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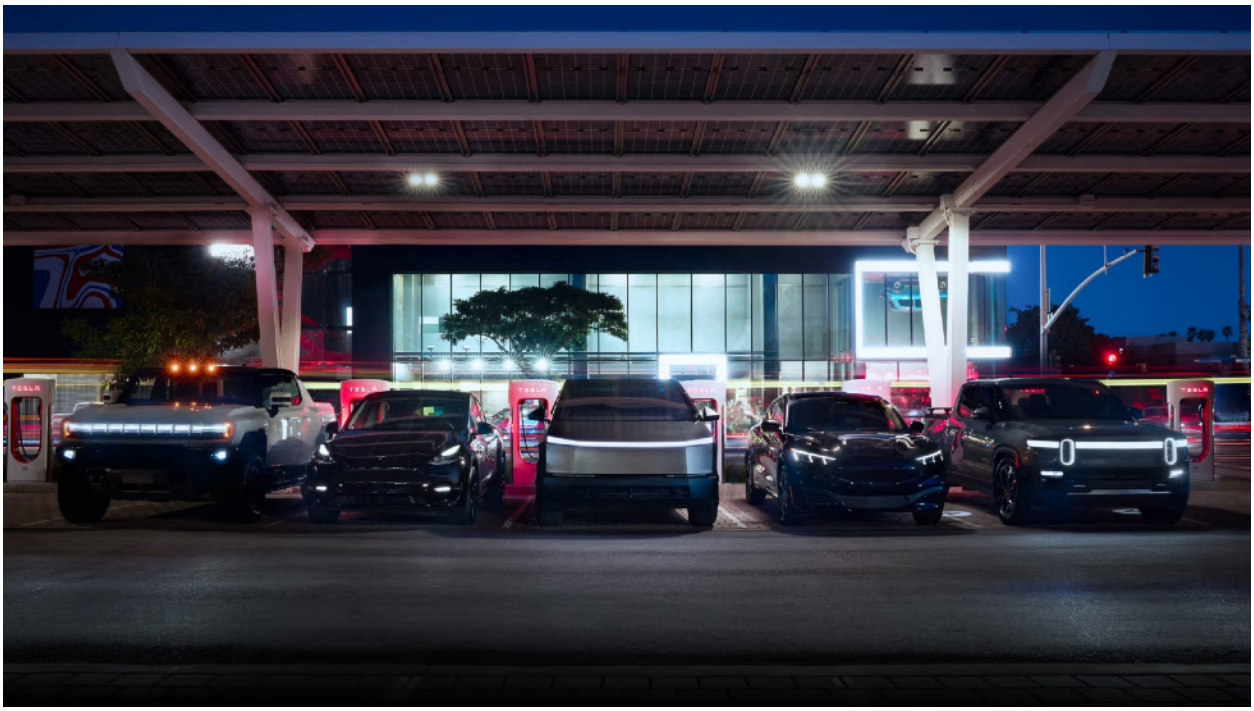
Electric Vehicle Competitive Landscape Analysis: Report



Problem Statement

Electric vehicle adoption has been growing rapidly and will continue to do so in the future. Several different car companies are also in competition with one another. Outside of considerations such as brand loyalty and personal preferences, the most important factor for neutral consumers deciding which electric vehicle to purchase is how much value they can get in return for their money. This project will seek to uncover insights into which car brands and models provide the best value for potential consumers.

Goals

- Create a novel ranking system for EV models based on the purchase price in relation to key metrics such as range and performance, and then assign a score to each model.
- Segment consumers into different groups based on sensitivity to price and preferences towards range or performance, then provide recommendations for which EV model to purchase within each segment.
- Build a linear regression model to predict what the MSRP values for each EV should be and then compare to actual MSRP values to determine which models are overpriced versus underpriced.
- Answer the question: Which brand is best positioned and which is worst positioned to continue growing their sales over the coming decade?

