THE EFFECTIVENESS OF RENEWABLE ENERGY POLICIES IN THE UNITED STATES: DO INCENTIVES AFFECT CAPACITY DEPLOYMENT, ELECTRICITY PRICES AND LOCAL ECONOMIC DEVELOPMENT?

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by

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Abstract

Renewable energy sources generate roughly one-fifth of the electricity in the United States. From 2019 to 2021, over one-half of new electric capacity will come from wind and solar photovoltaic (PV) technologies. In order to stimulate the growth in renewable energy, the U.S. government has issued hundreds of federal, state, and local renewable energy policies. Within this framework, it is important to analyze the effectiveness of these policies. First, this research outlines the current renewable policy landscape and provides state-by-state policy ranking. Second, the paper conducts an in-depth evaluation of the effectiveness of renewable energy policies on renewable power capacity and their impact on state and local economic activity. Third, the analysis delves deeper to provide insights on the causal link between regional retail electricity prices and renewable capacity before and after the implementation of different renewable energy policies. The paper concludes with the summary of policy implications.

1.0 Introduction

Energy is a fuel that propels the growth of the economy. Electricity is an especially vital part of our daily life and we rely heavily on affordable, reliable and accessible electricity. Three main electricity sources today in the U.S. are natural gas (35.10%), coal (27.4%), and nuclear (19.3%) (Electric Power Monthly, U.S. Energy Information Administration (EIA)). [12]

However, over the next two decades, the U.S. power mix is estimated to shift strongly towards renewable energy sources such as wind and solar (Annual Energy Outlook 2019 (AEO2019), EIA). [8] This change is driven by a shift in public perception towards renewables. The public view is also driving a change in the transportation industry where electric vehicles (EVs) are gaining popularity. This shift towards renewable energy and EVs will require the U.S. to create a new grid infrastructure to adapt to changing consumer demand (Osmani, 2013) [21].

By 2030, the U.S. plans to retire 75 GW (AEO 2019, EIA) [8] of its current coal power capacity which largely will be replaced by renewables. As a market driven economy, the U.S. needs to replace this capacity with a cost-effective option that will yield the highest economic and societal benefit. In order to make renewables viable alternatives to natural gas, nuclear energy or coal, the levelized cost of electricity (LCOE)[1] for renewables has to be cheaper or at least match the pricing of other energy sources. Fortunately, renewable energy sources such as solar photovoltaic and wind are technologies that follow the experience curve[2]. In fact, each time PV production doubles, the cost of manufacturing falls by roughly 20% (Samadi, 2013) [23]. This is the highest learning rate among all energy sources which indicates the high economic potential of PV and other renewable technologies. To initiate the shift towards renewable energy sources,

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[1] Levelized cost of electricity (LCOE) represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. LCOE is often cited as a convenient summary measure of the overall competitiveness of different generating technologies. (*EIA*)

[2] Experience curve typically describes the relationship between a technology's specific costs and the technology's experience. As experience grows, the costs fall.

lawmakers in the U.S. have passed legislation that provides financial incentives and regulatory policies for developers to further decrease the cost of renewable energy source and accelerate the adoption of renewable technologies.

This paper will focus on current renewable incentives in the United States. It will discuss the current policy landscape, offer state rankings based on Renewable Portfolio Standard (RPS)[3], test if RPS leads to a higher number of programs and installed capacity, and analyze the effectiveness of renewable policies from a perceptive of deploying new renewable capacity, enhancing economic growth, lowering energy prices.

2.0 Literature Review

Scholars have extensively researched the effects of renewable incentives on economic activities and renewable capacity deployment in the U.S. but found mixed results. The difference can be caused by a large variety of renewable incentives and different energy source used in analysis. A big part of scholarly articles is focused on RPS, a requirement on retail electric suppliers to provide a minimum percentage or amount of their retail load with eligible sources of renewable energy by a certain date. RPS is typically backed by financial penalties for noncompliance with the regulation and accompanied by Renewable Energy Certificates (RECs) or other forms of tradable credits to facilitate program compliance. Barbose, 2015 [1] calculates the impact of RPS on electricity rates and discusses the larger societal benefits of RPS on emissions, public health, and economic development. The study estimates that in most states, RPS compliance costs an average of two percent of retail rates. However, as RPS targets continue to grow, this puts an upward pressure on compliance costs which can lead to higher electric retail rates in the future.

[3] Renewable Portfolio Standard (RPS) is a requirement on retail electric suppliers to supply a minimum percentage or amount of their retail load with eligible sources of renewable energy (*Lawrence Berkeley National Laboratory*)

In addition to RPS, over three thousand diverse renewable policies exist in the United States today(Database of State Incentives for Renewables & Efficiency (DSIRE), 2018) [7]. These policies vary by geographical region, sector, energy source etc. Sarzynski, 2012 [24] outlines several types of financial renewable incentives and tests the effects of these incentives on PV capacity installation from 1997 to 2009. The research indicates that states offering cash incentives, such as rebates or grants, had a consistently stronger deployment of PV technology. The study also illustrates that RPS and specific solar carve-outs have a material impact on solar capacity deployment. In contrast, incentives such as income tax, sales tax, and property tax exemptions, were insufficient for solar deployment over the studying period of time. Additionally, Sarzynski indicates that solar capacity deployment is affected by electricity prices. Due to larger future electricity cost saving, the states with high electricity prices will provide a better return on investment for solar developers leading to a larger deployment of solar capacity. It is important to note that the methodology used in the research does not take into account scale, scope, and strength of each incentive as it uses dummy variables (1/0) to indicate the establishment of each policy type. This methodology could lead to skewed results.

