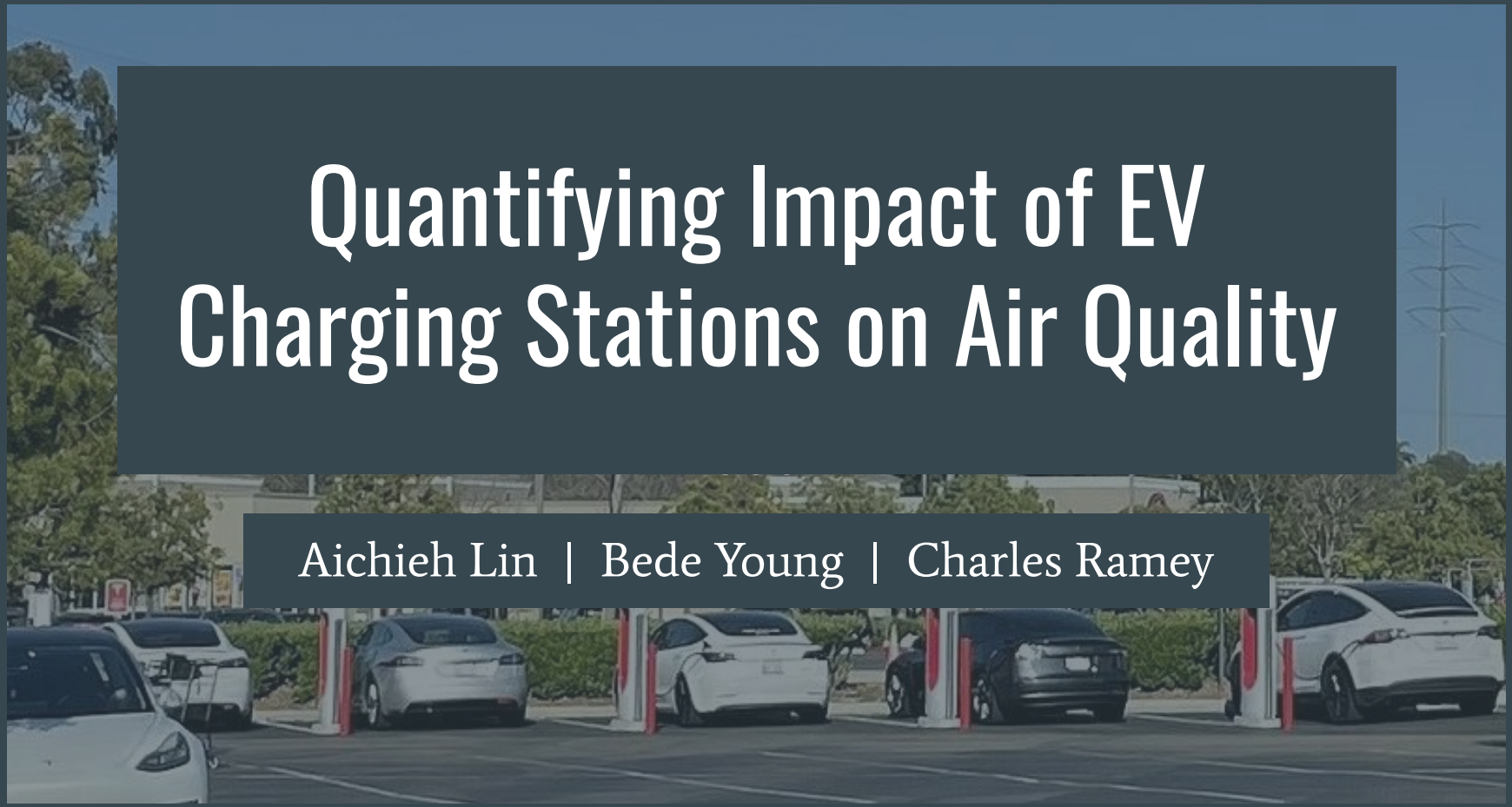
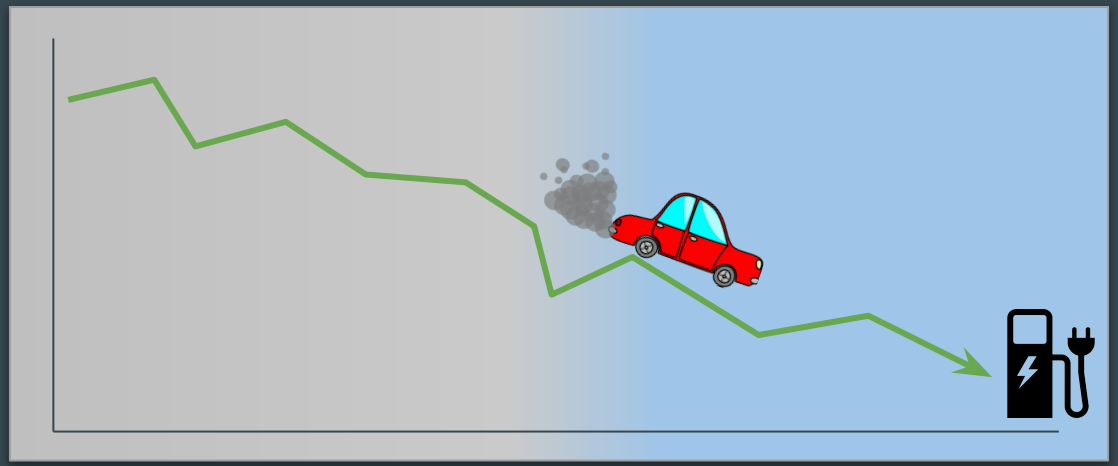
Quantifying Impact of EV Charging Stations on Air Quality



Aichieh Lin | Bede Young | Charles Ramey

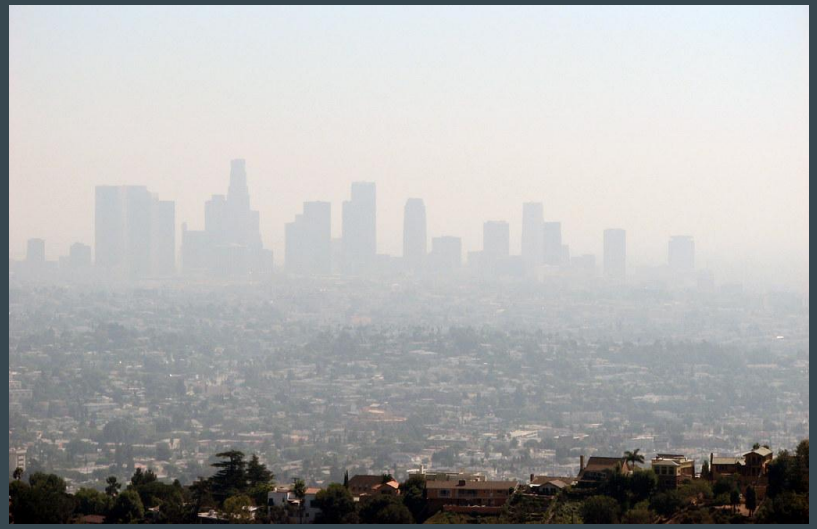
Problem Statement

This project seeks to quantify the impact of electric vehicle (EV) charging stations on air quality in the United States and create a tool to help policymakers and manufactures identify a benchmark for charging station installations that will yield a 10% reduction in the number of days with poor air quality.



Background - Air Pollution

- Major environmental issue
- Public health issue
- Motor vehicle emissions are a leading source of air pollution
- Ground level ozone (smog)
  - Respiratory and cardiovascular illness
- Target net zero emissions by 2050
- Efforts to reduce vehicle emissions
  - Public transportation
  - Pedestrian travel infrastructure (walking, cycling)
  - Efficient land use planning & zoning
  - Expand EV market



Background - EV Sales

- Sell more EVs!
  - +1 electric vehicle
  - -1 gas vehicle
- Target EVs accounting for 50% of all new car sales by 2030
  - $7500 tax credit
- Manufacturer pledges
  - Higher quality
  - More affordable
  - More appealing
  - *MORE*
- There's one problem...