Data

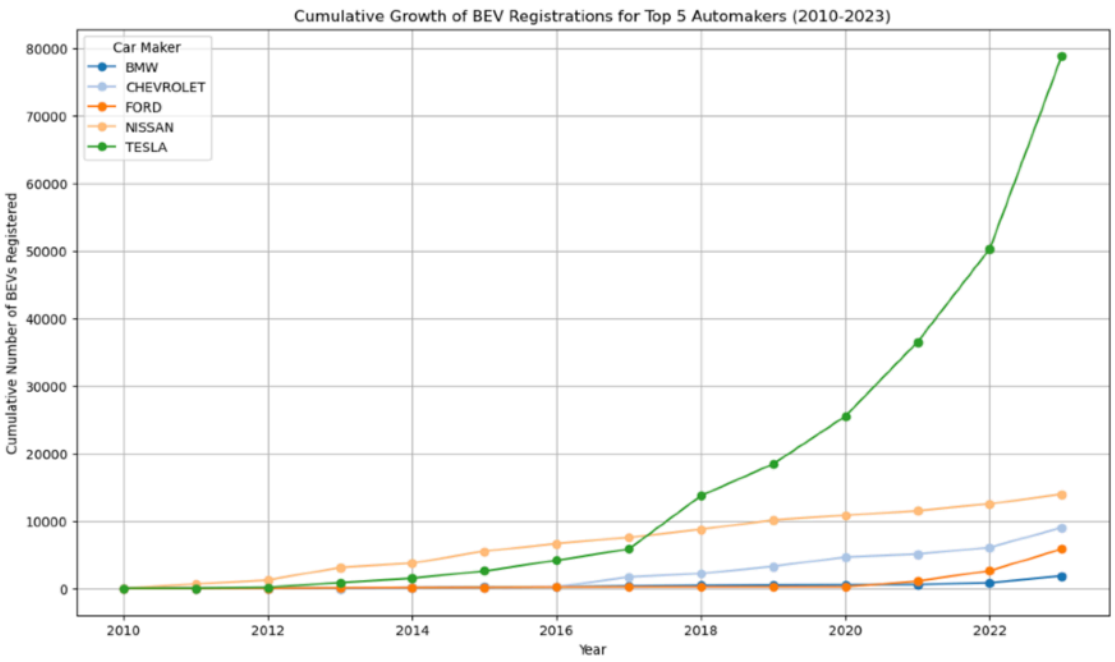
1. Electric Vehicle Population Data - This dataset shows the Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) that are currently registered through the Washington State Department of Licensing (DOL).
2. EV Ranking Data - This dataset contains the price, range, and acceleration for 36 BEV models from the top 5 best-selling brands in Washington State. It also includes a ranking system which assigns points to each model based on how much bang for the buck they provide.

   *This data was collected directly from each brand's website on May 4th, 2024.

Data Wrangling

The data wrangling notebook included separate steps for each of our two datasets. We first started with the Electric Vehicle Population Data, and the primary question we wanted to answer was: **What are the top 5 best-selling brands in Washington State?** The reason we wanted to first identify the top 5 best-selling brands was for us to do a comparative analysis between the pure BEV models that each of these brands currently offers, and then determine which ones provide the best value for consumers based on key metrics such as: price, range, and performance.

To isolate the top 5 best-selling brands, we first dropped several columns we didn't need from our dataset. We also noticed almost all the rows had missing data for "MSRP" and about half the rows had missing data for the "Electric Range". This meant we would have to separately research these missing values (which we did and later added them to our second dataset), since they would be crucial for our analysis. We then filtered our dataset by the "Make" and counted how many registrations each brand had. This gave us our answer, and the top 5 best-selling brands were (in order): **Tesla, Nissan, Chevrolet, Ford, and BMW.** We then created a graph to visualize how these top brands had grown their sales over time:



Some interesting things to note:

- Nissan was the leader in BEV registrations from at least 2011 up until 2017.
- At which point Tesla began to grow their sales exponentially (as the result of introducing the Model 3 and then Model Y to the market).
- Other brands have grown their sales mostly linearly.
- BMW and Ford were late entrants into the market, only starting to generate some real traction after 2021.

Next, we introduced our EV Ranking Data which would be relevant for our next phase of the project. It was ready to go for the EDA notebook, but we still had to prepare it to be used later on for the modeling notebook. We trimmed it down to include only the target variable (MSRP) and necessary features (vehicle type, range, and acceleration), along with the make and model for each vehicle. We then saved it as a separate csv file to be used for the modeling notebook.

