RPS mandates had increased residential electricity prices, which goes against the hypothesis outlines earlier. The first model used found that RPS mandates, overall, increased residential electricity prices by around 2.4%. The second model found that as the number of years RPS mandates are in place grows, residential electricity prices grow with them at 0.18% annually. This paper does confirm the previously established positive relationship between RPS mandates and electricity costs. However, previous literature which had fewer explanatory variables and years of data, showed that RPS mandates caused a much greater increase in electricity prices (Wang, 2014; Tra 2016; Upton and Snyder, 2017). These papers showed increases of 5%, 7%, and 10.9%, respectively. Thus, this paper shows that the electricity price increase from

RPS mandates is significantly lower than previous studies when recent data and more explanatory variables are included.

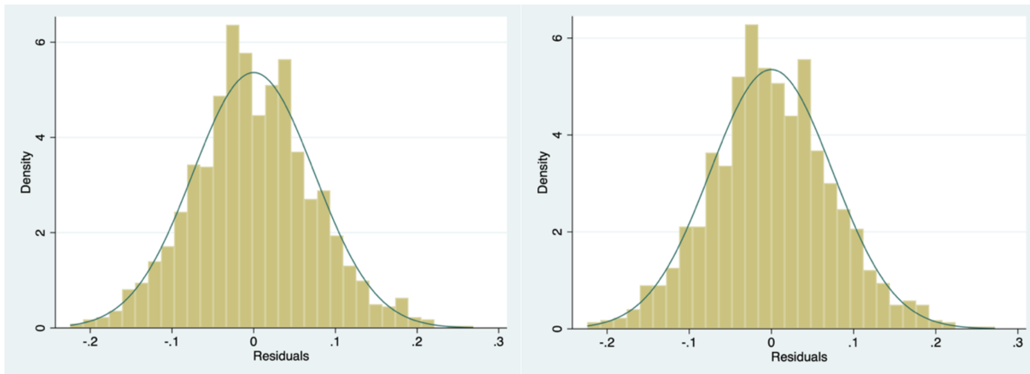
Although this does not support the main hypothesis of this paper, it does illuminate further implications for RPS mandates. If this trend continues, and the increase in residential electricity prices due to RPS mandates continues to decrease, then there may be no negative financial impact on constituents in states where RPS mandates are implemented. This suggests that RPS mandate adoptions, as renewable energy costs decrease, could be implemented in all states with little to no negative fiscal impact on residential electricity users. This could lead to less opposition of renewable energy, and potentially wide-spread support for the shift to clean energy alternatives.

Although these findings are significant and provide a framework for RPS mandates moving forward, there are various areas which could use improvement. One area which future studies should seek to improve upon is in the variation of RPS policies from state to state. This study failed to find a framework where different percentage levels of RPS mandates factored into the model. This was due to the various dates of enactment between states. If, in future studies, the correlation between electricity prices and different required percentage levels of renewable energy technologies could be isolated, policy makers would have a better framework for establishing the best policies. The other main improvement which future studies should seek to include would be the inclusion of the subsidized cost of different energy sources. This study failed to include the values of costs of renewable energy technologies due to lack of data. This inclusion would provide a deeper look into the recent cost-competitiveness of renewable energy technologies and how it is translated to consumers.

Overall, this study provides an up-to-date look at the main renewable energy policy driver in the United States. Although the results from this study are not consistent with the main hypothesis, the results are significant and show how the energy market is changing with increased renewable energy policy. The lower percentage increase in residential electricity prices due to RPS mandates provides concrete evidence for how future renewable energy policies will affect consumers.

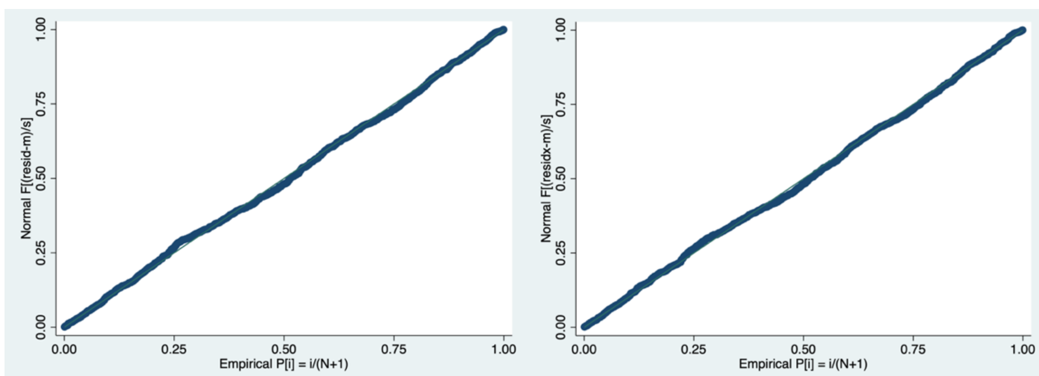
APPDENIX A

Figure 6.1: Normal Distribution plots of Model 1 and Model 2 residuals, respectively.



