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Project Title: Analysis of Electric Vehicle Population

Project Report

Group 6

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Table of Contents

Contents

Introduction

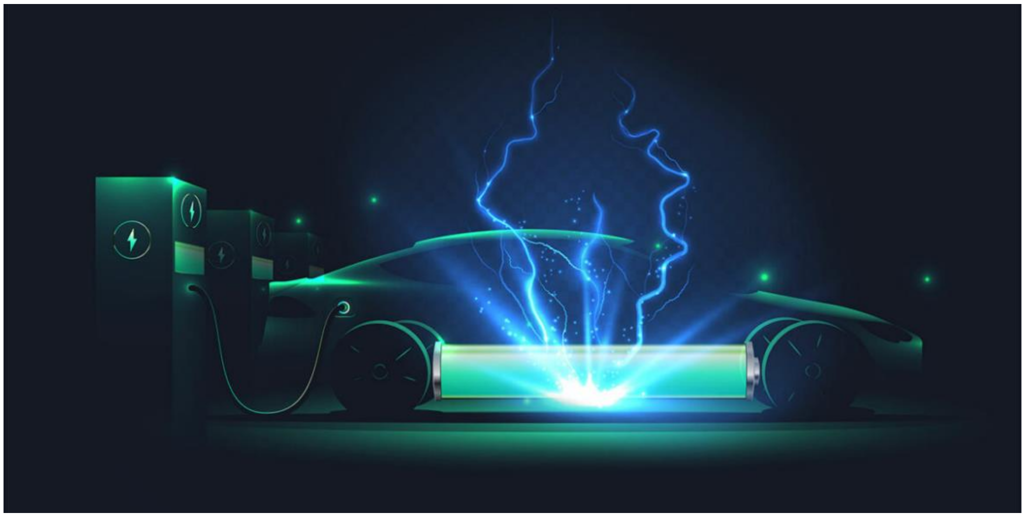

Figure 1: An Electric Vehicle

With the growing emphasis on sustainable transportation, electric vehicles (EVs) have become increasingly popular as an eco-friendly alternative to traditional gasoline-powered cars. The exploration of electric vehicle (EV) adoption and market trends provides critical insights into the evolving landscape of transportation and its impact on sustainability efforts. Washington State, known for its commitment to environmental conservation, has significantly increased adoption of Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). This project aims to analyze and visualize the current EV population data, obtained from the Washington State Department of Licensing (DOL), to uncover trends, distributions, and key factors influencing EV adoption across the state. Utilizing Python's robust data analysis and visualization tools, we plan to explore the complex trends of the electric vehicle market from 1997 to now, enabling stakeholders to make informed decisions and fostering the continued growth of EVs in Washington State. We have obtained our dataset from Data.gov.

Our investigation will encompass various dimensions such as the types of electric vehicles—Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs)—their range capabilities, pricing structures, and eligibility for clean alternative fuel vehicle programs. By analyzing these elements, we will identify key trends in consumer preference and market penetration on EV adoption. We aim to offer valuable insights that could influence future policies, market strategies, and the broader transition toward sustainable transportation.

Project Objectives

- The objective of this project is to analyze and visualize the Electric Vehicle (EV) population data, which includes Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) registered through the Washington State Department of Licensing (DOL).
- By leveraging Python's powerful data analysis and visualization libraries, such as pandas, matplotlib, and seaborn, we aim to gain insights into EVs' distribution, trends, and growth in Washington State. By achieving these insights, the project will contribute valuable knowledge to the understanding of electric vehicle trends in Washington State and support efforts to promote sustainable transportation solutions.

Raw Data

This dataset shows the Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) that are currently registered through the Washington State Department of Licensing (DOL). The dataset includes the following columns, each with specific information about registered electric vehicles in Washington State:

- **VIN (1-10):** The first 10 characters of each vehicle's Vehicle Identification Number (VIN).
- **County:** The geographic region of a state where a vehicle's owner resides. Vehicles registered in Washington State may be located in other states.
- **City:** The city in which the registered owner resides.
- **State:** The geographic region of the country associated with the record. These addresses may be located in other states.
- **Postal Code:** The 5-digit zip code where the registered owner resides.
- **Model Year:** The model year of the vehicle, determined by decoding the VIN.
- **Make:** The manufacturer of the vehicle, determined by decoding the VIN.
- **Model:** The model of the vehicle, determined by decoding the VIN.
- **Electric Vehicle Type:** This distinguishes the vehicle as an all-electric or a plug-in hybrid.
- **Clean Alternative Fuel Vehicle (CAFV) Eligibility:** Categorizes the vehicle as a Clean Alternative Fuel Vehicle based on fuel and electric-only range requirements in House Bill 2042.
- **Electric Range:** Describes how far a vehicle can travel purely on its electric charge.
- **Base MSRP:** The lowest Manufacturer's Suggested Retail Price (MSRP) for any trim level of the model.
- **Legislative District:** The specific section of Washington State where the vehicle's owner resides, as represented in the state legislature.
- **DOL Vehicle ID**: A unique number assigned to each vehicle by the Department of Licensing for identification purposes.
- **Vehicle Location:** The center of the ZIP Code for the registered vehicle.
- **Electric Utility:** Electric power retail service territories serving the address of the registered vehicle, including all ownership types. If overlapping, utilities are delimited by a single pipe for the same type and a double pipe for different types. Blanks occur for vehicles outside Washington or areas not mapped.
- **2020 Census Tract:** Census tract identifier combining state, county, and census tract codes as assigned by the United States Census Bureau in the 2020 census.

