Green House Gas Emissions in Washington

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Introduction

Industrialization has been both a boon and a curse to our planet. While it has generated employment, it also has produced harmful chemicals and waste that directly impact our atmosphere, soil, and water. Despite safety laws being in place, most pollutants are disposed of without being treated in accordance with the laws, harming the environment. Thus, to take the appropriate action, it is imperative to identify the source of these emissions. This research uses data from the Washington State Department of Ecology to perform exploratory analysis and identify the main contributors to greenhouse gas emissions in Washington state. This research consists of greenhouse gas (GHG) emission trends from 2012 to 2021 and counties in Washington state with more GHG emission rates. It was observed that power plants are the main contributors to GHG emissions followed by pulp and paper, petroleum systems, and suppliers.

Renewable energy provides eco-friendly options compared to traditional fossil fuels. Unlike limited resources like coal and oil, renewable energy comes from naturally replenishing sources, lessening environmental impact and promoting lasting energy security. The shift to renewable energy is fueled by the urgent need to tackle climate change, cut down on greenhouse gas emissions, and establish a more robust and decentralized energy infrastructure. The analysis of renewable energy usage in Washington State is based on insights drawn from the Washington State Profile and Energy Estimates data. In the state, hydropower stands out as the most widely utilized form of renewable energy, whereas solar power lags with the lowest consumption. However, it's noteworthy that the consumption of solar power has seen a remarkable exponential surge since 2012.

Since power plants are the main contributors to GHG emissions and Washington state has pledged to reduce the use of fossil fuels and GHG emissions, a goal is to examine the types of fuels used to produce electricity in Washington. Plus, another goal is to investigate how the different fuel types are changing over time and what are the potential factors impacting their growth. It is important to understand why electricity produced by hydroelectric plants is decreasing and electricity produced by natural gas plants is increasing during the years from 2012 to 2021.

Methodology/ Data Preparation

This research uses greenhouse gas emissions from the Washington State Department of Ecology, and powerplant and renewable energy data from the US Energy Information Administration.

The greenhouse dataset includes data on greenhouse emissions from 2012 to 2021 and consists of 27 variables. It incorporates variables such as the name of the industry reporting emissions; the year of emission; sector classification of the emission; subsector classification of the emission; City of reporter; county of reporter; total reported emissions in metric tons of carbon dioxide equivalents; GPS coordinates of the reporter; total reported biogenic carbon dioxide, carbon dioxide, methane, nitrous oxide,

hydrofluorocarbon, perfluorocarbons, sulfur hexafluoride, and other GHG emissions in metric tons of carbon dioxide equivalents(MTCO2e).

The renewable energy data gives information on the proportion of renewable energy generated by all the states in the US. In addition to that it gives the total energy consumed (billion btu) in Washington by energy type from 2012 to 2021.

The power plant dataset includes metrics on the type of fuel the power plants were using, how much electricity each plant produced by fuel type per month and per year in megawatt hours (MWh), and the total amounts of fuel consumed at the plants. Average rainfall data for areas across Washington from 2012 to 2012 was gathered from the National Weather Service and combined to give us the average rainfall for the state over those years. To compare the power plant data, we had to make some calculated fields. One was the total electricity generated by fuel type across all power plants each year. Furthermore, we calculated the percentage change from the previous year in the electricity generated by fuel type to display how the different fuel types were changing year over year. The average rainfall was then joined together with the power plant data by year. The power plant dataset was also joined with the greenhouse gas dataset, so the emissions of the power plants could be compared based on fuel type as well.