EV Ranking Data

Make	Model	Type	MSRP	EV_Tax_Credit	Purchase_Price	Range_(mi)	0-60mph	Range/Price	0-60mph*Price	Bang/Buck_Score
Tesla	Model 3 Base	Sedan	$38,990	$0	$38,990	272	5.8	6.98	2.26	4.71
Tesla	Model 3 Long Range	Sedan	$47,740	$0	$47,740	341	4.2	7.14	2.01	5.14
Tesla	Model 3 Performance	Sedan	$53,990	$7,500	$46,490	296	2.9	6.37	1.35	5.02
Tesla	Model Y RWD	Crossover SUV	$44,990	$7,500	$37,490	320	6.5	8.54	2.44	6.10
Tesla	Model Y AWD	Crossover SUV	$47,990	$7,500	$40,490	310	4.8	7.66	1.94	5.71
Tesla	Model Y Performance	Crossover SUV	$51,490	$7,500	$43,990	279	3.5	6.34	1.54	4.80
Tesla	Model S AWD	Luxury Sedan	$72,990	$0	$72,990	402	3.1	5.51	2.26	3.24
Tesla	Model S Plaid	Luxury Sedan	$87,990	$0	$87,990	359	2.0	4.08	1.75	2.33
Tesla	Model X AWD	Luxury SUV	$77,990	$7,500	$70,490	335	3.8	4.75	2.68	2.07
Tesla	Model X Plaid	Luxury SUV	$92,990	$0	$92,990	326	2.5	3.51	2.32	1.18
Nissan	Ariya Engage	Crossover SUV	$43,190	$0	$43,190	216	7.1	5.00	3.07	1.93
Nissan	Ariya Engage e-4ORCE	Crossover SUV	$47,190	$0	$47,190	205	5.1	4.34	2.41	1.94
Nissan	Ariya Venture+	Crossover SUV	$47,190	$0	$47,190	304	7.2	6.44	3.40	3.04
Nissan	Ariya Engage+ e-4ORCE	Crossover SUV	$51,190	$0	$51,190	272	4.8	5.31	2.46	2.86
Nissan	Ariya Empower+	Crossover SUV	$53,690	$0	$53,690	289	7.2	5.38	3.87	1.52
Nissan	Ariya Evolve+ e-4ORCE	Crossover SUV	$54,190	$0	$54,190	272	4.8	5.02	2.60	2.42
Nissan	Ariya Platinum+ e-4ORCE	Crossover SUV	$60,190	$0	$60,190	267	4.8	4.44	2.89	1.55
Nissan	Leaf S	Hatchback	$28,140	$3,750	$24,390	149	7.5	6.11	1.83	4.28
Nissan	Leaf SV Plus	Hatchback	$36,040	$3,750	$32,290	212	6.7	6.57	2.16	4.40
Chevrolet	Equinox 2LT eAWD	Crossover SUV	$45,200	$7,500	$37,700	285	5.9	7.56	2.22	5.34
Chevrolet	Blazer RS eAWD	Crossover SUV	$53,200	$7,500	$45,700	279	6.0	6.11	2.74	3.36
Ford	Mustang Mach-E Base	Crossover SUV	$39,995	$0	$39,995	250	5.6	6.25	2.24	4.01
Ford	Mustang Mach-E GT	Crossover SUV	$53,995	$0	$53,995	280	3.8	5.19	2.05	3.13
Ford	Mustang Mach-E Rally	Crossover SUV	$59,995	$0	$59,995	265	3.4	4.42	2.04	2.38
BMW	i4 eDrive35	Sedan	$52,200	$0	$52,200	276	5.8	5.29	3.03	2.26
BMW	i4 eDrive40	Sedan	$57,300	$0	$57,300	301	5.4	5.25	3.09	2.16
BMW	i4 xDrive40	Sedan	$61,600	$0	$61,600	307	4.9	4.98	3.02	1.97
BMW	i4 M50	Sedan	$69,700	$0	$69,700	269	3.7	3.86	2.58	1.28
BMW	i5 eDrive40	Luxury Sedan	$66,800	$0	$66,800	295	5.7	4.42	3.81	0.61
BMW	i5 xDrive40	Luxury Sedan	$70,100	$0	$70,100	266	5.2	3.79	3.65	0.15
BMW	i5 M60	Luxury Sedan	$84,100	$0	$84,100	256	3.7	3.04	3.11	-0.07
BMW	iX xDrive50	Luxury SUV	$87,250	$0	$87,250	309	4.4	3.54	3.84	-0.30
BMW	iX M60	Luxury SUV	$111,500	$0	$111,500	285	3.6	2.56	4.01	-1.46
BMW	i7 eDrive 50	Ultra-Luxury Sedan	$105,700	$0	$105,700	321	5.3	3.04	5.60	-2.57
BMW	i7 eDrive 60	Ultra-Luxury Sedan	$124,200	$0	$124,200	317	4.5	2.55	5.59	-3.04
BMW	i7 M70	Ultra-Luxury Sedan	$168,500	$0	$168,500	291	3.5	1.73	5.90	-4.17

*Above is a screenshot of the original EV Ranking Data. It includes a ranking system which assigns points to each model based on how much **"bang for the buck"** they provide.

How the Ranking System Works:

- First, all the relevant data is collected and placed into the first 8 columns:

1. **Make**: The brand of the vehicle.
2. **Model**: The specific model or name of the vehicle.
3. **Type**: Indicates the vehicle type (Sedan, Crossover SUV, Hatchback, Luxury Sedan, Etc).
4. **MSRP**: The Manufacturer's Suggested Retail Price.
5. **EV_Tax_Credit**: Whether a vehicle is eligible for a tax credit – if it is, the amount is shown.
6. **Purchase_Price**: MSRP minus the tax credit (if applicable).
7. **Range_(mi)**: The distance the vehicle can travel on electric power, measured in miles.
8. **0-60mph**: The time it takes to accelerate from 0-60mph, measured in seconds.