The raw data consists of 181458 rows × 17 columns.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
VIN (1-10)	County	City	State	Postal Cod	Model Yea	Make	Model	Electric Ve	Clean Alte	Electric Ra	Base MSRI	Legislative	DOL Vehic	Vehicle Lo	Electric Ut	2020 Census Tract
WAUTPBF	King	Seattle	WA	98126	2017	AUDI	A3	Plug-in Hy	Not eligibl	16	0	34	2.35E+08	POINT (-12	CITY OF SE	5.3E+10
WAUUPBF	Thurston	Olympia	WA	98502	2018	AUDI	A3	Plug-in Hy	Not eligibl	16	0	22	2.38E+08	POINT (-12	PUGET SO	5.31E+10
5YJSA1E22	Thurston	Lacey	WA	98516	2017	TESLA	MODEL S	Battery Ele	Clean Alte	210	0	22	1.54E+08	POINT (-12	PUGET SO	5.31E+10
1C4JJXP62	Thurston	Tenino	WA	98589	2021	JEEP	WRANGLE	Plug-in Hy	Not eligibl	25	0	20	1.55E+08	POINT (-12	PUGET SO	5.31E+10
5YJ3E1EC9	Yakima	Yakima	WA	98902	2020	TESLA	MODEL 3	Battery Ele	Clean Alte	308	0	14	2.26E+08	POINT (-12	PACIFICOR	5.31E+10
1C4JJXP66	Thurston	Olympia	WA	98501	2023	JEEP	WRANGLE	Plug-in Hy	Not eligibl	21	0	22	2.21E+08	POINT (-12	PUGET SO	5.31E+10
1G1RA6S5	Kitsap	Keyport	WA	98345	2017	CHEVROLE	VOLT	Plug-in Hy	Clean Alte	53	0	23	1.63E+08	POINT (-12	PUGET SO	5.3E+10
5YJ3E1EB5	Snohomisl	Mountlake	WA	98043	2020	TESLA	MODEL 3	Battery Ele	Clean Alte	322	0	1	6293899	POINT (-12	PUGET SO	5.31E+10
WA1F2AF	King	Seattle	WA	98119	2022	AUDI	Q5	Plug-in Hy	Not eligibl	23	0	36	2.08E+08	POINT (-12	CITY OF SE	5.3E+10
1G1RB6S5	Thurston	Olympia	WA	98501	2017	CHEVROLE	VOLT	Plug-in Hy	Clean Alte	53	0	22	2.37E+08	POINT (-12	PUGET SO	5.31E+10
1G1FW6S(	Snohomisl	Bothell	WA	98021	2018	CHEVROLE	BOLT EV	Battery Ele	Clean Alte	238	0	1	1.88E+08	POINT (-12	PUGET SO	5.31E+10
5YJSA1S22	King	Seattle	WA	98121	2015	TESLA	MODEL S	Battery Ele	Clean Alte	208	0	36	1.43E+08	POINT (-12	CITY OF SE	5.3E+10
KNDC3DL(	Kitsap	Port Orcha	WA	98366	2022	KIA	EV6	Battery Ele	Eligibility u	0	0	26	1.96E+08	POINT (-12	PUGET SO	5.3E+10
1N4AZ0CP	Kitsap	Port Orcha	WA	98367	2013	NISSAN	LEAF	Battery Ele	Clean Alte	75	0	26	2.07E+08	POINT (-12	PUGET SO	5.3E+10
1G1RB6S5	Kitsap	Bremertor	WA	98310	2018	CHEVROLE	VOLT	Plug-in Hy	Clean Alte	53	0	23	4.76E+08	POINT (-12	PUGET SO	5.3E+10
5YJ3E1EB4	Yakima	Moxee	WA	98936	2020	TESLA	MODEL 3	Battery Ele	Clean Alte	322	0	15	1.02E+08	POINT (-12	PACIFICOR	5.31E+10
5YJSA1E25	Snohomisl	Woodinvil	WA	98077	2017	TESLA	MODEL S	Battery Ele	Clean Alte	210	0	1	3.5E+08	POINT (-12	PUGET SO	5.31E+10
YV4BR0DL	Thurston	Olympia	WA	98512	2022	VOLVO	XC60	Plug-in Hy	Not eligibl	18	0	22	1.82E+08	POINT (-12	PUGET SO	5.31E+10
5YJ3E1EA1	Thurston	Olympia	WA	98506	2023	TESLA	MODEL 3	Battery Ele	Eligibility u	0	0	22	2.6E+08	POINT (-12	PUGET SO	5.31E+10
3C3CFFGE	Thurston	Olympia	WA	98506	2015	FIAT	500	Battery Ele	Clean Alte	87	0	22	3.49E+08	POINT (-12	PUGET SO	5.31E+10
1N4AZ1CP	Kitsap	Bremertor	WA	98310	2018	NISSAN	LEAF	Battery Ele	Clean Alte	151	0	23	4.76E+08	POINT (-12	PUGET SO	5.3E+10
1G1FZ6S0	Yakima	Yakima	WA	98908	2023	CHEVROLE	BOLT EUV	Battery Ele	Eligibility u	0	0	14	2.51E+08	POINT (-12	PACIFICOR	5.31E+10
KNDCM3L	Kitsap	Poulsbo	WA	98370	2022	KIA	NIRO	Plug-in Hy	Not eligibl	26	0	23	1.96E+08	POINT (-12	PUGET SO	5.3E+10
1G1FY6S0	Kitsap	Poulsbo	WA	98370	2020	CHEVROLE	BOLT EV	Battery Ele	Clean Alte	259	0	23	1.68E+08	POINT (-12	PUGET SO	5.3E+10
3C3CFFGE	Island	Oak Harbc	WA	98277	2017	FIAT	500	Battery Ele	Clean Alte	84	0	10	1.06E+08	POINT (-12	PUGET SO	5.3E+10
1G1FZ6S0	Kitsap	Bremertor	WA	98310	2019	CHEVROLE	BOLT EV	Battery Ele	Clean Alte	238	0	23	2.86E+08	POINT (-12	PUGET SO	5.3E+10

Figure 2: Raw Data from the dataset

Data Pre-Processing

In this project, we begin by importing the dataset from a CSV file obtained from data.gov.

```
[1]: #Importing the data file
import pandas as pd
import matplotlib.pyplot as plt
df = pd.read_csv('Electric_Vehicle_Population_Data.csv')

[9]: df
```

[9]:

	VIN (1-10)	County	City	State	Postal Code	Model Year	Make	Model	Electric Vehicle Type	Clean Alternative Fuel Vehicle (CAFV) Eligibility	Electric Range	Base MSRP	Legislative District	DOL Vehicle ID	Vehicle Location
0	WAUTPBFF4H	King	Seattle	WA	98126.0	2017	AUDI	A3	Plug-in Hybrid Electric Vehicle (PHEV)	Not eligible due to low battery range	16	0	34.0	235085336	POINT (-122.374105 47.54468)
1	WAUUPBFF2J	Thurston	Olympia	WA	98502.0	2018	AUDI	A3	Plug-in Hybrid Electric Vehicle (PHEV)	Not eligible due to low battery range	16	0	22.0	237896795	POINT (-122.943445 47.059252)
2	5YJSA1E22H	Thurston	Lacey	WA	98516.0	2017	TESLA	MODEL S	Battery Electric Vehicle (BEV)	Clean Alternative Fuel Vehicle Eligible	210	0	22.0	154498865	POINT (-122.78083 47.083975)
3	1C4JJXP62M	Thurston	Tenino	WA	98589.0	2021	JEEP	WRANGLER	Plug-in Hybrid Electric Vehicle (PHEV)	Not eligible due to low battery range	25	0	20.0	154525493	POINT (-122.85403 46.856085)

Figure 3: Screenshot showing the data file import

<u>Statistical summary:</u> After loading the data into a pandas DataFrame, we proceeded to obtain an initial understanding of the dataset by using the df.info() and df.describe() commands. These commands are crucial for summarizing the structure and basic statistics of the dataset, allowing us to identify potential data issues and gain insights into its composition. df.info() helped us understand the dataset's structure, identify columns with missing data, and verify the data types and df.describe() provided a quick overview of the central tendency, dispersion, and shape of the distribution of the numerical columns, helping us to understand the data better and identify any anomalies.

```
[4]: df.info()
df.describe()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 181458 entries, 0 to 181457
Data columns (total 17 columns):
 #   Column                                             Non-Null Count   Dtype
---  ------                                             --------------   -----
 0   VIN (1-10)                                         181458 non-null  object
 1   County                                             181455 non-null  object
 2   City                                               181455 non-null  object
 3   State                                              181458 non-null  object
 4   Postal Code                                        181455 non-null  float64
 5   Model Year                                         181458 non-null  int64
 6   Make                                               181458 non-null  object
 7   Model                                              181458 non-null  object
 8   Electric Vehicle Type                              181458 non-null  object
 9   Clean Alternative Fuel Vehicle (CAFV) Eligibility  181458 non-null  object
 10  Electric Range                                     181458 non-null  int64
 11  Base MSRP                                          181458 non-null  int64
 12  Legislative District                               181060 non-null  float64
 13  DOL Vehicle ID                                     181458 non-null  int64
 14  Vehicle Location                                   181450 non-null  object
 15  Electric Utility                                   181455 non-null  object
 16  2020 Census Tract                                  181455 non-null  float64
dtypes: float64(3), int64(4), object(10)
memory usage: 23.5+ MB
```

[4]:

	Postal Code	Model Year	Electric Range	Base MSRP	Legislative District	DOL Vehicle ID	2020 Census Tract
count	181455.000000	181458.000000	181458.000000	181458.000000	181060.000000	1.814580e+05	1.814550e+05
mean	98174.050718	2020.581793	57.826665	1040.236749	29.106904	2.214128e+08	5.297575e+10
std	2414.241968	2.991140	91.396074	8228.989085	14.892342	7.528561e+07	1.594876e+09
min	1545.000000	1997.000000	0.000000	0.000000	1.000000	4.385000e+03	1.001020e+09
25%	98052.000000	2019.000000	0.000000	0.000000	18.000000	1.830687e+08	5.303301e+10
50%	98122.000000	2022.000000	0.000000	0.000000	33.000000	2.289155e+08	5.303303e+10
75%	98370.000000	2023.000000	75.000000	0.000000	42.000000	2.561320e+08	5.305307e+10
max	99577.000000	2024.000000	337.000000	845000.000000	49.000000	4.792548e+08	5.603300e+10

Figure 4: Screenshot showing the output of Statistical Summary

Further, we went on to draw some insights from the dataset to enhance our understanding of the dataset.