Results (Plots)

Distribution of GHG Emissions across the Counties in Washington State

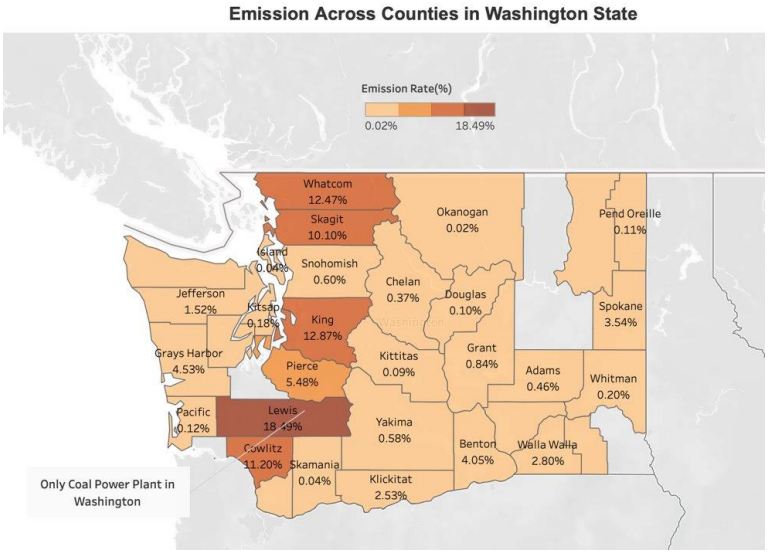

Figure 1 Tableau Link - [WA_Emission_Map]

The map illustrates the varying levels of greenhouse gas intensity across Washington state counties. Emission values are represented by color encoding, with 'orange-red' hues with bins indicating higher emissions. The choice of color aligns with the context, highlighting counties with the most emissions in red. The text encoding used in this graph makes it easy to find the emission rates in each County. This visualization aids in discerning geographical areas with elevated emission rates, particularly noting that counties near water bodies exhibit the highest greenhouse gas emissions. Lewis has the highest rate of greenhouse emissions, followed by King, Whatcom, and Cowlitz.

Sector-wise Emission Analysis

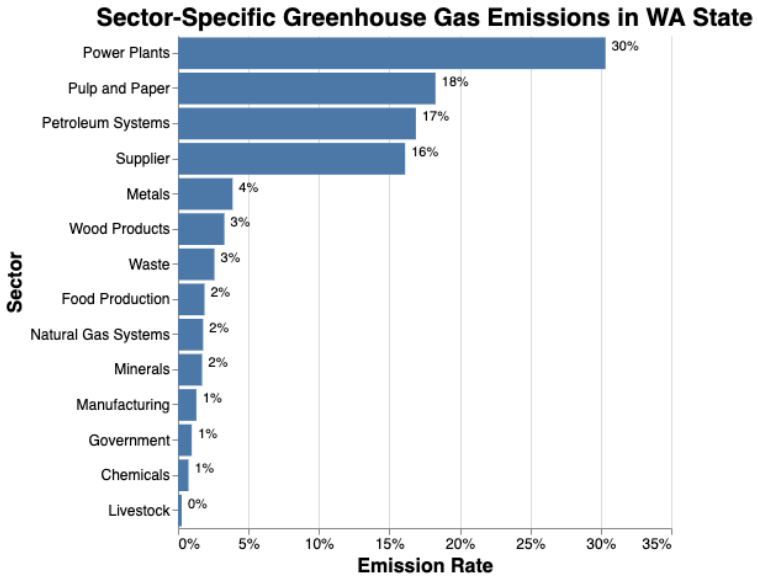

Figure 2: The emission rate for each sector was calculated by considering the total emissions in a specific sector and the total emissions in all the sectors

The sectors that contribute the most to greenhouse gas emissions were visualized using a bar graph. In this plot, the variables in the order of importance are the "Emission Rate" and "Sector". The quantitative variable "Emission Rate" and the nominal variable "Sector" are prioritized and given x and y position encodings, respectively. The text encoding used in this graph makes it easy to find the percentage of emissions contributed by each sector. It can be observed that "Power Plants" are the main contributors to greenhouse gas emissions followed by "Pulp and Paper", "Petroleum Systems", and "Suppliers".