In fact, later research, Ogunride, 2018 [18], suggests the absence of cause and effect relationship between RPS policy targets and the increases in the PV and wind energy capacity. Instead of investigating the state-level impact, this research looks at the impact of RPS on Regional Transmission Organizations (RTO) which monitor and control the stability of multi-state electric grids. The research implements a floating RPS target which is calculated by dividing the nominal RPS requirements in megawatt hours (MWh) by the total retail electricity sales in MWh for individual states. Ogunride compares the strength of RPS to the growth of solar and wind technologies across each RTO and calculates the correlation between renewable energy capacity growth and the strength of the RPS policy for each RTO. The analysis suggests that RPS does not necessarily drive the growth of renewable energy technologies across states which could be explained by the differences in RPS structures. Additionally, Delmas, 2010 [6] illustrates that effectiveness of renewable policies does not only depends on incentive structure but also depends on the renewable energy source.

3.0 Hypothesis

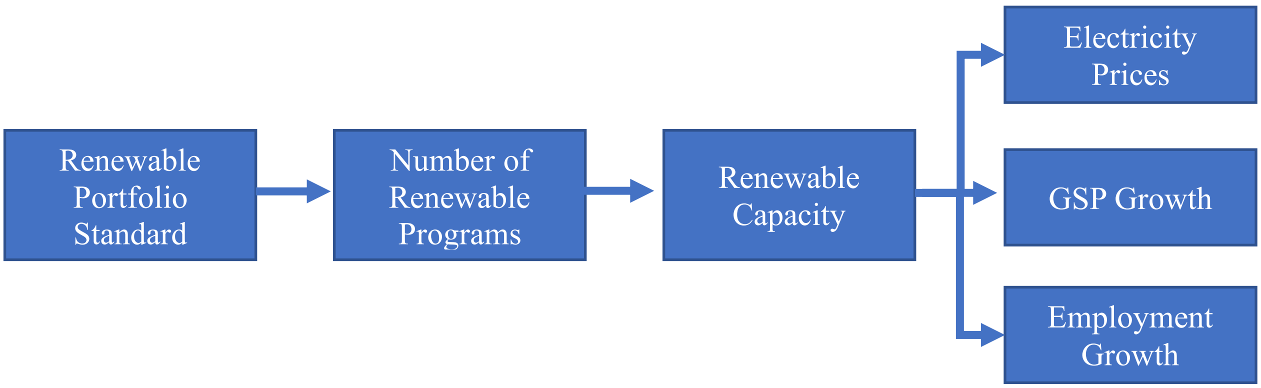

Figure 1 Research Framework. Source: Drew by author.

The renewable policy landscape is changing quickly, and this research provides the outlook on a current policy landscape in the U.S. Instead of observing the correlation between RPS and capacity deployment, this study examines if an establishment of RPS drives issuances of other renewable policies in a state. Next, it measures the relationship between the number of renewable programs and renewable capacity in a state. Lastly, it observes the effects of renewable capacity on electricity prices, growth state product (GSP) and labor growth. The study provides a different approach because it looks at the interconnectivity among a number of parts in the renewable energy value chain (*Fig. 1*).

The hypothesis for the study assumes that the establishment of RPS will cause the issuance of renewable programs. The issuance of renewable incentives will stimulate deployment of renewable capacity. Growth in renewable capacity will stimulate GSP and employment growth and decrease electricity prices in the long term.

4.0 Current Renewable Policy Landscape

4.1 Renewable Portfolio Standard

Renewable Portfolio Standard (RPS) is a major indicator of states' ambition towards renewable energy (Sarzynski, 2012) [24]. RPS policies are designed to increase the amount of renewable energy generation in a state (Bird, 2011) [3]. Today, 29 states plus 3 U.S. territories and the District of Columbia implemented Renewable Portfolio Standards. To put this in perspective, the territory with RPS account for sixty percent of total electricity consumption in the United States. In addition, eight states and one U.S. territory (GU, IN, KS, ND, OK, SC, SD, UT, VA) have Renewable Portfolio Goals (RPG). RPG is a voluntary goal imposed by state regulators and does not bear financial sanctions for non-compliance. The remaining thirteen states (AK, AL, AR, GA, FL, ID, KY, LA, MS, NE, TN, WV, WY) do not have renewable portfolio standards or renewable portfolio goals. To highlight, the absence of RPS or RPG does not prevent a state from deploying renewable capacity. For instance, Florida does not have an RPS or RPG but the state accounts for almost eight percent of the nation's biomass-fueled electricity generation, more than any other state except California (Electric Power Monthly, EIA 2019) [13]. Despite not having a renewable energy portfolio standard, Florida invests in state and local incentives, tax credits, and loan programs for certain renewable energy technologies.

In addition to long-term RPS goals, CA, HI, OR, and MA have mid-term RPS requirements.[4] Three states (CA, HI, and DC) established 100 percent renewable mandates but DC is scheduled to reach its fully renewable target 13 years ahead of the other two states. Due to smaller energy consumptions, HI and DC have significantly smaller RPS obligations [5] in MWh

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[4] CA have a target of 44 percent by 2024; 52 percent by 2027; 60 percent by 2030, and 100 percent clean energy by 2045. HI targets 30 percent renewable by 2020; 40 percent by 2030; 70 percent by 2040; 100 percent by 2045. OR targets 25 percent by 2025; 50 percent by 2040. MA requires 35 percent by 2030 and an additional 1 percent each year afterward.

[5] RPS Obligations (MWh) represent the nominal RPS requirement prior to the application of multipliers, alternative compliance payments, or waivers. (Barbose, Lawrence Berkeley National Laboratory 2018)

than California. Smaller RPS obligations may help these two states to reach a fully renewable goal faster. Even though 100 percent renewable initiatives from HI and DC are important, CA has the highest RPS obligation in MWh and currently holds 14% of nations renewable capacity (California State Energy Profile, EIA 2019) [9]. California's goal towards a fully renewable power mix is much more ambitious than HI and DC goals.