Top 5 Brands with the highest number of EVs: The analysis and output highlight the distribution of EV registrations among different manufacturers in Washington State. Tesla clearly dominates the market, followed by Nissan, Chevrolet, Ford, and BMW. This information is valuable for understanding market trends and the competitive landscape within the electric vehicle sector. The insights can help stakeholders, including policymakers and automotive industry players, to make informed decisions and strategies based on the current market dynamics.

```
[11]: #Top 5 Brands with highest number of EVs
      top_five_brands = df['Make'].value_counts().head(5)
      print(top_five_brands)

      Make
      TESLA        80819
      NISSAN       14037
      CHEVROLET    13864
      FORD          9527
      BMW           7680
      Name: count, dtype: int64
```

Figure 5: Screenshot showing the top 5 highest-selling EV Brands

Bottom 5 Brands with the lowest number of EVs: The analysis and output highlight the distribution of EV registrations among brands with the fewest vehicles in Washington State. These brands, including TH!NK, GMC, Bentley, WHEEGO ELECTRIC CARS, and Rolls Royce, have minimal presence in the EV market compared to the leading brands. This information can be useful for understanding the diversity of manufacturers participating in the EV market and identifying niche players.

```
[13]: #Bottom 5 Brands with lowest number of EVs
      bottom_five_brands = df['Make'].value_counts().tail(5)
      print(bottom_five_brands)

      Make
      TH!NK                    5
      GMC                      3
      BENTLEY                  3
      WHEEGO ELECTRIC CARS     3
      ROLLS ROYCE              1
      Name: count, dtype: int64
```

Figure 6: Screenshot showing the bottom 5 lowest-selling EV Brands

Top 5 States with the highest number of EVs: The analysis and output highlight the distribution of EV registrations among different states, with Washington State (WA) having the highest number by a considerable margin. This suggests that Washington State has a strong presence in electric vehicles compared to other states. California (CA), Virginia (VA), Maryland (MD), and Texas (TX) follow but with much lower counts. This information is valuable for understanding regional differences in EV adoption and can help policymakers, industry stakeholders, and market analysts to develop strategies for promoting EV adoption in different regions.

```
[12]: #Top 5 States with highest number of EVs
      top_five_states = df['State'].value_counts().head(5)
      print(top_five_states)

      State
      WA    181060
      CA       102
      VA        47
      MD        32
      TX        26
      Name: count, dtype: int64
```

Figure 7: Screenshot showing the top 5 states with the highest number of EVs

Data Cleaning and Preparation

Initially, we examined the dataset for missing values and duplicates. We found no duplicates, but there were missing entries in several columns including city, county, postal code, legislative district, vehicle location, electric utility, and the 2020 census tract. Initially, the function checking_for_missingVals_and_duplicates() is defined to identify missing values and duplicate rows within the DataFrame. The df.isnull().sum() method is utilized to calculate the total number of missing values for each column, revealing that several columns have missing values, with the 'Legislative District' column having the highest number at 398. Additionally, the df.duplicated().sum() method checks for duplicate rows, and the results indicate that there are no duplicate rows in the dataset, ensuring the data's uniqueness.

Data Cleaning

```
[10]: #Checking for missing values and duplicate rows
def checking_for_missingVals_and_duplicates():
    # Check for missing values in the dataset
    missing_values = df.isnull().sum()
    print("Missing values in the dataset: ",missing_values)
    # Check for duplicate rows in the dataset
    duplicate_rows = df.duplicated().sum()
    print("No. of duplicate rows in the dataset: ",duplicate_rows)
checking_for_missingVals_and_duplicates()
```

```
Missing values in the dataset:  VIN (1-10)                                           0
County                                               3
City                                                 3
State                                                0
Postal Code                                          3
Model Year                                           0
Make                                                 0
Model                                                0
Electric Vehicle Type                                0
Clean Alternative Fuel Vehicle (CAFV) Eligibility    0
Electric Range                                       0
Base MSRP                                            0
Legislative District                               398
DOL Vehicle ID                                       0
Vehicle Location                                     8
Electric Utility                                     3
2020 Census Tract                                    3
dtype: int64
No. of duplicate rows in the dataset:  0
```

Figure 8: Screenshot showing the function to check missing values and duplicate rows

Subsequently, the function replace_missing_values(df) is defined to address the identified missing values in the DataFrame. This function differentiates between non-numeric and numeric columns, replacing missing values in non-numeric columns with the mode (most frequent value) of the respective column and those in numeric columns with the median value. After calling this function, the dataset is updated to reflect these replacements. A follow-up check using df.isnull().sum() confirms the success of this operation, as all columns now show zero missing values. This rigorous data-cleaning process ensures that the dataset is complete and devoid of missing values, thereby enhancing the accuracy and reliability of subsequent analysis and visualization efforts.

```
[43]: # Function to replace missing values - For this, we have first identified if the variable is numeric or non-numeric
#Then for non-numeric datatypes, we have replaced the missing values with mode and for numeric data types, we have replaced
# it with the median.
def replace_missing_values(df):
    for column in df.columns:
        if df[column].dtype == 'object':
            # Replace missing values with the mode for non-numeric columns
            mode_value = df[column].mode()[0]
            df[column].fillna(mode_value, inplace=True)
        else:
            # Replace missing values with the median for numeric columns
            median_value = df[column].median()
            df[column].fillna(median_value, inplace=True)

# Function Call
replace_missing_values(df)
# Verify if there are any missing values left
missing_values_after_replacement = df.isnull().sum()
missing_values_after_replacement
```

```
[43]: VIN (1-10)                                           0
County                                               0
City                                                 0
State                                                0
Postal Code                                          0
Model Year                                           0
Make                                                 0
Model                                                0
Electric Vehicle Type                                0
Clean Alternative Fuel Vehicle (CAFV) Eligibility    0
Electric Range                                       0
Base MSRP                                            0
Legislative District                                 0
DOL Vehicle ID                                       0
Vehicle Location                                     0
Electric Utility                                     0
2020 Census Tract                                    0
dtype: int64
```

Figure 9: Screenshot showing the function which handles the missing values

```
[6]: # Identifying categorical variables
categorical_columns = df.select_dtypes(include=['object']).columns
print(categorical_columns)
```

```
Index(['VIN (1-10)', 'County', 'City', 'State', 'Make', 'Model',
       'Electric Vehicle Type',
       'Clean Alternative Fuel Vehicle (CAFV) Eligibility', 'DOL Vehicle ID',
       'Vehicle Location', 'Electric Utility', '2020 Census Tract'],
      dtype='object')
```

```
[7]: #The function integer_encode encodes the categorical variables to integers starting from 0
def integer_encode(df, column_names):
    df_encoded = df.copy()
    # Encode categorical variables in the specified columns
    for column in column_names:
        df_encoded[column], _ = pd.factorize(df_encoded[column])
    return df_encoded

column_names_to_encode_categorical_variables=['State', 'Model', 'Electric Vehicle Type', 'Clean Alternative Fuel Vehicle (CAFV) Eligibility']

df_encoded = integer_encode(df, column_names_to_encode_categorical_variables)
df_encoded.head()
```

Figure 10: Screenshot showing the encoding of categorical data in the dataset

Further into data cleaning, we identified and encoded categorical variables in a DataFrame to prepare the data. Initially, the df.select_dtypes(include=['object']).columns command was used to identify all categorical columns in the DataFrame, listing columns such as 'State', 'Model', 'Electric Vehicle Type', and 'Clean Alternative Fuel Vehicle (CAFV) Eligibility'. The integer_encode function was then defined to encode these categorical columns into integers using pd.factorize, which assigned unique integer values to each category. By creating a copy of the original DataFrame and applying the encoding function to the specified columns, the categorical data was transformed into a numerical format suitable for further analysis. By converting categorical data into numerical format, we ensured compatibility with various machine learning algorithms, facilitating accurate and efficient model training.

