Fueling the Green Revolution: Exploring State-wide Incentive Mechanisms for Accelerating Renewable Energy Production in the United States

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Abstract

This paper will be an exploration on the most effective state-wide incentive strategies used in promoting renewable energy adoption in the United States and the associated impact it has on the growth of the renewable energy market as well as the holistic incentive to reduce greenhouse gas emissions. Drawing upon existing research, reports, and data available, the paper examines key incentive strategies such as Renewable Portfolio Standards (RPS) (Sarzynski et al., 2012b), Feed-in Tariffs (FiTs), tax incentives, Net Energy Metering (NEM), public financing and grants, and interconnection standards. By analyzing indicators such as electricity generation, and market competitiveness, the study will assess the effectiveness of these strategies in driving renewable energy adoption and fostering market growth. It is important to consider regional differences, available resources, and contextual factors that may influence the effectiveness of these strategies. The research highlights the need for ongoing analysis and up-to-date data to capture the evolving landscape of state-level incentive strategies and their impact on renewable energy markets in the US. Additionally, this exploration aims to assess the cost-effectiveness and long-term manageability of state-wide incentives for renewable energy sources. To achieve this goal, a comprehensive analysis is conducted, incorporating various datasets encompassing economic, environmental, and energy-related factors. The datasets utilized include energy generation and consumption data, cost data, energy market data, and environmental impact data as

well as policy and incentive data. By analyzing these datasets, the study aims to provide insights into the potential benefits of state-wide incentives for renewable energy sources, emphasizing their sustainability and economic viability.

Introduction

The adoption of renewable energy sources has gained significant traction as a means to address environmental concerns and reduce reliance on fossil fuels. The transition to renewable energy sources has been seen as a viable option for mitigating climate change and achieving sustainable development. State-wide incentives play a crucial role in promoting renewable energy development (Economic Incentives | US EPA, 2022b). By examining the various tangible incentives that stimulate renewable energy usage, we aim to gain a comprehensive understanding of the current state of the renewable energy market in the country.

Statewide incentives for renewable energy encompass a wide range of measures, including tax credits, grants, rebates, and mandates. These incentives play a crucial role in encouraging individuals, businesses, and utilities to embrace renewable energy technologies. By analyzing these incentives, we can uncover valuable insights into the dynamics of renewable energy production in the United States.

An exemplar of a significant state-wide incentive is the Renewable Portfolio Standard (RPS), which mandates utilities to generate a specific percentage of their electricity from renewable sources. With 30 states and the District of Columbia adopting RPS policies as of 2021, these regulations have proven effective in fostering the growth of renewable energy within those states (Economic Incentives | US EPA, 2022b).

Furthermore, numerous states offer tax incentives aimed at facilitating the installation of renewable energy systems, such as solar panels and wind turbines. These incentives substantially mitigate the initial costs associated with implementing renewable energy technologies, enhancing their competitiveness when compared to traditional energy sources.

By examining these examples and delving into a broader analysis of statewide incentives, we can develop a comprehensive understanding of the factors driving renewable energy adoption in the United States. This research will contribute to the knowledge base on renewable energy market dynamics and provide insights that can inform future policy decisions and initiatives.

Background

This section reviews the existing literature on state-wide incentive mechanisms for renewable energy production. It covers studies on the economic impact of renewable energy incentives, the role of policy frameworks, and the relationship between incentives and renewable energy deployment. The literature review sets the foundation for the research methodology and data analysis (Renewable Energy Explained - Incentives - U.S. Energy Information Administration (EIA), n.d.-b).

The solar industry in several U.S. states is experiencing rapid growth and transformation. However, its progress is hindered by uncertain policies and recent disruptions in the market and industry. Certain states have taken proactive measures to support the expansion of solar markets, ensuring their continued strength. On the other hand, inaction on policy matters in some states has resulted in a decline in the solar market.

The state of renewable energy incentives for electricity generation in the United States is characterized by a mix of policies and initiatives at both the federal and state levels. These incentives aim to promote the adoption and expansion of renewable energy sources, such as solar, wind, and geothermal power. They typically include measures like tax credits, grants, rebates, renewable portfolio standards (RPS), and net metering.

At the federal level, the United States offers incentives such as the Investment Tax Credit (ITC) and the Production Tax Credit (PTC) to support the development of renewable energy projects. The ITC provides a tax credit for qualifying solar, wind, and geothermal installations, while the PTC offers a tax credit for renewable energy production, primarily wind energy.

State-level incentives play a crucial role in driving renewable energy adoption, with varying approaches across different states. Many states have implemented RPS, which mandate a certain percentage of electricity to be generated from renewable sources. States also offer their own tax credits, grants, and other financial incentives to encourage renewable energy investments (Renewable & Alternative Fuels - U.S. Energy Information Administration (EIA), n.d.).

In recent years, there has been a growing focus on reducing greenhouse gas emissions and transitioning to cleaner energy sources, resulting in increased support for renewable energy incentives (Renewable & Alternative Fuels - U.S. Energy Information Administration (EIA), n.d.). However, the availability and extent of these incentives can vary widely from state to state, with some states providing more comprehensive and generous incentives than others.