4.2 Renewable Portfolio Standard Ranking

The ultimate RPS target may not be the best representation of state's renewable profile because the final goal does not represent a current state of renewable profile in a state. This research provides current RPS Ranking (*Table 1*) based on the following formula:

$$Score = RPS\%RS_i * RPST_i * \mu\, RPSC_i * \frac{M\ ED_{national}}{ED_i} * \frac{M\ TD_{national}}{TD_i} \quad (1)$$

where subscript *i* refers to a state, $RPS\%RS_i$ is a state's Renewable Portfolio Standard obligation (in MWh) as a percent of total retail sales of electricity (in MWh) within a state. This variable is a better measurement for RPS because it accounts for a size of electricity market and represents a current percentage of state's generation that has to come from qualified renewable sources. $RPST_i$ is an ultimate Renewable Portfolio Standard target that a state has established. $\mu\, RPSC_i$ stands for an average state's compliance with RPS. In other words, it indicates if a state has been regularly achieving its annual RPS obligations. $\frac{M\ ED_{national}}{ED_i}$ is a variable that tracks when a state has established its RPS (ED_i) compare to the national median date (M $ED_{national}$) which is derived as a median of 30 RPS listed in *Table 1.* $\frac{M\ TD_{national}}{TD_i}$ is a similar variable that tracks when a state is targeting to reach its RPS target (TD_i) compare to the national median target date M $TD_{national}$ which is derived as a median of 30 RPS listed in a table. For comparative purposes, *Table 1* also includes the RPS obligation in MWh and a number of renewable incentives available in a state.

Renewable Portfolio Ranking 2017

Rank	State	ED_i Establishment Date	TD_i Target Date	$RPST_i$ RPS Target	$\mu\ RPSC_i$ Average RPS Compliance	$RPS\%RS_i$ RPS Obligation as % of Retail Sales	RPS Obligation (MWh)	# Renewable Incentives	Score
1	VT	2015	2032	75.0%	100.00%	54.92%	2,978,607	60	40.821%
2	CA*	2002	2045	100.0%	96.61%	24.91%	64,093,551	263	23.858%
3	ME	1999	2017	40.0%	99.95%	38.60%	4,328,142	33	15.531%
4	DC	2005	2032	100.0%	99.06%	15.56%	1,698,687	20	15.355%
5	HI*	2001	2045	100.0%	100.00%	14.70%	1,370,330	42	14.575%
6	NJ	1999	2030	50.0%	99.84%	16.34%	11,993,860	52	8.159%
7	CT	1998	2030	44.0%	95.36%	18.42%	5,183,524	90	7.734%
8	MA*	1997	2030	35.0%	83.95%	17.37%	9,119,590	121	5.108%
9	RI	2004	2035	38.5%	97.18%	12.48%	922,000	39	4.648%
10	MN	2007	2025	26.5%	88.37%	19.78%	13,283,747	157	4.626%
11	OR*	2007	2040	50.0%	100.00%	9.25%	4,627,119	156	4.582%
12	CO	2004	2020	30.0%	100.00%	13.41%	7,352,035	133	4.033%
13	MD	2004	2020	25.0%	99.95%	15.19%	9,005,810	82	3.804%
14	NV	1997	2025	25.0%	82.86%	17.06%	6,253,286	39	3.546%
15	NH	2007	2025	25.2%	73.32%	18.46%	1,991,436	49	3.406%
16	PA	2004	2021	18.0%	100.00%	14.05%	20,094,641	75	2.534%
17	NM	2002	2020	20.0%	91.59%	11.27%	2,593,274	57	2.072%
18	MI	2008	2021	15.0%	100.00%	10.14%	10,336,231	103	1.522%
19	DE	2005	2026	25.0%	99.07%	4.96%	551,883	36	1.227%
20	WA	2006	2020	15.0%	98.80%	7.02%	6,456,183	172	1.042%
21	MT	2005	2015	15.0%	99.74%	6.90%	1,015,484	56	1.037%
22	WI	1998	2015	10.0%	96.67%	9.47%	6,538,870	103	0.922%
23	IL	2007	2026	25.0%	36.29%	9.35%	12,832,897	84	0.847%
24	NC	2007	2021	12.5%	100.00%	6.10%	8,017,814	102	0.763%
25	MO	2007	2021	15.0%	100.00%	3.39%	2,589,737	64	0.508%
26	AZ	2006	2025	15.0%	73.61%	3.54%	2,750,421	78	0.391%
27	OH	2008	2026	12.5%	99.88%	3.11%	4,566,053	77	0.388%
28	TX	1999	2025	10,000 MW	99.51%	3.67%	14,737,099	129	0.273%
29	NY	2004	2030	50.0%	46.54%	0.04%	56,028	104	0.009%
30	IA	1983	-	105 MW	100.00%	0.60%	295,800	77	0.003%

Table 1 Renewable Portfolio Ranking 2017. Source: Lawrence Berkeley National Laboratory, DSIRE, Author's Analysis

The study ranks Vermont as the strongest RPS in the U.S. Vermont takes the first place because the state currently requires more than half of its electricity generation to come from qualified renewable sources[6]. Today, Vermont's electricity generation comes almost entirely from renewables, and more than half of it is hydroelectric power. (Vermont State Energy Profile, EIA 2019) [10]. However, the state produces only forty percent of the electricity consumers and depends on power from Canada and neighboring states to meet customer demand. Since,

[6] Qualified renewable sources vary by states. This could lead to inconsistencies in comparison of RPS among different states.

Renewable Portfolio Standard is focused on electricity generation within a state, it does not take into account imported energy and may not adequately represent state's renewable profile.

