How Have Renewable Portfolio Standards Impacted the Renewable Energy Sector in the US?

Team 11
Citadel Data Open East Coast Hackathon
Spring 2019

Executive Summary

An important consideration when tackling the issue of renewable energy (RE) in the U.S is the impact that policies have in its adoption. While researching for this project, we noted that there are a broad array of policies and initiatives that drive renewable energy growth. Most notably, we came across **Renewable Portfolio Standards** - regulations that requires electric suppliers to supply a specific percentage of their service through means of RE.This regulation is implemented at a state level in the country, and is enforced by penalty levels if a service percentage is not reached. The motivation to research this specific policy and its impact came from RPS' broad application across different states as well as its potential to increase RE generation at scale. However, the implementation of such a policy is not the same in any two states. An important research question for us then becomes how does this policy vary across different states, and how does its variance impact RE generation since its enactment.

By utilizing the available datasets provided by the datathon, paired with external research, we explored the differences in policy adoptions in different states, and concluded that the policy doesn't play out the same way in any two states. The exploratory phase findings enabled us to come up with a regression model that policy enactments have a statistically high significance. While their impact is not very big in market share, they do seem to increase renewables growth. Additionally, a closer analysis on 'ambition vs realization' of target goals by looking at the use cases of Vermont and South Dakota indicated that even though several states implement more aggressive targets for RE growth, the realization of these targets is not any different from what other states are conducting, thus further analysis may be required to understand what are the drivers behind such a strategy.

Research Scope & Questions

Measuring Impact of Renewable Portfolio Standards

Background & Research Motivation

In our research on renewable energy policies, Renewable Portfolio Standards (RPS) stood out as a state-level regulation that incentivizes renewable energy generation based on specific goals. The regulation provides a venue for states to diversify their energy sources and encourage green energy consumption. The motivation to focus on RPS lies predominantly on the span of RPS adoption across many states (Figure 1), as well as it being considered as a key driver in renewable energy (RE) generation targets, accounting for half of the total U.S generation since 2000.

RPS have been around since the 1980s, with the majority of the states adopting them from 2017 onward. To date, only 5 states have passed their RPS target goals, with almost half of the states aiming to hit the target by 2025, while the rest aiming beyond 2030. There are varying dynamics among states in the way they have set up their goals: California for instance has set aggressive goals of 100% RE generation by 2045, while Oregon aims at 50% for a similar time span.

The different adoption strategies and target goals led us to approach this problem in two fronts: first, how does the RPS enactment vary across different states and whether the enactment of RPS has any impact in the RE generation, and what makes these policies successful.