- Then, the data is used to calculate scores for the final 3 columns based on the following relationships:

9. **Range/Price**: The range in miles divided by the purchase price, multiplied by a scaling factor of 1,000.
   - (Higher values are better. Essentially, it measures how far you can travel per dollar spent).
10. **0-60mph*Price**: The acceleration multiplied by the purchase price, divided by a scaling factor of 100,000.
    - (Lower values are better. Essentially, it measures the quickness of the acceleration times dollar spent. Multiplication is used in this case because of the inverse relationship).

11. **Bang/Buck_Score**: The difference between the “Range/Price” and “0-60mph*Price” scores.
    - (Higher values are better. This is the overall score of how much **"bang for your buck"** a vehicle provides).

*The reason why the scaling factors were applied is so that each score could be within the same order of magnitude in order to calculate the overall score, and so that the ranking scale could also be in a familiar range (most values fall between 0-5).

Lessons Learned From Collecting the Data Above:

- EV prices are subject to change, and whenever they do, the respective scores will also get affected. This dataset is only accurate as of May 4th, 2024, and any other dates where the prices and specs for each EV model remained the same. This data is meant to represent only a snapshot of the market at this given point in time.
- As time goes on, the scores for each EV model will also likely change. However, as long as the data gets updated, the formula for the ranking system remains the same.
- Some brands, (such as Tesla, BMW, and Ford), make it easy to find information on range and performance for each model on their websites, while other brands, (such as Chevrolet and Nissan), make it difficult to find the relevant information.
- On the webpage for the Equinox, for example, Chevy lists out the maximum range on its FWD model and the 0-60mph time of its quickest eAWD model, but won't show both the range and performance specs together for each individual model. From Chevy's website alone, it is impossible to know the 0-60mph time on the long range model, or the range of the quickest model. There is always a trade-off between range and performance, but the way Chevy

presents its specs online makes it seem to the consumer like they would be getting the best of both worlds, which is not the case.

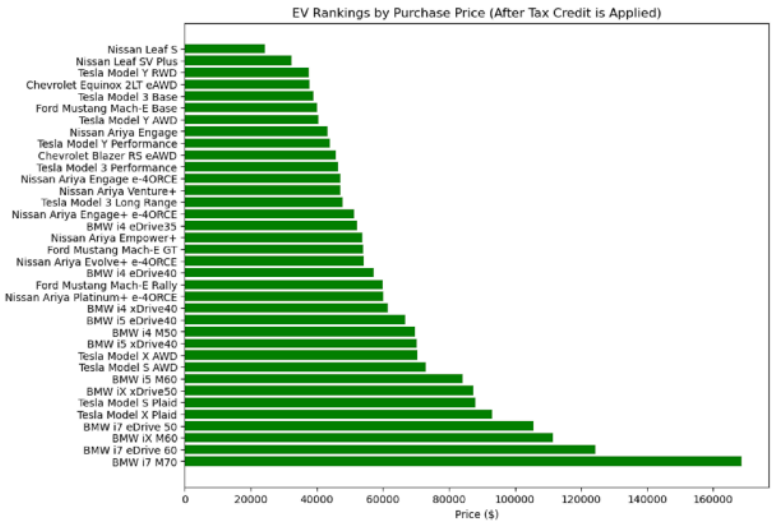
- To collect the necessary data for some of Chevy's and Nissan's models, we had to look at other sources such as MotorTrend reviews which had tested certain trims and had information on the full specifications on range and performance we needed.
- Because of this, several trims of the Chevy Equinox and Blazer were left out since there was incomplete information on both the range and performance for them (at the time this dataset was collected). Hopefully there will be more transparency in the future.

Exploratory Data Analysis

The purpose of this section was to explore the EV Ranking Data in order to help us answer the main question we are interested in: Which brand is best positioned and which is worst positioned to continue growing their sales over the coming decade? To get a sense of which models will most likely be the best sellers going forward, we segmented consumers into the following groups and then provided recommendations for which EV model to purchase within each group:

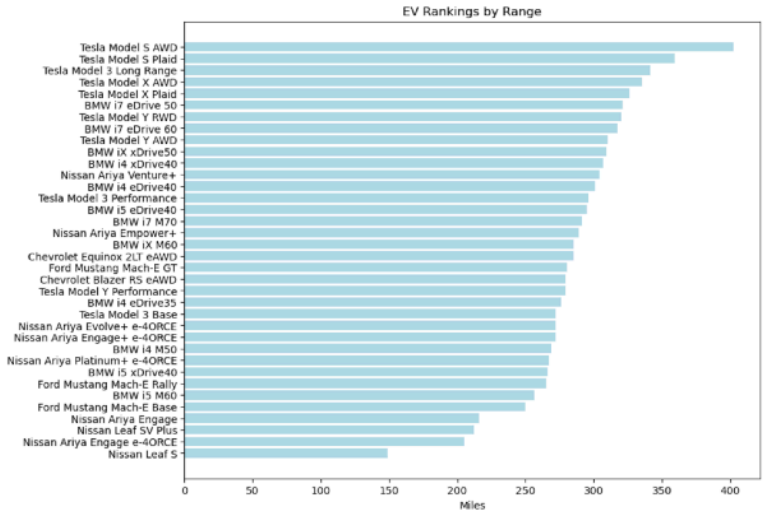
- Those who are most sensitive to price.
- Those who care most about range.
- Those who want the best value for range.
- Those who care most about performance.
- Those who want the best value for performance.
- Those who want the best value for money overall.