Interestingly, Texas has the second largest renewable energy generation capacity in the country and during some month, as much as fifty percent of state's electricity generation comes from wind. However, Texas RPS is ranked 28 out of 30 RPS described in a table. It is important to highlight that RPS rank should not be interpreted as state's renewable energy profile. RPS is a regulatory incentive established to stimulate adoption of renewable energy sources and there are other factors that drive adoption of renewables, such as weather condition, power market structure and electricity prices. Due to favorable electricity market structure and weather conditions, renewables are a natural fit for Texas. Texas is a deregulated energy market, meaning that almost anyone in a state could generate energy and sell it to power providers. This free market approach makes it harder for power suppliers to overcharge customers for energy which incentives power suppliers to find the cheapest energy generation options. As wind and solar have some of the lowest LCOE, this open market structure leads to high adaptation of cheap renewable resources.

Next, only six states out of 29 with RPS were trailing their renewable goals as of 2017. *(Figure 2)* Illinois is significantly lagging in its RPS obligation but the state has recently established an *Adjustable Block Program (ABP)* that will bring at least 500 MW photovoltaic capacity to the state and will help IL to meet its RPS obligation. (ABP, IPA) [16]

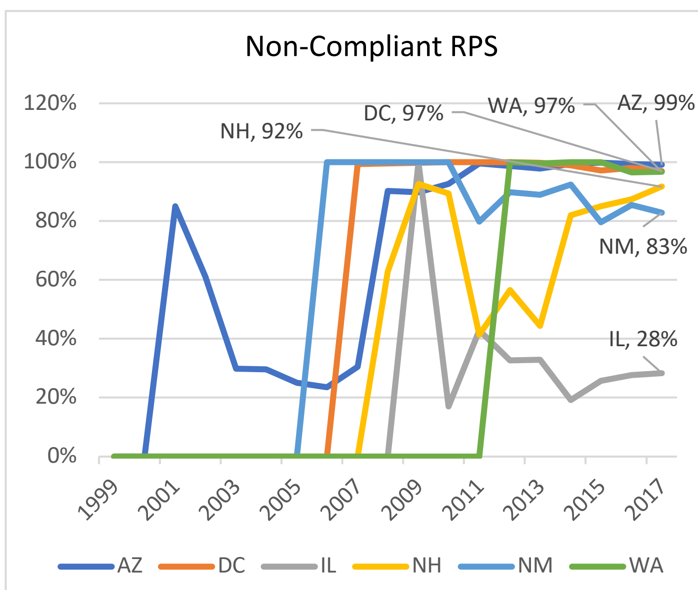

Figure 2 Non-Compliant RPS. Source: Berkeley Lab

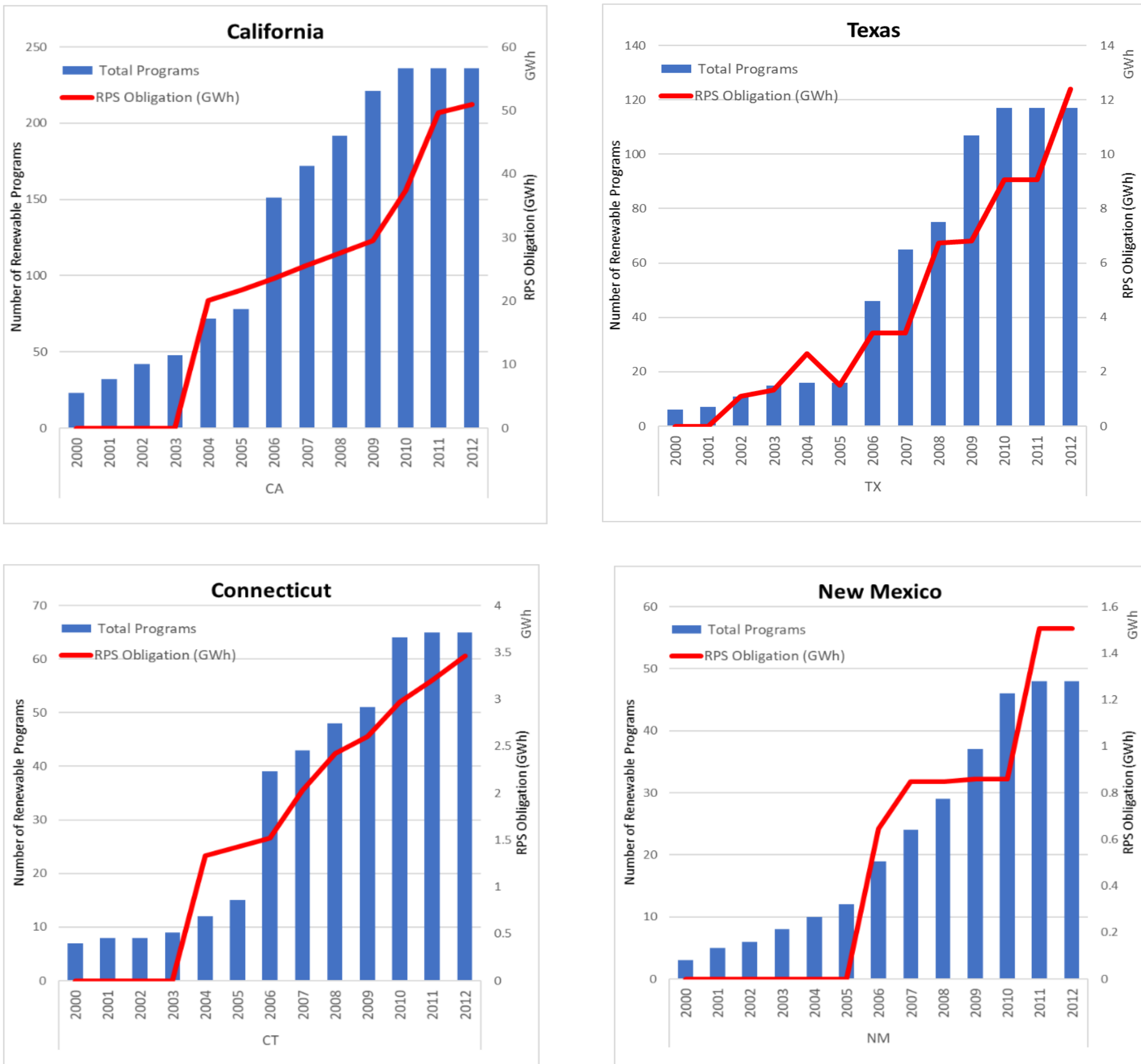

Figure 3 RPS Impact on a Number of Renewable Programs. Source: DSIRE, Lawrence Berkeley National Laboratory, Author's Analysis

