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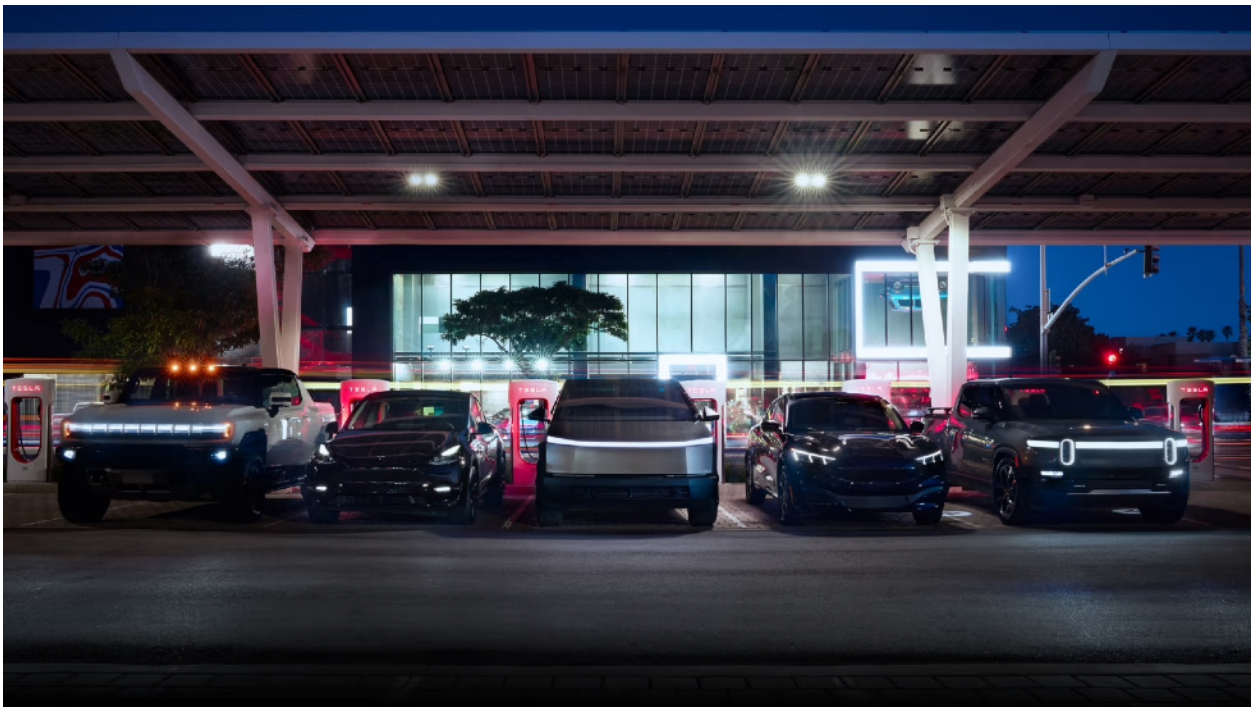
Electric Vehicle Competitive Landscape Analysis: Report



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 model 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 of 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 dataset was collected on May 4th, 2024.

EV Ranking Data

The motivation for creating this dataset and ranking system was to come up with an objective way of finding out which car brands and models provide the best value for potential consumers looking to buy a new EV. Although there may be a variety of factors that any particular consumer might take into account before making a purchase, we determined that the three main factors of interest are the: price, range, and performance. These are the key metrics all car brands directly compete on and the ones that influence the overall value of each model the most.

To determine value, our approach was to calculate the ratios of how much "range" and "performance" each model provides in relation to its price. We then applied a scaling factor to each ratio in order to get scores that would be within the same order of magnitude. This allowed us to calculate an overall score for each model and create a ranking scale that would be in a familiar range (most values fall between 0-5).