Data Visualization

1. Line Graph - Trends in EV Adoption Rates Over the Years

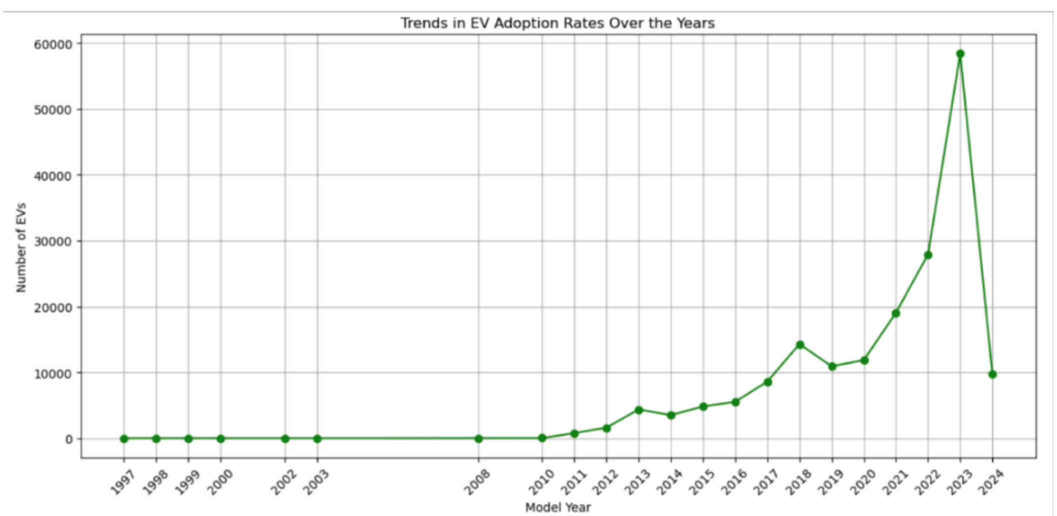

Figure 11: Trends in EV Adoption Rates Over the Years

Insights:

- The line graph titled "Trends in EV Adoption Rates Over the Years" (*Figure 11*) depicts the number of electric vehicles (EVs) registered over different model years, ranging from 1997 to 2024.
- The x-axis represents the model years, while the y-axis shows the number of EVs. Each point on the graph represents the number of EVs for a specific model year, connected by lines to illustrate the trend over time.

- The green color of the line and points provides a clear visual distinction of the data points and the trend.
- The peak in 2023 reflects the culmination of improved technology, wider model availability, and strong governmental incentives, while the sharp decline in 2024 may indicate market saturation or other economic factors.
- This trend highlights the evolving landscape of the EV market and the importance of strategic planning to sustain growth.
- Understanding these trends is crucial for policymakers, manufacturers, and stakeholders in the EV market to make informed decisions about future strategies, investments, and policies to sustain and further accelerate EV adoption.

2. Bar Chart - Distribution of Electric Vehicle Types

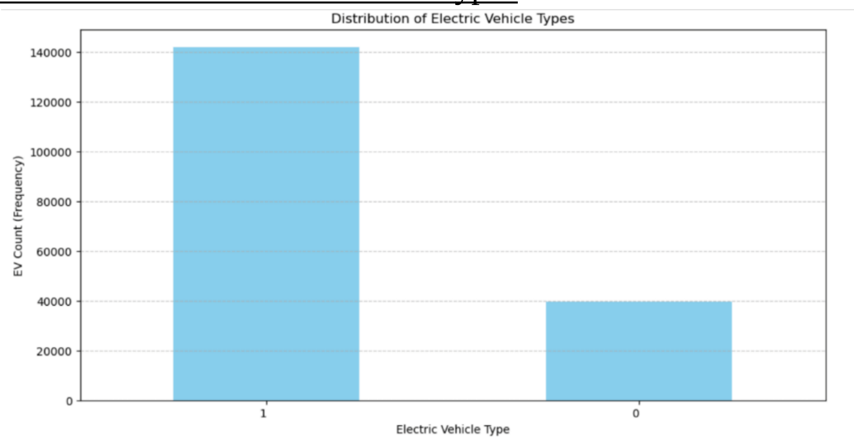

Figure 12: Distribution of Electric Vehicle Types

Insights:

- The bar graph titled "Distribution of Electric Vehicle Types" (*Figure 12*) presents the frequency of two types of electric vehicles: all-electric vehicles (EV Type 1) and plug-in hybrid electric vehicles (EV Type 0). The x-axis represents the electric vehicle type, while the y-axis shows the count of vehicles.
- With approximately 140,000 all-electric vehicles compared to around 40,000 plug-in hybrids, the data highlights a significant market trend favoring fully electric options.
- This preference can be attributed to advancements in battery technology, increased driving ranges, enhanced charging infrastructure, and supportive government policies targeting zero-emission vehicles.
- The dominance of all-electric vehicles underscores a growing consumer inclination towards more sustainable and cost-effective transportation solutions, reflecting the broader shift in the EV market.

3. Bar Graph – Top 10 Cities by EV Adoption Rates

Insights:

- Continuing the analysis of electric vehicle (EV) adoption, the bar graph titled "Top 10 Cities by EV Adoption Rates" (*Figure 13*) highlights the cities in Washington State with the highest number of registered EVs.
- Seattle stands out significantly with nearly 30,000 EV registrations, indicating its leading position in EV adoption. Bellevue follows with around 10,000 EVs, while other cities like Redmond, Vancouver, Bothell, Kirkland, Sammamish, Renton, Olympia, and Tacoma each have between 5,000 and 7,000 EV registrations.
- This distribution mirrors broader trends in EV adoption where urban centers, often with better infrastructure and higher environmental awareness, lead in the number of EVs.
- The prominence of Seattle and Bellevue underscores their role as early adopters and key players in the transition to sustainable transportation.

- The substantial gap between Seattle and other cities further emphasizes Seattle's proactive stance in promoting EV use through initiatives such as extensive charging networks and supportive policies.

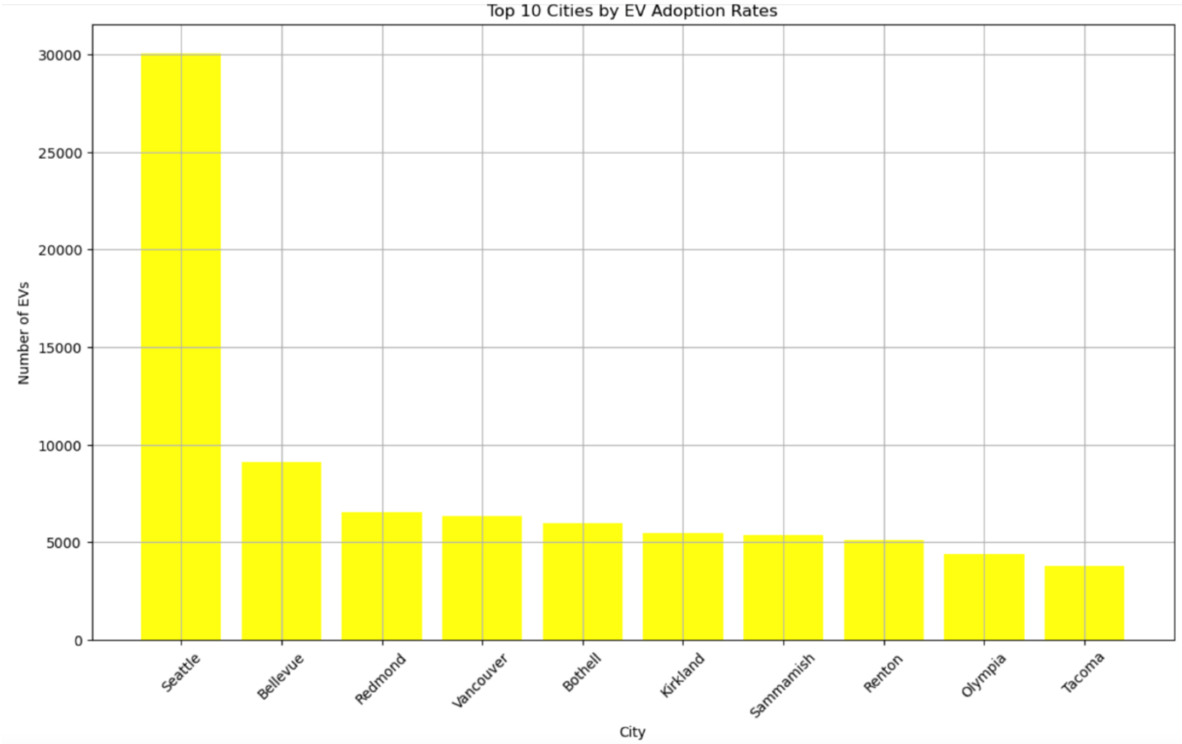

Figure 13: Top 10 Cities by EV Adoption Rates

- This urban focus aligns with the previous graph showing the dominance of all-electric vehicles over plug-in hybrids, suggesting that cities with robust EV adoption rates also favor all-electric models.
- As such, understanding the dynamics in these leading cities can provide valuable insights for policymakers and manufacturers aiming to replicate this success in other regions, ultimately supporting the broader goal of accelerating EV adoption statewide.