Those Who are Most Sensitive to Price:



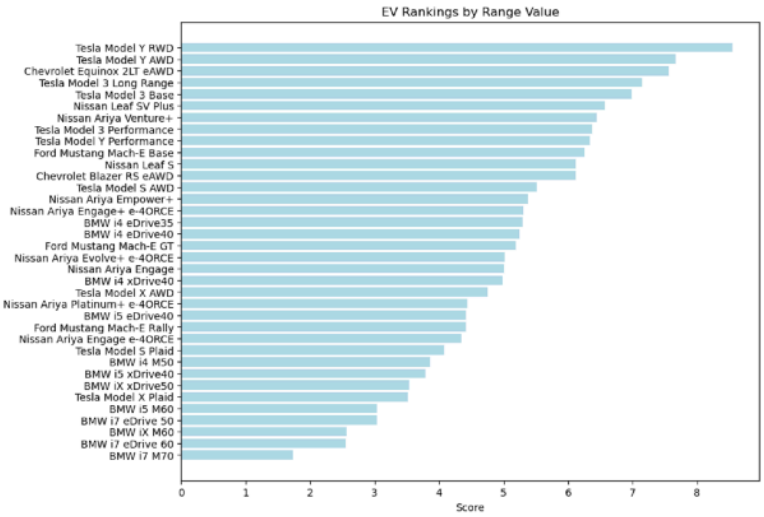
- The Nissan Leaf S is the most affordable vehicle in our dataset.
- BMW models tend to be the most expensive.

Those Who Care Most About Range:



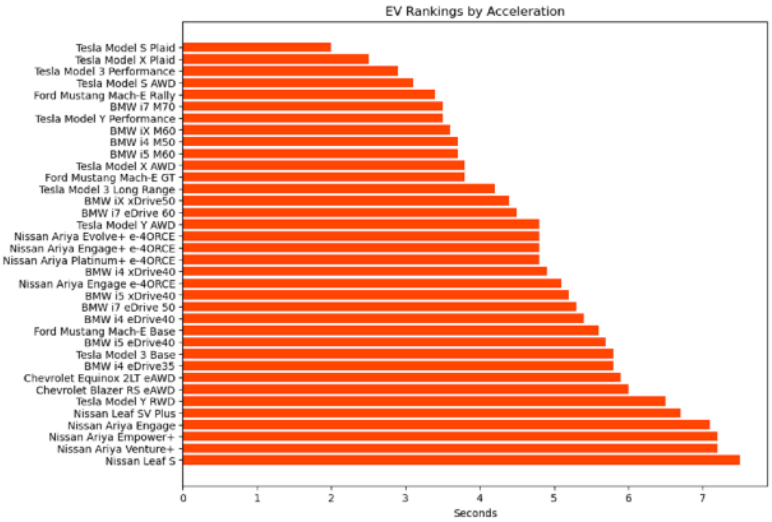
- The Tesla Model S AWD is the vehicle with longest range at 402 miles.
- Nissan tends to offer models with the least amount of range.

Those Who Want the Best Value for Range:



- The Tesla Model Y RWD wins, providing 320 miles of range for a $37,490 purchase price.
- BMW tends to offer the worst value for range in the dataset.

Those Who Care Most About Performance:

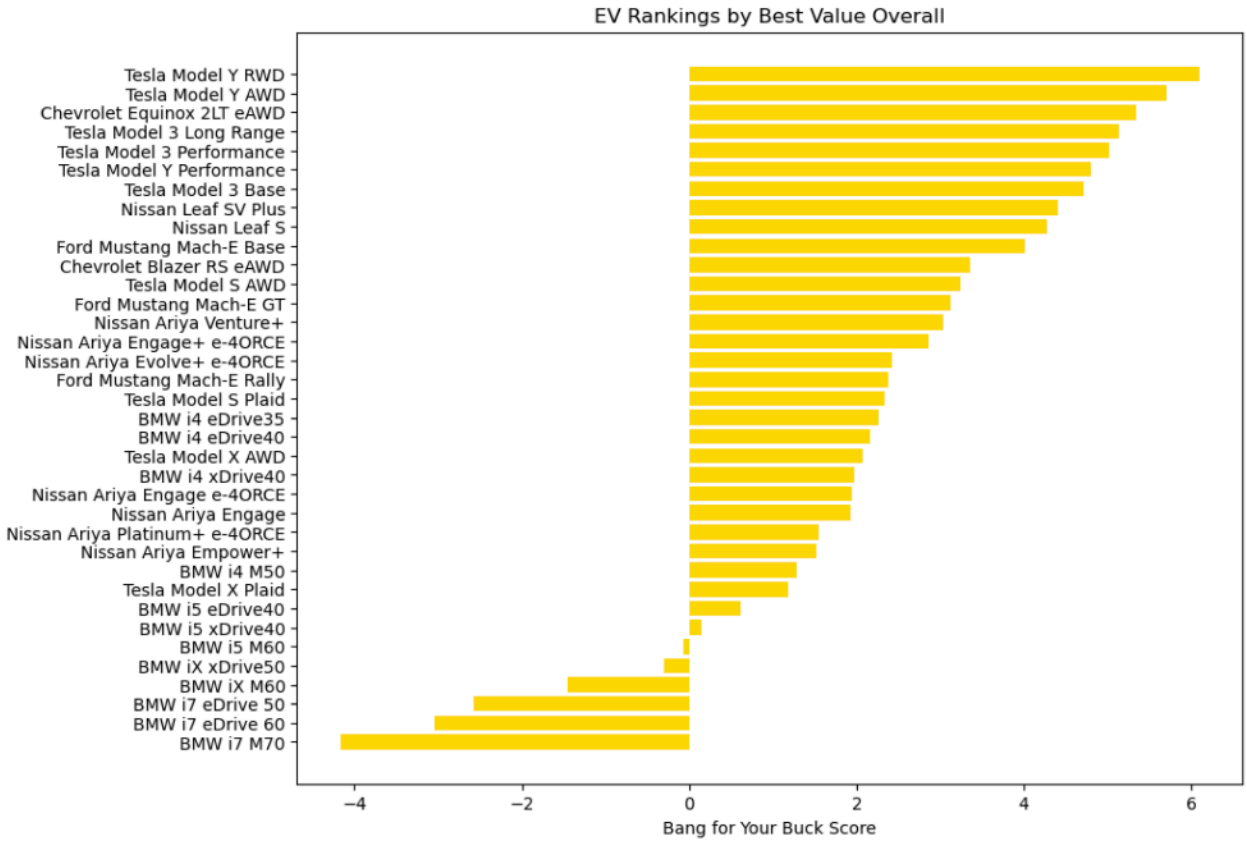


- The Tesla Model S Plaid comes in 1st place with a 2s 0-60mph time!
- Nissan tends to offer the slowest EVs.

Those Who Want the Best Value for Performance:

- The Tesla Model 3 Performance wins this one, offering a 2.9s 0-60mph time for only $46,490.
- BMW tends to offer the worst value for performance in the dataset.

Those Who Want the Best Value for Money Overall:



- Most of the top 7 best EVs for best value overall are from Tesla, except for the Chevy Equinox 2LT eAWD which makes an impressive appearance at #3.
- Nissan and Ford also have models which make it into the top 10.
- BMW fares the worst, its best value model (i4 eDrive35) coming in at #19, while most of its remaining lineup can be found at the bottom of the list.

Modeling

The purpose of this section was to create a linear regression model that predicts what the MSRP price of each vehicle should be, and then contrast that with the actual MSRP values in the dataset to determine which models are overpriced compared to the market. At the end, we also compared our linear regression model to random forest and gradient boosting models, and determined that the linear regression model worked best. These were the metrics:

Mean Absolute Error (MAE): $11,223

- This result indicates that, on average, the predicted MSRP values are about $11,223 off from the actual MSRP values.
- This was actually a reasonable amount to expect since some EV models were shown to offer good value for money while others offered bad value for money, so we expected the MAE to reflect the fact that some models are underpriced and others are overpriced compared to the market.

R2 Score: 0.786

- The R2 score suggests a relatively good fit of the model to the data, showing that it explains about 78.6% of the variance in MSRP.