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 EV Ranking Data

How the Ranking System Works:

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

3. **Make**: The brand of the vehicle.
4. **Model**: The specific model or name of the vehicle.
5. **Type**: Indicates the vehicle type (Sedan, Crossover SUV, Hatchback, Luxury Sedan, Etc).
6. **MSRP**: The Manufacturer's Suggested Retail Price.
7. **EV_Tax_Credit**: Whether a vehicle is eligible for a tax credit – if it is, the amount is shown.
8. **Purchase_Price**: MSRP minus the tax credit (if applicable).
9. **Range_(mi)**: The distance the vehicle can travel on electric power, measured in miles.
10. **0-60mph**: The time it takes to accelerate from 0-60mph, measured in seconds.

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

11. **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).
12. **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).
13. **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).

If we take a quick glance at the scores in the dataset above, we can already get an intuition for which brands and models offer the best value, but we will later explore in more detail how they compare to one another in the EDA section. For now, we will go over the steps we took to clean our datasets:

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 the key metrics we identified: price, range, and performance.

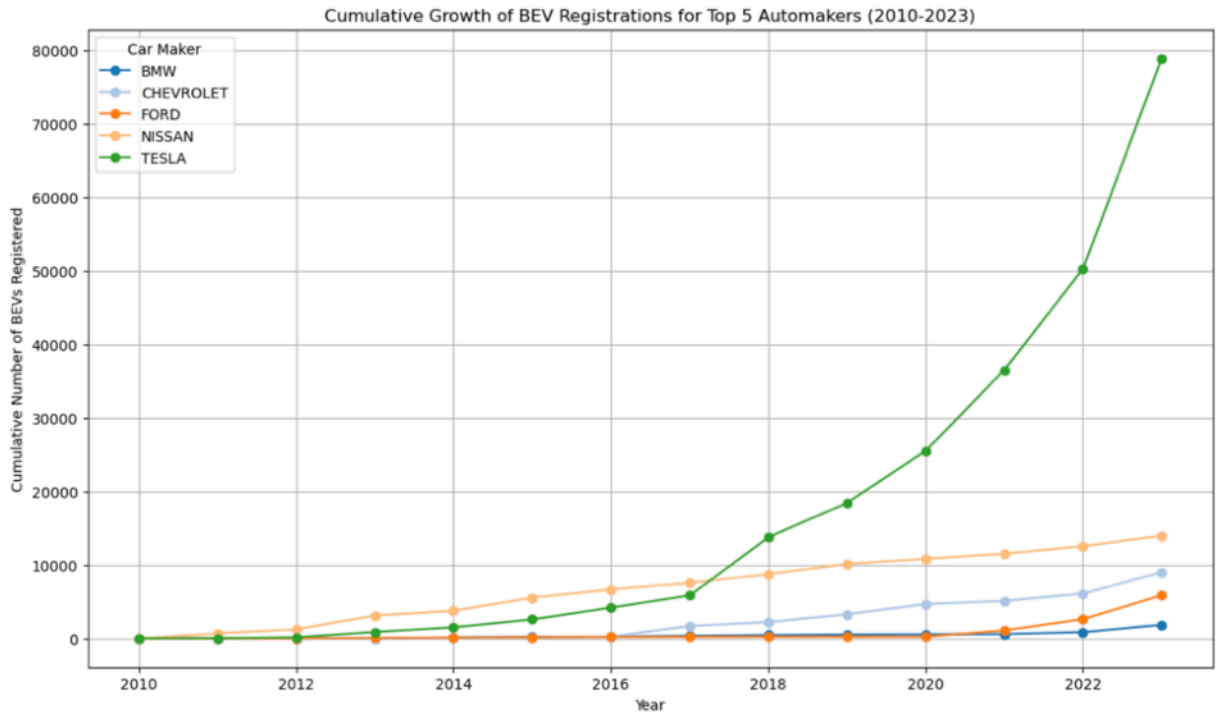
To isolate the top 5 best-selling brands, we first dropped several columns we did not need from our dataset. We also noticed almost all the rows had missing data for “MSRP” and about half the rows had missing data for the “Electric Range”. This meant we would have to separately research these missing values (which we later did and added them to our second dataset), since they would be crucial for our analysis. We then filtered our dataset by “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.**

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 for modeling. The steps were quite simple, we just trimmed it down to include only the target variable (MSRP) and the 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 later on in the modeling notebook.

