Module 6: Final Project Report

An analysis of electric vehicle adoption patterns and factors in Washington State

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ALY6110 | Data Management and Big Data

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Introduce the real-world problem that can be solved with big data

The adoption of electric vehicles (EVs) is a critical step towards reducing greenhouse gas emissions and promoting sustainable transportation solutions. However, the widespread adoption of EVs presents several challenges, including infrastructure planning, consumer behavior analysis, and energy management. The "Electric Vehicle Population Data" provides a valuable opportunity to leverage big data techniques for addressing these challenges.

As the adoption of EVs increases, various stakeholders, including governments, urban planners, automakers, and energy providers, require insights into key aspects such as the geographic distribution of EVs, charging patterns, battery performance, etc. For example, efficient deployment of charging stations is crucial for the convenience and adoption of EVs. Big data analytics can help identify optimal locations for charging stations based on factors like EV adoption population, model preferences, and…. Furthermore, under other circumstances, understanding how users interact with EVs is vital for market expansion. Analyzing data on EV customer behaviors, charging times, and distances traveled can provide insights into user preferences, informing marketing strategies and future product developments.

We can utilize big data to stream, aggregate, analyze, and visualize the insights, in this case, publishing on the government website for all stakeholders and consumers to interact with.

The dataset selected, including a reason for selecting the data

Electric Vehicle Population Dataset is sourced from the official website of government data. “This dataset shows the Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) that are currently registered through Washington State Department of Licensing (DOL).”

Electric vehicle adoption in Washington State has already achieved remarkable heights, ranking among the top in the nation with approximately 17,140 registrations as of November 2021. Data from EVadoption.com reveals that the state accumulated an impressive 80,397 electric vehicles between 2011 and September 2021, positioning it as the fourth highest in the country. Also, "Washington has only recently joined California's Advanced Clean Cars II rules, aiming to make all new cars electric by 2030." Washington State remains steadfastly committed to its journey towards a fully electric future for transportation.

In summary, the dataset consists of 139K rows and 17 columns. Each row is a record of a registered vehicle.

```
# Source: spark<?> [?? x 17]
  VIN_110 County City  State Posta…¹ Model…² Make  Model Elect…³ Clean…⁴ Elect…⁵
  <chr>   <chr>  <chr> <chr>   <int>   <int> <chr> <chr> <chr>   <chr>     <int>
1 1N4AZ0… Kitsap Brem… WA      98310    2013 NISS… LEAF  Batter… Clean …      75
2 1N4AZ1… Kitsap Port… WA      98366    2019 NISS… LEAF  Batter… Clean …     150
3 5YJXCA… King   Seat… WA      98199    2020 TESLA MODE… Batter… Clean …     293
4 SADHC2… Thurs… Olym… WA      98503    2019 JAGU… I-PA… Batter… Clean …     234
5 JN1AZ0… Snoho… Ever… WA      98204    2011 NISS… LEAF  Batter… Clean …      73
6 1G1RB6… Yakima Selah WA      98942    2018 CHEV… VOLT  Plug-i… Clean …      53
# … with 6 more variables: Base_MSRP <int>, Legislative_District <int>,
#   DOL_Vehicle_ID <int>, Vehicle_Location <chr>, Electric_Utility <chr>,
#   `2020_Census_Tract` <dbl>, and abbreviated variable names ¹Postal_Code,
#   ²Model_Year, ³Electric_Vehicle_Type,
#   ⁴Clean_Alternative_Fuel_Vehicle_CAFV_Eligibility, ⁵Electric_Range
```

After dropping some identifiers and unused columns, I have some key variables to look at:

- 'County': Where the car owner lives.
- 'Model Year': When the car was made.
- 'Make': Car brand.
- 'Model': Specific car type
- 'Electric Vehicle Type': Fully electric or partly electric
- 'Clean Alternative Fuel Vehicle Eligibility': If it's eligible for green incentives

- ‘Electric Range’: How far it can go on electric-only power (miles)
- ‘Base MSRP’: The basic retail price recommended by manufacturers