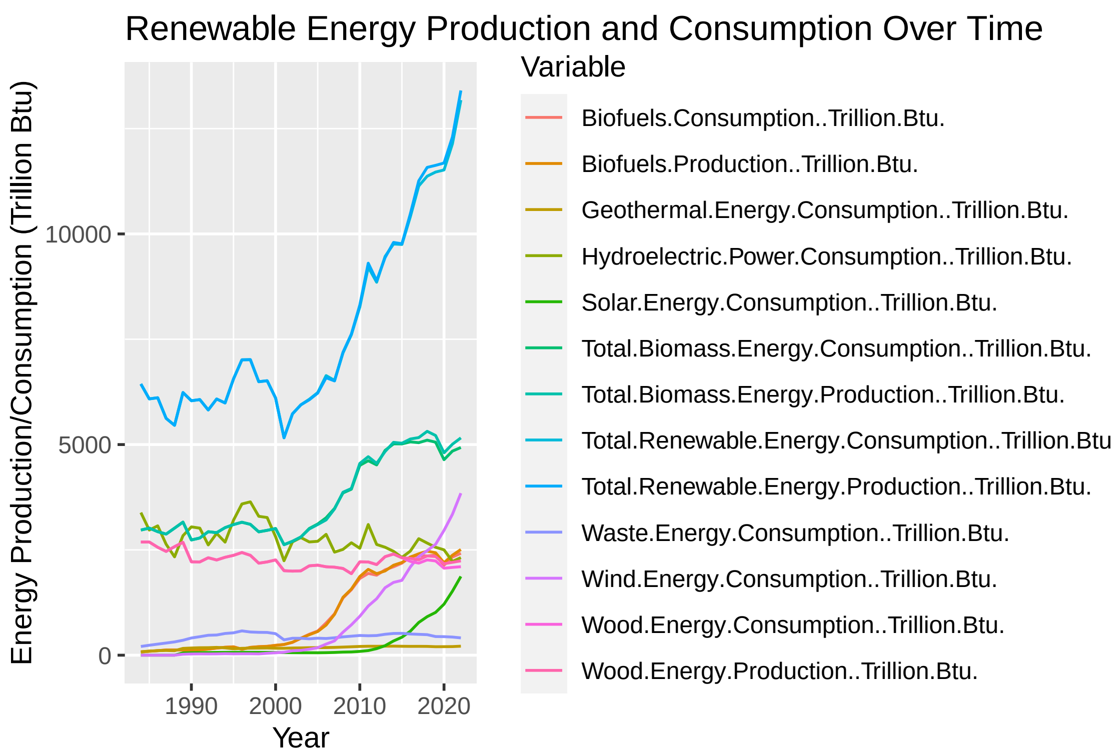
Data and Methodology

There will be a number of datasets that I will be using to analyze the effectiveness of these state-wide incentives. By analyzing the number of incentives available annually, followed by an analysis of the current state of renewable energy generation in the United States, this methodology will prove why incentives which under my hypothesis will increase renewable energy retention on the state level, which thereby reduces the cost of renewable energy production and electricity.

2.1 Energy generation and consumption data

This first dataset shows the production and consumption of different renewable energy sources in the United States. This includes: biofuels, geothermal energy, hydroelectric power, solar, biomass, waste, wind and wood.

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
## v tibble  3.1.8     v dplyr   1.1.0
## v tidyr   1.2.0     v stringr 1.4.0
## v readr   2.1.2     v forcats 0.5.1
## v purrr   1.0.1
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

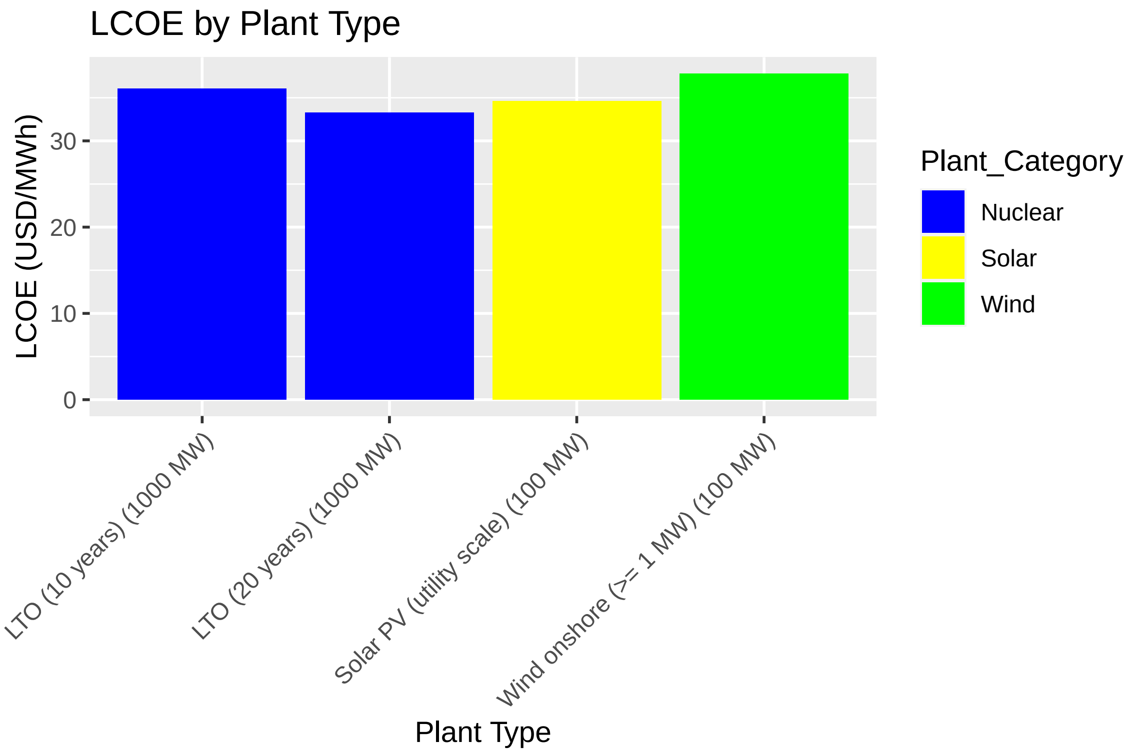


As you can see, the general trend exists that renewable energy production has increased over time. This graph represents the current energy landscape and how there is a growing culture and acceptance of renewable energy alternatives in the energy market and the production and consumption of these energy sources are increasing as well.