Source: Author's calculations.

Figure 6.2: Normaility plot of Model 1 and Model 2 residuals, respectively.



Source: Author's calculations.

APPENDIX B

Figure 6.3: Model 1 Breusch-Pagan / Cook-Weisburg test results.

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of lrp

         chi2(1)      =    11.99
         Prob > chi2  =   0.0005
```

Source: Author's calculations.

Figure 6.4: Model 2 Breusch-Pagan / Cook-Weisburg test results.

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of lrp

         chi2(1)      =    11.27
         Prob > chi2  =   0.0008
```

Source: Author's calculations.

APPDENIX C

Figure 6.5: Full multi-collinearity matrix.

	lrp	rps	dereg	sun	wind	jan_temp	jul_temp
lrp	1.0000						
rps	0.3171	1.0000					
dereg	0.4287	0.4876	1.0000				
sun	-0.0617	0.0221	-0.1348	1.0000			
wind	-0.2518	-0.0519	-0.1021	0.3435	1.0000		
jan_temp	-0.1321	-0.1581	-0.0959	0.3625	-0.3451	1.0000	
jul_temp	-0.1022	-0.1889	-0.1565	0.4308	-0.2818	0.8351	1.0000

Source: Author's calculations.

REFERENCES

Butler, L., Neuhoff, K., (2008). Comparison of feed-in tariff, quota and auction mechanisms to support wind power development. Renew. Energy 33, 1854–1867.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071–3081. doi: 10.1016/j.enpol.2009.03.062

Choi, G., Huh, S.-Y., Heo, E., & Lee, C.-Y. (2018). Prices versus quantities: Comparing economic efficiency of feed-in tariff and renewable portfolio standard in promoting renewable electricity generation. Energy Policy, 113, 239–248.

Cory, K., Couture, T., & Kreycik, C. (2009). Feed-in Tariff Policy: Design, Implementation, and RPS Policy Interactions. *National Renewable Energy Laboratory*. doi: 10.2172/951016

Database of State Incentives for Renewables & Efficiency (DSIRE) . (2019). Retrieved from https://programs.dsireusa.org/system/program.

de Mello Santana, P. H. D. M. (2016). Cost-effectiveness as energy policy mechanisms: The paradox of technology-neutral and technology-specific policies in the short and long term. *Renewable and Sustainable Energy Reviews*, *58*, 1216–1222. doi: 10.1016/j.rser.2015.12.300

Dong, C. (2012). Feed-in tariff vs. renewable portfolio standard: An empirical test of their relative effectiveness in promoting wind capacity development. Energy Policy, 42, 476–485. doi: 10.1016/j.enpol.2011.12.014

Dormady, N., Hoyt, M., Roa-Henriquez, A., & Welch, W. (2018). Who Pays for Retail Electric Deregulation?: Evidence of Cross-Subsidization from Complete Bill Data. *SSRN Electronic Journal*. doi: 10.2139/ssrn.3174939

Environmental Protection Agency (EPA), (2019),"Overview of Greenhouse Gases".Retrieved from https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide.

He, Q., Lee, J. M., & Madjd-Sadjadi, Z. (2016). Cost savings and deregulation: an analysis of fuel cost savings in deregulated electricity markets. Applied Economics Letters, 23(16), 1173–1176. doi: 10.1080/13504851.2016.1142646

IRENA (2019), "Renewable Power Generation Costs in 2018", International Renewable Energy Agency, Abu Dhabi.

Kilinc-Ata, N. (2016). The evaluation of renewable energy policies across EU countries and US states: An econometric approach. *Energy for Sustainable Development*, *31*, 83–90. doi: 10.1016/j.esd.2015.12.006

Klitgaard, T., & Reddy, R. (2000). Lowering Electricity Prices through Deregulation. Current Issues in Economics and Finance, 6(14).

