Reducing Emissions from the GA State Vehicle Fleet

Formulation and Application of a Vehicle Replacement Model

Caleb Weed
Master’s of Sustainable Energy & Environmental Management Capstone Project
Introduction

- Research question: How much would it cost to reduce CO$_2$ emissions from public vehicles?
- 28% of GHG emissions came from transportation sector in 2018 (EPA)
- State fleet data acquired via Open Records Request
- Calculated life-cycle emissions for Georgia’s publicly owned and operated light-duty cars, SUVs, and PUTs
- Designed a vehicle replacement model to make fleet management decisions and quantify emissions abatement costs for different market scenarios, demonstrating which policy mechanisms are most important for low-emissions vehicles
The Georgia State Fleet

- Purchased, leased, rented
- 20,264 vehicles
- 16,929 light duty (< 10,000 lbs)
- 957 medium duty (< 26,000 lbs)
- 2,378 heavy duty (> 26,001 lbs)

- Only 94 hybrids, PHEVs, & EVs

11,000  4,000  2,000

15 million gallons
211 million miles
Cleaning the Dataset

- Focus on light-duty vehicles to refine analysis
- Vehicles lacking fuel consumption or VMT data omitted
- Lack of telematics
- Fire, medical, emergency, law enforcement, and off-road vehicles omitted
- 9,031 vehicles analyzed

3,325 cars  1,139 SUVs  4,567 PUTs
Baseline Methodology & Emissions

- Missing CO₂ was calculated via model-specific per-mile emissions rates (FuelEconomy.gov)
  - Operation conducted for 1,026 vehicles
- Upstream fuel pathway emissions calculated using GREET lifecycle model
  - Gasoline (E10), CNG, LNG, flex fuel (E85)
- Upstream vehicle pathways emissions also via GREET
  - Engine types: ICE, EV, PHEV, natural gas

<table>
<thead>
<tr>
<th>Tailpipe</th>
<th>Fuel</th>
<th>Vehicle</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>39,217 t</td>
<td>14,998 t</td>
<td>3,119 t</td>
<td>57,336 t</td>
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</table>
Vehicle Replacement Model

- Spreadsheet model selects most economic new replacement vehicles to purchase each year
  - Assumed 15 year operational lifetime, modelled lifecycle of vehicles until MY2030
  - Tesla Model 3, Nissan Leaf, Toyota Prius, Kia Forte, Hyundai Kona (EV), Toyota RAV4, Mazda CX-5, Honda CRV, Chevy Silverado, Ford F-150, Ford F-150 Diesel, Toyota Tacoma, Rivian R1T (MY2021+)
- Increased demand modelled with increased VMT, not increased vehicle count (1% per year)
- MSRP +2% ICE, -8% EVs until 2025 (price parity)
- MPG +1.5%; grams CO₂ per mile -0.017%
- Assumed VMT replaced directly by new vehicles
- 3% discount rate
VRM - Formulation of Scenarios

- 8 unique policy/market scenarios
- Filled boxes indicate high values used
- Each scenario modelled for purchased to 2030, lifetime impacts to 2044
- 88 executions

<table>
<thead>
<tr>
<th>S0</th>
<th>Baseline</th>
<th>Base Case</th>
<th>Extreme Case</th>
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<tbody>
<tr>
<td>S1</td>
<td>High Fuel</td>
<td></td>
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<tr>
<td>S2</td>
<td>EV Credit</td>
<td>Gasoline Price ($/gallon)</td>
<td>$2.49</td>
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<tr>
<td>S3</td>
<td></td>
<td>Diesel Price ($/gallon)</td>
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<td>S4</td>
<td>High Fuel</td>
<td>Electricity Price ($/kWh)</td>
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<td>S5</td>
<td></td>
<td>EV Tax Credit</td>
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<td>S6</td>
<td></td>
<td>GHG Cost ($/ton CO2)</td>
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<tr>
<td>S7</td>
<td>High Fuel</td>
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VRM - Optimization Function & Constraints

Minimize:
Total Capital Costs + Maintenance Costs + Fuel Costs + Emissions Charges - Salvage Values