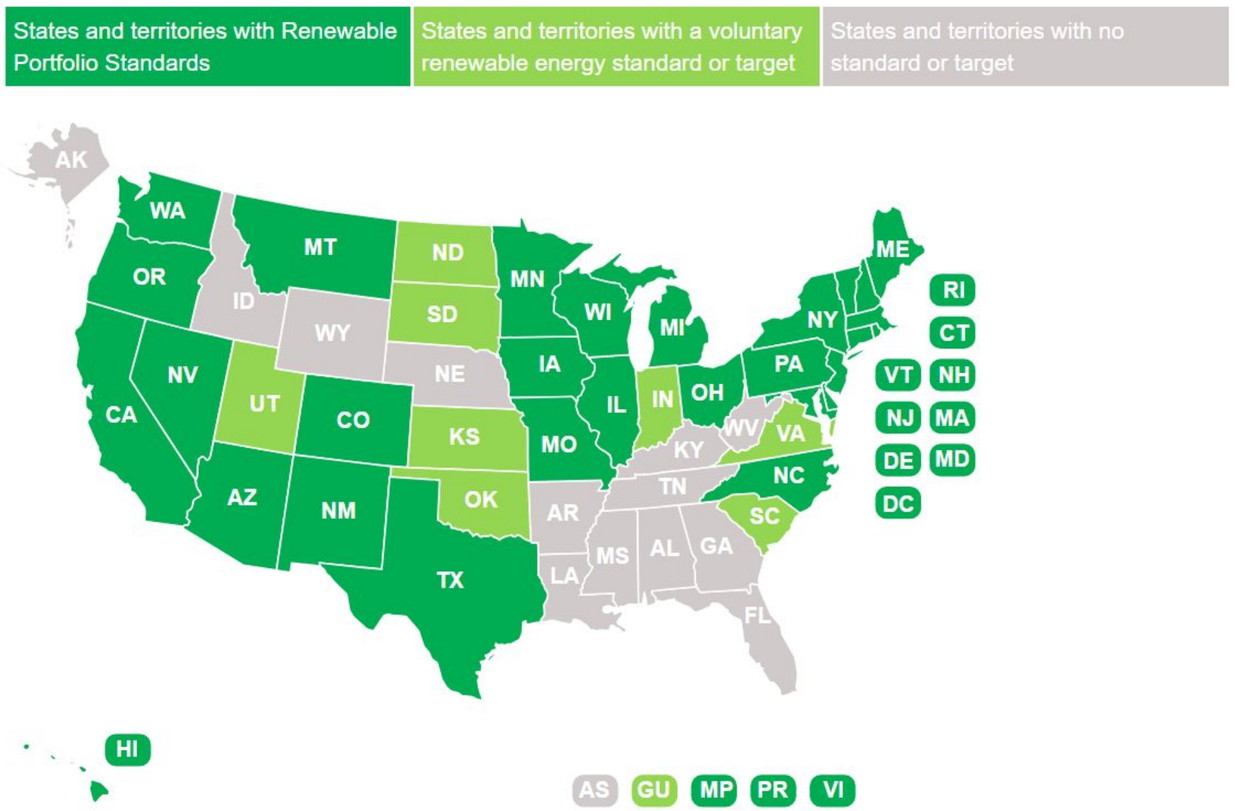


Figure 1: Renewable Portfolio Standards or Voluntary Targets

Source: National Conference of State Legislatures

Data Wrangling & Exploratory Phase

Datasets Used

For this project, we worked with the following datasets:

1. **SEDS *(seds.csv)***
   - Dataset provided by the datathon, which details energy sources by energy sector for all states across years (1960-2017)
   - Dataset format: 1711736 rows, 8 columns (year, msn, state_name, state_code, description, energy_bin, value, unit)

2. **RPS Target Goals based on Target Year for each State *(NCSL)***
   - Dataset created by the team which aggregates state-specific RPS target goals in terms of percentage of RE generation and target reach year.
   - Dataset format: 51 rows, 12 columns (state, state_code, voluntary?, repealed?, year_enacted, first_target_pct, first_target_abs(MW), first_target_year, second_target_pct, second_target_year, sectors, cost_cap)
   - Data source: http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx

Data Wrangling & Feature Engineering

Scraping

- The RPS policy data by state was manually scraped from NCSL for relevant features including specific state target goals. These target goals were either percentages of RE generation or absolute values in terms of MW. For the purposes of the project, everything was converted to percentage points. Boolean attribute “Voluntary” was used to determine whether states have target goals based on RPS enactment or voluntary targets.

Metrics

- Two primary columns in the SEDS data were identified as relevant: renewable energy and aggregate energy consumption (RETCB, TETCB)
  - TC: total consumption of all energy consuming sectors
  - B: british thermal units (BTU)
- These metrics were chosen as a direct means of establishing increase or decrease in renewable energy use in a given state

Data Wrangling & Feature Engineering

SEDS Engineering

- Data concerning the 37 states that have enacted RPS policies was collected and the SEDS data was filtered accordingly.
- Iterated over all relevant states and engineered the following features: prop_RE, abs_diff, perc_diff which give the proportional RE consumption for a given state in a given year, along with deltas from year to year (absolute and percent).