Exploratory Data Analysis

The purpose of this section was to visually explore our datasets 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? We first started by having a look at how the previous decade had unfolded (looking at data from 2010 up to 2023). Tesla has been the clear leader in recent times, will that remain the case?



Some interesting things to note:

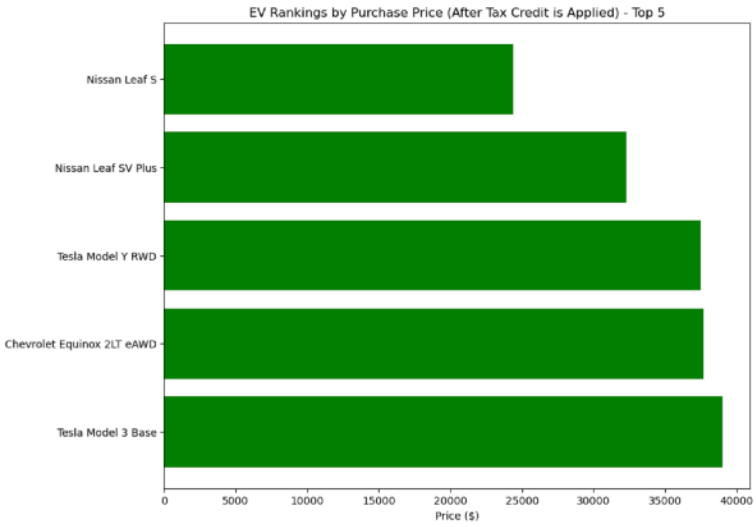
- Nissan was the leader in BEV registrations from at least 2011 up until 2017.
- At which point, Tesla began to grow their sales exponentially (as the result of introducing the Model 3 and then the Model Y to the market).
- Other brands have grown their sales mostly linearly.
- BMW and Ford were late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

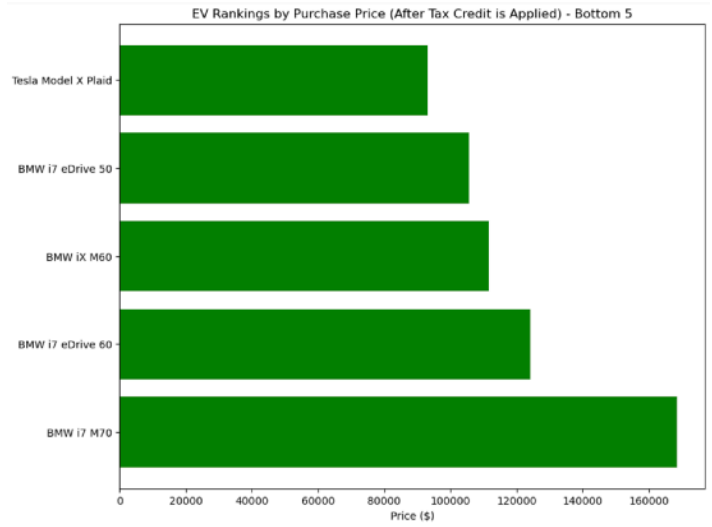
To get a better sense of which models will most likely be the best sellers going forward, we segmented consumers into the following groups:

- 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 overall.

We then provided recommendations for which EV model to purchase within each group. The reason these groups were created is because they cover the majority of the circumstances or preferences each consumer might have. Some people might have range anxiety and seek the most amount of range they can afford, while others might prioritize the quickest acceleration available within their budget. There are also those who prefer to have a balance between the two.