In the next step of data preprocessing, I changed the column name of ‘Clean_Alternative_Fuel_Vehicle_CAFV_Eligibility’ into a shorten name, filtered the ‘state’ column with only ‘WA’ records (since there is a small number of other states), and filtered out the 2024 data year. After checking on the ‘Electric_Range’ and Base_MSRP’ columns, I observed the lack of data in both of columns. A majority of the base cost column shows zero values, while almost half of the ‘Electric_Range’ values are zero, where the electric range has not been researched. Therefore, I decided to drop out the ‘Base_MSRP’ column and still keep the ‘Electric_Range’ column for calculating the mean electric range for vehicle models.

```
%r
# change one column to a short name
df <- df |> select(CAFV_Eligibility = Clean_Alternative_Fuel_Vehicle_CAFV_Eligibility,
everything())
```

```
%r
# filter WA state only
table(df$State) # have a small number of other states
df <- df |> filter(State == 'WA')
```

```
%r
# remove the year 2024 data out
df <- df |> filter(Model_Year != '2024')
```

```
%r
# What's the range of 'Base_MSRP' values?
ggplot(df, aes(x = Base_MSRP)) +
  geom_histogram()
  # A huge number of '0' values

# drop this column
df <- df |> select(-Base_MSRP)
```

```
%r
# What's the range of 'Electric_Range' values?
ggplot(df, aes(x = Electric_Range)) +
  geom_histogram()
  # Electric Range is no longer maintained for Battery Electric Vehicles (BEV) because new BEVs have an electric range of 30 miles or more. Zero (0) will be entered where the
electric range has not been researched
```

The methodology used to analyze the data

In this big data analysis, the methodologies encompass data preprocessing, exploratory analysis, statistical analysis, and visualization. I utilized Sparklyr, R packages, and databricks cloud cluster processing.