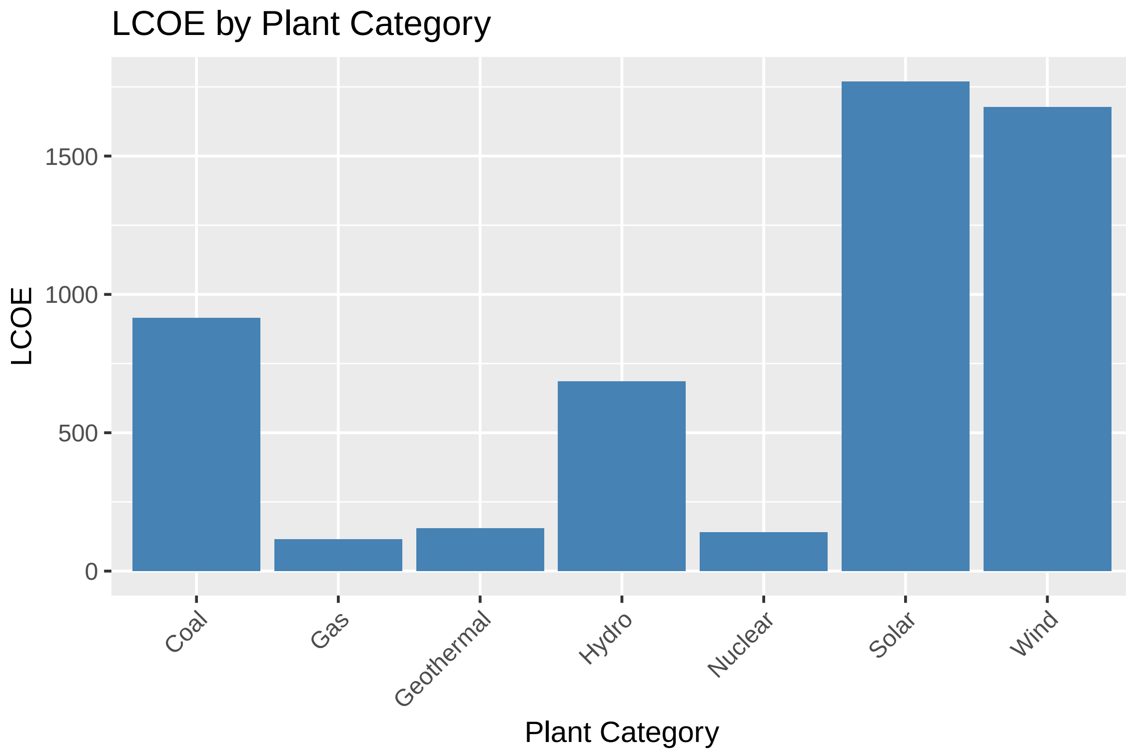
2.2 Cost data

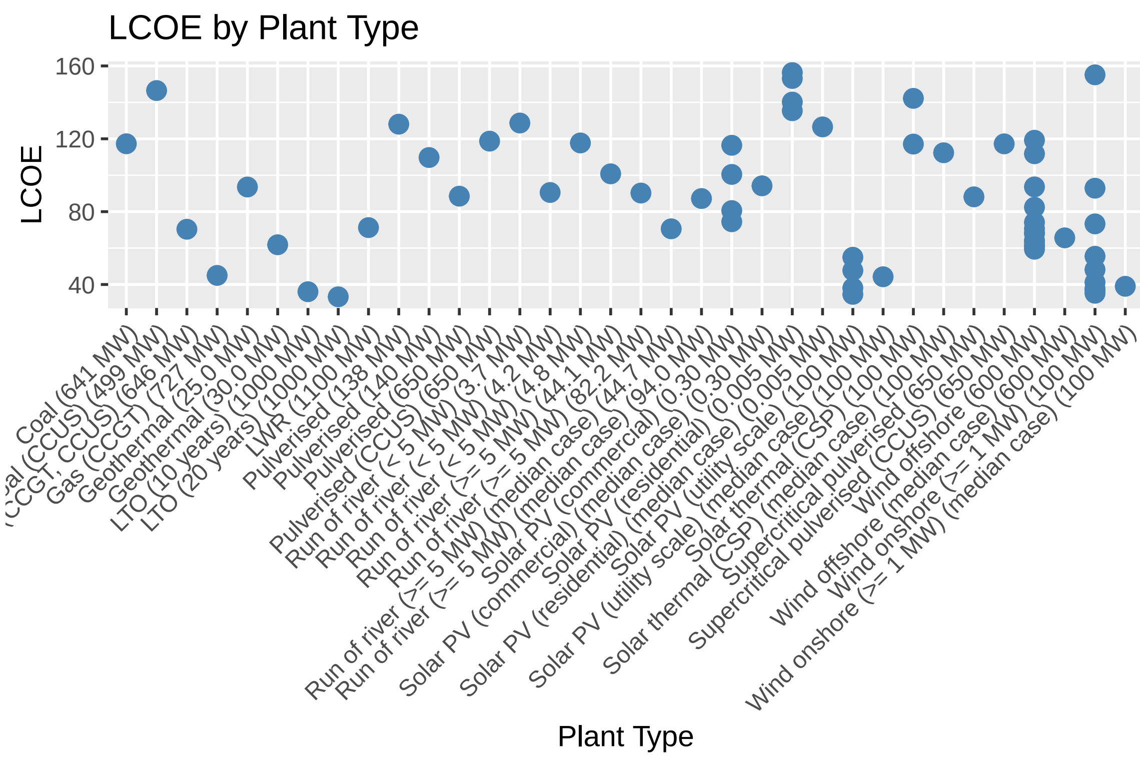
To evaluate the effectiveness of statewide incentives, we have to understand what kind of monetary relief they provide in terms of cost of electricity generation in the United States. The dataset below and subsequent graphs represent the “Levelized Cost of Electricity” (LCOE) which is a determined metric used to assess the cost of generating electricity from a particular power plant or energy source over its lifetime. LCOE is commonly used to compare the cost competitiveness of different energy generation technologies (Levelised Cost of Electricity Calculator – Data Tools - IEA, n.d.).