In addition to RPS, the ranking includes a count of renewable programs issued in a state.[7] *Table 1* doesn't clearly identify the correlation between the number of renewable incentives issued in a state and RPS rank. *Figure 3* provides state-level examples of RPS impact on issuance of renewable polices in a state. Blue bars indicate the total number of renewable programs issued in the state and red line illustrates state's RPS obligation in gigawatt hours (GWh). The graphs indicate positive a correlation between RPS and issuance of renewable incentives in a state.

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[7] The count of renewable programs was gathered from DSIRE Database in March 2019 and excludes 342 expired programs. The data does not include local policies, recently issued legislation and statutes that pending approval.

The graphs also indicate a large increase in programs in 2006. If we look at a renewable policy landscape over the last two decades (*Figure 4*), we will notice a spike in state-level renewable policies in 2006. This spike is likely triggered by The Energy Policy Act of 2005 (P.L. 109-58) which has established an Investment Tax Credit (ITC).[8] ITC is one of the most important federal policy mechanisms to support the deployment of renewable energy in the United States and as the timeline indicates, this federal policy led to significant growth in the issuance of state-level renewable policies. This observation indicates that state-level renewable policies are heavily impacted by the federal policy landscape.

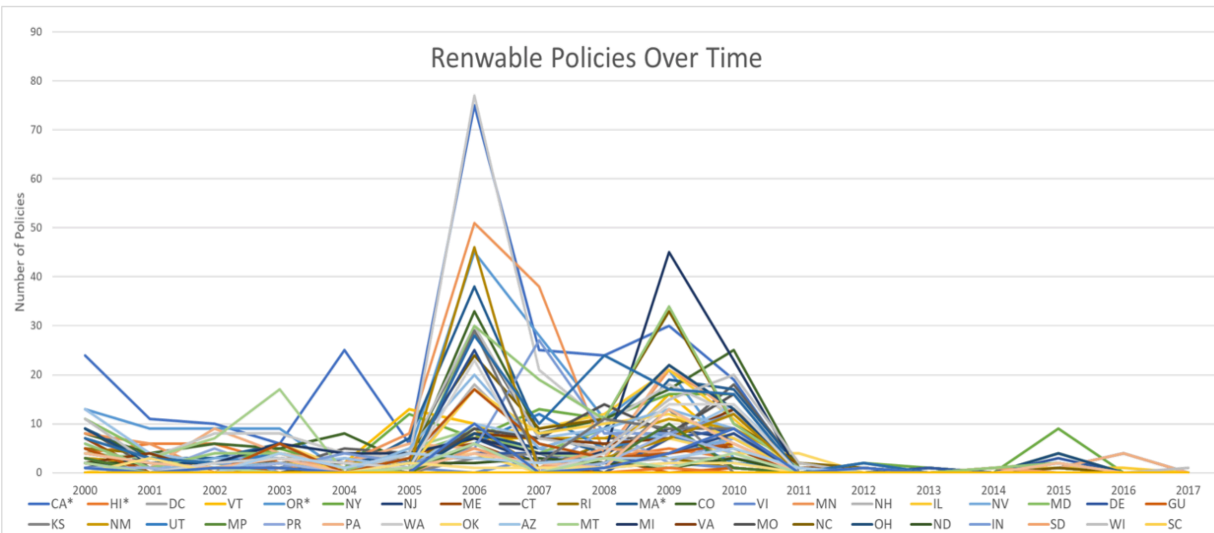

Figure 4 Renewable Policy Issuance by State. Source: DSIRE

The results of this observation may depend on the definition of eligible renewable incentives that are chosen in the analysis. Since there are over three thousand renewable incentives recorded in DSIRE database, this research breaks down the state-level policy used in this analysis.

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[8] A tax credit is a dollar-for-dollar reduction in the income taxes that a person or company claiming the credit would otherwise pay to the federal government. The ITC is based on the amount of investment in renewable property. Both the residential and commercial ITC are equal to 30 percent of the basis that is invested in eligible property which have commence construction through 2019. The ITC then steps down to 26 percent for projects that begin construction in 2020 and 22 percent for projects that begin in 2021. After 2021, the residential credit will drop to zero while the commercial and utility credit will drop to a permanent 10 percent.

4.3 Renewable Policy Classifications

The analysis of current renewable energy landscape indicates that renewables vary greatly on state and local (utility) levels. Over three thousand renewable programs were identified during our research (DSIRE) [7]. Due to a large range of incentives, a pull of renewable programs was broken down into categories to present the diversity of incentives and illustrate the complexity of policy comparison among states. The policies described below exemplify programs included into the count of renewable incentives.

By Geographic Level:

(1) Federal – Federal programs are available across the nation. Investment Tax Credit (ITC) described above is a good example of a federal incentive. ITC is the single largest driver for solar development that provides 30 percent tax credit for solar system (or other eligible technology) of any scale.