Business questions and Results of the analysis

1. Where are EVs more popular?

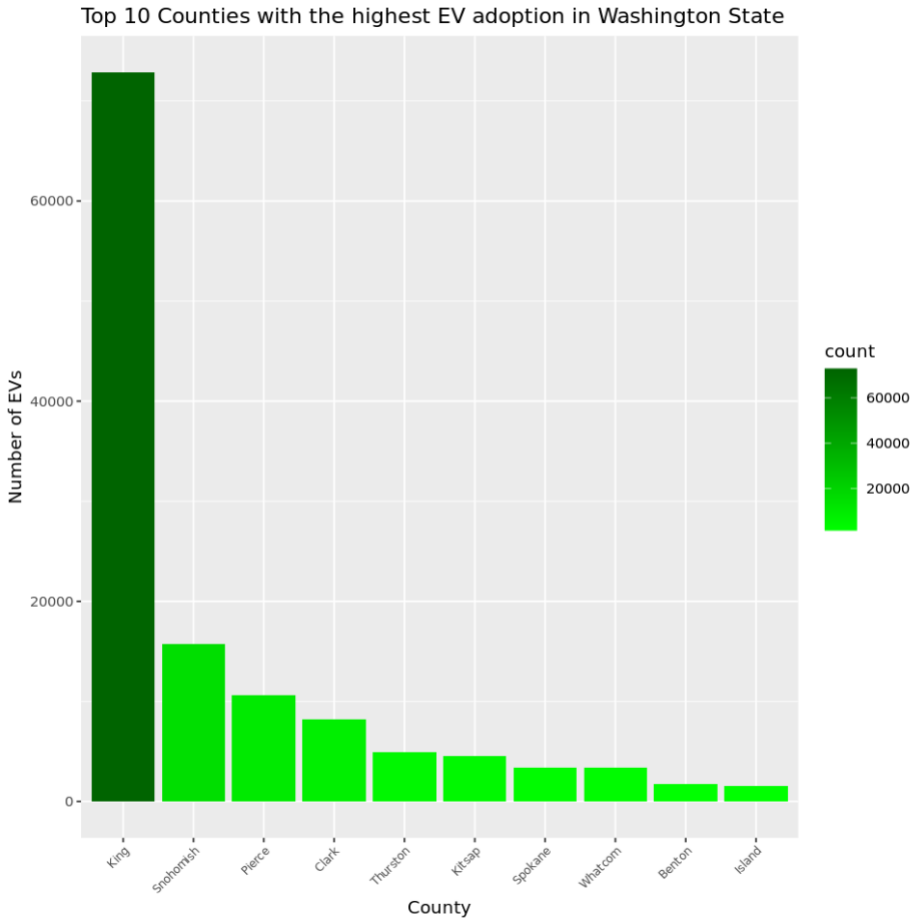

Figure 1: Top 10 Counties with the highest EV adoption in WA

The findings of this question would reveal the EVs population density patterns that assist in charging infrastructure, customer services centers, marketing strategies, and EV incentives. Looking at Figure 1, King County stands out with the largest number of electric vehicles (over half of the records with more than 70,000 vehicles), significantly exceeding the counts in other counties. If instead, the number of EVs per 1000 people is examined, we can have a better understanding of the adoption density compared to the counties' population. From another source of Washington State Standard, I have the map below (Figure 2) showing EV registrations

per 1,000 people in each Washington county updated till May 10, 2023. So, there's a little more nuance to consider. The data continues to highlight King County as having the highest rate of EV registrations per 1,000 people. Given its significant prominence, energy providers and manufacturers might want to pay particular attention to this county, aptly named 'King'.