LCOE takes into account various factors, including the initial investment, operational and maintenance costs, fuel costs (if applicable), and the expected electricity generation over the plant’s lifetime. It represents the average cost per unit of electricity generated, usually expressed in dollars per kilowatt-hour (USD/kWh).



From the plot above, we can deduce that relative to conventional sources of energy such as nuclear, oil and gas, renewable energy sources such as solar and wind have higher LCOE prices. This can be attributed to the higher sources of maintenance costs and high capital costs that drive the price of the LCOE higher (Levelised Cost of Electricity Calculator – Data Tools - IEA, n.d.). This is conventional, in that it is widely accepted that the overall costs of producing electricity through renewable energy sources is much higher than oil and gas. However, contextually this allows us to analyze the effect of the incentive with more precision.

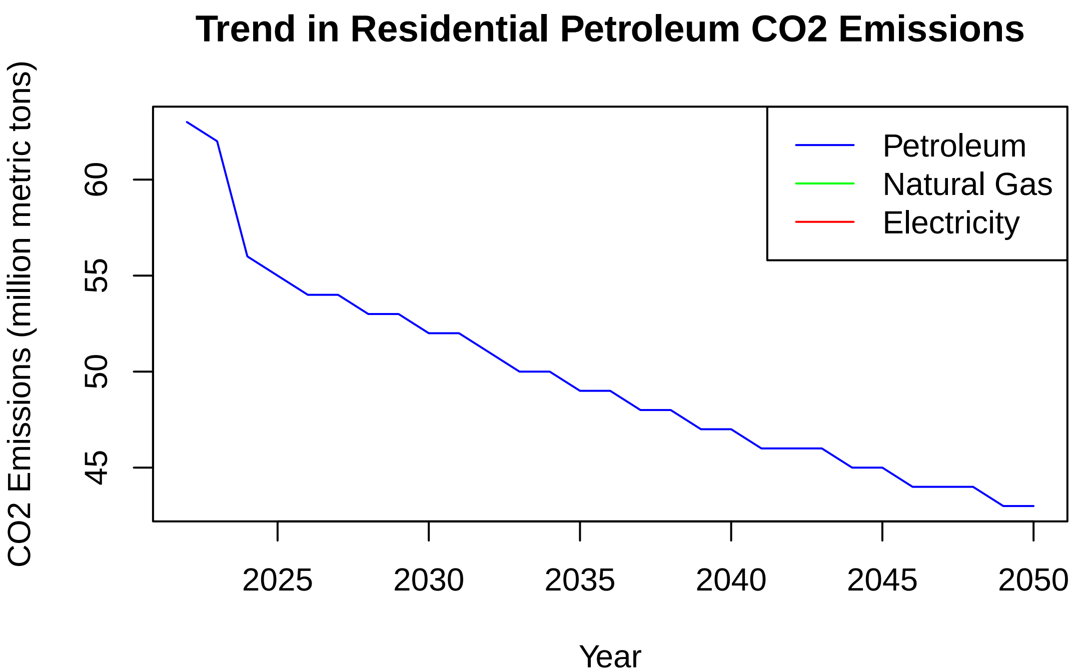


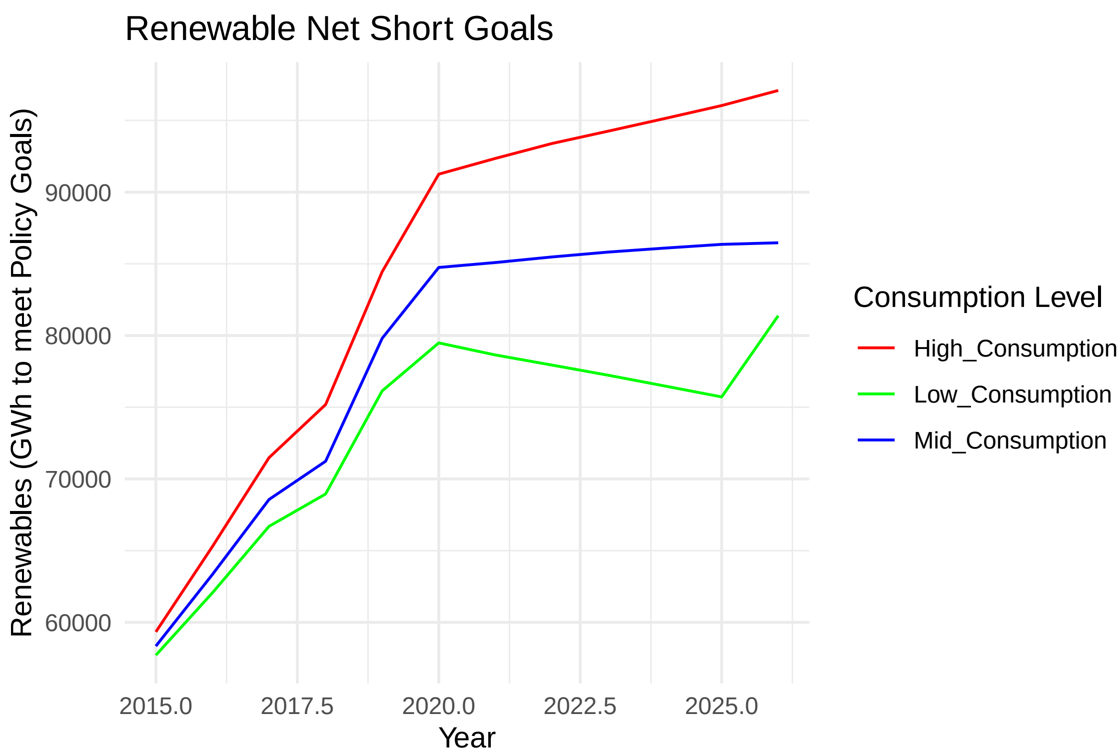


The plots above give a wider contextual understanding of the same principle of LCOE when it comes to analyzing the cost of electricity production amongst all energy types. The conclusion is the same in that the LCOE prices are relatively much higher for renewable sources of production in comparison to conventional sources of energy (Levelised Cost of Electricity Calculator – Data Tools - IEA, n.d.).