4. <u>Pie Chart – Make-wise (Manufacturer-wise) Distribution</u>

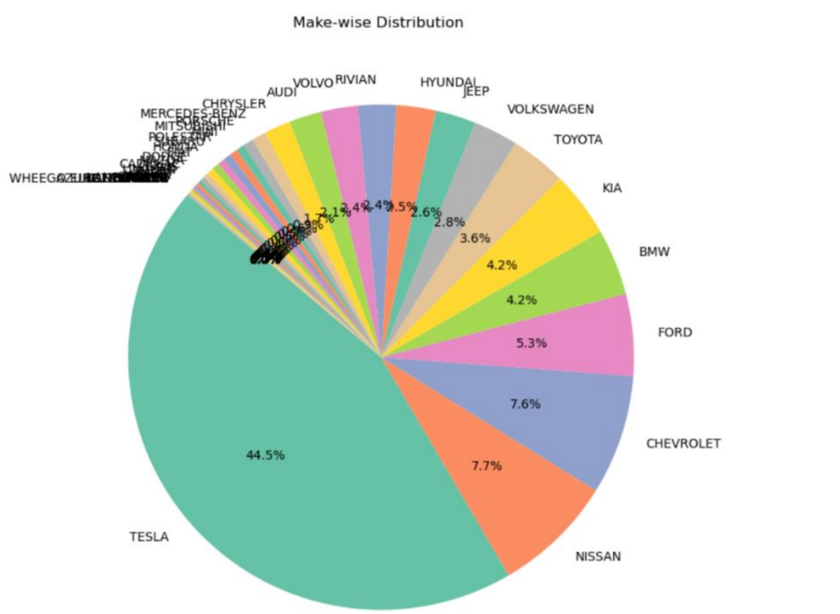

Figure 14: Make-wise Distribution

Insights:

- Continuing the analysis, the "Make-wise Distribution" (*Figure 14*), pie chart highlights Tesla's dominance with 44.5% of the EV market in Washington State, aligning with high adoption rates in cities like Seattle.
- Nissan and Chevrolet follow with 7.7% and 7.6%, respectively, showing their significant market presence. Other notable brands include Ford (5.3%), BMW (4.2%), and KIA (4.2%).
- This variety indicates a healthy market evolution, driven by technological advancements and consumer demand for more sustainable transportation solutions.
- This make-wise distribution reinforces the trend observed in earlier graphs, where urban centers like Seattle lead in EV adoption, and all-electric vehicles are preferred over hybrids.
- The dominance of Tesla, combined with significant shares held by other major brands, reflects the concentrated yet expanding nature of the EV market.
- Policymakers and manufacturers can use these insights to understand market dynamics better, tailor their strategies, and support further growth in EV adoption across the state.

5. <u>Stacked Bar Graph – Distribution of EV Types by Manufacturer (Make)</u>

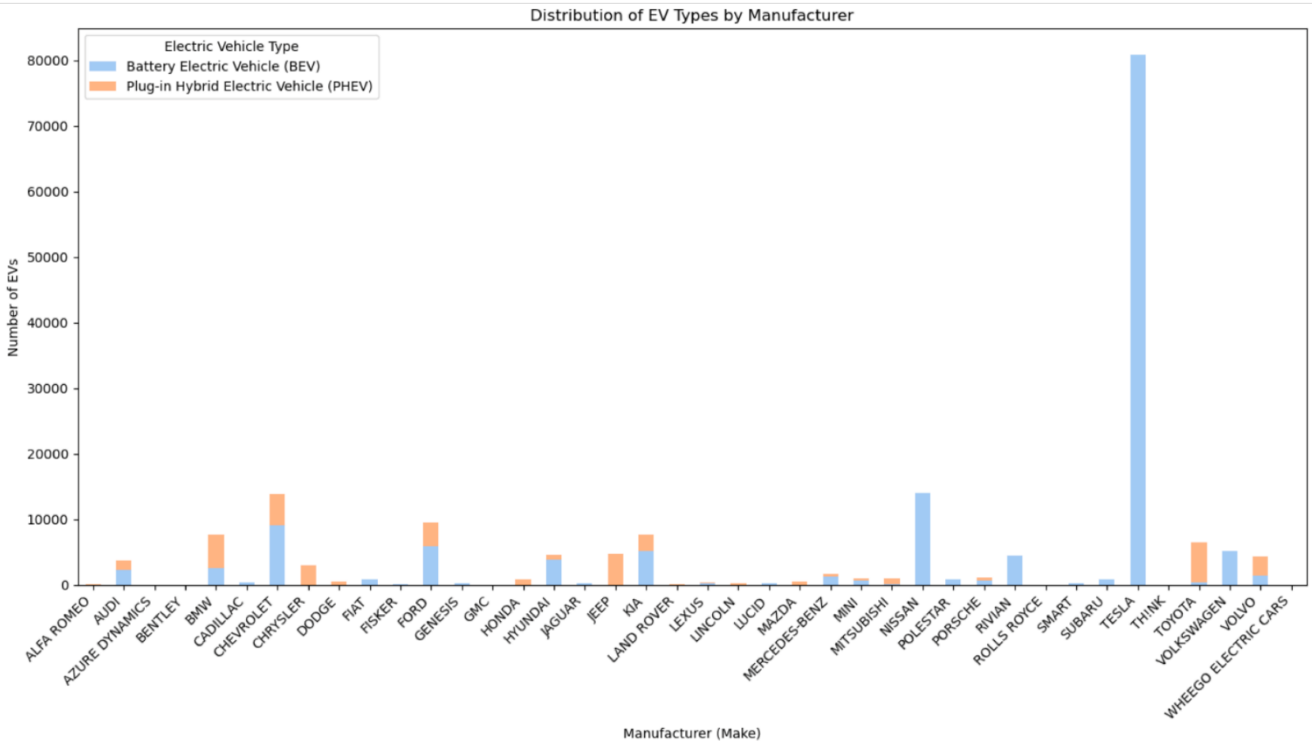

Figure 15: Distribution of EV Types by Manufacturer

Insights:

- The bar graph "Distribution of EV Types by Manufacturer" (*Figure 15*) breaks down the number of Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) for each manufacturer.
- Tesla overwhelmingly leads with nearly 80,000 BEVs, far outpacing all other manufacturers.
- This aligns with the previous pie chart showing Tesla's dominant market share of 44.5%.
- Nissan and Chevrolet also show significant numbers, with Nissan having a balanced distribution between BEVs and PHEVs, while Chevrolet leans slightly towards PHEVs.
- This reflects the earlier observation of Nissan and Chevrolet having substantial market shares of 7.7% and 7.6%, respectively.
- Other manufacturers like Ford, BMW, and Volkswagen also show a mix of BEVs and PHEVs but in smaller quantities.
- This detailed breakdown confirms the overall trend that all-electric vehicles are more prevalent, especially with market leaders like Tesla.

- The insights from this graph support the narrative of a strong preference for BEVs in urban centers, as seen in Seattle's high adoption rates, and highlight the competitive landscape among various manufacturers in the EV market.
- This data underscores the ongoing transition towards all-electric models and the importance of supporting infrastructure and policies to sustain this growth.

6. Horizontal Bar Graph – Top 5 EV Makes by Number of Vehicles

Insights:

- The bar graph "Top 5 EV Makes by Number of Vehicles" (*Figure 16*) provides a clear visual representation of the leading electric vehicle manufacturers by the number of registered vehicles.
- Tesla stands out prominently with over 80,000 vehicles, reaffirming its dominant position in the EV market, as seen in previous graphs.
- This substantial lead underscores Tesla's significant influence and consumer preference for its all-electric models.
- Following Tesla, Nissan and Chevrolet have notable but much smaller shares, with around 14,000 and 13,000 vehicles, respectively.