Background - EV Charging Stations

- Need reliable access to charging stations
- 3 in 4 people say...there aren't enough
- Charging stations are a limiting factor
- Target 500,000 EV chargers by 2030
- More EV chargers = more EVs = cleaner air

The Data

- Air Quality Index (AQI)
  - By county
  - 2000-2022

	0 - 50	51 - 100	101 - 150	151 - 200	201 - 300	301 - 500
Days with AQI	Good Days	Moderate Days	Unhealthy for Sensitive Groups Days	Unhealthy Days	Very Unhealthy Days	Hazardous Days
257	111	96	39	10	1	0
106	38	66	2	0	0	0
354	169	123	58	4	0	0

The Data

- Air Quality Index (AQI)
  - 2000-2022
  - By County

	0 - 50	51 - 100	101 - 150	151 - 200	201 - 300	301 - 500
Days with AQI	% Good	% Moderate	% Unhealthy for Sensitive Groups	% Unhealthy	% Very Unhealthy	% Hazardous
257	0.43	0.37	0.15	0.04	0.00	0.00
106	0.36	0.62	0.02	0.00	0.00	0.00
354	0.48	0.35	0.16	0.01	0.00	0.00

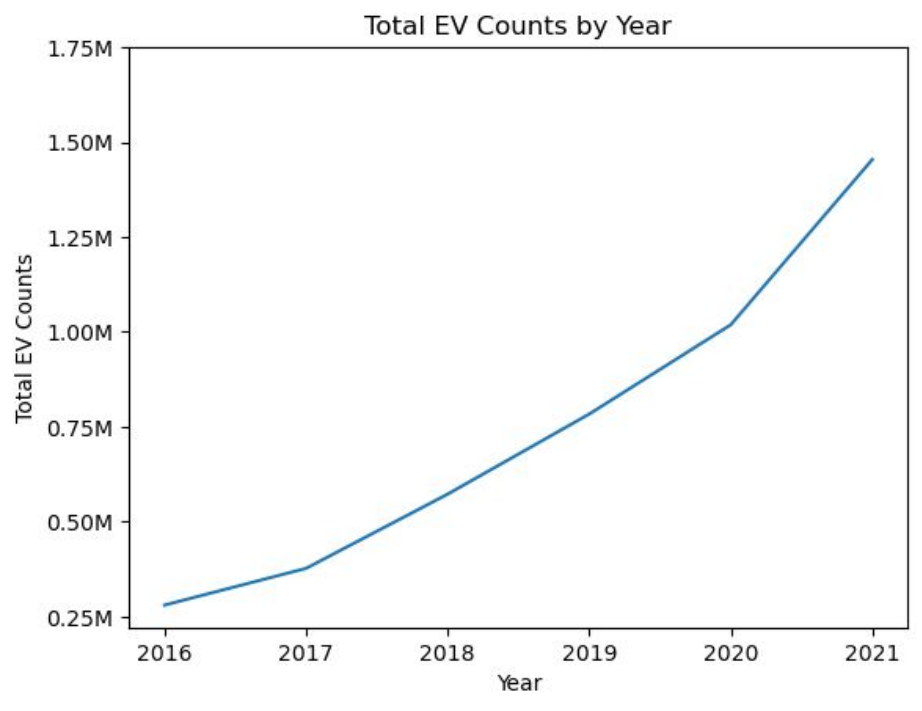
The Data

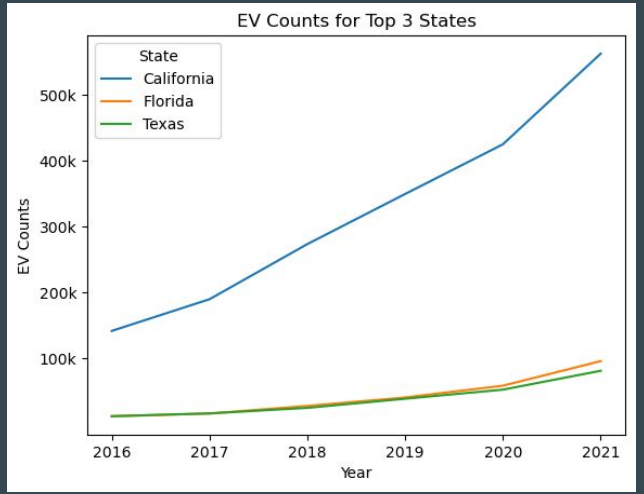
- Vehicle counts
  - EVs and other
  - By state
  - 2016-2021
- EV charging station counts
  - By state
  - 2007-2022

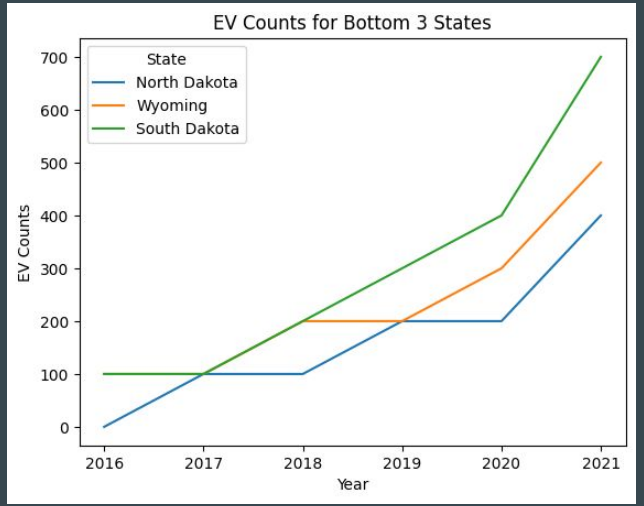
State	Year	EV	PHEV	HEV	Biodiesel	E85	CNG
Alabama	2021	4,700	3,300	42,500	40,500	449,500	500
Alaska	2021	1,300	500	7,300	7,600	50,100	100
Arizona	2021	40,700	15,500	132,200	51,000	460,400	900
Arkansas	2021	2,400	1,800	26,100	28,700	290,200	300
California	2021	563,100	315,300	1,355,900	163,600	1,343,200	12,600

State	Biodiesel	CNG	E85	Electric	Hydrogen	LNG	Propane
Alabama	10.0	30.0	31.0	848	0.0	2.0	62.0
Alaska	0.0	1.0	0.0	115	0.0	0.0	2.0
Arizona	75.0	28.0	17.0	2,638	1.0	5.0	65.0
Arkansas	17.0	10.0	74.0	598	0.0	0.0	36.0
California	32.0	314.0	326.0	43,400	58.0	40.0	246.0