2.4 Environmental impact data

This next dataset is important in understanding policy structure and the need for implementing incentives from a government's standpoint. The incentive structures that most states have in place are generalized around their renewable net shorts which is derived from the RPS that was discussed earlier (Renewable Power Generation Costs in 2019, 2020). The dataset includes data for different years (2015-2026) and three levels of consumption (Low_Consumption, Mid_Consumption, High_Consumption). These consumption levels represent different scenarios or targets for renewable electricity generation.






```
## NULL
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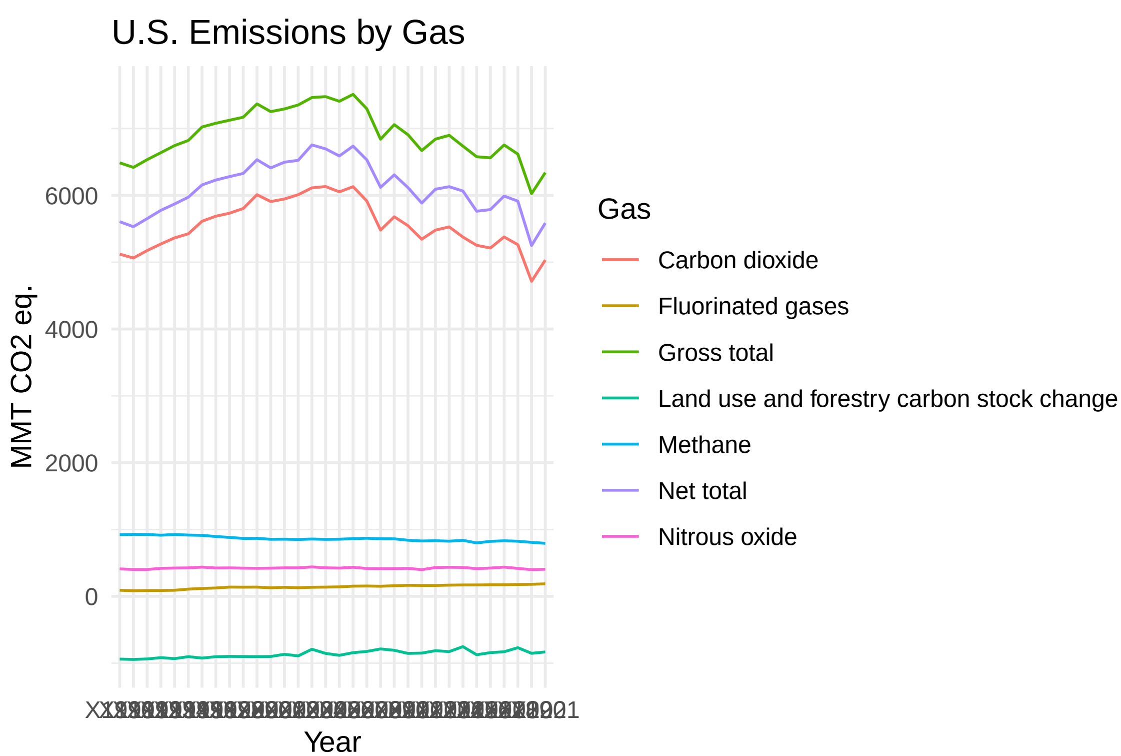


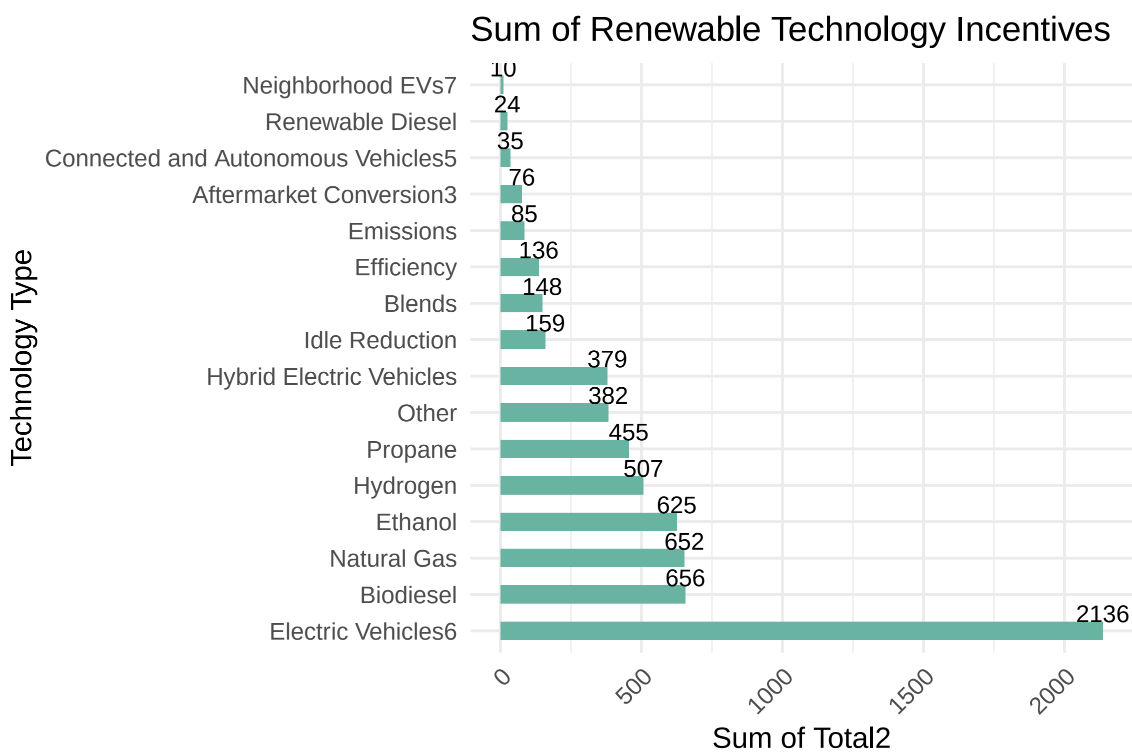
As you can see from the plots above, the general trend of greenhouse gas emissions has decreased over the years. I will be examining whether this can be attributed to the state-wide policy incentives later on in this exploration. Filtering by the most common of the greenhouse gases, carbon dioxide, we can see that its individual emissions levels have decreased over time.

2.5 Policy and incentive data

Finally, the last dataset that I will be working with includes the state-wide incentives by policy and technology type. By analyzing the sum of incentives offered by policy and fuel type we can see which incentive is most viable and cross