(2) State – State programs are run by state authorities and accessible to developers within a state. State incentives are driven by state's RPS and usually apply in addition to federal policies. As different states have different renewable ambitions, renewable energy development ranges widely. One example of a state-level program is Solar Renewable Energy Certificate (SREC). SREC is the energy credit rewarded for every megawatt-hour of solar electricity generated by a system. In SREC state markets, RPS requires electricity suppliers (utilities) to secure a portion of their electricity from solar systems. If a utility cannot produce enough solar energy in a given period, they would have to make a solar alternative compliance payment (SACP) for every SREC they fall short of the requirement. This creates an opportunity for 3rd parties to sell SREC to utilities to help them meet regulatory requirements.

(3) Utility – Some incentives are offered exclusively by specific utilities within a state. For instance, NIPSO, an investor-owned utility in Indiana, offers feed-in electric tariffs to its commercial customers. A feed-in tariff is a program that allows renewable energy

generators to sell power back to NIPSCO at a predetermined rate. This provides stability and almost riskless investments for developers and project owners. NIPSO is the only utility in a state of Indiana that offers this incentive for commercial customers which gives a unique advantage to NIPSO customers. Nevertheless, most electricity markets (32 out of 50 states) are heavily regulated and energy providers can only provide services to a specific area. This makes harder if not impossible for utilities to grow customer base and makes utility-level incentives very localized.

By Type:

(1) *Financial Incentives*

a. Cash: Rebates, Grants, Feed-in Tariffs, Net Metering. These incentives decrease upfront costs or provide predictable cash flows to pay off the project costs.

b. Tax Exemptions: Property Tax, Income Tax, Sales Tax, Deprecation. These incentives decrease entity's tax liability. Most tax incentives are calculated as a percentage of system cost that is exempt either from property tax, income tax or sales tax. As a simple percentage of cost incentive, there is no risk associated with system underproduction that developers experience with cash incentives. Due to the low risk of not being able to claim the incentive, tax exemption provides a high level of certainty to project developers.

c. Financing: Renewable Energy Loans, Leasing. These incentives provide low-interest rate loans to individuals and corporate entities for the development of renewable facilities.

(2) *Regulatory Policy*

These policies do not offer direct monetary assistance and do not impact the cash flows of renewable projects. However, they impact renewable development indirectly by imposing new renewable requirements on market makers. Some examples of the regulatory policy include new building energy codes and standards, mandatory utility green power options, energy efficiency standards and others.

Eligible Technology:

Renewable energy sources also need to be separated by eligible technology. Renewable technology sources have different system costs and different energy production profile. Depending on the flexibility of the electric grid, some policy regulators issue legislation that benefits a particular renewable source. The breakdown includes:

(1) Solar: includes photovoltaic passive, water heating, space heating, solar thermal electric, solar pool heating
(2) Wind
(3) Hydro
(4) Biomass: landfill gasses, wood, renewable gas, etc.
(5) Other: Geothermal; Hydroelectric; Other Distributed Generation Technologies

System Size:

Depending on a regulator's perspective some states prioritize small-scale renewable systems that create a more decentralized grid infrastructure and provide additional grid resilience. To incentivize small-scale renewable generation, policymakers have to impose system size restrictions to limit the number of utility-scale projects. Due to an economy of scale, utility-scale projects are the most cost-effective to develop but these large systems do not provide the benefits of decentralized grid infrastructure. In addition, by imposing system size limits, policymakers carve out power capacity available only for residential customers. System size breakdown:

(1) Residential
(2) Commercial
(3) Utility-Scale

Eligible Sector:

Some renewable energy policies are designed to provide additional benefits to specific sectors or entities. For instance, federal and local governments often provide special incentives for the agricultural sector to lower the operating cost of this important sector of the economy. Policy sector breakdown:

(1) Government
(2) School
(3) Agriculture
(4) Commercial
(5) Non-profit

5.0 Econometric Analysis

Based on several data plots and trend analysis, we show that the initial hypothesis that RPS influences a number of renewable programs in a state is significant. In the subsequent section, we employ a random effects model to further test our key hypotheses econometrically. First, we want to show using the random effects model whether there is a statistically significant positive correlation between RPS and a number of renewable energy programs across states. Second, we want to show econometrically whether the number of renewable programs influences the renewable energy capacity in a state. Last, we want to test whether renewable energy production and renewable capacity affects economic activity, such as state gross product (GSP) and employment growth.

5.1 Renewable Portfolio Standard (RPS) Obligations versus Number of Renewable Programs

We used the following regression equation to investigate the relationship between renewable policy standard obligation in megawatt hours in a state versus change in a number of renewable policy programs.

$$Ren.Program_{i,t} = \gamma_0 + \gamma_1 RPS\ Obligation_{i,t} + \varepsilon_{i,t} \quad (2)$$

where $Ren.Program_{i,t}$ stands for number of renewable programs issued in a state *i,* at time *t*. $RPS\ Oblihation_{i,t}$ refers to a percent change in RPS obligation from a previous year. $\varepsilon_{i,t}$ is a standard error and γ_0 is the slope of a regression line. γ_1 is the coefficient on RPS obligation.

5.2 Number of Renewable Programs versus Renewable Capacity

In the second stage of the analysis, we investigate whether the number of renewable energy programs drives the size of capacity in a state. In addition, we control for residential, commercial, industrial and overall average electricity pricing. Because residential, commercial, industrial and overall average electricity prices are highly correlated, we include each type of pricing in a regression, one at a time, to control for collinearity bias in our dependent variables.

We therefore estimate the following regression equation to test for this correlation.

$$Ren.Cap_{i,t} = \beta_0 Ren.Program_{i,t-1} + Electricity\ pricing_{i,t} + \varepsilon_{i,t} \quad (3)$$

where $Ren.Cap_{i,t}$ stands for renewable capacity in a state, *i* at time, *t*. $Ren.Program_{i,t-1}$ refers to the lag of change in the number of renewable energy programs issued in a state. Because changes in the number of renewable energy programs do not contemporaneously affect renewable energy capacity in a state, the one-year lag was used to account for the project development time.