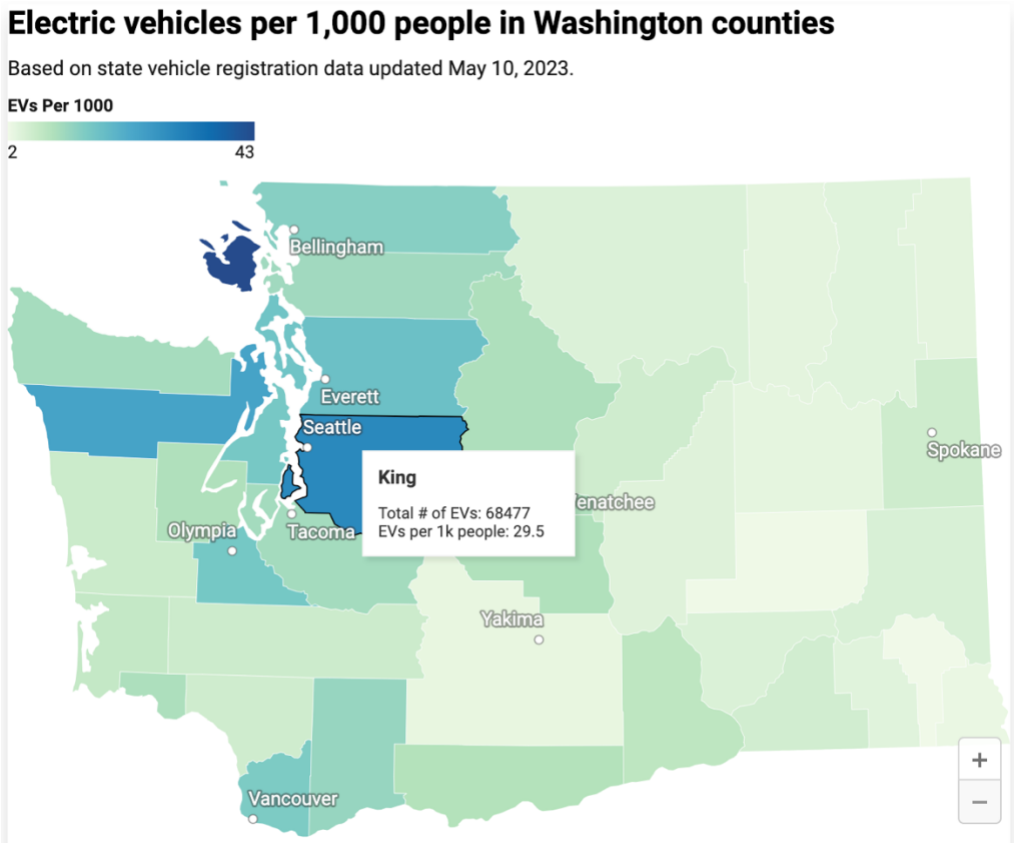

Figure 2: Sourced from Washington State Standard

2. Which manufacturers are preferred in Washington State?

Figure 3 presents the market share of brands in the Washington State, not surprisingly, Tesla tops the list and is far ahead of other competitors. The color gradient is filled based on their mean electric range. We can see that the top 3 most popular brands: Tesla, Nissan, and Chevrolet are also in the group having the highest mean electric range. Kia, BMW, and Volkswagen are also quite impressive in their mean electric range.

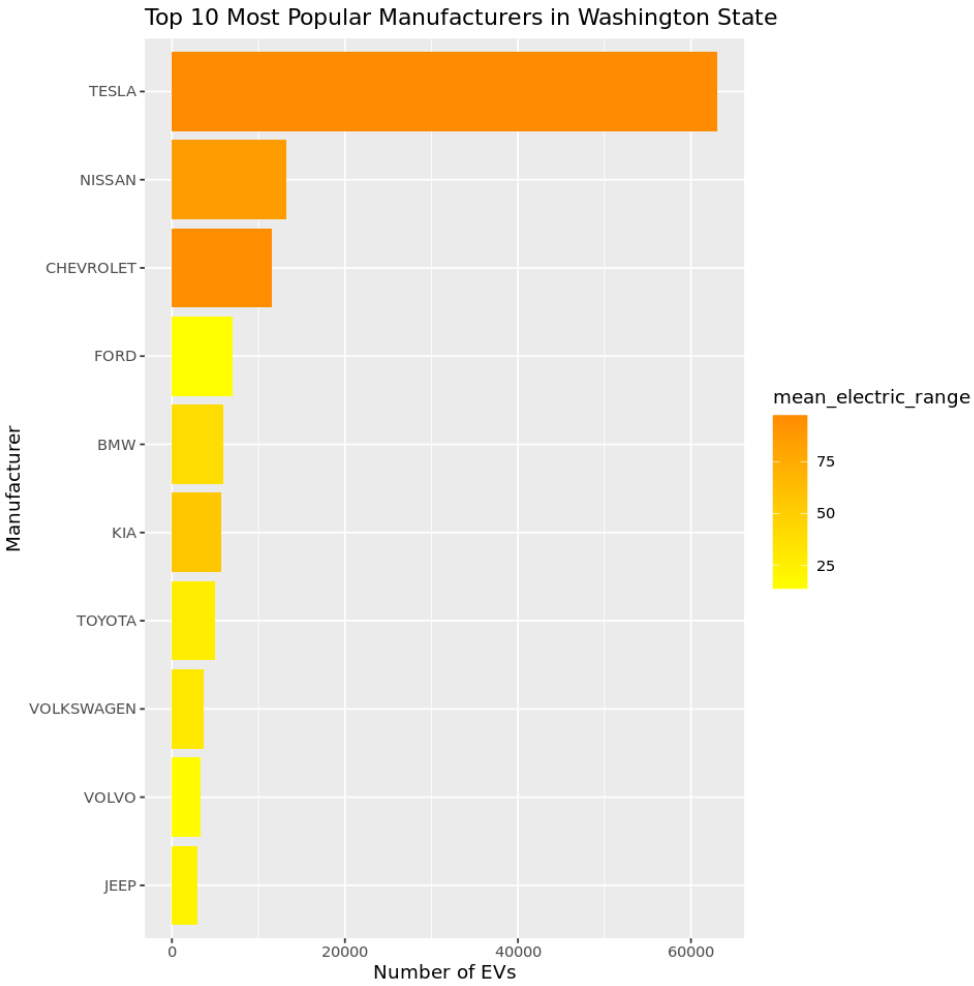

Figure 3: Top 10 Most Popular Manufacturers in WA

3. Top 10 Models and Their Manufacturers

To dive deeper into customer preferences, the following graph (Figure 4) reveals which EV models are the most preferred models in Washington state. Model 3 and Model Y from Tesla are at the top of the list, followed by LEAF model from Nissan. Tesla's models account for almost haft of the list, followed by the Chevrolet brand, which has two models in this list.