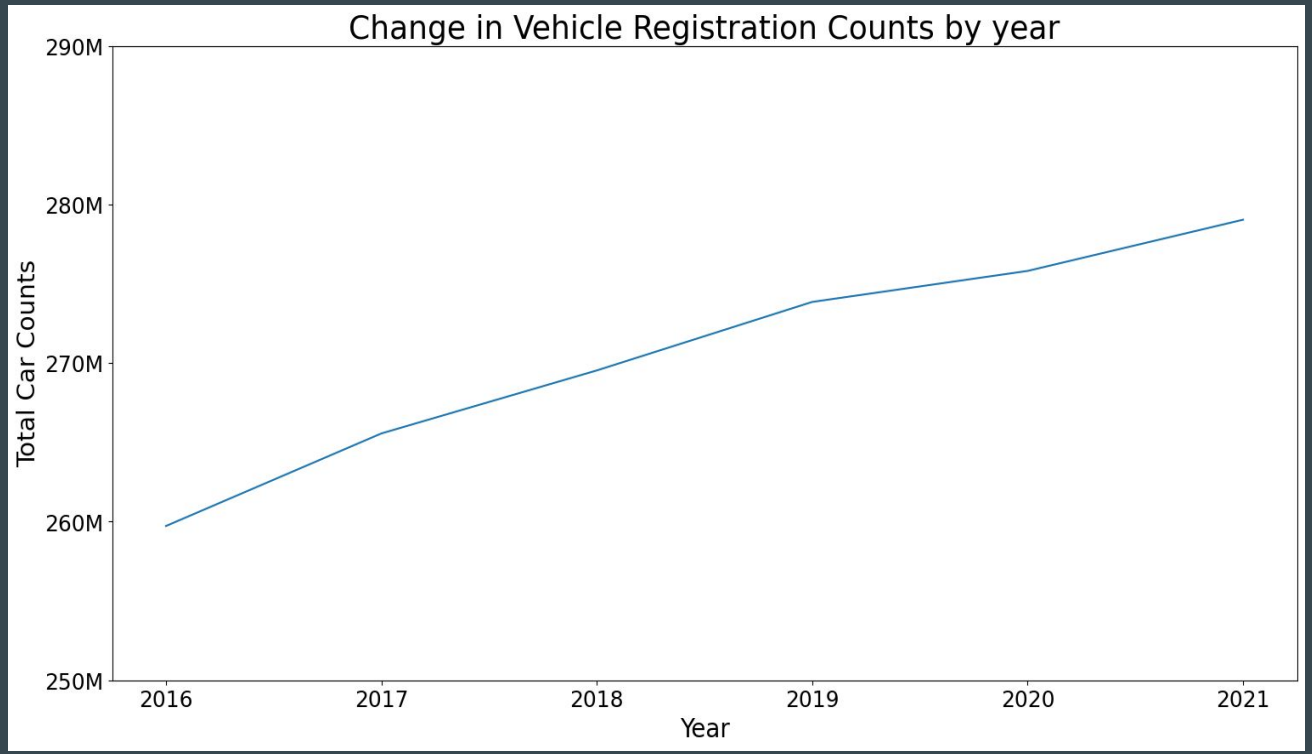
EDA - Change in EV Counts



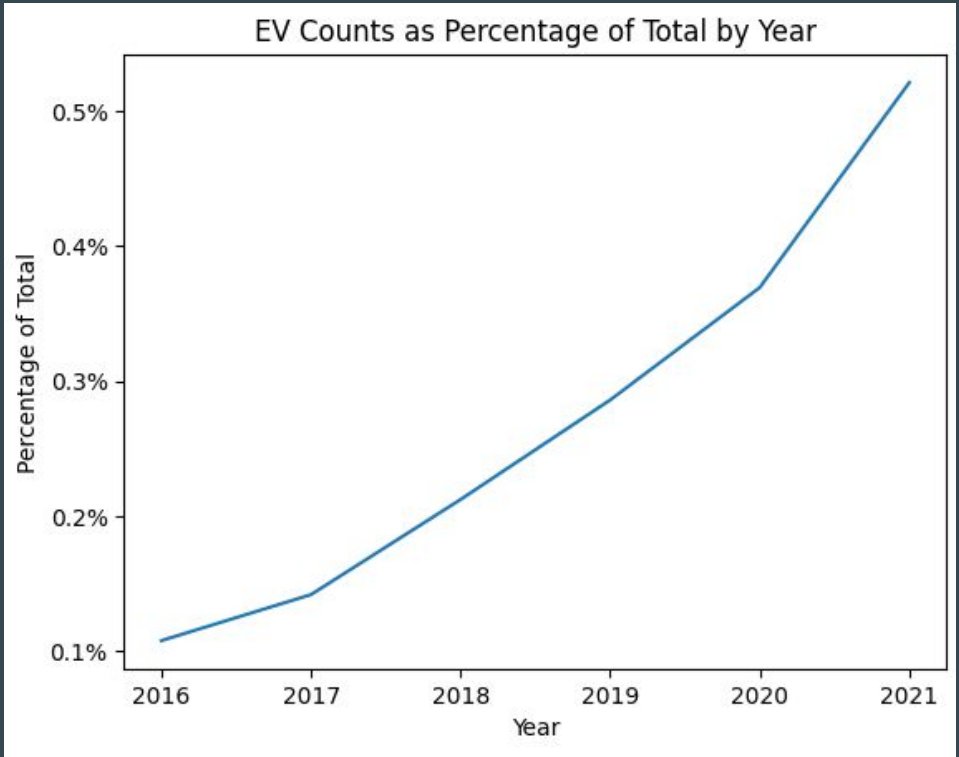




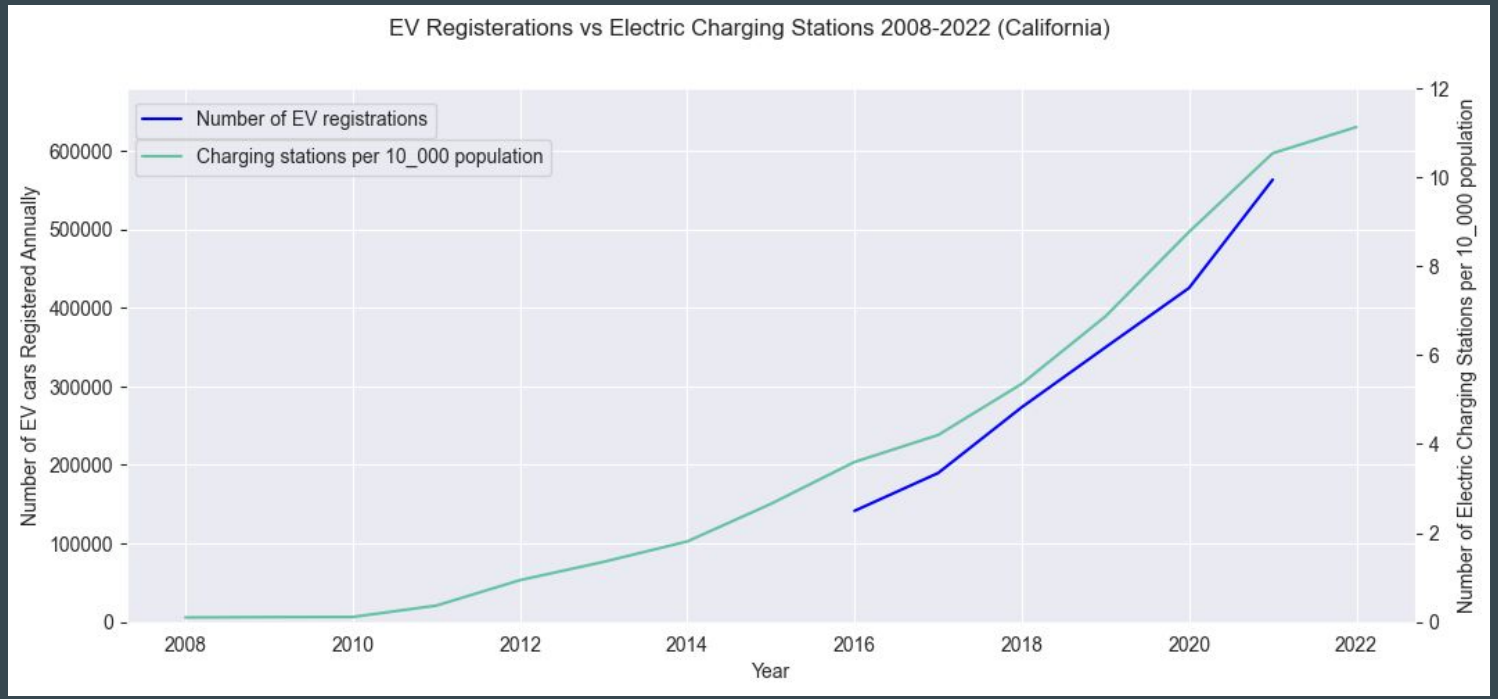
EDA - Change in Vehicle Registration Counts