Kydes, Andy S. (2007) “Impacts of a Renewable Portfolio Generation Standard on US Energy Markets,” Energy Policy, 35, 809-814.

Langniss, O., & Wiser, R. (2003). 03/01873 The renewables portfolio standard in Texas: an early assessment. *Fuel and Energy Abstracts*, *44*(5), 316. doi: 10.1016/s0140-6701(03)91989-8

Lazard (2018), "Lazard's Levelized Cost of Energy Analysis - Version 12.0", Lazard, New York City.

Lipp, J. (2007). Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. Energy Policy 35, 5481–5495.

Maguire, K., & Munasib, A. (2016). Electricity Price Increase in Texas: What is the Role of RPS? *Environmental and Resource Economics*, *69*(2), 293–316. doi: 10.1007/s10640-016-0079-2

Mai, T., Wiser, R., Barbose, G., Bird, L., Heeter, J., Keyser, D., … Millstein, D. (2016). A Prospective Analysis of the Costs, Benefits, and Impacts of U.S. Renewable Portfolio Standards. *Environmental Research Letters*. doi: 10.2172/1337612

Menz, F. C., & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy*, *34*(14), 1786–1796. doi: 10.1016/j.enpol.2004.12.018

Morey, M. J., & Kirsch, L. D. (2013). Retail Rate Impacts of State and Federal Electric Utility Policies. *The Electricity Journal*, *26*(3), 35–49. doi: 10.1016/j.tej.2013.03.001

National Conference of State Legislatures (NCSL), 2019 "State Renewable Portfolio Standards and Goals". Retrieved from http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx. World Watch Institute, Washington, DC.

National Renewable Energy Laboratory (NREL), (2018). "Annual Technologies Baseline". Retrieved from https://atb.nrel.gov/electricity/2018/index.html?t=sr

NOAA National Centers for Environmental information, Climate at a Glance: Statewide Time Series, published October 2019, retrieved on October 16, 2019 from https://www.ncdc.noaa.gov/cag/

Sawin, J. L. (2004). *Mainstreaming renewable energy in the 21st century*. Washington (D.C.): Worldwatch Institute.

Schmalensee, R. (2011). Evaluating Policies to Increase Electricity Generation from Renewable Energy. *Review of Environmental Economics and Policy*, *6*(1), 45–64. doi: 10.1093/reep/rer020

Sovacool, B. K. (2010). A comparative analysis of renewable electricity support mechanisms for Southeast Asia. *Energy*, *35*(4), 1779–1793. doi: 10.1016/j.energy.2009.12.030

Taber, John T. & Chapman, Duane & Mount, Timothy D. (2005). Examining the Effects of Deregulation on Retail Electricity Prices, Working Papers 127082, Cornell University, Department of Applied Economics and Management.

Tra, C. I. (2016). Have Renewable Portfolio Standards Raised Electricity Rates? Evidence From U.s. Electric Utilities. *Contemporary Economic Policy*, *34*(1), 184–189. doi:10.1111/coep.12110

U.S. Energy Information Administration (EIA), (2011), " History of energy consumption in the United States, 1775–2009". Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=10

U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2019). Retrieved from https://www.eia.gov/energyexplained/electricity/prices-and-factors-affecting-prices.php.

Upton, G. B., & Snyder, B. F. (2017). Funding renewable energy: An analysis of renewable portfolio standards. *Energy Economics*, *66*, 205–216. doi: 10.1016/j.eneco.2017.06.003

Wang, H. (2014). Do Mandatory U.S. State Renewable Portfolio Standards Increase Electricity Prices? *Growth and Change*, *47*(2), 157–174. doi:10.1111/grow.12118

Wiser, R., Namovicz, C., Gielecki, M., & Smith, R. (2007). The Experience with Renewable Portfolio Standards in the United States. *The Electricity Journal*, *20*(4), 8–20. doi: 10.1016/j.tej.2007.03.009

Yamamoto, Y. (2018). Feed-in Tariffs in Comparison with the Renewables Portfolio Standard. Feed-in Tariffs and the Economics of Renewable Energy, 11–19. doi: 10.1007/978-3-319-76864-9_2

Yin, H., & Powers, N. (2010). Do state renewable portfolio standards promote in-state renewable generation?. *Energy Policy*, *38*(2), 1140–1149. doi: 10.1016/j.enpol.2009.10.067