Greenhouse gas emission trend over time

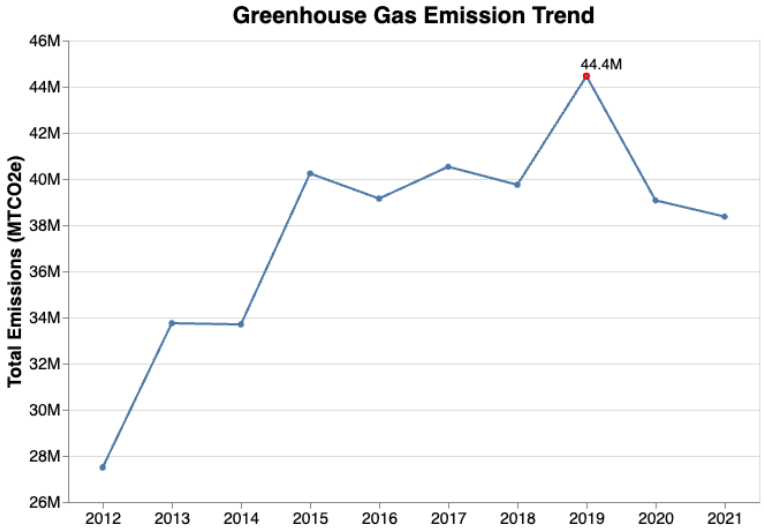

Figure 3. The graph contains the aggregated value from the overall county-level data of Washington State for 14 different Industrial sectors

A line graph was used to understand the greenhouse gas emission trend from 2012 to 2021. In this plot, the variables in the order of importance are the “Year” and “Total Emissions (MTCO2e)”. The x and y position encodings are given to the quantitative variables “Year” and “Total Emissions (MTCO2e)”, based on their priority. The Y-axis represents the total emissions in metric tons of CO2 equivalents. It can be observed that the emissions have increased by 61% from 2012 – 2019, before declining to approximately 38.1M metric tons of CO2 equivalents in 2021.

Total Emission Trend in Top 5 Sectors

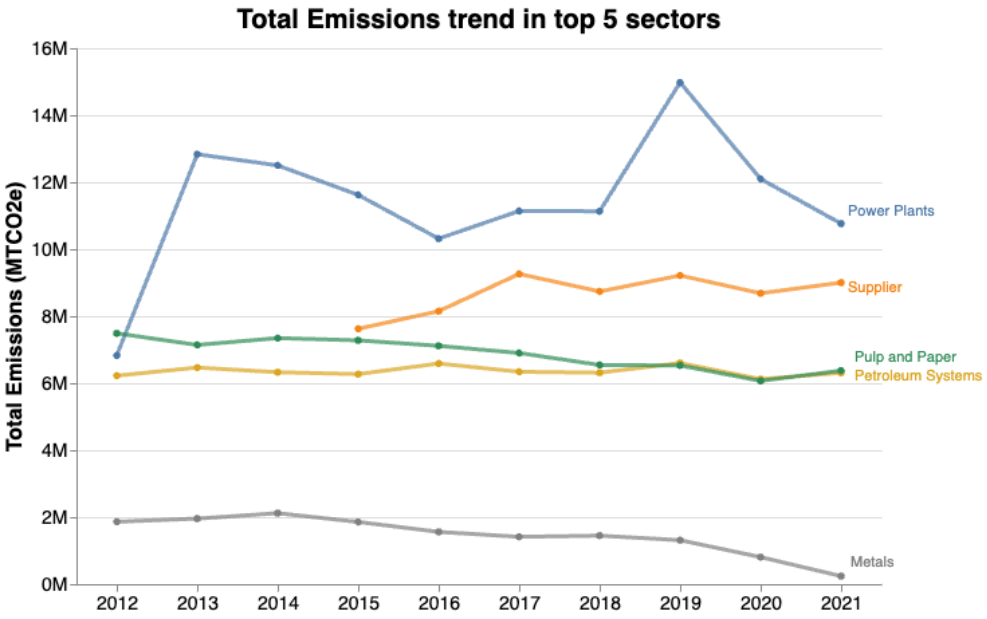

Figure 4 . There are 14 different sectors in the data, while the sector with the highest emission is plotted. The fluctuation in the power plant trend is due to the type of fuel used by the sector over the years.