5.3 Renewable Capacity, Renewable Energy Production and State Economic Activity

Extant literature has explored the relationship between renewable energy production/consumption and economic growth. For instance, Soava, Georgeta; Mehedintu, Anca; Sterpu, Mihaela; Raduteanu, Mircea 2018, have found a positive impact of renewable energy consumption on economic growth in the European Union (EU).[26] Their results justify the political decisions of the EU concerning the necessity of increasing the renewable energy consumption and prove that this type of energy consumption has a strong positive impact on economic growth.

Even though several scholars have investigated the impact of renewable energy production on a state economic activity, only a few have focused on a full 'value chain' of renewable energy in the U.S. Our research is unique because we looked at a comprehensive renewable energy production in the United States and established a statistically significant impact between the share of renewable energy sources on the grid and economic growth.

We evaluate the effect of the increase in renewable energy production on the state economic activity. One of our hypotheses was to test whether increasing renewable energy capacity and production increases economic activity. We estimated the state production function and regress growth state product (GSP) on inputs such as private investment share (a flow measure of capital stock in a state), state employment growth, percent of college educated people in a state, unionization, and renewable energy production. We also control for other state specific factors, including share of college graduates in a state and the degree of unionization in a state. We therefore estimated the following regression equation:

$$GSP\ growth_{i,t} = \alpha_0 + \alpha_1 srpg_{i,t} + \alpha_2 employ_{i,t} + \alpha_3 invest_{i,t} + \alpha_4 college_{i,t} + \alpha_5 union_{i,t} + \varepsilon_{i,t} \tag{4}$$

where $GSP\ growth_{i,t}$ is the growth state product (GSP), $srpg_{i,t}$ is the share of renewable energy as a share of total energy production in a state, *i* at time *t*; the variable $employ_{i,t}$ is the employment growth, $invest_{i,t}$ private investment share (a flow measure of capital stock in a state), $college_{i,t}$ percent of college educated people in a state, $union_{i,t}$ is unionization.

Several studies on economic growth in subnational economies control for employment growth, investment share of state GSP college and unions. For instance Ojede and Yamarik (2012) [19], Ojede, Atems and Yamarik (2018) [20]; Segura (2017) [25]; Reed (2008) [22] as well as earlier papers by Helms (1985) [15] and Carroll and Wasylenko (1994) [4]; and others have all found statistically significant positive correlation between share of employment growth and investment share of state GSP on economic growth. Our results can be put into context with those previous empirical studies of state income growth that use similar control variables.

6.0. Data

In this research, we employ data from 48 US states excluding the District of Columbia, Hawaii, and Alaska to conduct the econometric analysis to test for the hypothesis identified in section 5.0 above. We use panel (longitudinal) data from 2000-2012. We selected this time period because of consistency and availability of data. We collected data on electricity prices, disaggregated into residential, commercial and industrial electricity prices. We also gathered data on the change in the number of renewable policy programs in all 50 states. We collected data on state GSP, employment, renewable energy capacity, renewable energy production as a share of total energy production in a state. In addition, we controlled for other economic variables that affect state economic activity, such as investment share of income (which is a flow measure of capital stock) and controlled for the degree of unionization in a state as well as a share of college graduates in a state.

Table 2 below provides summary statistics, descriptions of variables and data sources. Data on renewable energy production, capacity, electricity prices were obtained from the Energy Information Administration. The information on number of renewable programs was gathered from Database of State Incentives for Renewables & Efficiency (DSIRE). State level economic data, such as college attainment, union size, state GSP, employment, investment share were obtained from the Bureau of Economic Analysis, Regional Economic Databank.

Table2:
Summary Statistics & Variable Descriptions

Variable	Variable Description	Mean	Standard Deviation	Minimum	Maximum
The log of renewable capacity	Measures size of renewable energy capacity in terms of megawatt summer peak production	7.546249	1.275523	2.639057	10.71637
The change in the number of renewable energy programs	Measures the change in number of renewable energy programs issued in a state in any given year	4.966146	8.651138	0	77
The log of residential electricity price	The price of electricity for residential use in dollars per kilowatt hour	2.034719	0.3581432	0.8241754	2.765942
The log of commercial electricity price	The price of electricity for commercial use in dollars per kilowatt hour	1.958969	0.3496986	0.7793249	6.465317
The log of industrial electricity price	The price of electricity for industrial use in dollars per kilowatt hour	1.623228	0.3088818	0.5259113	2.479559
The log of overall average electricity price	The price of overall average electricity price in dollars per kilowatt hour	1.920087	.2531324	0.8224195	2.634332
GSP	The growth in state gross domestic product in percent	1.822135	2.973601	-8.8	13.3
srpg	Renewable energy as a share of total energy production	0.1229688	0.1976466	0	0.9479603
RPS obligation	The log of RPS obligation in megawatt hours	14.36307	1.315909	10.1213	17.74718
Employment growth	Measures growth in employment in a state	0.7289063	2.345124	-7.2	7
Investment share of GSP	A flow measure of capital stock	0.0801262	0.0409873	0.0054891	0.3227782
College	Share of college graduates in total state population	0.2676432	0.048176	0.151	0.39
Union	Share of union workers in total state workforce	0.1081901	0.0513732	0.023	0.261

6.1 Data Limitations

Since data is longitudinal, we do not capture in our econometric analysis the impact of Federal government programs or incentives in a state energy production because there could be no cross-sectional variation. We instead used data that is state specific to identify state renewable portfolio standard on programs.

In addition, DSIRE database does not have consistent data on establishment of renewable energy programs. A large number of programs in a database miss a program establishment date. In a case when a program did not have an establishment date, we substituted it with a date when a program was entered into the database.

