Effect of Vehicular Electrification on Air Quality in Florida

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BACKGROUND

- Vehicular emissions refer to the gases and particles that are released into the air from vehicles, including nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), and particulate matter (PM).[1]
- Recent estimates suggest that ambient air pollution exposure leads to significant environmental health risk contributing to over three million premature deaths per year worldwide.[2]
- Transportation accounts for the largest portion of greenhouse gas (GHGs) emissions in the U.S. (29%), with petroleum-based fuel, primarily gasoline and diesel, making up over 90% of those emissions.[3]
- Adopting electric vehicles (EVs) instead of fossil-fueled alternatives, known as electrification, has been and continue to be a sustainable decarbonization strategy that improves air quality and addresses climate change (Fig. 1).[4]

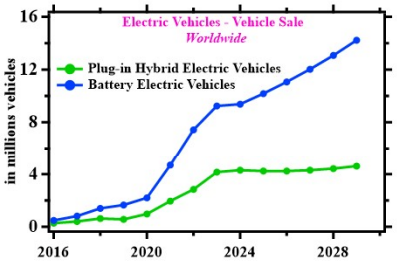

Fig. 1: Portfolio of current and projected worldwide EVs sale. (adapted from[5])

OBJECTIVE

- The aim of this study is to investigate the impact of replacing of fossil fuel powered vehicles by EVs on air quality across different counties in the state of Florida.

METHODOLOGY

1. Study location. Five counties in Florida are investigated for five consecutive years (2018 to 2022), comprising major urban cities in the state (Fig. 2), namely:

(1) **Maimi**: Maimi-Dade County
(2) **Jacksonville**: Duval County
(3) **Tampa**: Hillsborough County
(4) **Orlando**: Orange County, and
(5) **Tallahassee**: Leon County.

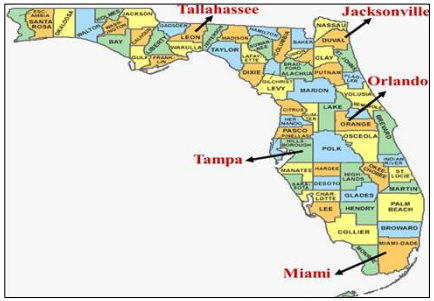

Fig. 2: Florida map showing counties investigated in this study.

2. The **EPA's Motor Vehicle Emission Simulator (MOVES)** is used to estimate atmospheric pollutant and GHGs emissions from vehicles on national, county, and project levels (Fig. 3).

- ***Pollutants:*** Carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and particulate matter ($PM_{2.5}$ and PM_{10})
- ***MOVES input:*** Total on-road emissions by passenger-car for each pollutant using EPA's MOVES4.0 on county scale. The following is used as an input for the county scale of the model.
  - Road type distribution
  - Source type population
  - Vehicles type VMT
  - Age Distribution
  - Average Speed Distribution
  - Fuel
  - Meteorology Data
- ***MOVES output:*** HeidiSQL is used to extract the data in from output.

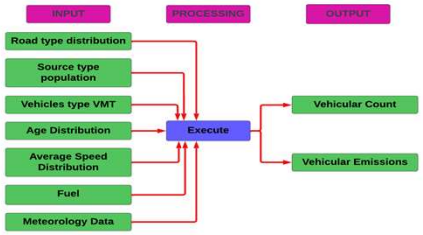

Fig. 3: Flow Diagram of MOVES for County Scale.

3. A ***Random Forest Regression (RFR) model*** is trained using GridSearchCV for hyperparameter tuning to reduce error while maximizing the accuracy of predictions.

- RFR averages predictions from multiple decision trees to improve accuracy and reduce overfitting (Fig. 4).
- RFR predicts population and emissions in 2025, 2035, and 2050 based on the Paris Agreement predictions.[6]
- ***Model testing.*** The correlation coefficient, R^2, is calculated for both the population and emission predictions to evaluate the effectiveness of the RFR model in predicting these values.
- **Parameters Tuned**:
  - Number of trees = 100, 200, 300.
  - Depth of each tree = None, 10, 20, 30.
  - Minimum samples to split a node = 2, 5, 10.
  - Minimum samples at a leaf node = 1, 2, 4.