The trend lines for total emissions in the top 5 sectors with the highest emissions from 2012 to 2021 were visualized using a multi-line graph. The variables in the order of importance are “Year” and “Total Emissions (MTCO2e)”. The Nominal variable “Year” and the quantitative variable “Total Emissions (MTCO2e)” are prioritized and given x and y position encodings respectively. The Y-axis represents the total emissions in metric tons of CO2 equivalents. There are 14 categories for the nominal variable “Sector”, but only the top 5 sectors i.e., Power Plants, Supplier, Pulp and Paper, Petroleum Systems, and Metals with the highest emissions were considered for the analysis. Therefore, the “Sector” variable is least prioritized and is encoded using a color channel. It can be seen that “Power Plants” are the major contributors to emissions followed by Suppliers, and Pulp and Paper. It can be observed that the emissions from power plants increased between 2012-2018 and peaked in 2019, and declined in 2020 and 2021, potentially due to COVID-19. While emission trends of the Supplier, Pulp and Paper, and Petroleum Systems sectors remain consistent, the emissions from Metals tend to decline over the last decade.

Emissions by Gas Type

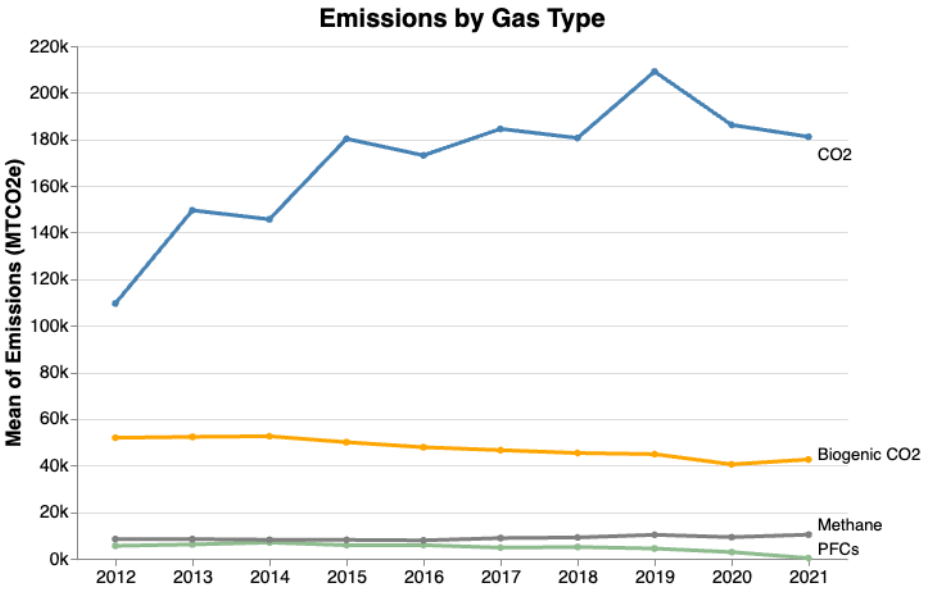

Figure 5: The concentration of different gases in the atmosphere is primarily due to the combustion of fuel by type. Coal is recorded to produce the highest emission of greenhouse gases

A multi-line graph was used to display the trend lines for greenhouse emissions by gas from 2012 to 2021. Year" and "Mean of Emissions (MTCO2e)" are variables in order of importance. Prioritized x and y position encodings are assigned to the quantitative variable "Mean of Emissions (MTCO2e)" and the nominal variable "Year". The Y-axis represents the mean of the emissions in metric tons of CO2 equivalents. The gases CO2, Biogenic CO2, Methane, and PFCs are least prioritized and are encoded using a color channel. Therefore, each gas has a unique color. It can be seen that CO2 emissions are significantly higher in WA compared to the other gases. Over the last decade, it can be observed that CO2 emissions have increased by approximately 80%. While the emissions of Biogenic CO2, methane, and PFCs remain consistent.