reference this with the level of emissions over time. Additionally we can look at the level of electricity generation amongst all renewable energy sources such as what we looked at earlier and see if the implementation of these incentives create a marked difference in these categories. This dataset contains information about state incentives from 2002-2022.

The dataset did contain multiple non-numeric values and N/A's as federally some of the incentive structures were not implemented or were not registered in the dataset. In order to counter this, I filtered and removed all the possible N/A's to clean the data and to check for the sums of the incentives in each category.

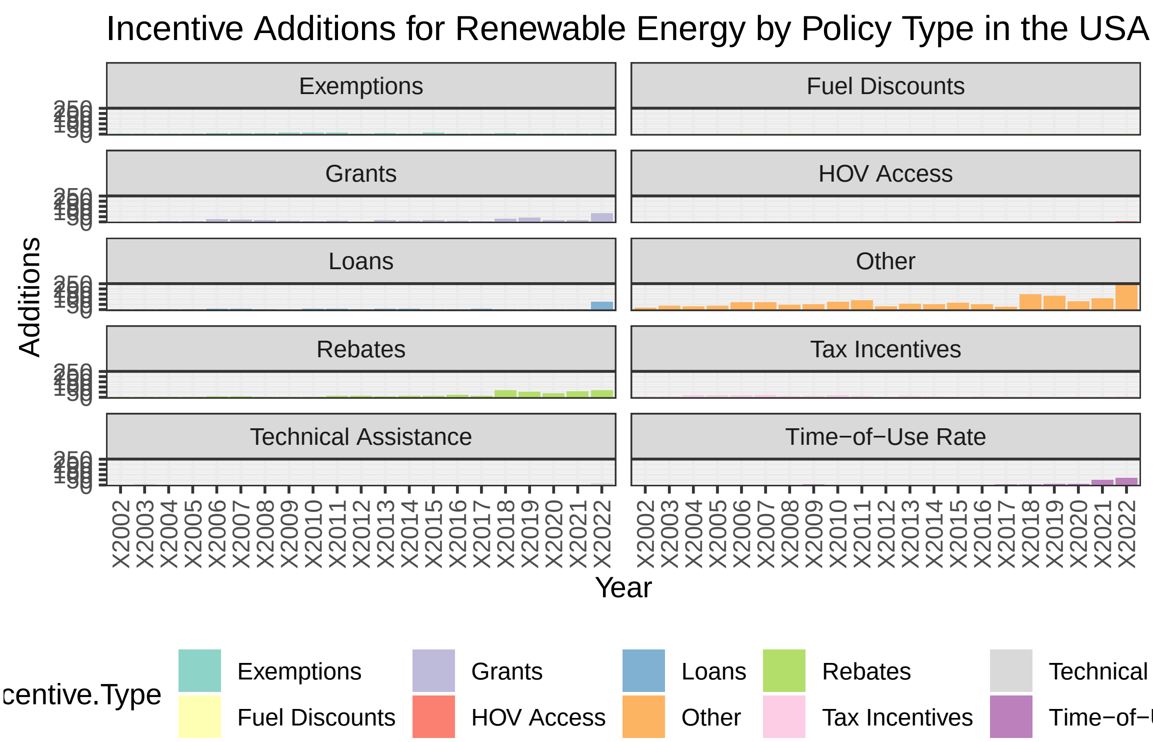
```
## `geom_smooth()` using formula = 'y ~ x'
```



The graph above shows that the largest sum of incentives are given to electric vehicles in terms of the renewable energy technology type. The general trend in the United States has been that many subsidies have been offered to many electric vehicle companies and the emergence of EV companies such as Tesla and Rivian have encouraged states to offer incentives for more production.

The figure below shows the distribution of incentives by policy type. This is important to see the change and fluctuations in incentives annually and to see where most incentives are offered. We can see that the majority of incentives are offered via grants, loans and rebates.