Covariates

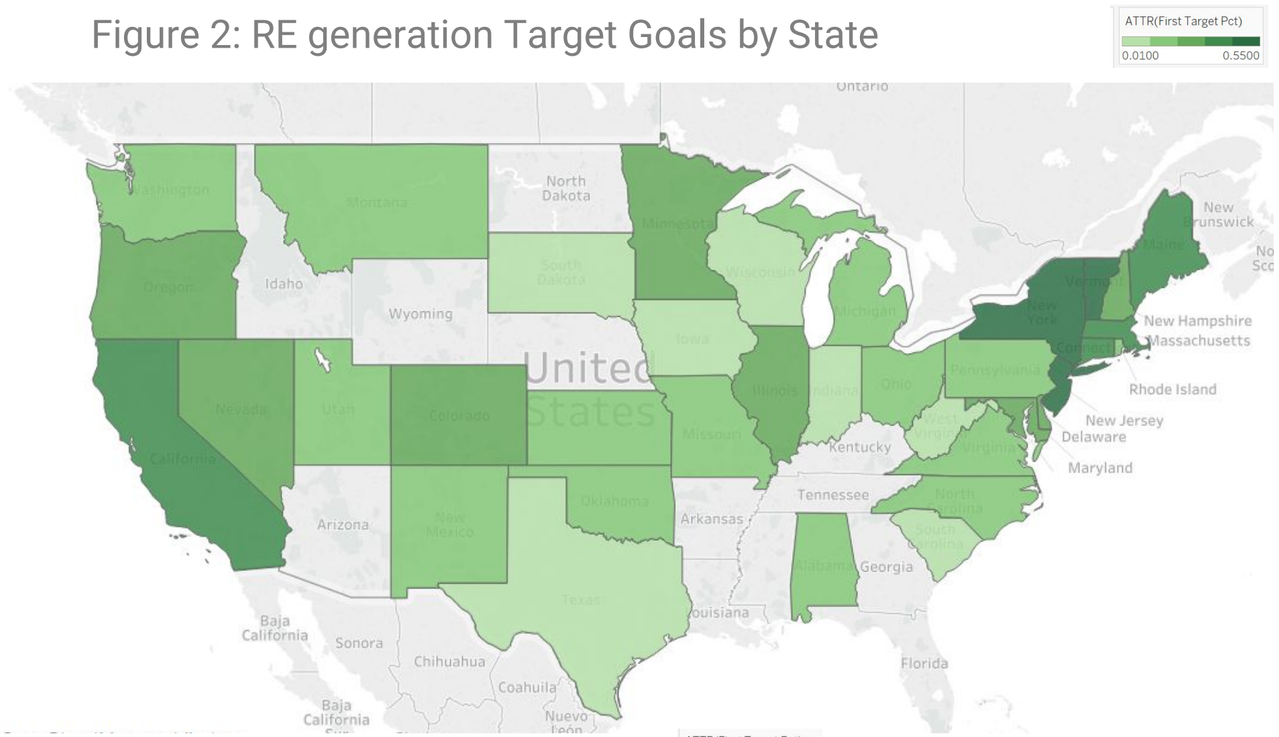
- As we are interested in the impact of a policy, we created features for time series regression
  - *(years - 1960)(year ≥ enactment_year)* - the coefficient identifies the ‘additional slope slope’
  - (*year ≥ enactment_year)* - coefficient of this identifies new mean effect

Exploratory Analysis: East & West Coast Set Aggressive Goals Towards Renewable Energy

Differences in Target Goals among States

Even though RPS is widely spread across the country, our intuition led us to question whether its effects across states is the same or similar. For this reason, utilizing the target goals dataset developed, we decided to visualize and analyze how this policy is enacted among different states. This analysis supported our intuition and revealed that RE generation target goals vary. In Figure 2, target goals are more aggressive in states like California, NY and Vermont. While this might not come as a surprise, given CA's and NY's hub status, it is important to understand the drivers behind such an aggressive strategy. On the other hand, Texas, despite having attractive wind energy economics, doesn't rank at the same level in terms of RE goals.

Figure 2: RE generation Target Goals by State



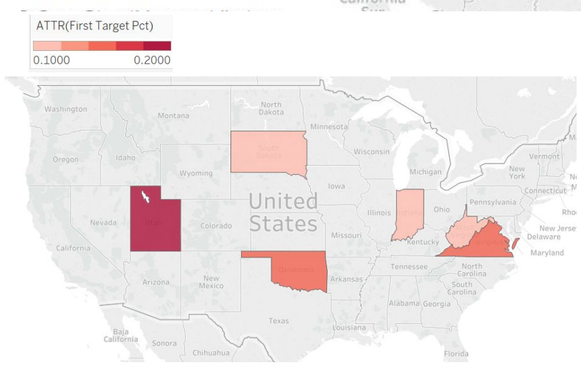


Figure 3: RE generation Target Goals for States with Voluntary Goals

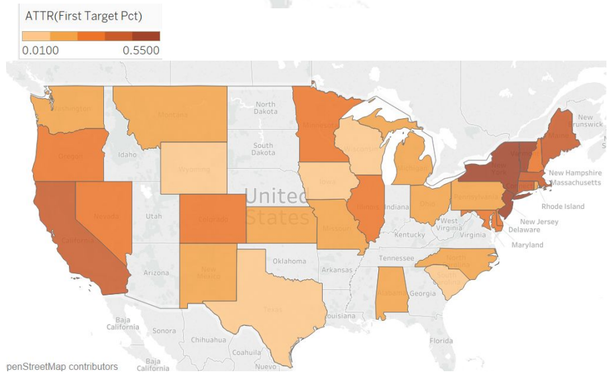
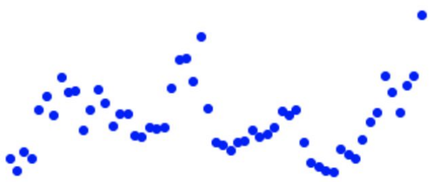
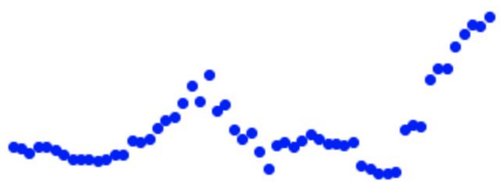