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The Surge of Renewable Energy in the United States

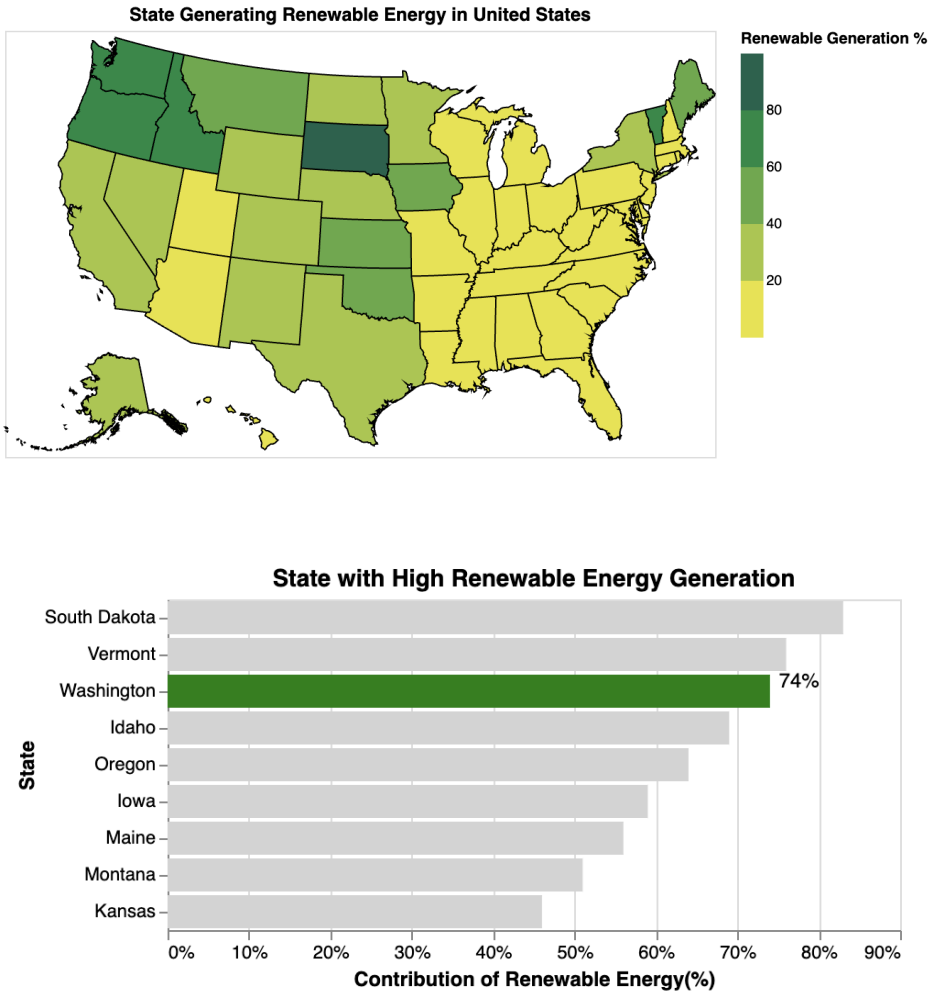

Figure 6: South Dakota Ranks 1, Washington Ranks 3 and Burlington City, VT use 100% renewable energy

The map shows the percentage of renewable energy produced by every state in the US. The percentage of energy generated is represented by color encoding, with 'yellow green' hues with bins to highlight the state with the highest generation of renewable energy. The choice of color aligns with the context, highlighting states with the most renewable energy generation in green. This visualization aids in understanding the geographical areas with more energy generation. Washington ranks number 3 among all other states in the US and in addition to that most of the energy generated is hydroelectric power. The map is supported by a bar chart to highlight the position of Washington state with state names along the y-axis for readability and Renewable energy generation along the y-axis. The bars of Washington state are highlighted to show that the state uses 74% of renewable energy.