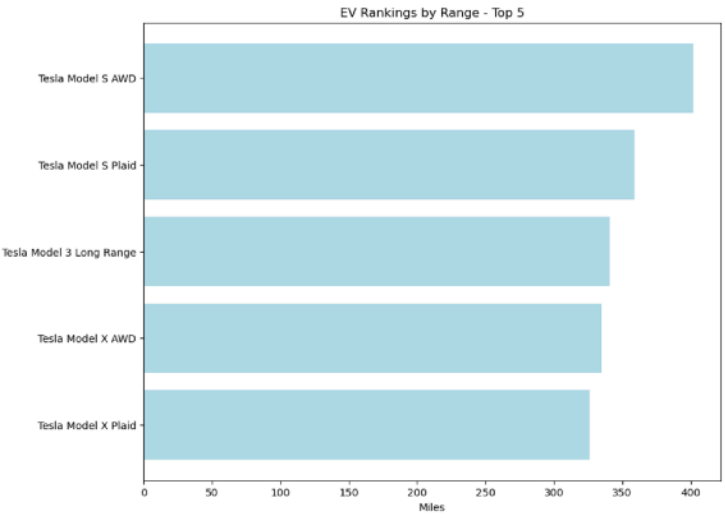
Those Who are Most Sensitive to Price:

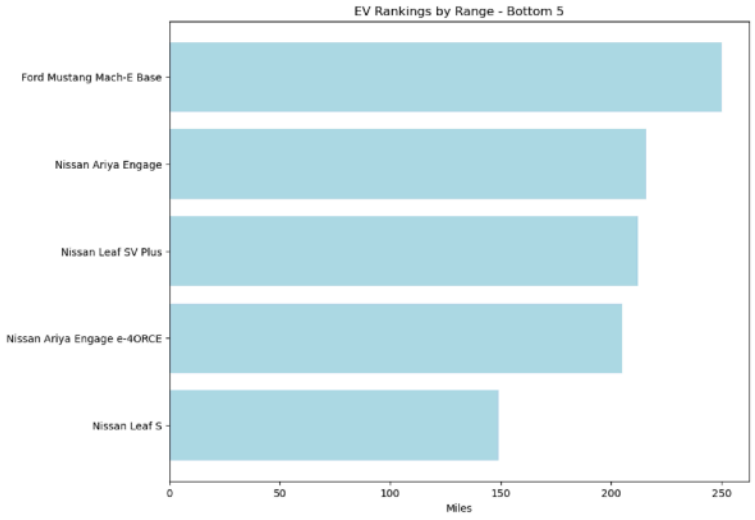




- The Nissan Leaf S is the most affordable vehicle in our dataset with a $24,390 purchase price.
- BMW models tend to be the most expensive, with the i7 M70 starting at $168,500.

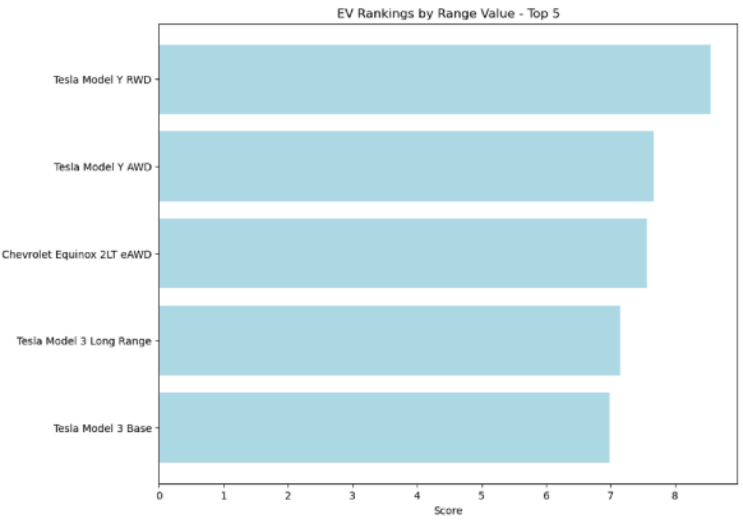
Those Who Care Most About Range:

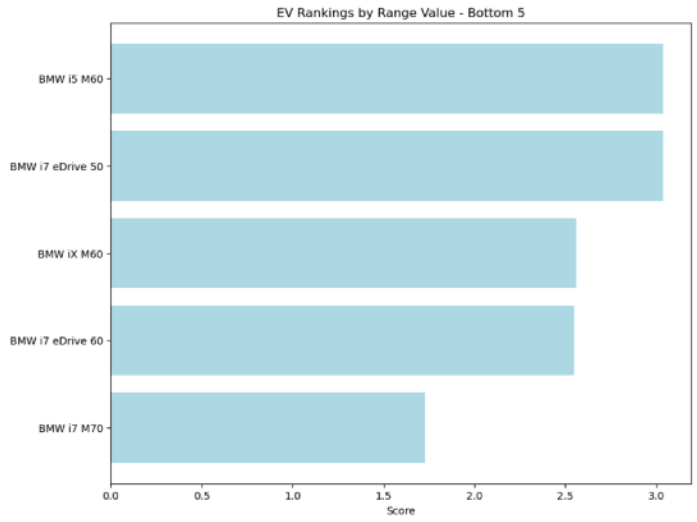




- The Tesla Model S AWD is the vehicle with the longest range, offering 402 miles.
- Nissan tends to offer models with the least amount of range, the Leaf S only has 149 miles.

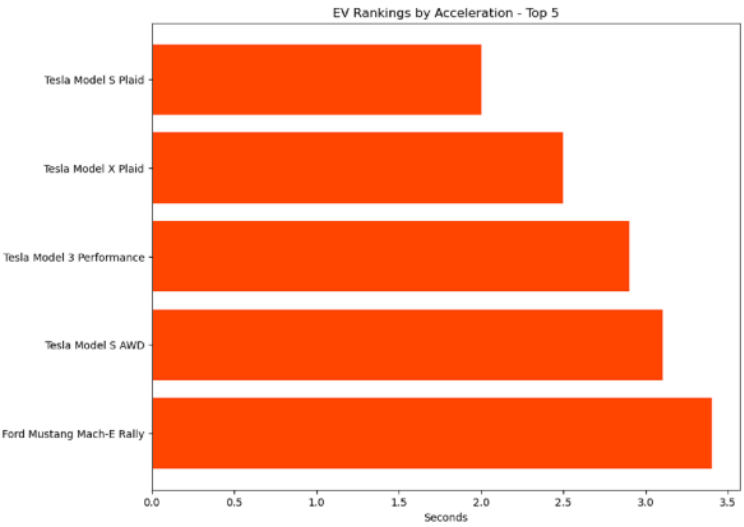
Those Who Want the Best Value for Range:

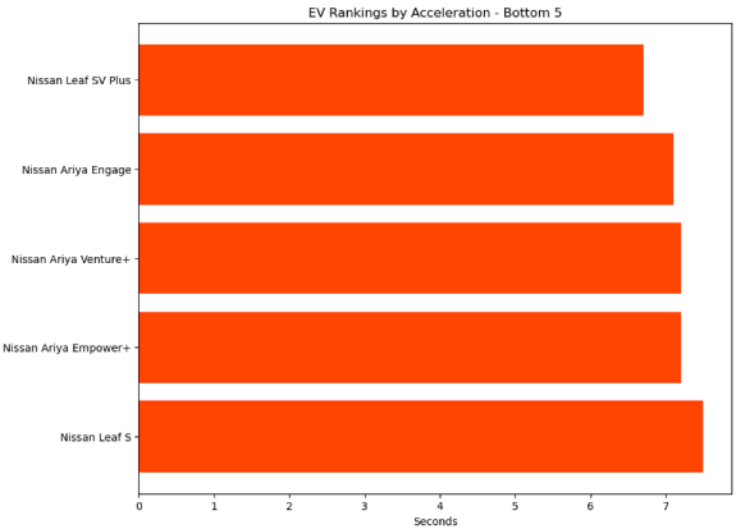




- The Tesla Model Y RWD received the highest score, providing 320 miles of range for $37,490.
- BMW models tend to offer the worst value for range in the dataset.