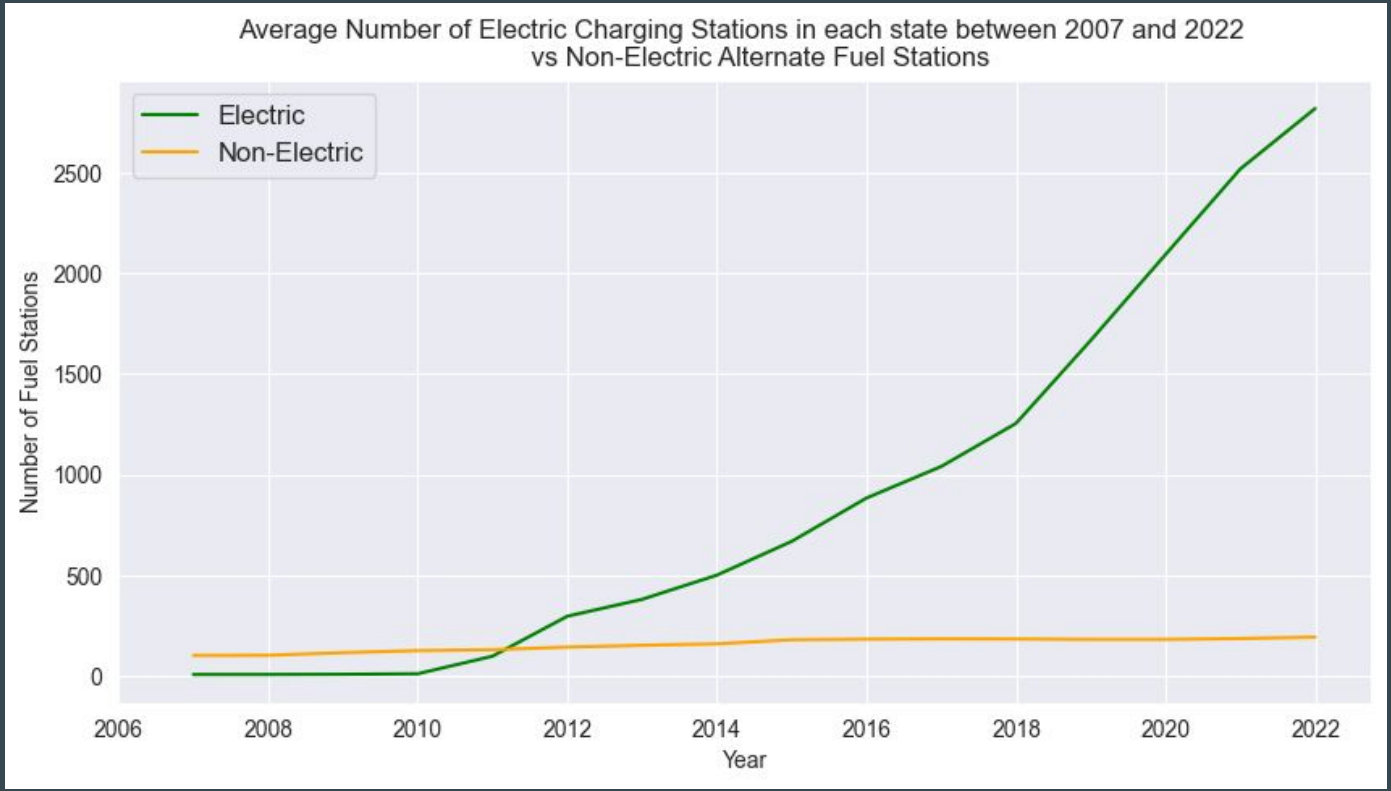
EDA - Change in Vehicle Registration Counts



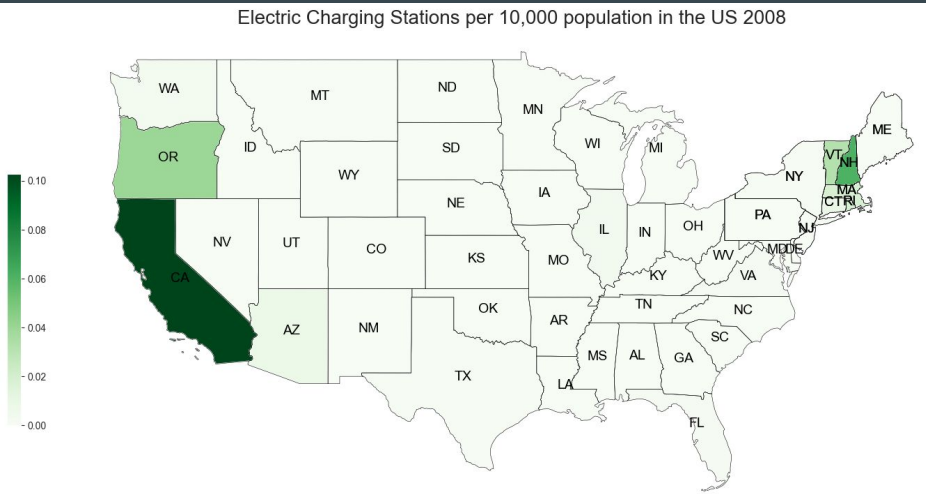
EDA - Electric Charging Stations vs Number of EV cars Registered

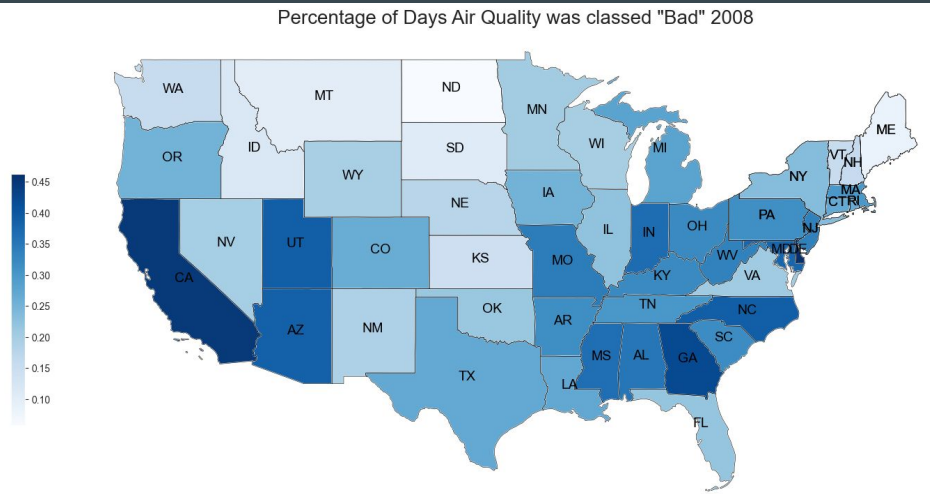


EDA - Electric Charging Stations vs Fuel Stations



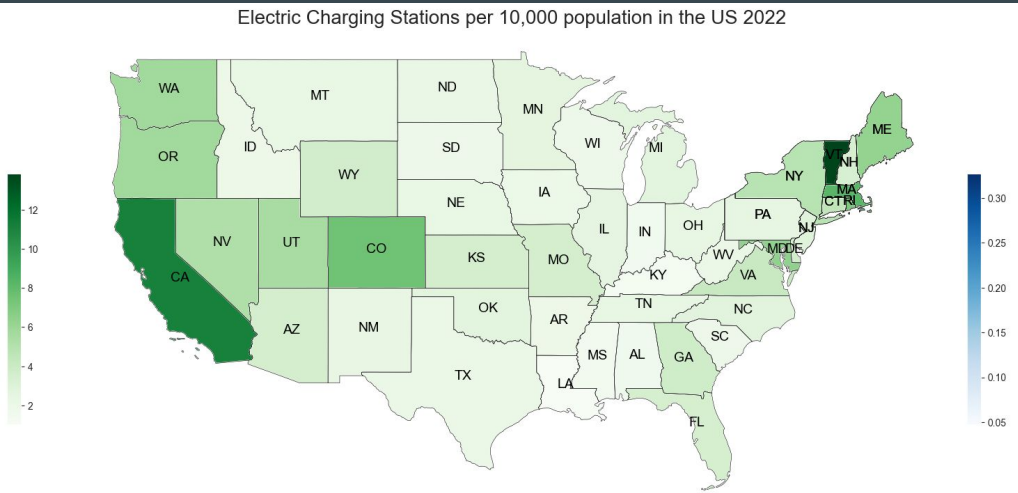
Distribution of Air Quality and EV charging stations across the US