Renewable Energy Consumption

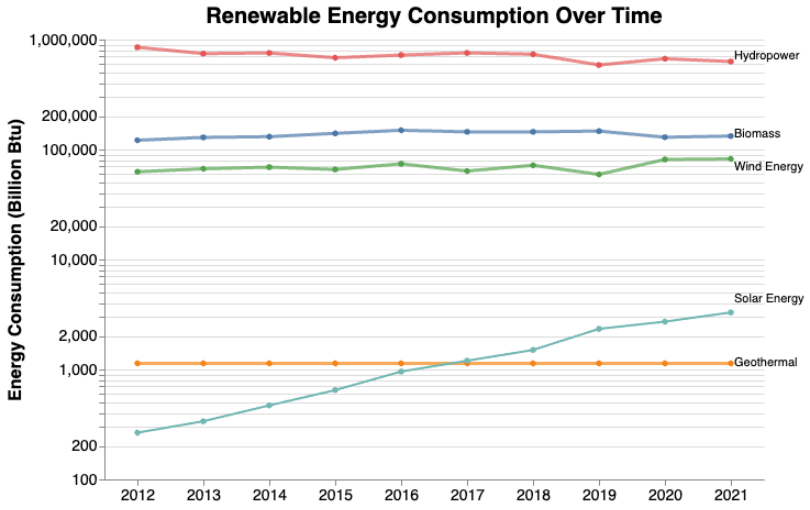

Figure 7: Hydroelectric power primarily depends on the rainfall in the state, a drop in the consumption of energy in the year 2019 is seen

To see the trend in different renewable energy usage in Washington state between the years 2012 to 2021, a multi-line chart is the best design of choice to investigate the dips and spikes. The energy consumption in Billion btu units is taken along the y-positional with logarithmic transformation encoding and the years along the x-positional encoding. The type of energy is double encoded with color and text to improve the effectiveness and accessibility of the plot. Hydropower is the most consumed energy in the state. For the year 2019, there is a slight dip in hydropower and wind energy, while solar power has drastically increased in 2019.

Power Plant Analysis

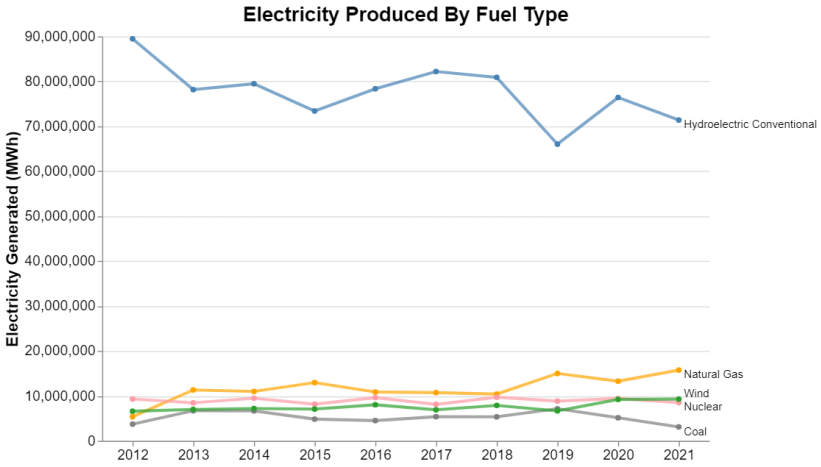

Figure 8: Total electricity generated per year for the top 5 fuel types used by Power Plants in Washington state between 2012 and 2021. The electricity generated is represented in Megawatt hours.

This line chart is used to display the amount of electricity produced by the top 5 fuel types used by power plants each year. The amount of electricity generated is a quantitative variable and the most important for comparing the fuel types, so it has been placed on the Y axis. Year, which is a nominal variable, was

put along the X-axis so the data could be easily read from left to right. Then the colors and a text label were used to represent the fuel type, which is categorical. The legend was hidden because it wasn't necessary with the text label added.

This chart shows that hydroelectric power produces the most electricity compared to any other fuel type, with over 70,000,000 Megawatt hours (MWh) produced in 2021. There is a large gap until the next fuel type, which is natural gas. Natural gas appears to have increased quite a lot over time and produced approximately 15,000,000 MWh in 2021. Another detail the graph shows is that hydroelectric power is decreasing and has large spikes or dips in the amount of electricity generated, while natural gas is increasing. This is interesting for a state that is committed to using fewer fossil fuels. So, this relationship needs to be investigated further.