7.0. Econometric Results and Discussions

7.1 Renewable Energy Program Growth

Tables 3 summarizes the results from estimating equation (2), which tests the relationship between RPS Obligation in MWh and the change in the number of renewable energy programs issued in a state. The results indicate the increase in RPS Obligation by one percent on average will lead to issuance of 1.44 renewable policies in a state.

Table 3
The effect of RPS as Percent of Retail sales on change in renewable energy programs

Variable	Coefficient	p-value
Change RPS Obligation	1.4411** (0.5116)	0.005
Constant	-14.3345 (7.3788)	0.052
R-squared	0.0407	

*Notes: ***, **, * imply significance at the 1 percent, 5 percent, and 10 percent level. The numbers in parentheses are standard errors.*

7.2 Renewable Energy Capacity Growth

Tables 4a-4d report the random effects of change in the number of renewable energy programs in a state on renewable capacity. The results in *Tables 4a-4d* indicate that a one-point increase in the change in renewable energy programs significantly increases renewable energy capacity, all else being equal. We also find that an increase in electricity prices leads to more renewable capacity.

Table 4a
The impact of the change in renewable energy programs & residential electricity pricing on renewable capacity

Variable	Coefficient	p-value
Change in the number renewable energy programs	0.0718*** (0.0199)	0.000
Residential electricity pricing	0.2825*** (0.0897)	0.002
Constant	6.9046*** (0.2370)	0.000
R-Squared	0.1211	

Table 4b
The impact of the change in renewable energy programs & commercial electricity pricing on renewable capacity

Variable	Coefficient	p-value
Change in the number renewable energy programs	0.0862*** (0.0196)	0.000
Commercial electricity pricing	0.0759 (0.0528)	0.151
Constant	7.3186*** (0.1866)	0.000
R-Squared	0.0913	

Table 4c
The impact of the change in renewable energy programs & industrial electricity pricing on renewable capacity

Variable	Coefficient	p-value
Change in the number renewable energy programs	0.0562*** (0.0206)	0.006
Commercial electricity pricing	0.4114*** (0.1011)	0.000
Constant	6.8303*** (0.2198)	0.000
R-Squared	0.1473	

Table 4d
The impact of the change in renewable energy programs & average electricity pricing on renewable capacity

Variable	Coefficient	p-value
Change in the number renewable energy programs	0.0555*** (0.0207)	0.007
Average electricity pricing	0.5205*** (0.1317)	0.000
Constant	6.4970*** (0.2907)	0.000
R-Squared	0.1424	

Limitation of the results in Tables 4a-4d

The results presented in Tables 4a-4d obtained by estimating regression specification (3) may have a limitation, in that, while electricity pricing may drive renewable capacity, the correlation run from renewable capacity may also drive electricity pricing. This reverse casualty can bias the results reported in Tables 4a-4d for different types of electricity pricing. In addition, the electricity prices were not adjusted for inflation which could skew the results. Therefore, the results in Tables 4a-4d must be interpreted while bearing this limitation in mind.

7.3 Economic Growth

The results for the above regression equation are reported in *Table 5.* We find that a one percentage point increase in the share of renewable energy production in total energy production increases GSP growth by 0.8 percent. Our results also show that increases in investment share of income (a flow measure of capital) and state employment growth are positively correlated with state income growth and the results are statistically significant at the 99 percent confidence. The R-squared for the regression in Table 5 is impressive. Though we controlled for union share in the workforce and share of the population with college graduates, the coefficients on those variables are not statistically significant.

Table 5
The effect of renewable energy production on state economic activity (GDP growth)

Variable	Coefficient	p-value
Share of renewable energy power generation to total energy production	0.0088* (0.0052)	0.094
Employment growth	0.8932*** (0.0459)	0.000
Investment share of income	0.613*** (0.0261)	0.019
Percentage of college graduates	0.0008 (0.0225)	0.972
Percentage of union workers in the workforce	-0.0230 (0.0215)	0.284
Constant	0.0080 (0.0062)	0.197
R-squared	0.555	

For robustness, we ran a separate regression of state employment growth on the renewable energy production and other control variables and the results (not reported here) show a statistically significant positive correlation between renewable energy production and state employment growth.

8.0 Conclusion

To summarize, the findings confirm the hypothesis that the establishment or an increase in RPS lead to the issuance of renewable policies in a state which then leads to growth in renewable capacity. This research concludes that the growth of renewable energy sources has a positive impact on economic activities in a state. In fact, one percentage point increase in the share of renewable energy production to total energy production increases GSP growth by 0.8 percent. We also found the relations between a state's policies and renewable capacity is not linear. There are other factors that impact the growth of renewable capacity such as federal energy policies and electricity prices. Finally, this research indicates that electricity prices are one of the key drivers of renewable energy and states with high residential electricity rates will find the largest growth in renewables. However, we did not establish that the growth in renewable production decreases average electricity prices. In fact, we saw a short-term increase in state's electricity prices due to rate adders[9]. We learned that the implementation of RPS leads to an increase in electricity rates, but the long run effect of renewable deployment on average electricity prices is still uncertain because of the limited time renewable systems have been in operations. It is important to point out that despite the increase in average electricity process, the rates of power purchase agreements[10] (PPAs) from renewable sources continue to decline and currently reach as low as $25 per megawatt hour (Bolinger, 2018) [2]. This highlights the fact that renewables are able to supply power at historically low prices. Nevertheless, renewable energy sources are still a small portion of the overall U.S. power mix. It will take time until renewables capture a more significant portion of total energy generation to see a significant decline in average electric prices.

[9] Rate adder refers to additional item line on customers electric bill included to pay out expenses of a renewable energy program.
[10] PPA is a financial agreement where a developer arranges for the design, permitting, financing and installation of an energy system on a customer's property at little to no cost. The developer sells the power generated to the host customer at a fixed rate that is typically lower than the local utility's retail rate.

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