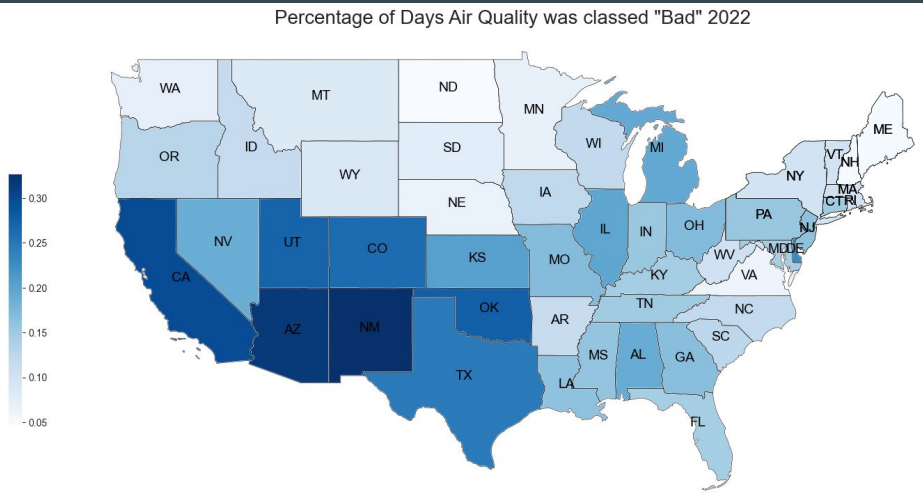




2008

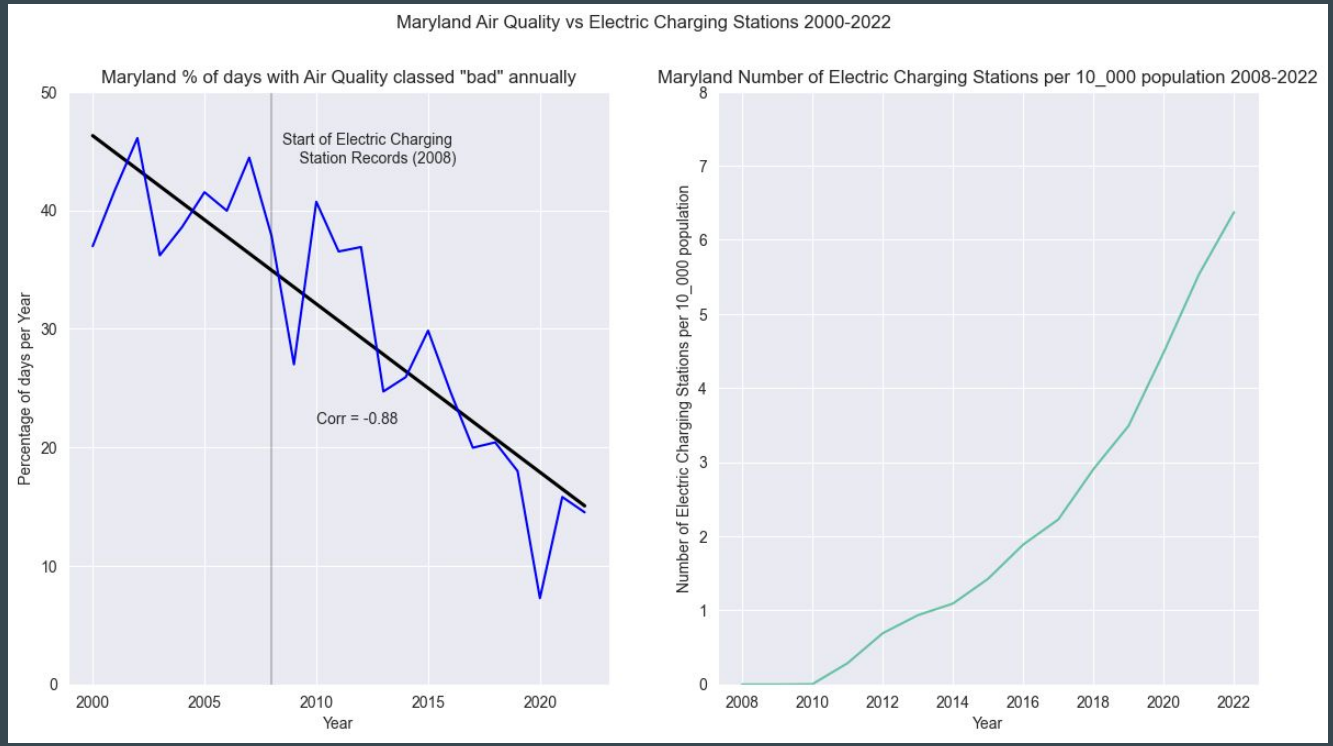
Distribution of Air Quality and EV charging stations across the US