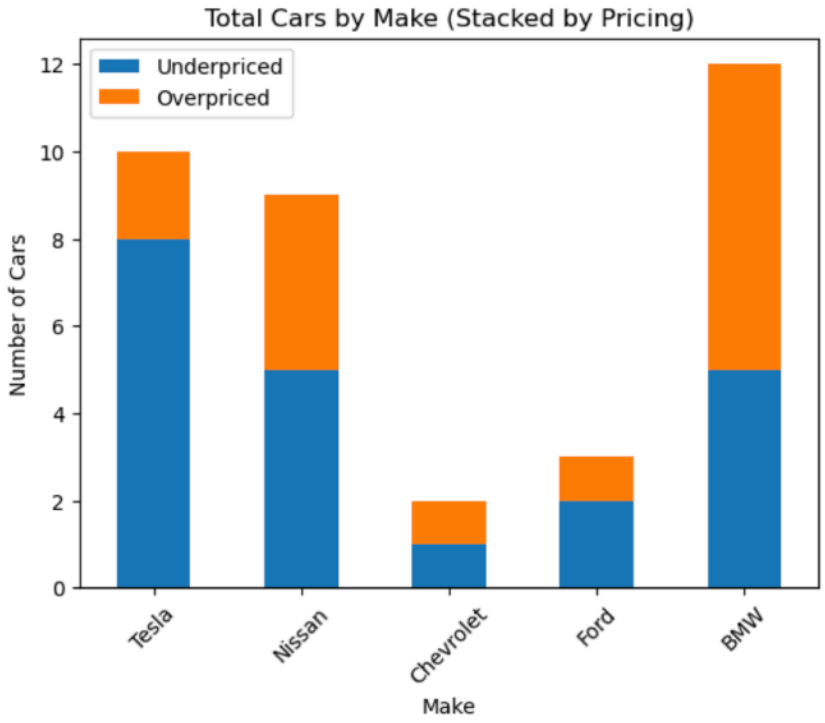
Actual MSRP Versus Predicted MSRP Table:

Make	Model	Actual MSRP	Predicted MSRP	Pricing
Tesla	Model 3 Base	$38,990	$52,883	Underpriced
Tesla	Model Y RWD	$44,990	$45,546	Underpriced
Tesla	Model 3 Long Range	$47,740	$57,164	Underpriced
Tesla	Model Y AWD	$47,990	$50,535	Underpriced
Tesla	Model Y Performance	$51,490	$63,327	Underpriced
Tesla	Model 3 Performance	$53,990	$69,034	Underpriced
Tesla	Model S AWD	$72,990	$69,801	Overpriced
Tesla	Model X AWD	$77,990	$97,786	Underpriced
Tesla	Model S Plaid	$87,990	$80,593	Overpriced
Tesla	Model X Plaid	$92,990	$104,232	Underpriced
Nissan	Leaf S	$28,140	$36,564	Underpriced
Nissan	Leaf SV Plus	$36,040	$25,994	Overpriced
Nissan	Ariya Engage	$43,190	$45,446	Underpriced
Nissan	Ariya Venture+	$47,190	$42,031	Overpriced
Nissan	Ariya Engage e-4ORCE	$47,190	$59,400	Underpriced
Nissan	Ariya Engage+ e-4ORCE	$51,190	$52,308	Underpriced
Nissan	Ariya Empower+	$53,690	$36,398	Overpriced
Nissan	Ariya Evolve+ e-4ORCE	$54,190	$55,751	Underpriced
Nissan	Ariya Platinum+ e-4ORCE	$60,190	$52,501	Overpriced
Chevrolet	Equinox 2LT eAWD	$45,200	$47,778	Underpriced
Chevrolet	Blazer RS eAWD	$53,200	$44,258	Overpriced
Ford	Mustang Mach-E Base	$39,995	$50,148	Underpriced
Ford	Mustang Mach-E GT	$53,995	$55,654	Underpriced
Ford	Mustang Mach-E Rally	$59,995	$57,324	Overpriced
BMW	i4 eDrive35	$52,200	$52,495	Underpriced
BMW	i4 eDrive40	$57,300	$48,425	Overpriced
BMW	i4 xDrive40	$61,600	$51,754	Overpriced
BMW	i5 eDrive40	$66,800	$66,412	Overpriced
BMW	i4 M50	$69,700	$56,461	Overpriced
BMW	i5 xDrive40	$70,100	$74,938	Underpriced
BMW	i5 M60	$84,100	$78,487	Overpriced
BMW	iX xDrive50	$87,250	$90,264	Underpriced
BMW	i7 eDrive 50	$105,700	$141,526	Underpriced
BMW	iX M60	$111,500	$86,690	Overpriced
BMW	i7 eDrive 60	$124,200	$135,929	Underpriced
BMW	i7 M70	$168,500	$121,306	Overpriced