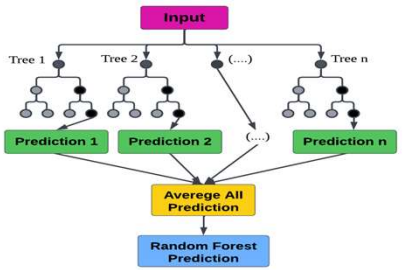

Fig. 4: Flow Diagram of Random Forest Regression Prediction. (adapted from[7])

VEHICULAR COUNTS

- In 2032, 30% of all passenger cars are will to be EVs worldwide.[8]

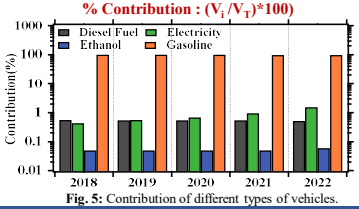

Fig. 5: Contribution of different types of vehicles.

- The average increase in the number of EVs from 2018 to 2022 is 217.68% ± 52.11% for all four counties (Fig. 6).

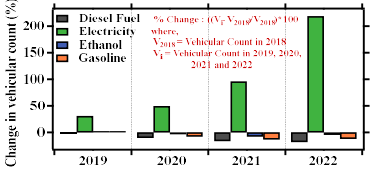

Fig. 6: Cumulative percentage change in vehicular count.

VEHICULAR EMISSIONS

- Overall, ethanol cars produce the least emissions while gasoline cars emit the most pollutants (Fig. 7).
- EVs produce no NO_2 nor CO emissions.
- Increase in PM emissions from EVs are due to non-exhaust source, i.e., tires and brake.

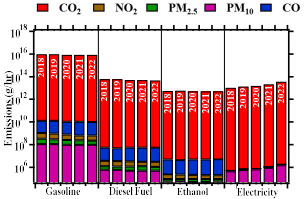

Fig. 7: Annual pollutant emissions from different passenger cars in all four counties.

- With the increase in the use of EVs, emissions are decreasing (Fig. 8):
  - CO : 20.93% ± 11.73%
  - CO_2 : 13.77% ± 7.44%
  - NO_2 : 41.77% ± 26.42%
  - $PM_{2.5}$: 42.52% ± 27.04%
  - PM_{10} : 11.99% ± 6.42%

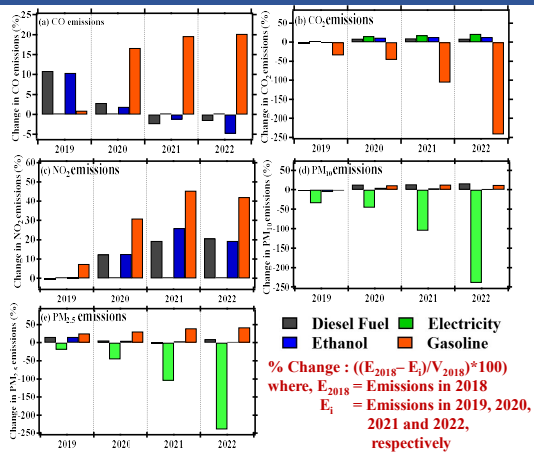

Fig. 8: Cumulative percentage change in (a) CO, (b) CO_2, (c) NO_2, (d) PM_{10} and (e) $PM_{2.5}$ emissions for all four counties.

MACHINE LEARNING MODEL PREDICTIONS

In the future,

- Gasoline vehicles will remain the same.
- The number of EVs will continue to increase (Fig. 9) leading to an overall decrease in air pollutants except for CO_2 and PM (Fig. 10).

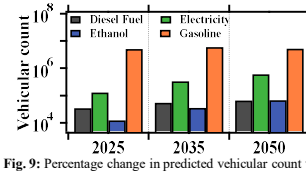

Fig. 9: Percentage change in predicted vehicular count w.r.t. 2022.

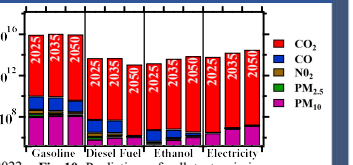

Fig. 10: Predictions of pollutant emissions.

CONCLUSIONS & FUTURE WORK

- While EVs present a more sustainable solution from air quality standpoint, challenges still persist regarding the GHGs emitted through charging the batteries and the subsequent consequences on climate change.
- ***Future Work:*** Compare modeled data to scenarios based on electrification recommendations by the Paris Agreement and the targeted U.S. projections in 2025, 2035 and 2050.

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