Figure 4: RE generation Target Goals for States that have implemented RPS

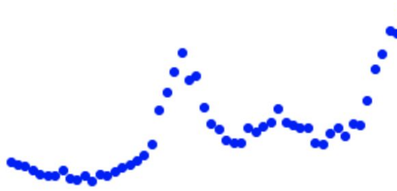
Exploratory Analysis: Varying Rates of Renewable Energy Adoption



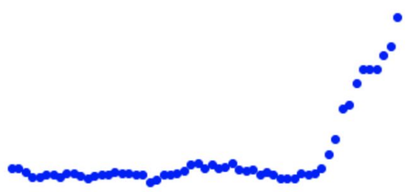
Utah RE/TE



New Jersey RE/TE



Pennsylvania RE/TE



Texas RE/TE

New York RE/TE

Maine RE/TE

Differences in Renewable Energy Consumption Rates Show an Upward Trend Post Policy Enactment

Expanding on our exploratory analysis of differing policies across states, we noticed a clear rise and fall in renewable energy consumption as a portion of total energy over time (even occasionally periodic trends). In states such as Texas, renewable energy consumption grew rapidly after the adoption of RPS policies in 1999. In other states, the trend is not so clear, for example in New York, which enacted the policy in 2004. These findings lead us to further question the impact of policies on RE and understand the explainability of RE growth.

Modelling and Analysis

Model Specifications: Trends of RE Generation Upon Policy Enactment

Model Used - RDD via OLS

We used a regression discontinuity design to test whether trends of RE generation changed upon the enactment of policies. Our primary specification is as follows:

$$y_t = \beta_0 + \beta_1 t + \beta_2 \cdot \mathbf{1}[(t \geq t^*)]t + \epsilon_t$$

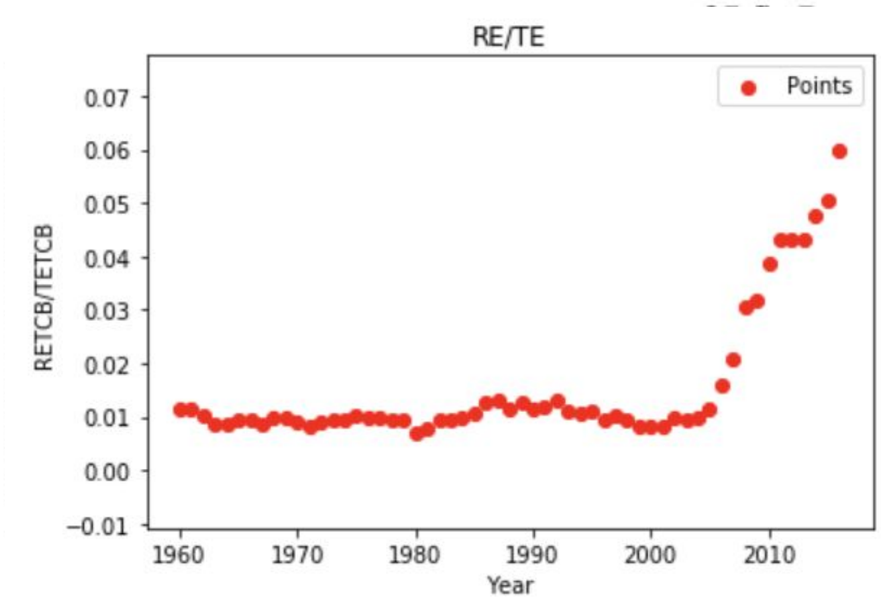
where $\mathbf{y_t}$ represents the fraction of the state's resources that come from renewables, **t*** is the date of policy enactment, and **t** is the number of years since 1960 (when our dataset begins). We estimate this model for each state which implemented a policy using ordinary least squares.

Separately, we test a model of the same specification in which $\mathbf{y_t}$ be the year-over-year growth of the renewable energy consumption. This is to test whether policies encouraged renewable growth directly, even if growth of non-renewables continued enough to eliminate renewable market share growth.

Modeling Results (RDD via OLS)

We observe a significant positive coefficient on treatyear, which corresponds to variable t*(t<t^*) in our equation. This indicates that the (visually striking) uptick is unlikely to be random chance if the null hypothesis (no policy effect) is true.