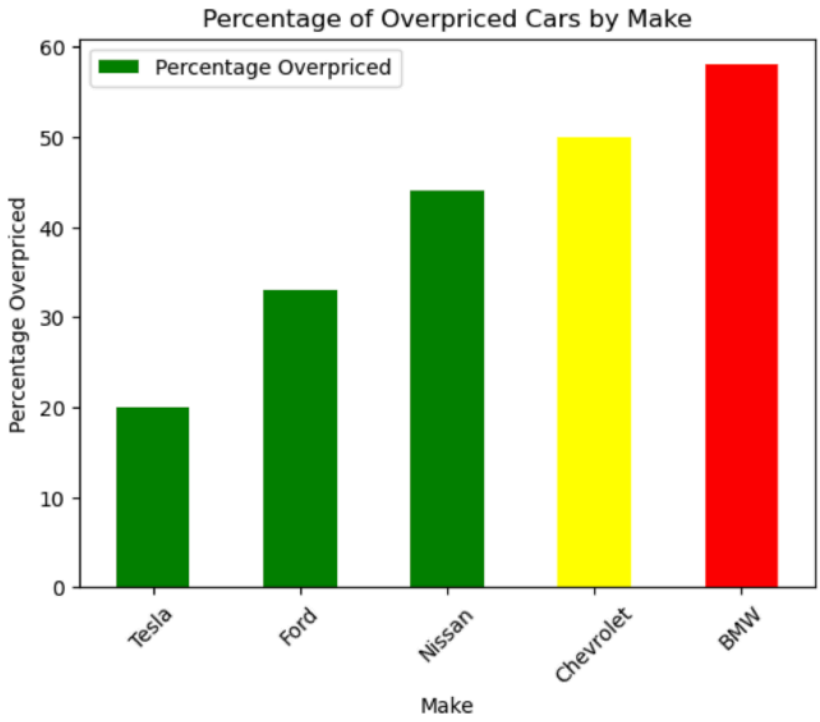
- We ran cross-validation on our dataset to get MSRP comparisons for all EV models.
- We also added a new column to visualize which models were overpriced versus underpriced.

Results:

Pricing	Overpriced	Underpriced
Make		
Tesla	2	8
Nissan	4	5
Chevrolet	1	1
Ford	1	2
BMW	7	5



- The amount of models for each brand that are either overpriced or underpriced.



- The percentage of each brand's lineup that is overpriced.
- Tesla has the lowest percentage at 20%.
- BMW has the highest percentage at 58%

Model Comparison Table:

Model	Mean Absolute Error (MAE)	R^2 Score
Linear Regression	$11,223	0.786
Random Forest	$15,882	0.496
Gradient Boosting	$11,948	0.713

Conclusion

We were successful in creating a novel ranking system for EV models which was used to calculate scores for the best value for range, performance, and overall rating. This allowed us to provide the best recommendations for which EV models to purchase for potential consumers in each of the different segments. We then also built a linear regression model that predicted what the MSRP values for each EV should be (to a reasonable degree), and then compared that to the actual MSRP values to determine which models were overpriced. After all of our analysis, it is clear that Tesla is best positioned to continue growing their sales over the coming decade while BMW is worst positioned.

Future Improvements

1. Include more brands and EV models to compare across many more regional markets as well as globally.
    - The main difficulty includes creating the necessary datasets. New EV models are constantly introduced to the market and their prices and specs are also subject to change over time. As these factors change so will the ratings for each EV model.
2. Include more factors such as battery charging speeds, safety ratings, cost of ownership, brand reputation, access to the Supercharger Network, Autonomous Driving capabilities, Etc.

- Adding more dimensions could add more completeness to the overall final score, but may also add more complexities.

3. Add missing vehicle categories (such as pickup trucks).
   - The reason why pickup trucks were left out in this iteration is because they come with their own set of ranking criteria, such as: torque, towing capacity, and payload capacity.

Sources for the EV Ranking Data:

Tesla:

https://www.tesla.com/

Nissan Ariya:

https://www.nissanusa.com/shopping-tools/build-price?models=nissan-ariya

https://www.nissanusa.com/vehicles/electric-cars/ariya/features/range-charging-battery.html

Nissan Leaf:

https://www.nissanusa.com/vehicles/electric-cars/leaf/features.html

https://www.motortrend.com/cars/nissan/leaf/

Chevy Equinox:

https://www.chevrolet.com/electric/equinox-ev

https://www.chevrolet.com/shopping/configurator/model?bodyStyle=equinox-ev&bodyType=&make=chevrolet&model=equinox-ev&radius=100&year=2024&zipCode=48362

https://www.motortrend.com/news/2024-chevy-equinox-ev-price-msrp/

Chevy Blazer:

https://www.chevrolet.com/shopping/configurator/model?bodyStyle=blazer-ev&bodyType=&make=chevrolet&model=blazer&radius=100&year=2024&zipCode=84101

https://www.motortrend.com/news/chevrolet-blazer-ev-2024-suv-of-the-year/

Ford Mach E:

https://www.ford.com/finder/2024/mach-e?intcmp=vhpOverview-singleStat-vft

BMW i4:

https://www.bmwusa.com/vehicles/all-electric/i4/gran-coupe/build-your-own.html

BMW i5:

https://www.bmwusa.com/vehicles/all-electric/i5/sedan/build-your-own.html

BMW iX:

https://www.bmwusa.com/vehicles/all-electric/ix/suv/build-your-own.html

BMW i7:

https://www.bmwusa.com/vehicles/all-electric/i7/sedan/build-your-own.html

Tax Credit Eligibility:

https://fueleconomy.gov/feg/tax2023.shtml