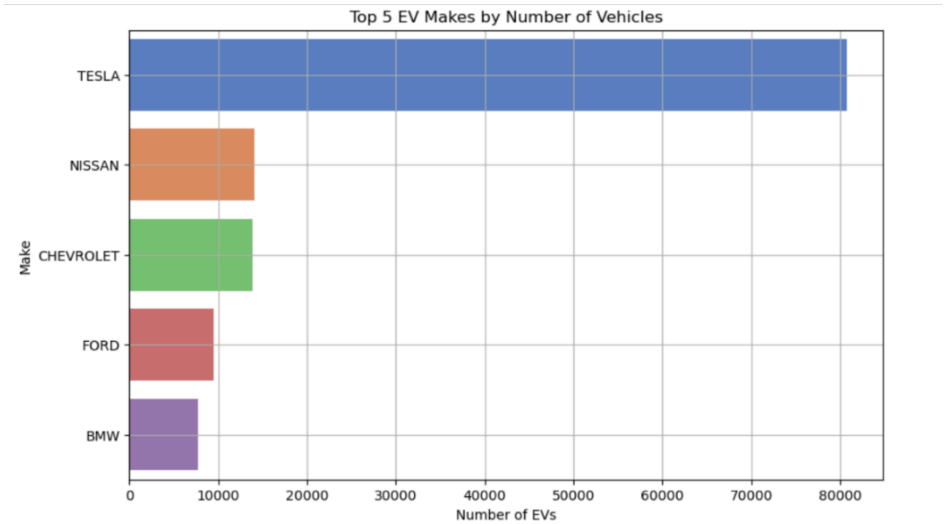

Figure 16: Top 5 EV Makes by Number of Vehicles

- This aligns with earlier insights showing Nissan and Chevrolet as major players, each holding significant portions of the market.
- Ford and BMW round out the top five with approximately 9,500 and 7,700 vehicles, indicating their presence in the competitive landscape but with lesser impact compared to the top three manufacturers.
- This graph reinforces the trend of a strong preference for Tesla's vehicles, contributing to high EV adoption rates in leading cities like Seattle.
- It also highlights the competitive dynamics among other manufacturers who are striving to gain a larger share in the growing EV market.
- These insights are crucial for understanding the market composition and guiding future strategies for manufacturers and policymakers to support the continued growth of electric vehicles.

7. Horizontal Bar Graph – Bottom 5 EV Makes by Number of Vehicles

Insights:

- The bar graph "Bottom 5 EV Makes by Number of Vehicles" (*Figure 17*) highlights the manufacturers with the lowest number of electric vehicles registered.
- TH!NK leads this group with 5 vehicles, followed by GMC, Bentley, and WHEEGO ELECTRIC CARS, each with 3 vehicles. Rolls Royce has the least with just 1 registered EV.

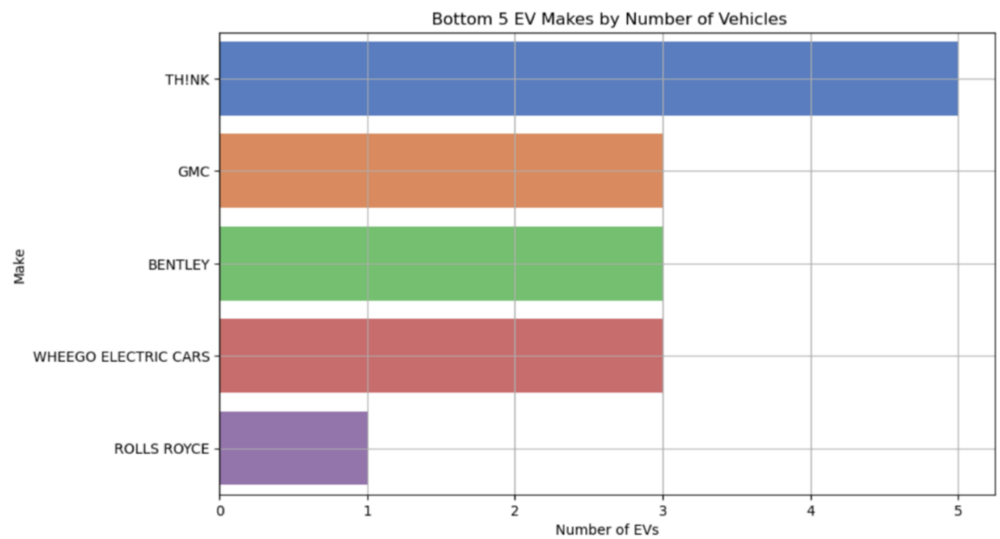

Figure 17: Bottom 5 EV Makes by Number of Vehicles

- This distribution underscores the wide disparity in market presence among different manufacturers, as previously noted.
- While Tesla dominates the EV market, these brands show minimal penetration, indicating limited consumer adoption or availability of their EV models in Washington State.
- The small numbers for luxury brands like Bentley and Rolls Royce suggest that high-end EVs are less prevalent compared to more mainstream options.
- The insights from this graph complement the broader market trends observed earlier. Major manufacturers like Tesla, Nissan, and Chevrolet hold significant shares, while niche and luxury brands have a minimal presence.
- This disparity emphasizes the importance of broader product availability, competitive pricing, and market strategies to enhance EV adoption across different consumer segments.
- Understanding these dynamics can help stakeholders focus on promoting EV adoption through targeted incentives and infrastructure development, especially for less represented brands.

8. <u>Bar Graph – Yearwise Trend for Tesla</u>

Insights:

- The bar graph "Yearwise Trend for Tesla" (*Figure 18*) illustrates the number of Tesla vehicles registered by model year from 2008 to 2024. The data shows a substantial increase in registrations starting from 2018, with a sharp rise reaching its peak in 2023.
- This trend aligns with Tesla's dominant market share observed in previous graphs (*Figure 16 and Figure 14*), where Tesla accounted for 44.5% of the EV market in Washington State.
- The early years (2008-2016) show minimal registrations, reflecting Tesla's initial phase of market entry and limited model availability.
- From 2017 onwards, there is a notable upward trajectory, with a significant jump in 2018. This period coincides with the introduction of more accessible models like the Tesla Model 3, which broadened Tesla's market appeal.
- The registrations continue to grow, with substantial increases in 2021 and 2022, culminating in a peak in 2023, suggesting strong consumer confidence and market penetration.