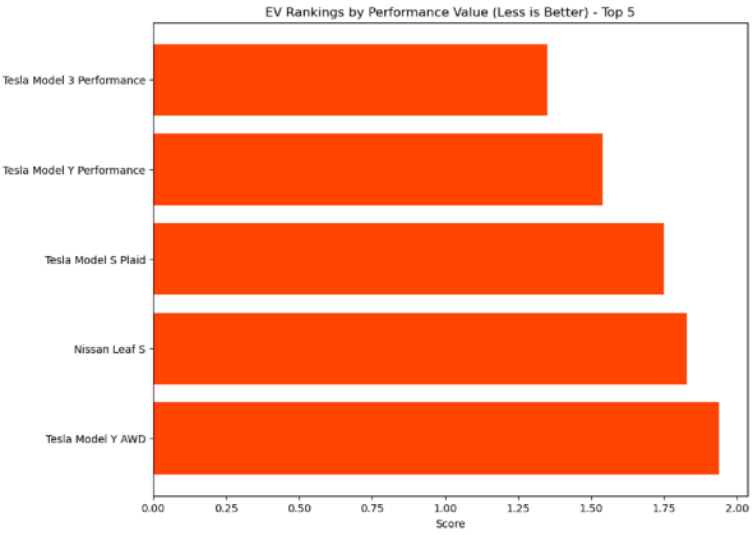
Those Who Care Most About Performance:

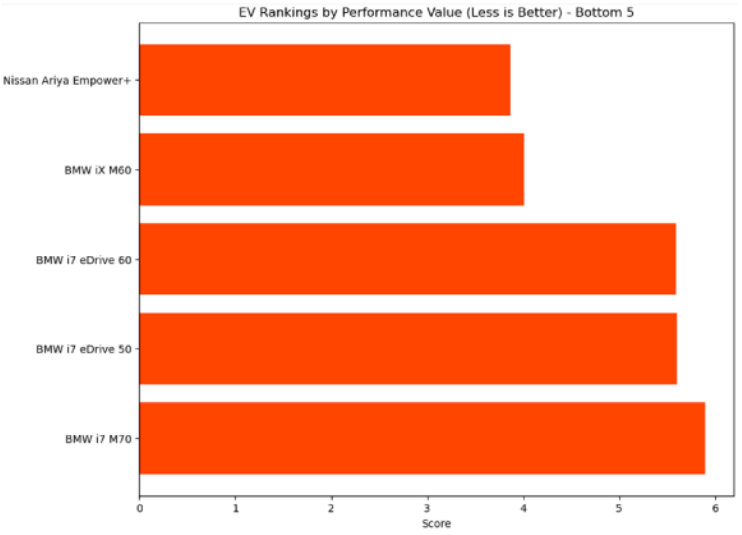




- The Tesla Model S Plaid has the quickest 0-60mph time – only 2 seconds!
- Nissan tends to offer the slowest models, the Leaf S takes 7.5 seconds to reach 60mph.