How are Hydroelectric and Natural Gas Impacted by Rainfall?

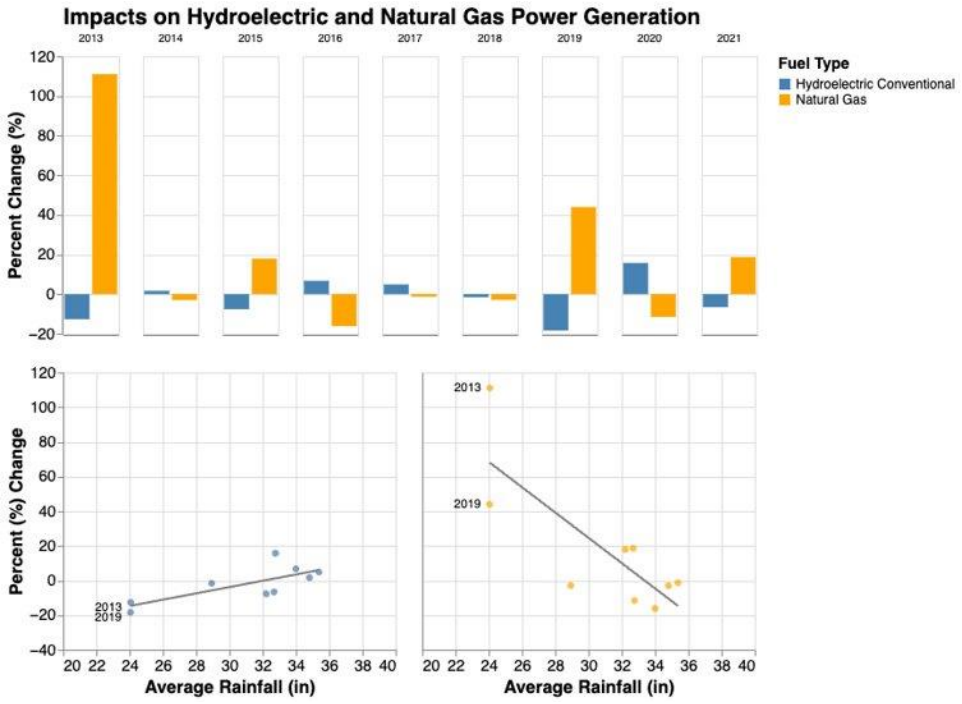

Figure 9: The percentage of change is based on the difference between the electricity generated between the current year and the previous year. This value was then compared against the average rainfall.

To compare the details of the two most used fuel types, a bar graph of the percentage change from the previous year was paired with scatter plots of the increases based on average precipitation. Both sets of charts use position to display the percentage change variable. The top set of graphs uses bars because there is only one quantitative variable being measured over the year. The type of fuel used is encoded using colors that match the fuel type features. A blue color was for hydroelectric because of its use of water and an orange color was used for encoding natural gas because it is burned. The bottom set of graphs measures two quantitative variables, so it uses a scatter plot along with a regression line to display the relationship between percentage change and average rainfall.

Since hydroelectric and natural gas were the two most used fuel types for producing electricity, a plot was created to compare their different properties. The percentage change from the previous year shows an interesting relationship between the two fuels. The percentages for the two appear to alternate between positive and negative growth based on the opposite of the other fuel type. For example, hydroelectric had negative growth in 2013, positive growth in 2014, and negative growth in 2015, while natural gas had positive growth in 2013, negative growth in 2014, and growth in 2015. The growth between each fuel type is the opposite for all years except for 2018. In 2018, both had slightly negative growth.

This introduced a new question about this relationship, why is Washington state appearing to use more fossil fuels to produce electricity? Part of the answer is that lack of rainfall reduces the amount of electricity hydroelectric power plants can generate. The two years with the lowest average rainfall were 2013 and 2019, which resulted in a –12.64% percent and a –18.39% percent decrease in hydroelectric generated power from the previous year. During those same years, natural gas increased by 111% and 43% over the previous year. When matching the percentage growth against average yearly rainfall, two relationships can be seen. When average rainfall increases, hydroelectric electricity production tends to increase. When average rainfall decreases, then natural gas electricity production generally tends to increase. The state appears to be supplementing the electric grid with natural gas power.