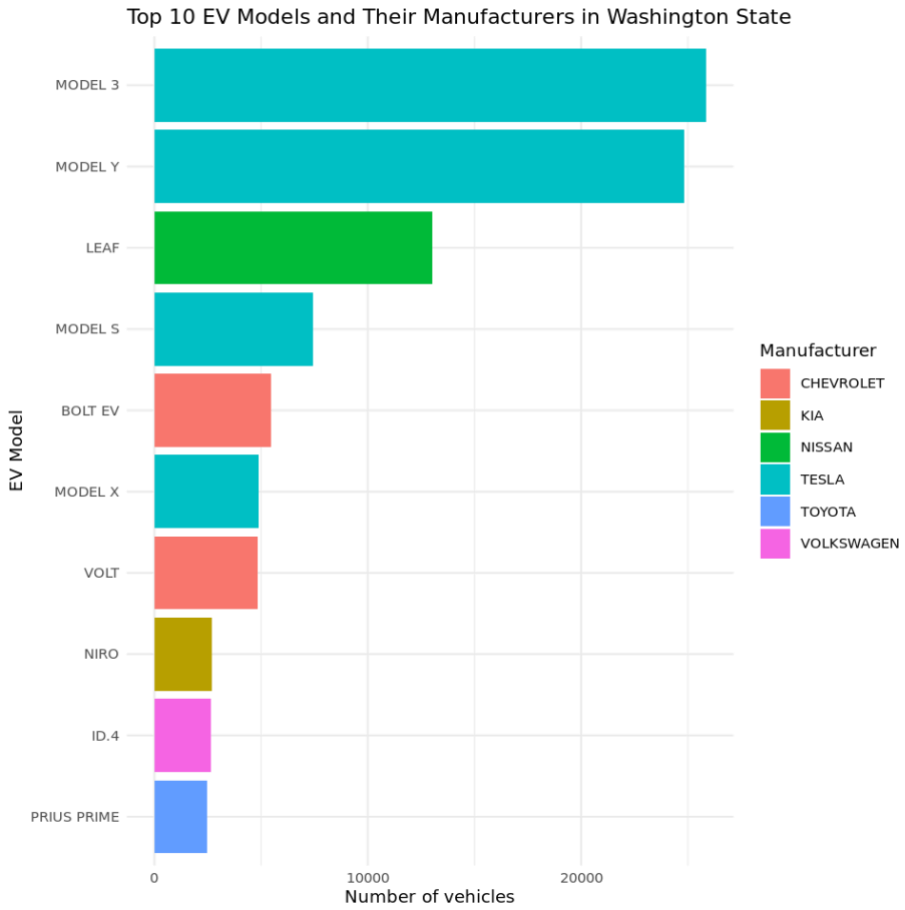

Figure 4: Top 10 EV Models in WA

These preferences signal consumers' affinity for high-performance electric vehicles with advanced features. One big reason why Tesla is so popular is because of this company's diversity and familiarity with its electric vehicle lineup. In 2022, Tesla had four electric cars available, which was more than any other company.

4. Distribution of EVs Model Year from 2011 to 2023

We first look at the frequency table of the 'Model_Year' column. There are small records of model years from 1997 to 2010 (below 25 vehicles per year). So, I filter out rows with Model Years from 1997 to 2010 before plotting the line graph of EV Model Year distribution.

```
%r
table(df$Model_Year) # small records of Model Year from 1997 to 2010
```

```
 1997  1998  1999  2000  2002  2003  2008  2010  2011  2012  2013  2014  2015
    1     1     4     9     2     1    18    24   786  1648  4561  3566  4905
 2016  2017  2018  2019  2020  2021  2022  2023
 5643  8538 14339 10482 11024 18187 27634 26967
```

There was a sharp increase in the number of registered EVs from 2016 to 2018, a downtrend in 2019 and 2020, and subsequently a vertical increase in 2021 and 2022. The data for 2023 is not enough so far so we should not talk about it here.