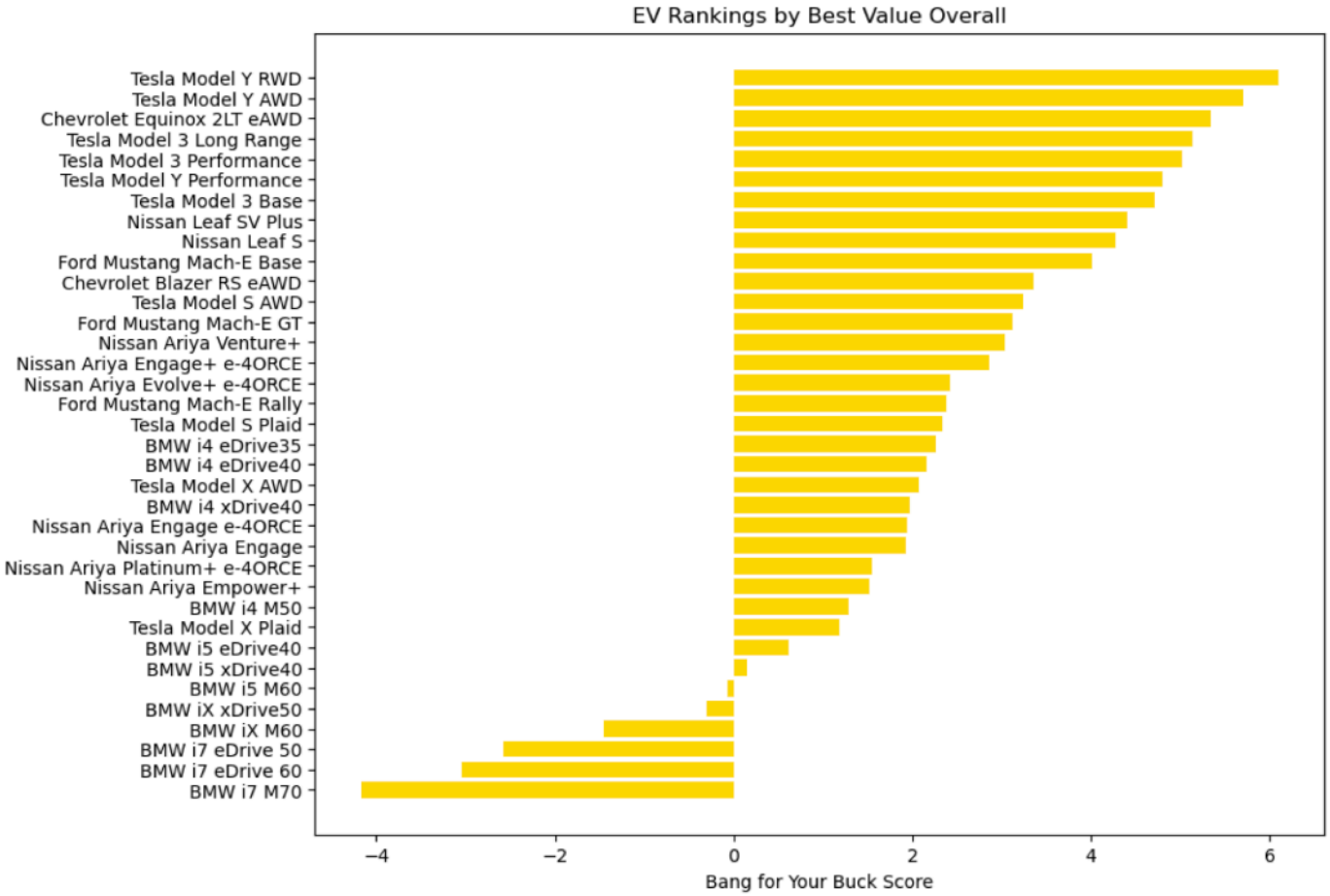
Those Who Want the Best Value for Performance:





- The Tesla Model 3 Performance received the best score for its 2.9s 0-60mph time at $46,490.
- BMW tends to offer the worst value for performance in the dataset.

Those Who Want the Best Value Overall:



- Most of the top 7 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 made it into the top 10.
- BMW fares the worst, with 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 a random forest and a gradient boosting model, 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 the market is not perfectly priced. We found that 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 while 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.

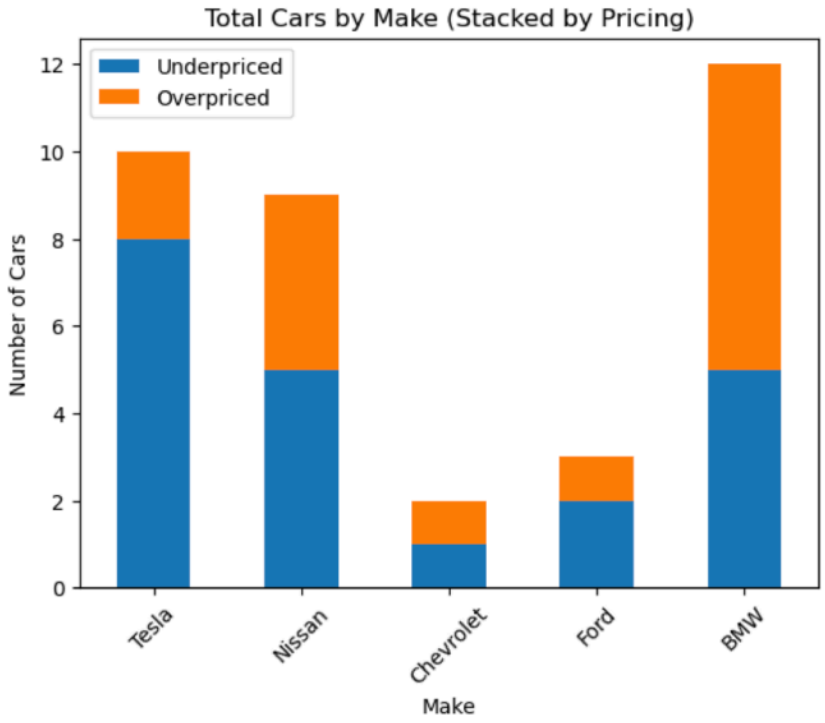
Actual MSRP Versus Predicted MSRP Table:

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

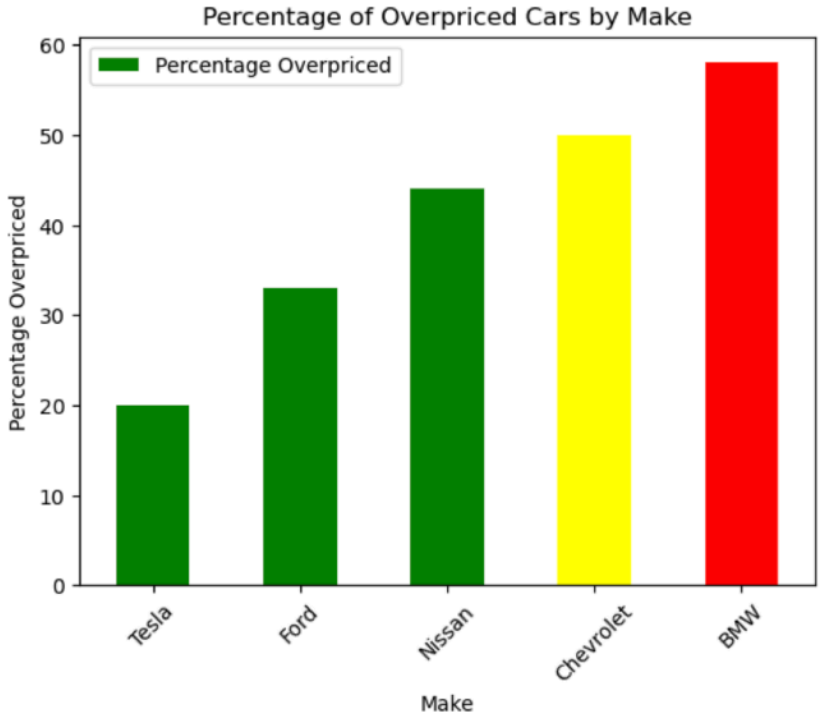
- We ran cross-validation on our dataset to get MSRP comparisons for all EV models.
- We also added a new column to visualize which models were overpriced versus underpriced.

Results:

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



The graph above shows the amount of models for each brand that are overpriced or underpriced.



The graph above shows 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

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. Tesla was shown to offer the best option in almost all of the different consumer segments we looked at – only Nissan won the segment for the most affordable model. BMW, on the other hand, was shown to offer some of the worst value for money available in the market. Anyone looking to buy a BMW would most likely only be doing so because of the badge and the status symbol it might represent, but not because of its value based on key metrics.

The linear regression model we built also corroborated our findings from the EDA section. It showed that most of Tesla's models were predicted to be underpriced compared to the market, while most of BMW's models were predicted to be overpriced. We also built three different models in total to see which one worked best. The gradient boosting model performed similarly but slightly worse compared to the linear regression, while the random forest model performed very poorly, with an R2 score below 50%.

In the end, we were successful in creating a novel ranking system for EV models which we used to calculate scores for the best value for range, performance, and overall rating.

This is what allowed us to provide recommendations for which EV model to purchase within each of the different consumer segments. It was also nice to see how the order in which each EV model was ranked in our “best overall value” graph made a lot of sense. It really compares well to the data on how each car brand has historically grown their sales, and is indicative of how they will continue to grow into the future.

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

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Chevy Equinox:

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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

Lessons Learned From Collecting the Data Above:

- EV prices are subject to change, and whenever they do, the respective scores will also get affected. The EV Ranking Data 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 that 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 it 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.