Texas 1999



ssion Results

R-squared:			0.540			
Adj. R-squared:			0.523			
F-statistic:			31.66			
Prob (F-statistic):			7.96e-10			
Log-Likelihood:			190.44			
AIC:			-374.9			
BIC:			-368.8			
	coef	std err	t	P>|t|	[0.025	0.975]
normyear	0.0002	0.000	1.241	0.220	-9.49e-05	0.000
treatyear	0.0003	9.18e-05	3.463	0.001	0.000	0.001
ones	0.0064	0.003	2.343	0.023	0.001	0.012
Omnibus:		4.328	Durbin-Watson:			0.122
Prob(Omnibus):		0.115	Jarque-Bera (JB):			5.034
Skew:		-0.003	Prob(JB):			0.0807
Kurtosis:		4.456	Cond. No.			94.8

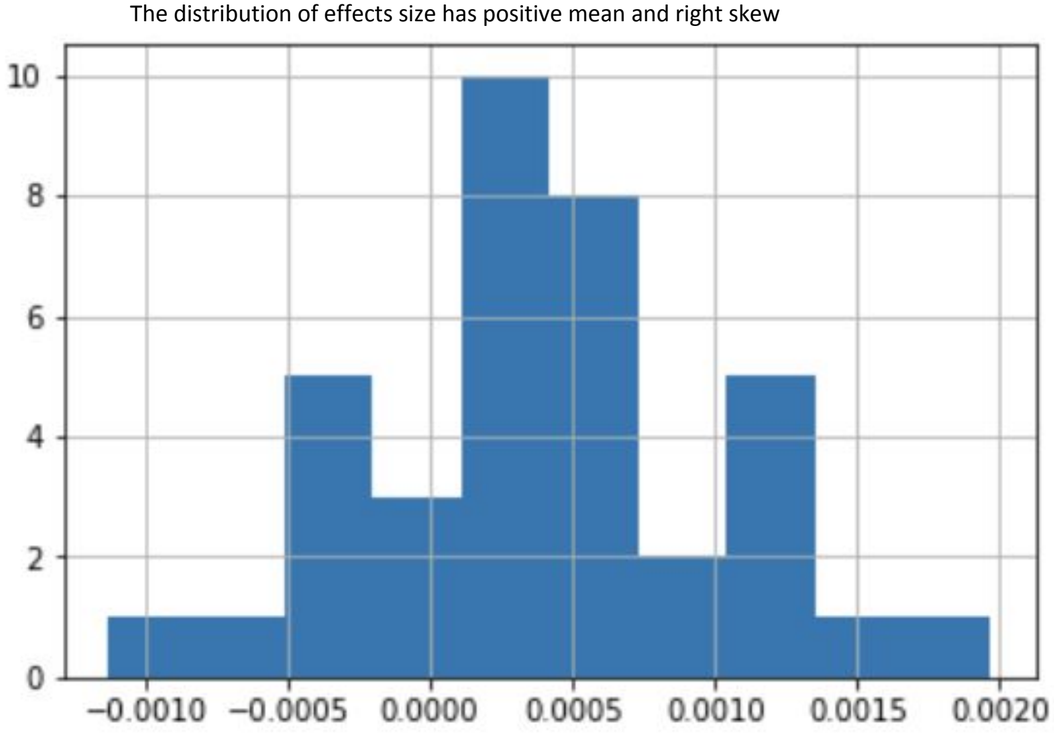
Results for Texas, which implemented its policy in 1999.