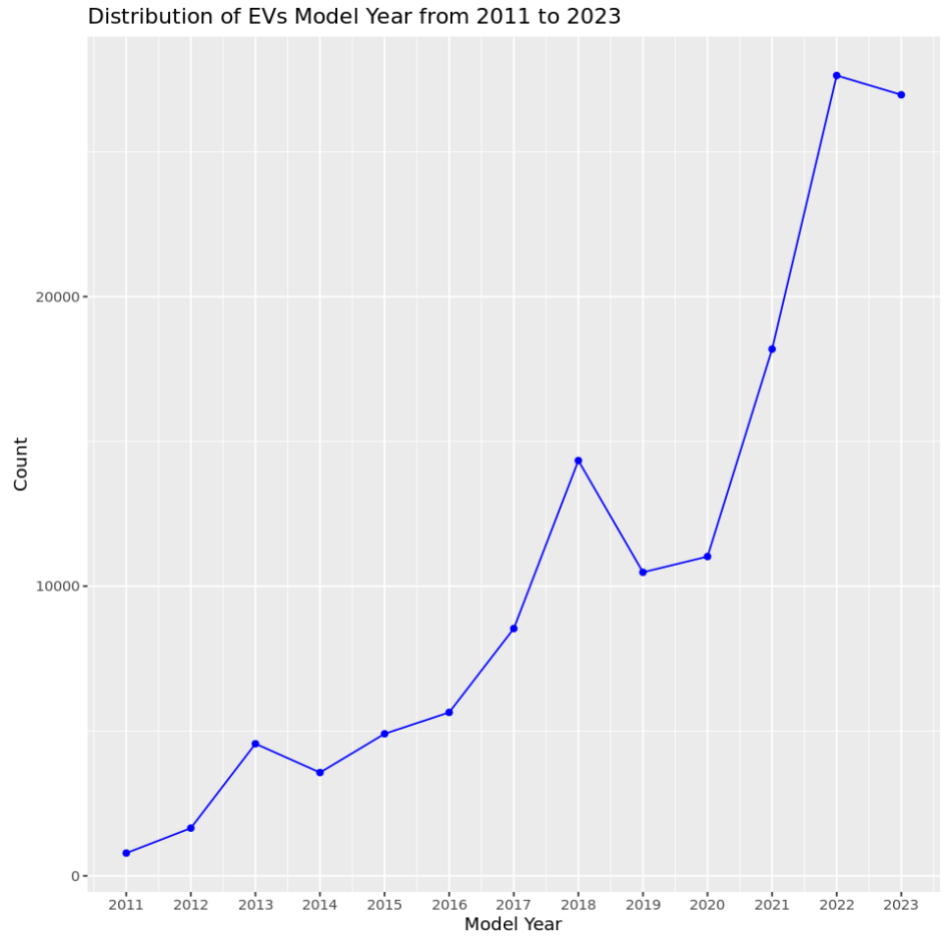

Figure 5: Distribution of EVs Model Year from 2011 to 2023

Overall, the EV market has witnessed substantial growth in recent years. The period of the COVID-19 pandemic, spanning from 2019 to 2020, can account for the decline in the number of registered EV models during these years. This decline can be attributed to challenges in manufacturing, releasing, testing, and purchasing that were influenced by the pandemic's impact.

5. Distribution of EV types and the Clean Alternative Fuel Vehicle Eligibility in Washington State

- Figure 6 below shows that more than 2 out of 3 is a Battery Electric Vehicle type, which partly explains the strong transition into an all-electric vehicle type in Washington state.