```
## Warning: Removed 39 rows containing missing values (`position_stack()`).
```



Analysis

To analyze the datasets that I have explored to answer the question of firstly are state-wide incentives important in increasing renewable energy generation, we need to see the correlation between the sum of incentives per year correlated with the level of greenhouse gas emissions. The initial hypothesis was that as the number of incentives increased over time, the level of emissions would decrease.

Correlation Analysis

In order to conduct this first analysis, I filtered the "techtype" dataset which contains the sums of incentives per year for the years between 2002-2022.

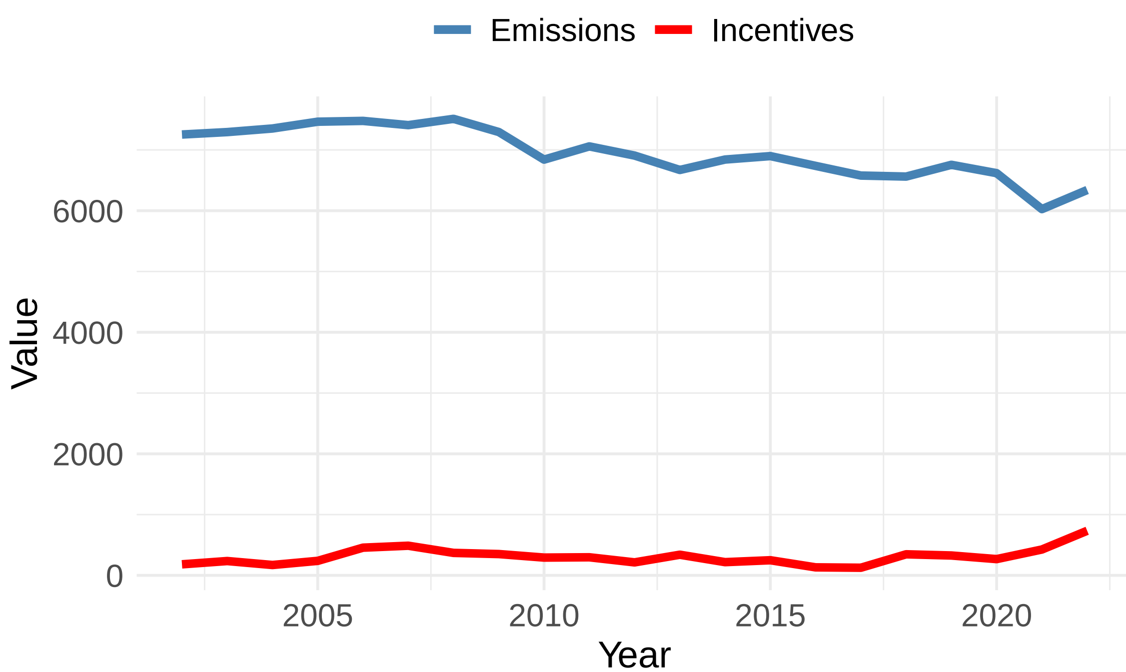
```
## Warning: NAs introduced by coercion