Modeling Results

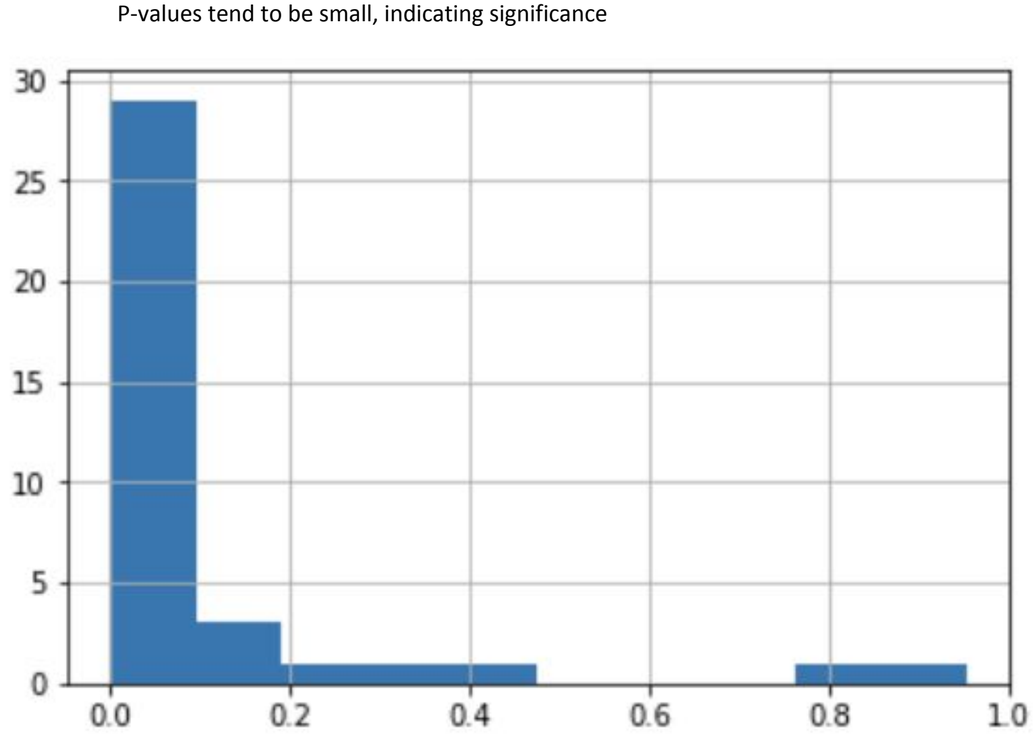
Model Results - Distribution of effect size and significance (Renewable Share)

Each state is different and faces a different set of contexts, but plotting the distribution of effects sizes and the distribution of p-values suggests that these policies do tend to have a statistically significant effect. However, these effects are quite small.