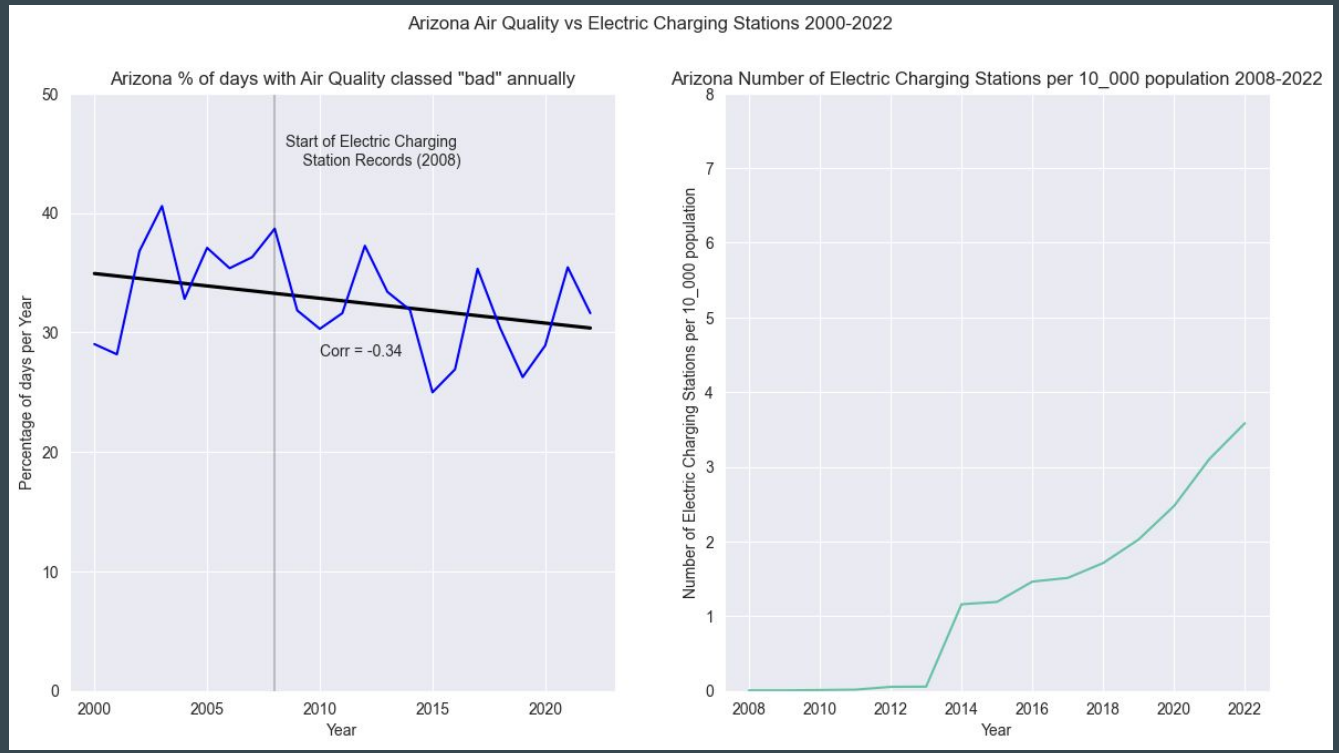


2022

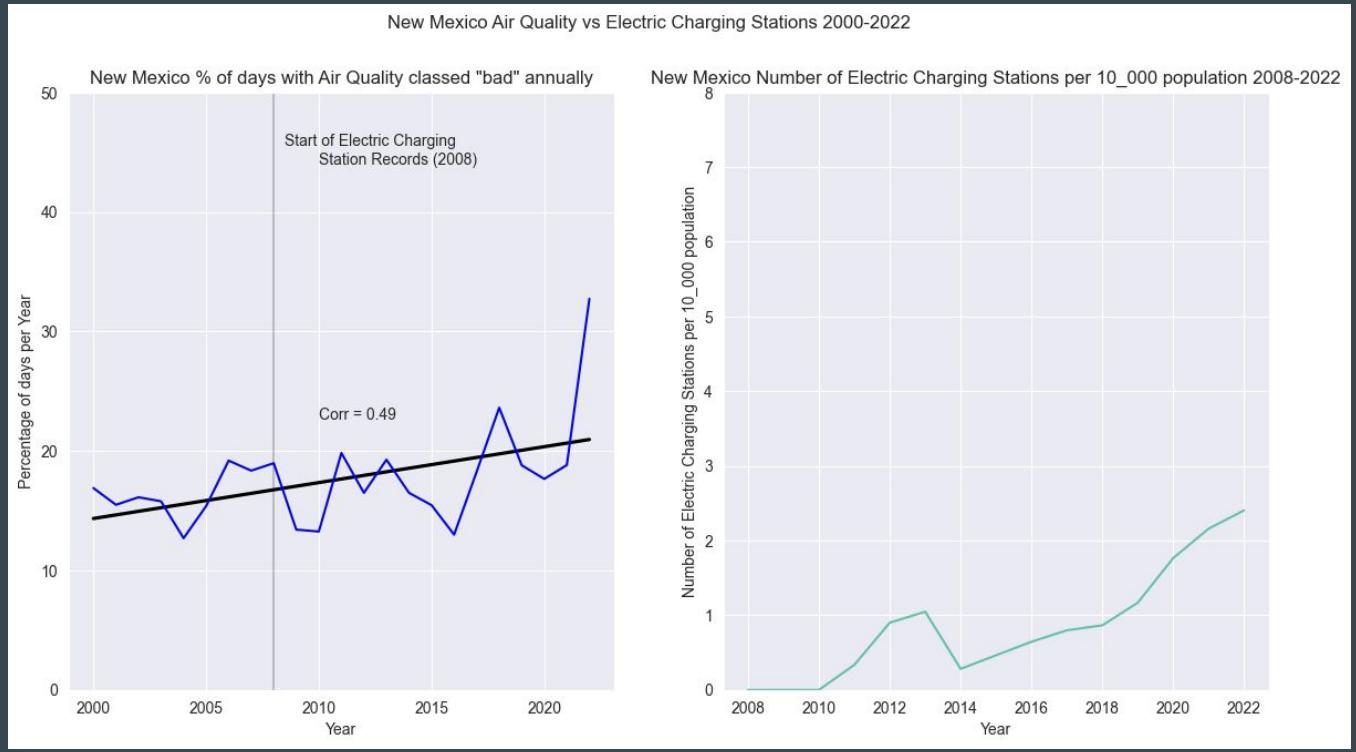
Maryland Air Quality vs Electric Charging Stations



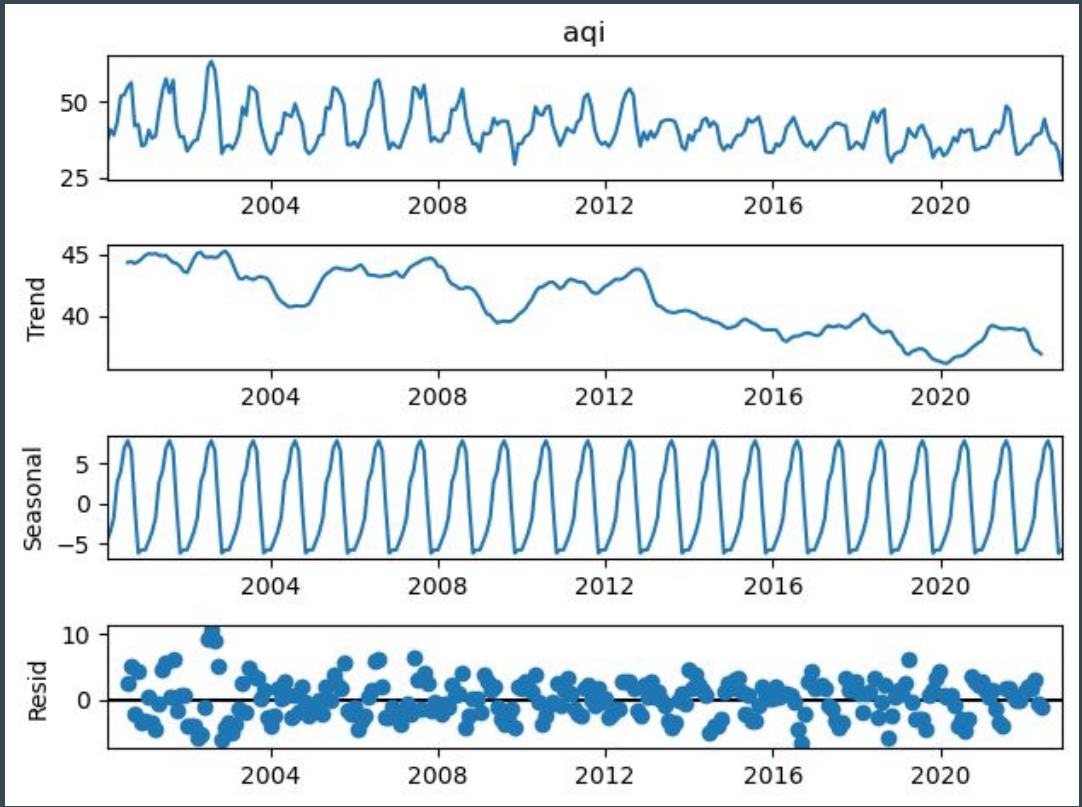
Arizona Air Quality vs Electric Charging Stations 2000-2022



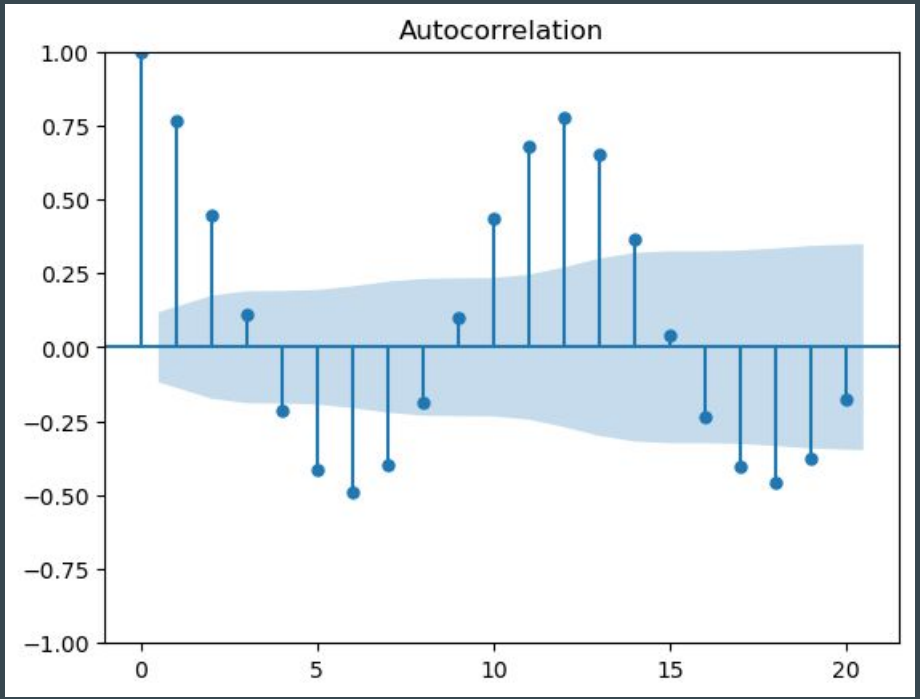
New Mexico Air Quality vs Electric Charging Stations 2000-2022