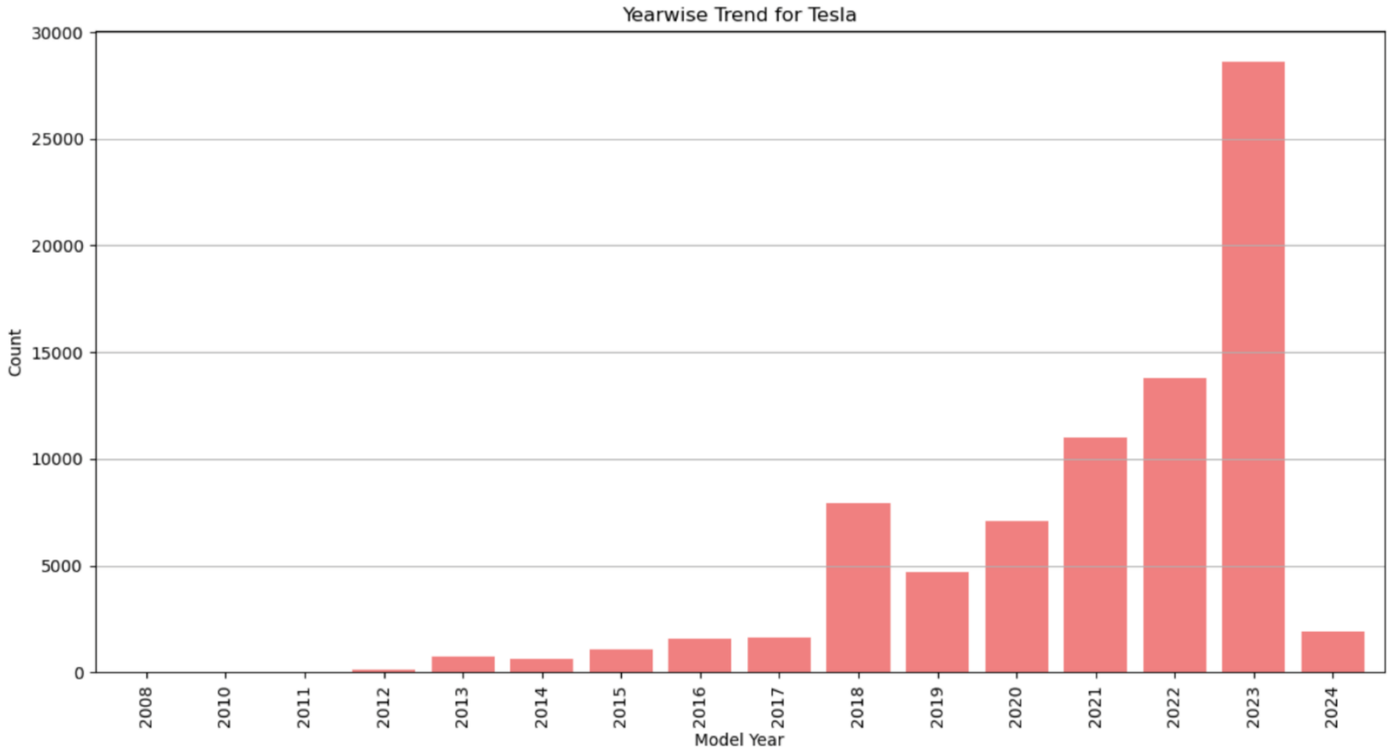

Figure 18: Yearwise Trend for Tesla

- This exponential growth underscores Tesla's leadership in the EV market, supported by factors such as advanced technology, expanding charging infrastructure, and increased production capacity.
- The spike in 2023, followed by a slight drop in 2024, might indicate a market saturation point or supply chain constraints.
- These insights, combined with the high adoption rates in cities like Seattle and the overall preference for all-electric vehicles, highlight Tesla's significant role in driving the EV market forward.
- The data emphasizes the importance of continuing to support infrastructure and policy initiatives to maintain this growth trajectory and encourage broader adoption of electric vehicles across different manufacturers.

9. <u>Pie-chart – Top 10 EV Models</u>

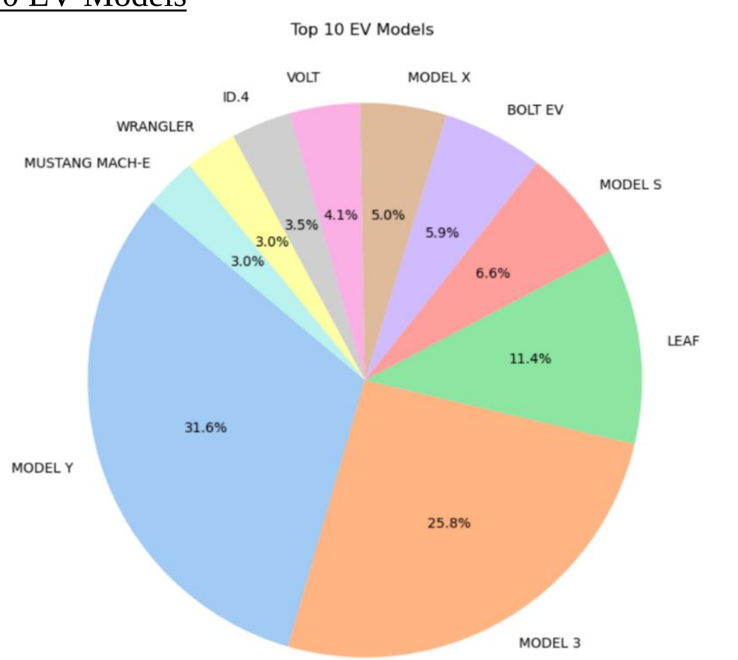

Figure 19: Top 10 EV Models

Insights:

- The pie chart "Top 10 EV Models" (*Figure 19*) illustrates the distribution of the most popular electric vehicle models in Washington State.
- Tesla models dominate the chart, with the Model Y leading at 31.6% and the Model 3 following at 25.8%.
- These two models alone account for over half of the top 10 EVs, underscoring Tesla's substantial market influence, as seen in previous graphs.
- The Nissan Leaf ranks third with 11.4%, reflecting its consistent popularity and solid market presence.
- Other notable models include the Chevrolet Bolt EV (6.6%), Tesla Model S (5.9%), and Model X (5.0%), further emphasizing Tesla's dominance across multiple models.
- The presence of models like the Chevrolet Volt (4.1%), Ford Mustang Mach-E (3.5%), Jeep Wrangler (3.0%), and Volkswagen ID.4 (3.0%) indicates a diverse market with competitive offerings from various manufacturers.
- This distribution highlights the strong consumer preference for Tesla's vehicles, consistent with earlier findings showing Tesla's overwhelming market share and rapid year-wise growth.
- The data also suggests a competitive landscape where other manufacturers are gaining traction with their unique models.
- The strong showing of Tesla's Model Y and Model 3 reflects their widespread appeal, likely due to factors like advanced technology, performance, and expanding charging infrastructure.
- As the market continues to evolve, maintaining this diversity will be crucial for sustaining the growth and adoption of electric vehicles across different segments.

10. Scatter Plot – Electric Range Vs Model Year

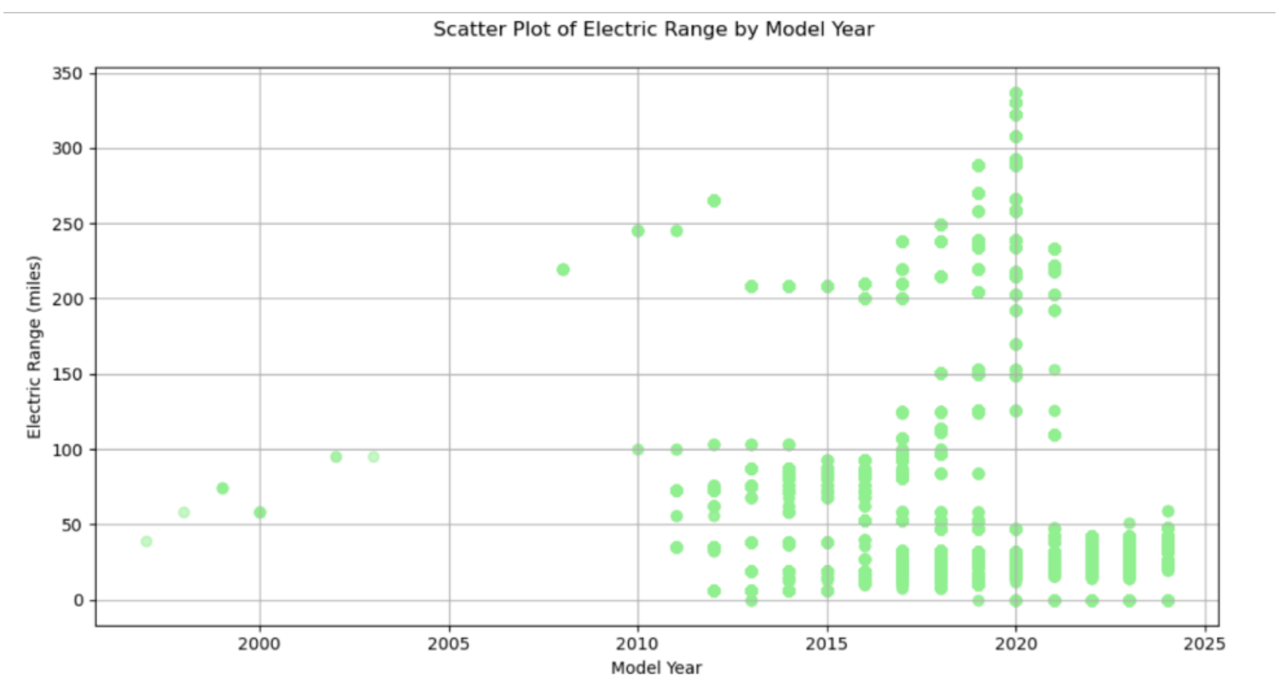

Figure 20: Scatter Plot of Electric Range by Model Year

Insights:

- The scatter plot "Electric Range by Model Year" (*Figure 20*) shows the electric range (in miles) of EVs over different model years from 2000 to 2025.
- The plot reveals significant improvements in electric vehicle range over time, particularly from 2010 onwards, reflecting advancements in battery technology and increased efficiency.