The distribution of effects size has positive mean and right skew



P-values tend to be small, indicating significance

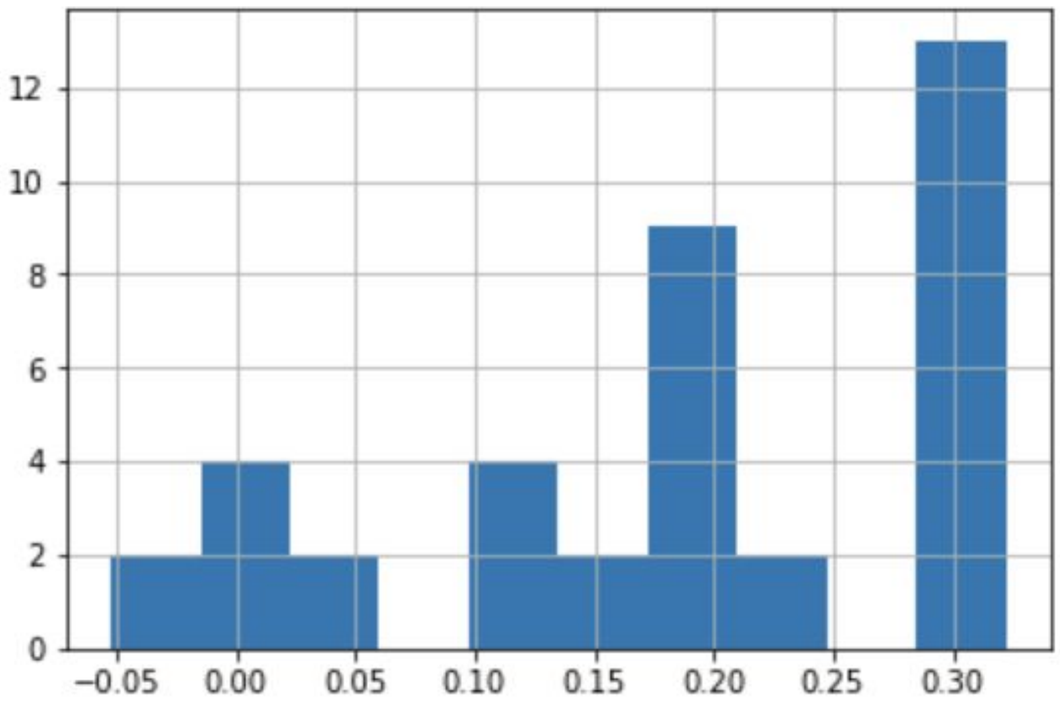


Modeling Results

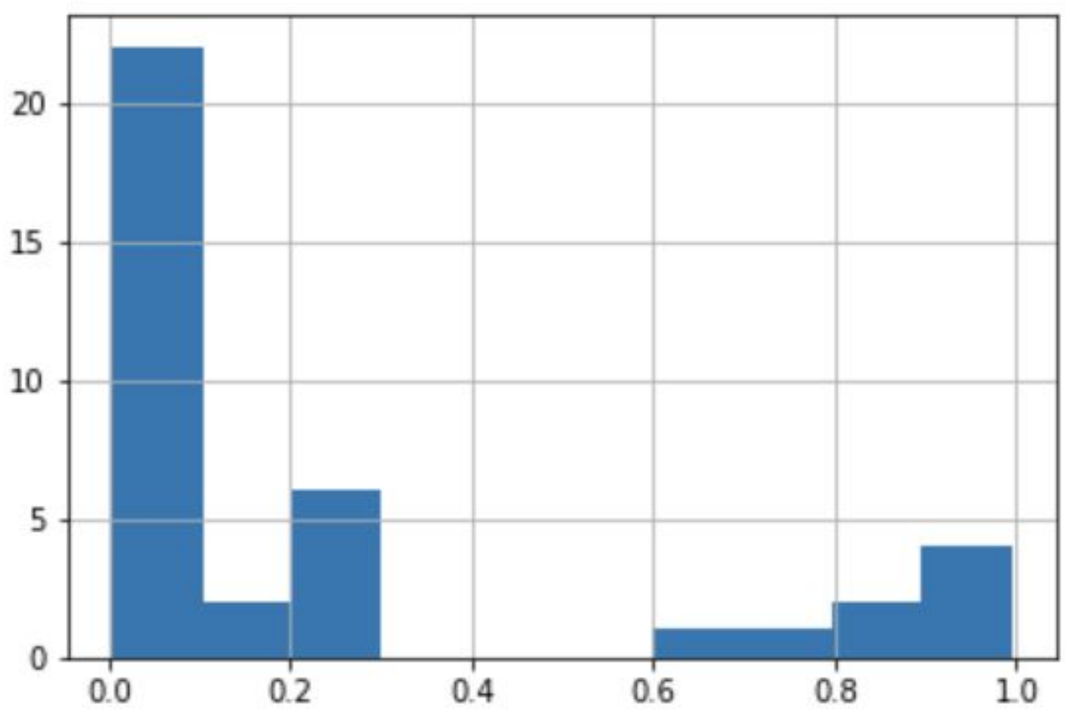
Model Results - Distribution of effect size and significance (Renewable Growth)

We conduct a similar exercise with growth figures. Here growth is measured as $\mathbf{100(RE_t/RE_{t-1})}$. Here, we again see small p-values, indicating significance, but we also see very large growth in renewables.

The distribution of effects size has positive mean and right skew



P-values tend to be small, indicating significance



Resulting Policy Analysis

Our second order analysis dealt with deciphering which aspects of these renewable portfolio policies made them successful. The biggest differences the legislation we examined were their ambitiousness--certain states implemented lofty goals with only short time frames to realize them, while others implemented much less lofty goals with more time for their realization. We formulated measures of “ambition” and “realization” to better quantify this dichotomy:

Ambition *= (Ending Percentage of Renewables - Starting Percentage) / Number of years between enactment and deadline*

Realization *= (Current _Percentage - Starting Percentage) / Number of years between enactment and present*

We chose these metrics because they take into account the number of years allowed, the loftiness of the goal, and varying levels of the starting point between states. The same logic applies for realization.