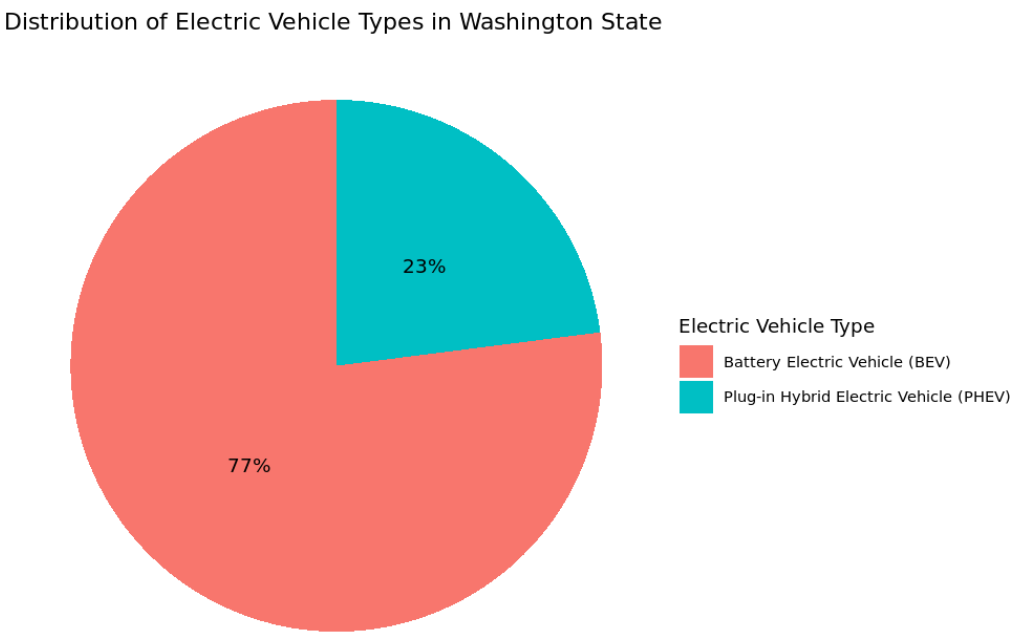

Figure 6

- However, policymakers, manufacturers, and researchers definitely want to improve the 'clean alternative fuel' area, which is one of the key factors in this EV era. Among the EV-registered vehicles in Washington state, 43% of them could not be verified the clean alternative fuel eligibility status as they mentioned in the data dictionary that the battery range has not been researched. Besides, 12% of EV vehicles is not eligible due to low battery range. So there is still room for encouraging and setting more incentives for the EVs that have a battery range meeting the CAFV eligibility in this state, in order to foster clean transportation adoption and green energy development.

Figure 7

Conclusion and Recommendations

The Electric Vehicle Population Dataset, sourced from official government data, provides valuable insights into the electric vehicle adoption trends in Washington State. Key findings underscore the geographic popularity of electric vehicles, manufacturer and model preferences, model year trends, the distribution of EV types, and Clean alternative fuel eligibility. These patterns and insights will assist in infrastructure planning, consumer behavior analysis, and clean fuel incentives policy in fostering sustainable EV adoption in Washington state.

- The analysis highlights King County as the leader in EV adoption, making it a prime location for charging infrastructure. Stakeholders should consider expanding charging networks and service centers to meet the increasing demand.
- Manufacturers should recognize Tesla's dominance in the market due to its diverse and innovative electric vehicle lineup. Competitors should focus on offering similar technological advancements to stay competitive.
- The preference for specific EV models captures Tesla's Model 3 and Model Y. Automakers should prioritize producing EVs with similar and competitive attributes to meet consumer demands and further drive EV adoption.
- In terms of Clean Alternative Fuel Vehicle (CAFV) Eligibility, policymakers, manufacturers, and researchers should collaborate to improve the clean alternative fuel vehicle eligibility status. Incentives should be provided for EVs that meet CAFV eligibility criteria, encouraging the adoption of vehicles with sufficient battery ranges.

References

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