Constraints:
1. The quantity of each vehicle model purchased must be greater than or equal to 0
2. The quantity of each vehicle model purchased must be an integer value
3. The quantity of new cars purchased must equal the quantity of cars retired
4. The quantity of new SUVs purchased must equal the quantity of SUVs retired
5. The quantity of new PUTs purchased must equal the quantity of PUTs retired
6. There must be a negative change in total emissions
**VRM - Example**

Example model run for S0 - 2030

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Vehicle M&amp;M</th>
<th>Capital Costs</th>
<th>Mntnce Costs</th>
<th>Fuel Cost</th>
<th>Fuel Consumption</th>
<th>VMT</th>
<th>Tailpipe</th>
<th>Vehicle</th>
<th>Fuel</th>
<th>Salvage</th>
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<tbody>
<tr>
<td>0 Tesla Model 3</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>- kwh</td>
<td>Cars</td>
<td>5,641,146.94</td>
<td>-</td>
<td>-</td>
<td>Cars</td>
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<tr>
<td>0 Nissan Leaf</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>- kwh</td>
<td>SUVs</td>
<td>1,540,477.25</td>
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<td>-</td>
<td>SUVs</td>
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<tr>
<td>0 Toyota Prius</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>- gal</td>
<td>PUTs</td>
<td>3,483,800.07</td>
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<td>PUTs</td>
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<tr>
<td>332 Kia Forte</td>
<td>$7,098,228.41</td>
<td>$166,000.00</td>
<td>$60,881.29</td>
<td>24,469.97 gal</td>
<td>1,300.47</td>
<td>82</td>
<td>49.18</td>
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<tr>
<td>106 Hyundai Kona EV</td>
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<td>360,734.07 kwh</td>
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<td>-</td>
<td>32</td>
<td>165.94</td>
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<td>0 Toyota RAV4</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>- gal</td>
<td>Cars</td>
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<td>0 Mazda CX-5</td>
<td>$0.00</td>
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<td>- gal</td>
<td>SUVs</td>
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<td>0 Honda CRV</td>
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<td>$0.00</td>
<td>- gal</td>
<td>PUTs</td>
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<tr>
<td>0 Chevy Silverado</td>
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<td>$0.00</td>
<td>$0.00</td>
<td>- gal</td>
<td>-</td>
<td>-</td>
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<tr>
<td>0 Rivian RT1</td>
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<td>- kwh</td>
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<tr>
<td>0 Ford F150</td>
<td>$0.00</td>
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<td>$0.00</td>
<td>$0.00</td>
<td>- gal</td>
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<tr>
<td>0 Ford F150 Diesel</td>
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<td>- gal</td>
<td>-</td>
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<tr>
<td>185 Toyota Tacoma</td>
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<td>$15,726,291.78</td>
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<table>
<thead>
<tr>
<th>Total</th>
<th>Total Reduced Emissions</th>
<th>Total Cost 2020</th>
<th>Total Emissions 1</th>
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<td>$15,849,535.20</td>
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Findings & Discussion

- Lowest cost under Scenario 2 ($671/ton CO₂ abated)
- Highest cost under Scenario 5 ($1166/ton CO₂ abated)
Findings & Discussion

- Tax credits remain crucial for EVs under modelled market scenarios
  - With tax credits, EVs become cheaper than ICEVs by 2023 (Leafs & Konas)
  - S2 - 2,265 EVs by 2030; S7 - 2,737
- No competitive low-emitting PUT, but on the way
- Abatement costs way too high to justify for reducing CO₂ alone
  - Public procurement for pilot & demonstration
  - Economies of scale
- CO₂ is not the whole story!
  - CH₄, CO, SOₓ, NOₓ, PM, VOCs
Next Steps...

- Telematics device deployment for more dynamic modelling of emissions from on-road activity
  - Could help identify specific vehicle activities that should be targeted for electrification, diesel, hybrid
- Re-visit and update as electric trucks come on the market
  - Ford F-150 EV in MY2022
- Attempt to quantify benefits of public procurements on EV technology costs
- Potentially expand to include M/HD vehicles as alternative technologies become available in that space
Thanks for a great year!