- In the early years (2000-2010), most EVs had a limited range, typically below 100 miles. Starting around 2012, there is a noticeable increase in range, with several models exceeding 200 miles.
- The trend continues upward, with more recent models (post-2018) frequently achieving ranges of 250 miles and beyond.
- This improvement aligns with the introduction of Tesla's long-range models, such as the Model S and Model 3, which have set new benchmarks for electric vehicle performance.
- The increased range in newer models correlates with the surge in EV adoption seen in previous graphs. The rise in the number of Tesla vehicles and their significant market share can be partly attributed to these advancements in range.
- Consumers are more inclined to adopt EVs as their ranges improve, addressing one of the major concerns of limited driving distance on a single charge.
- This scatter plot complements the narrative of the strong presence of Tesla, as implemented earlier, with its models like the Model Y and Model 3 leading the market.
- The data underscores the ongoing technological advancements driving the EV market forward, making electric vehicles more viable for a broader audience and fostering increased adoption.
- This trend is crucial for the continued growth of the EV market, highlighting the importance of continuous innovation in battery technology and efficiency.

11. Heatmap – Correlation Matrix for EV Data

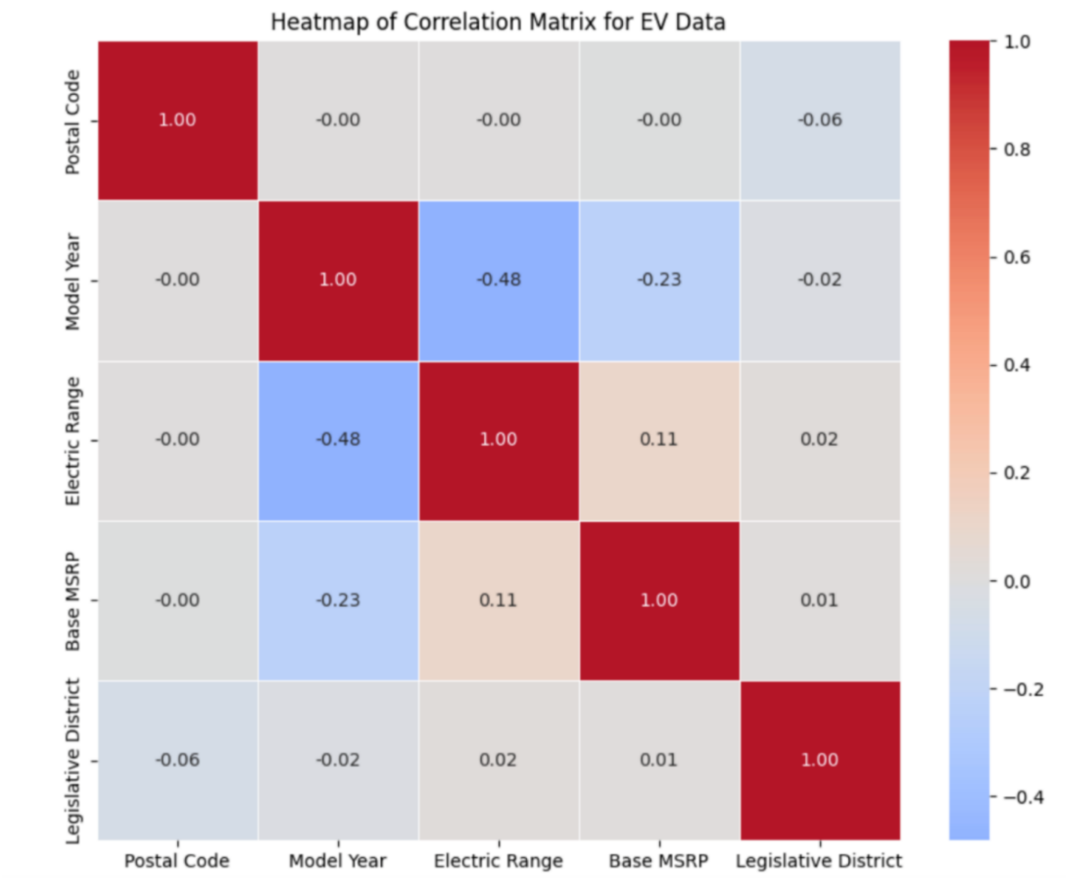

Figure 21: Heatmap of Correlation Matrix for EV Data

Insights:

- The heatmap of the correlation matrix for EV data (*Figure 21*) provides insights into the relationships between different variables in the dataset, such as Postal Code, Model Year, Electric Range, Base

MSRP, and Legislative District. The values range from -1 to 1, indicating the strength and direction of correlations.

- There is a moderate negative correlation (-0.48) between Model Year and Electric Range, suggesting that newer models generally have longer electric ranges.
- This aligns with the scatter plot that showed significant improvements in EV range over time, especially in recent years.
- A slight negative correlation (-0.23) exists between Model Year and Base MSRP, indicating that newer models might be priced lower on average. This could reflect advancements in technology making EVs more affordable, contributing to their increased adoption as seen in previous graphs.
- Other variables such as Postal Code and Legislative District show very weak or no significant correlation with the other variables, indicating that these factors are largely independent of vehicle characteristics like Model Year, Electric Range, and Base MSRP.
- There is a small positive correlation (0.11) between Electric Range and Base MSRP, indicating that vehicles with longer ranges tend to be more expensive. This is expected as higher range often comes with advanced battery technology, which typically costs more.
- This heatmap complements previous analyses by confirming the trend of increasing electric range in newer EV models and the impact of pricing on vehicle features.
- The moderate correlation between Model Year and Electric Range underscores the technological advancements driving EV market growth, as highlighted by Tesla's dominance and the increasing adoption of long-range models like the Model Y and Model 3.
- Overall, these insights highlight the ongoing improvements in EV technology and affordability, which are crucial for sustaining market growth and achieving broader adoption of electric vehicles.

Inferences and Conclusion

The comprehensive analysis of the graphs provides a detailed understanding of the electric vehicle (EV) market trends and dynamics in Washington State. Key inferences are as follows:

1. **Tesla's Dominance:** Tesla leads the EV market with a 44.5% share, particularly with models like the Model Y (31.6%) and Model 3 (25.8%). Tesla's exponential growth peaked in 2023.
2. **Rising EV Adoption:** Significant growth in EV registrations since 2018, with Seattle as the leading city. All-electric vehicles (BEVs) are preferred over plug-in hybrids (PHEVs).
3. **Manufacturer Diversity**: Besides Tesla, Nissan, and Chevrolet are major players, with Ford, BMW, Rivian, and others contributing to a competitive market.
4. **Technological Advancements:** Newer models show substantial improvements in electric range, boosting consumer confidence and adoption.
5. **Affordability and Range:** Newer models with better range are becoming more affordable, as indicated by a moderate correlation between model year and range, and a slight negative correlation between model year and MSRP.
6. **Urban Focus:** High EV adoption in urban areas like Seattle, Bellevue, and Redmond highlights the importance of infrastructure and policies.
7. **Luxury Market Presence**: Luxury and niche brands like Rolls Royce and Bentley have a minimal presence, suggesting potential growth opportunities.

Conclusions:

The EV market in Washington State shows robust growth driven by Tesla's dominance, technological advancements, and urban adoption. The preference for all-electric vehicles and improving affordability are key trends. Continued investment in infrastructure and diverse EV offerings will sustain growth and support the transition to sustainable transportation.

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[2] John Ryan, "More than 20% of new cars purchased in Washington state are electric", *Kuow Network* [Online]. Available: https://www.kuow.org/stories/electric-vehicles-keep-charging-ahead-in-washington