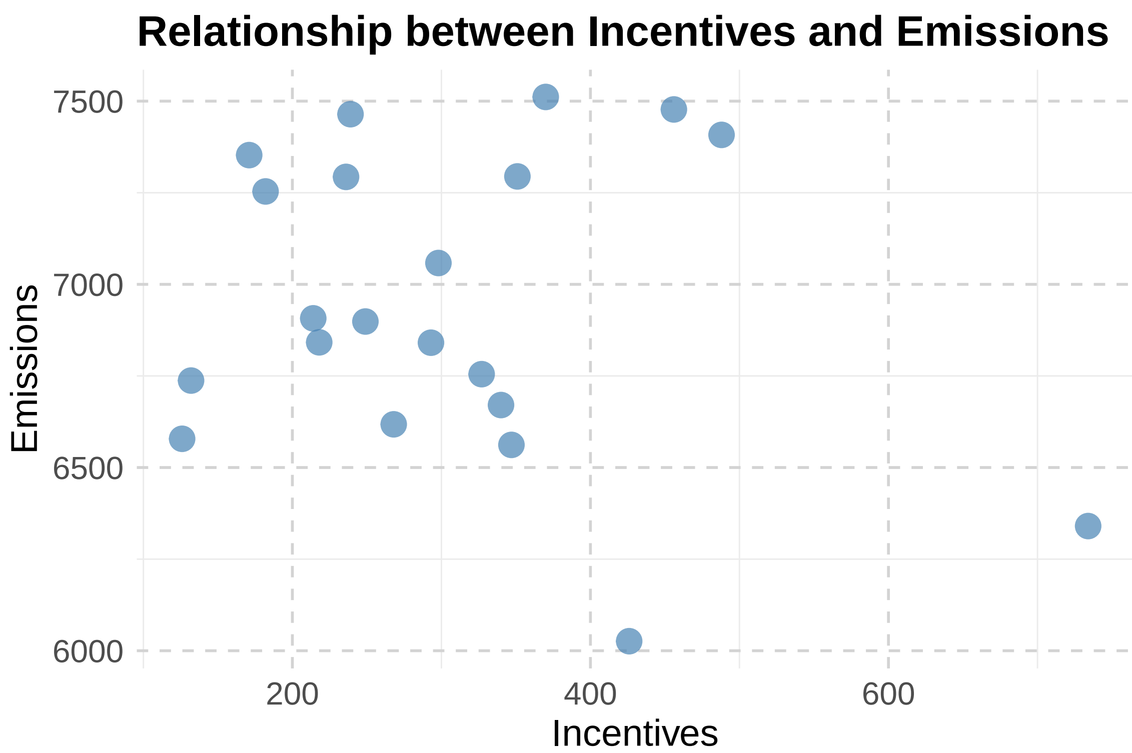
## Warning: NAs introduced by coercion

## Warning: Using 'size' aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use 'linewidth' instead.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was
## generated.
```

Incentives for Emissions Reduction

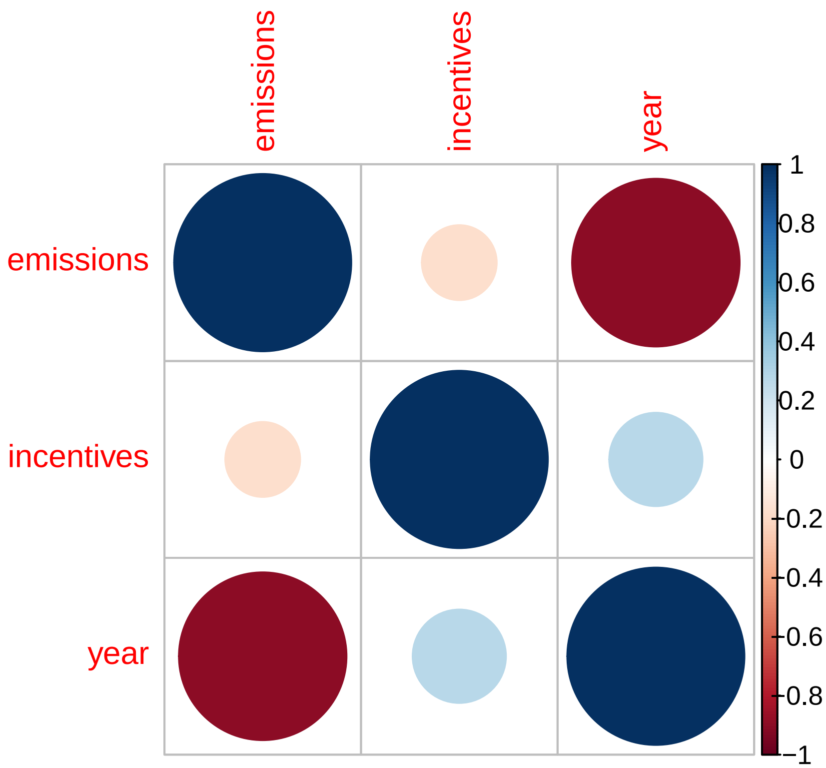
Emissions and Incentives Over Time






```
##             emissions incentives       year
## emissions   1.0000000 -0.1780852 -0.8951410
## incentives -0.1780852  1.0000000  0.2767642
## year       -0.8951410  0.2767642  1.0000000

## corrplot 0.92 loaded
```



The dataset which contains the sum of incentives per year shows that the number of incentives per year is steadily increasing. This can be attributed to the growing acceptance of renewable energy alternatives within energy markets and states are recognizing their value.

The first plot which shows the level of incentives offered yearly shows the general trajectory of the sentiment towards renewable energy incentives offered in the US. It can be deduced that the number of incentives have increased over the years with spikes in 2022.

The second plot shows the emissions and incentives side by side over time. As you can see, the value of emissions have in fact decreased as the number of incentives have increased. This can be seen in spike in the early 2020's. This concurs with the initial hypothesis that renewable energy incentives can in fact decrease greenhouse gas emissions but we cannot ascertain completely if this is the case. This could be due to the number of companies entering the market as the barriers to entry become lower with lower maintenance costs and capital costs.

The third plot also indicates that in years where the level of incentives are higher the levels of emissions are respectively lower.

The correlation matrix provided above shows that there is some correlation between the the level of emissions and the level of incentives. This can be seen by the slightly negative correlation that we can see in the correlation matrix.

Conclusion

Incentive strategies have been crucial in reducing greenhouse gas emissions by encouraging the use of renewable energy technologies and promoting energy efficiency. Financial mechanisms like feed-in tariffs, tax credits, grants, and subsidies have helped reduce the upfront costs of renewable energy projects and incentivized investments. This has led to a significant increase in the use of renewable energy sources, such as solar, wind, hydro, and geothermal power, which has reduced greenhouse gas emissions associated with power generation.

Incentive strategies have also played a significant role in promoting energy efficiency measures, such as incentives for energy-efficient appliances, buildings, and industrial processes. This has reduced energy consumption and lowered greenhouse gas emissions, particularly in sectors like transportation, industry, and buildings, which are major contributors to greenhouse gas emissions.

Despite the progress made, there are still challenges associated with incentive strategies. One challenge is the need for sustained and predictable policy frameworks to provide long-term support and stability for renewable energy investments. Additionally, the effectiveness of incentives may vary depending on factors such as the maturity of renewable energy markets, technological advancements, grid integration capabilities, and political will.

To achieve substantial emissions reductions, it is necessary to combine these incentives with comprehensive policies and strategies that address emissions across multiple sectors. A holistic approach that includes energy efficiency measures, electrification of transportation, decarbonization of industrial processes, and the development of carbon capture and storage technologies is crucial.

In conclusion, incentive strategies have played a significant role in reducing greenhouse gas emissions, but more needs to be done. The continued support and enhancement of incentive programs, along with the integration of complementary measures, will be crucial for accelerating the transition to a low-carbon economy and achieving long-term climate goals.

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