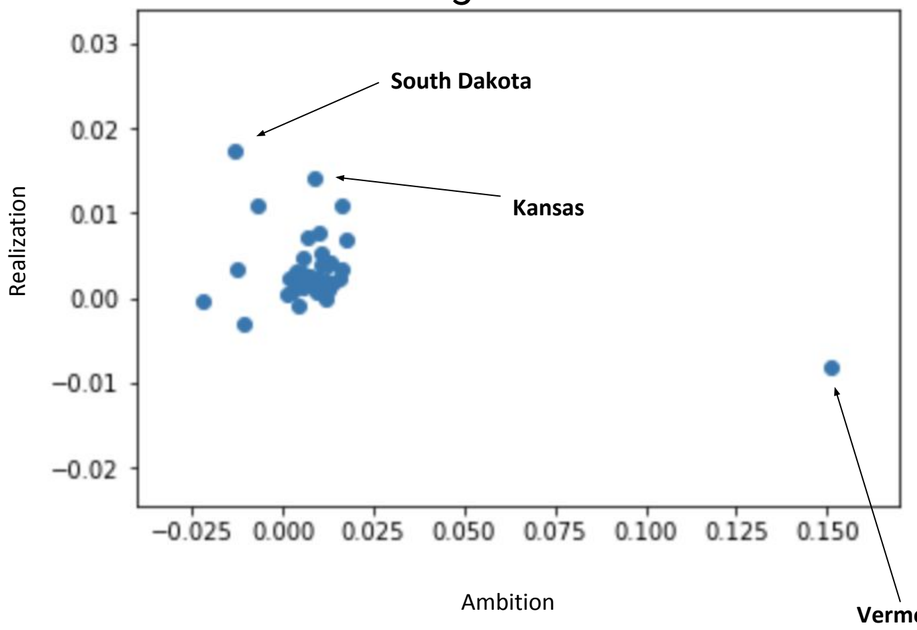
Resulting Policy Analysis

We plotted the ambition vs realization metrics for each of the 37 states with some form of RPS legislation, and we found that ambition in fact had very little to do with how much progress was actually made. In fact, the “superstar” of them all, South Dakota, was one of the least ambitious. Vermont, by far and away the most ambitious, had a negative realization.

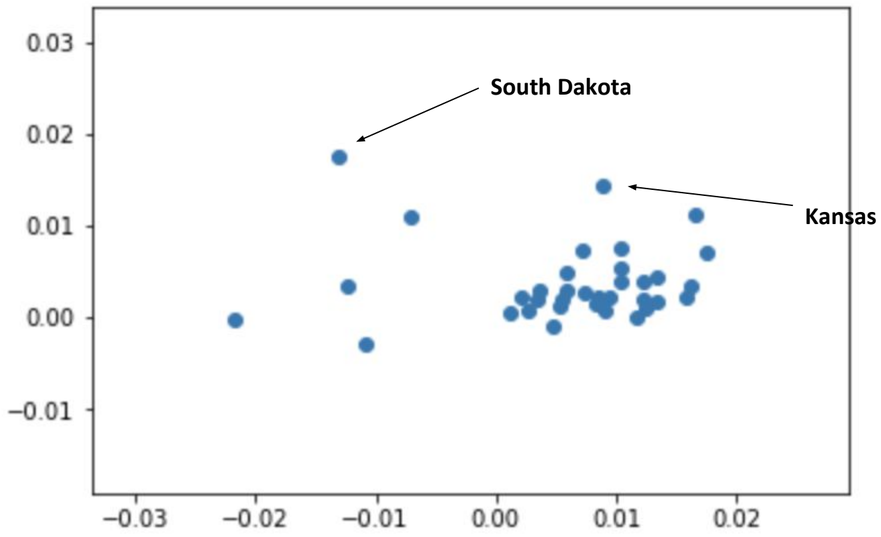
Of course, it is impossible to draw conclusions from these two outlier cases. However, we did have the counterintuitive finding that overall there was very little evidence that ambition of the policies had any bearing on the success states had in converting to more renewable energy sources.

An important note about negative ambition values: this is due to a discrepancy in what different states deem to qualify as “renewable” vs “non-renewable.” The fact remains that lower ambition values correspond to less ambitious policies.

Ambition vs Realization for the 37 states with RPS Legislation



Same Plot, Without Vermont



Conclusions

Conclusions and Lessons Learned

Trends of RE Generation Upon Policy Enactment

Across the 37 states RPS has been implemented in, we find statistically significant increases in adoption of renewable energy at ~2% over the span of 10 years. While results were not drastic with respect to market share, growth in renewables sectors saw large effects.

Policy Ambition vs Realization

Furthermore, we identify an approximate relation between the “ambition” of RPS policies and their “realization”. While more ambitious states, on the whole, did not show any evidence of making more progress than less ambitious ones, we see that all RPS policies cluster tightly in the upper left quadrant. Making this even more surprising, this is relative to their absolute progress, not their progress relative to their goal. While this question definitely demands further research, it is an important factor for lawmakers to keep in mind--lofty goals do not necessarily lead to lofty outcomes.

Future Considerations

Impact of multiple policies on RE growth

While policies like RPS are strong enough to be considered as a standalone pillar in understanding RE adoption, it is important to note that policies operate in an intertwined environment, impacted by different forces all working at the same time. If more time were allowed for the project, it would be interesting to explore the enactment of various RE policies and further analyze their relative strength in contributing to RE generation growth. For example, we might explore the effect that cap and trade policies have when combined with these RPS policies.

Impact of RE policies on infrastructure and innovation

The introduction of RE policies has the potential to change the dynamics of the RE marketplace. A potential outcome of such movement in the sector can be a spur of innovation which can take various forms, such as increased R&D spending, increased employment, new RE startups etc. An analysis of drivers of innovation enabled by RE policies at a state level could be a potential continuation of this project.