Power Plants Increasing Use of Renewable Energy

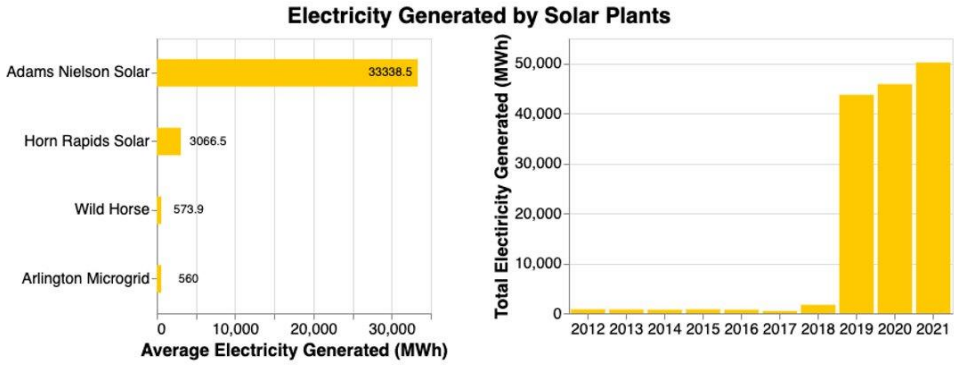

Figure 10: The average megawatts per hour was calculated for the 4 solar plants in Washington and compared with the annual electricity produced.

This bar chart was used to communicate how solar electricity generation has increased quite dramatically. The percent change on the Y axis versus the year on the X axis makes it easy to compare how much solar energy has increased. Also, the graph was encoded with a yellowish color to represent solar power. Also, text encoding was used to display the average value of electricity generated due to some of the very small values by the other power plants.

Electricity produced by solar farms has drastically increased between 2012 and 2021 in Washington state. Solar power was not generating more than 2,000 MWh between 2012 and 2018, and then solar farms began generating over 40,000 MWh of electricity in 2019, 2020, and 2021. The reason behind this large increase was the opening of the Adams-Nielson Solar Power Generation Plant at the end of the 2018 year, which is generating on average at least 33000 MWh per year.

Conclusions

According to the findings of this research, power plants are the main contributors to the emission of greenhouse gases. From 2012 to 2019, the emissions trend increased dramatically, reaching a peak of 44.4 million metric tons of CO2 equivalents. After that, the emission trend tends to decline in 2020 and 2022. This decrease in the emission rate could be due to the shutdown of industries due to COVID-19 during this time. Lewis County has the highest emission rate compared to all the other counties. This may be because the only coal power plant in Washington state is located in Lewis. It was observed that the percentage of CO2 in the emission was very high compared to the other gas emissions.

The production of renewable energy across states is visualized and Washington state ranks number 3 among other states by producing 74% of power from renewable energy sources. While observing the trends in the different energy sources used by Washington to produce electricity, key relationships were identified. Between 2012 and 2021, electricity from Hydroelectric power plants decreased. This appears to be partially due to decreases in average rainfall in the state for certain years. Consequently, the use of natural gas to produce electricity is increasing in a state that has pledged to reduce the use of fossil fuels and greenhouse gas emissions. However, when analyzing renewable energy used by power plants, electricity production was identified as increasing for solar. Solar power has increased from less than 800 MWh in 2012 to over 50,000 MWh in 2021 mainly due to the opening of the Adams Nielson Solar plant. To decrease the emissions, Washington should increase the amount of renewable energy plants that aren't impacted by rainfall.

Improvements to the analysis could be made by considering data from more greenhouse gas emissions, such as transportation emissions. In addition, when comparing electric generation for the power plants, it could be enhanced by pulling average rainfall for the cities that the plants are in, instead of using the whole average rainfall for Washington state.

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