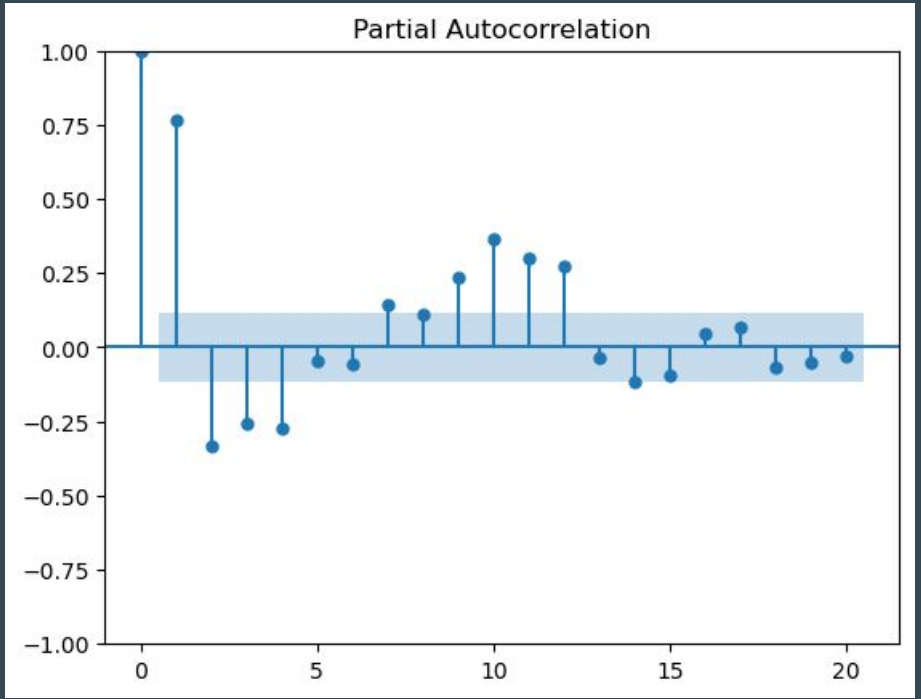


Decompose Time Series of AQI - Monthly, 2000 - 2022

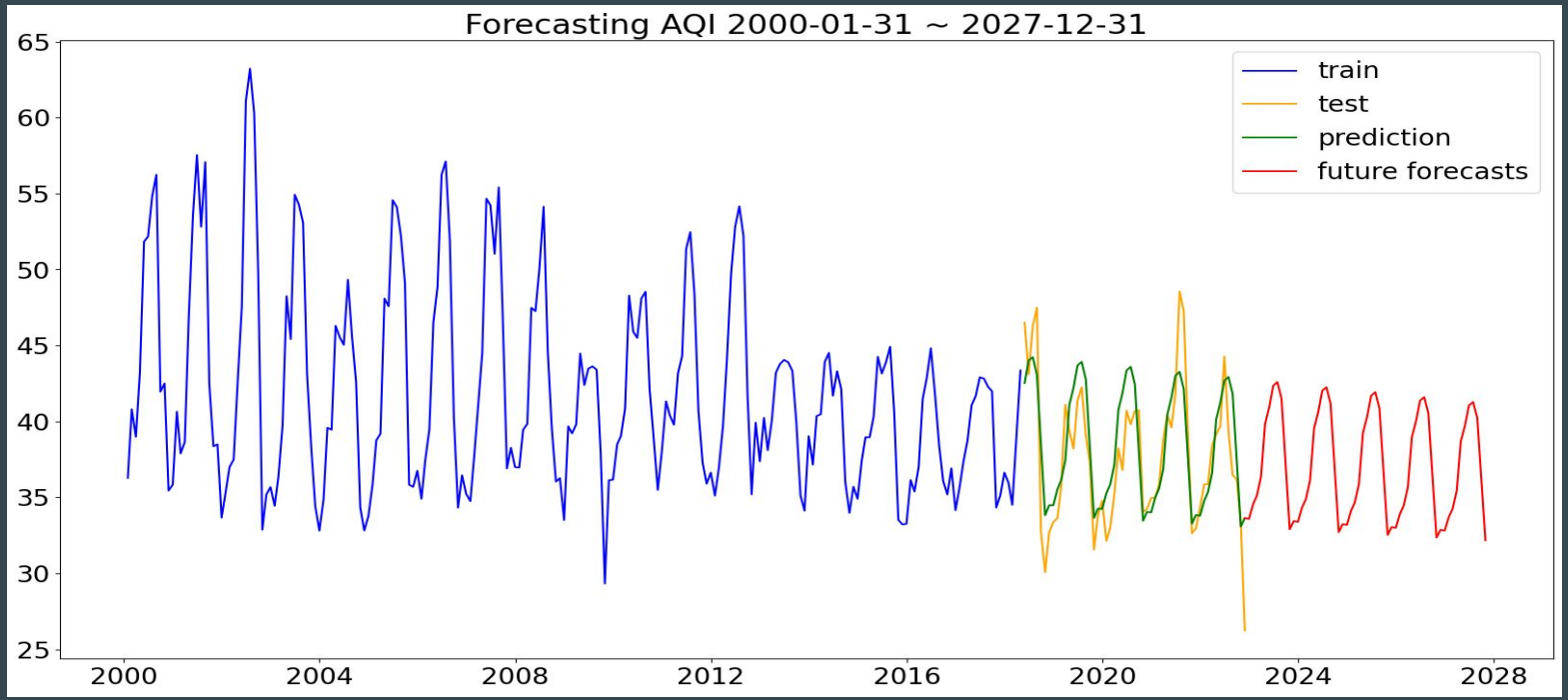


ACF Plot and PACF Plot on AQI Data



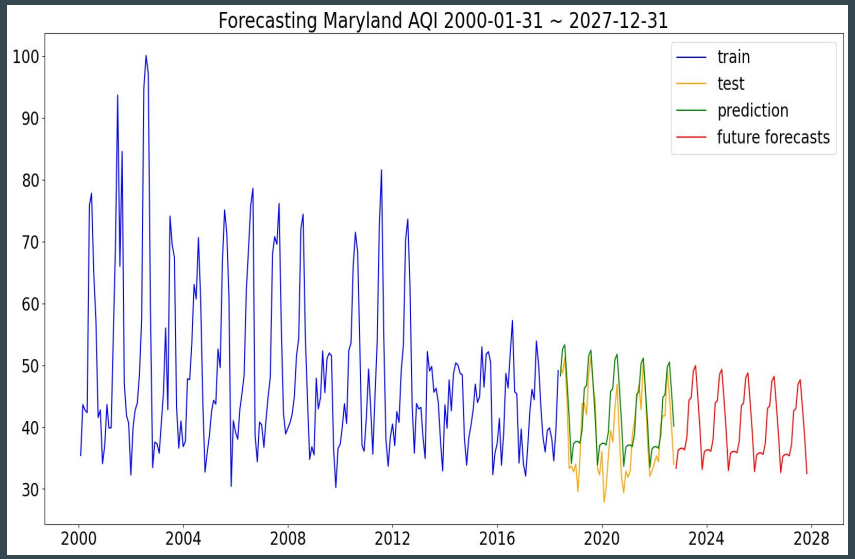


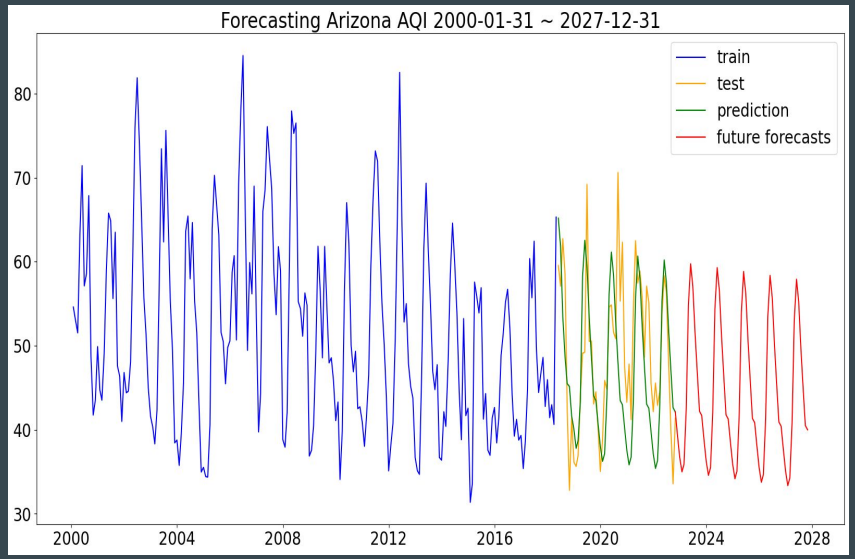
SARIMA Model



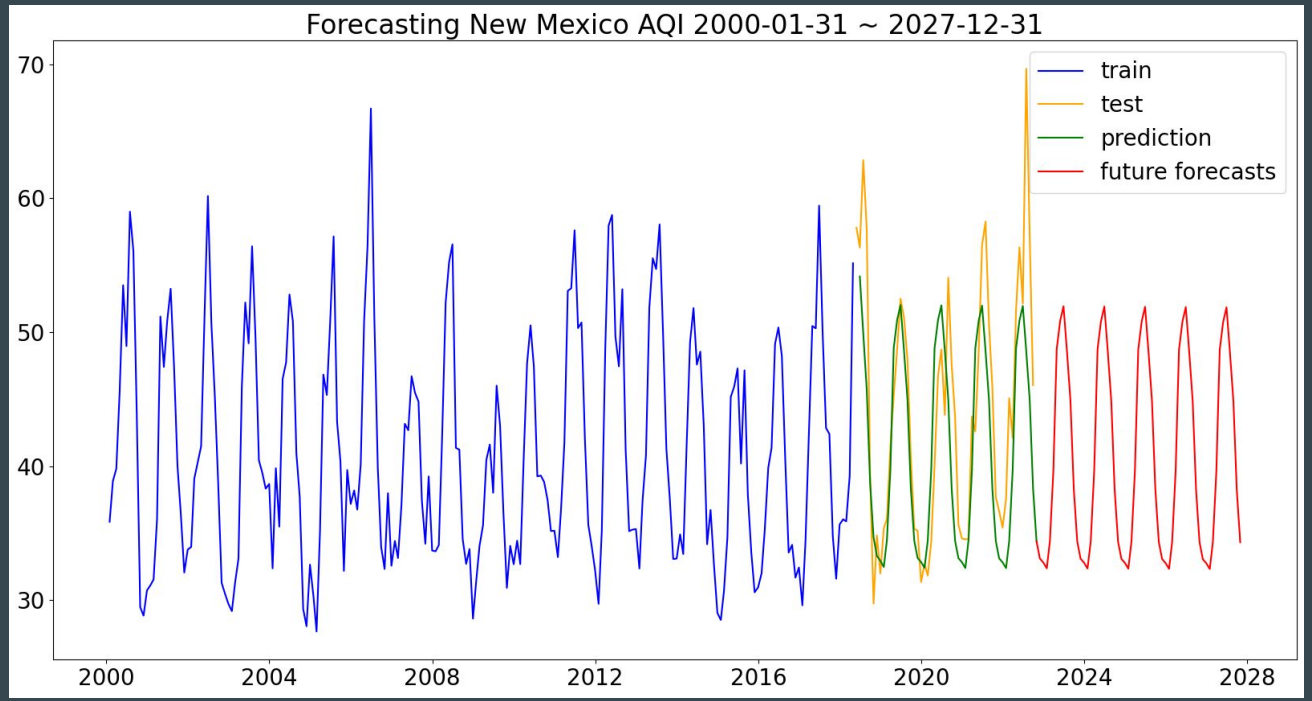
R2 Score = 0.65 | RMSE = 2.76 | Mean AQI = 37.68

Forecasting AQI: Maryland vs Arizona





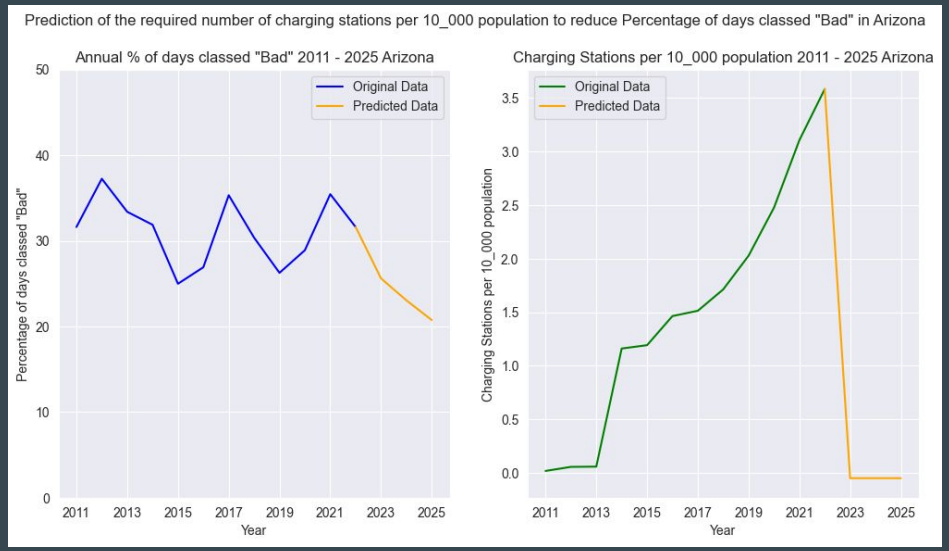
Forecasting AQI: New Mexico



Modeling

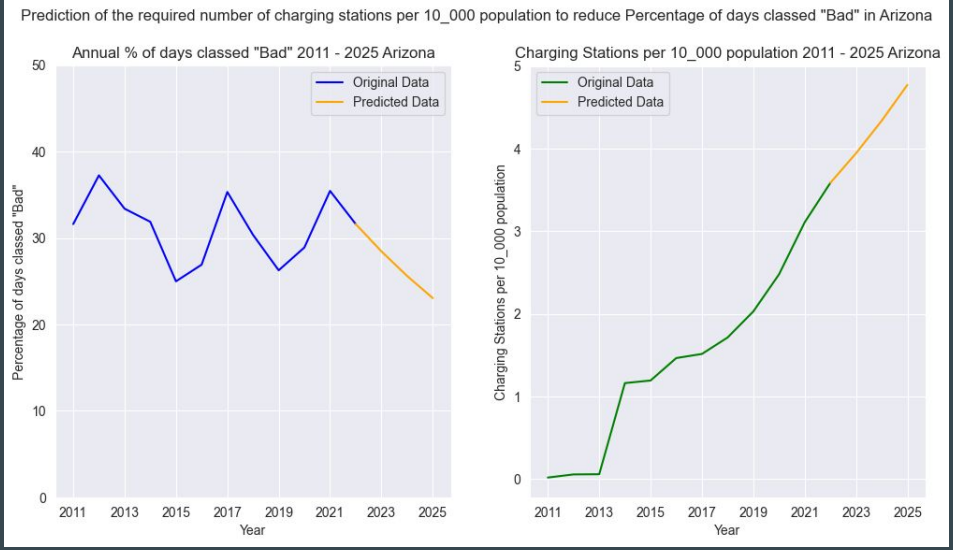
Model_Name	Training_R^2	Test_R^2
BaseLine	0.000	-0.003
KNN	0.632	0.290
Grid_KNN	0.696	0.280
Poly_KNN	0.146	-0.105
Poly_Linear_Regression	1.000	0.310
Ridge	0.784	0.578
Random_Forest_Regressor	0.814	0.416
Bagging	0.706	0.452
Stack	0.759	0.472

Arizona Predictions



- Predictions from the model do not match initial expectations
- This may be due to several factors:
  - Data which is unsuitable for machine learning
  - Errors during preprocessing
  - Overfit models which are unable to predict effectively
- Using air quality data describing compound proportions would be a better evaluator of air quality than ‘percentage of days’ metrics

Theoretical Predictions - Arizona



- Theoretical predictions for the number of charging stations per 10,000 population
- Current number of installed stations:

  2022 : **2257** stations

- Projected number required to meet 10% annual air pollution reduction target:

  2023 : **2936** stations

  2024 : **3269** stations

  2025 : **3639** stations

- Assuming a constant population growth

Conclusions

- There is an observed relationship between the number of charging stations installed and the average air quality of a state
  - Many other factors may contribute
- East coast states:
  - proportionally shown the largest improvement in air quality in the US
  - Also recorded a large increase in EV charging station availability
- South-Western states:
  - Showing the lowest improvements in air quality
  - Not increasing EV charging station availability at the same rate as other states
- The predicted values from both SARIMA and OLS model are fairly close to actual values
- General Air quality in the US is forecast to improve in the future

Recommendations

- **Data Alterations:**
  - Using specific concentrations of pollutants
    - This would be more accurate than classifying whether a day is above a threshold concentration of pollutant.
    - Other factors, such as desert dust and wildfires may be impacting air quality indexes
  - AQI data is collected daily in some states, but much less frequently in others
    - Collecting daily data would improve the representative air quality data for that state.
- **Improving the Models:**
  - Additional optimisation given more time could have produced better predictions.
- **Investigating Other Factors:**
  - Other factors may be influencing a customers decision to not buy an EV
    - Cost
    - Battery range
    - General Preference for gasoline vehicles