Adoption of green fleets – economic and environmental life cycle assessment of electric vehicles in New England.

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Overarching Questions

- How much more expensive are EVs than traditional fleet vehicles?
  - EVs high purchasing price
  - Lower maintenance, fuel costs
- How do emissions for EVs compare?
  - Transportation sector: 28% national CO2e emissions
  - All New England States over 28% (36% RI to 53% ME, 42% NH)
  - 62% total emissions from light duty vehicles
- Vehicles considered in a fleet setting
  - Large potential CO2e reductions for businesses, municipalities, and Gov. agencies
  - Accounting for New England climate, energy grid, driving conditions
Economic Life Cycle Costs Analysis

- LCCA = Investment + PV (maintenance) + PV (energy) + PV (disposal) – PV (salvage)

<table>
<thead>
<tr>
<th>Analysis Requirement</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Cost</td>
<td>Vehicle purchase price (MSRP)</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>Repair, operations, and maintenance costs for vehicles and infrastructure (ex. oil change, tires, brake, battery replacement, etc.)</td>
</tr>
<tr>
<td>Energy Cost</td>
<td>Total cost of energy input (cost per charge, cost per gallon)</td>
</tr>
<tr>
<td>Disposal/Salvage</td>
<td>Projected resale value at end of vehicles life cycle (KBB 5 year resale value, 5% annual decrease thereafter)</td>
</tr>
</tbody>
</table>

*All final costs discounted to the present value (PV) using 3% discount rate*
Environmental Life Cycle Analysis

- **Scope:** GHG emissions inventory
- **Output**
  - Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model (GREET) from the Argonne National Laboratory
  - Vehicle Cycle: Material extraction, vehicle production, operation, and disposal
  - Fuel Cycle: Upstream emissions relating to extraction, processing, transport of fuel, and EV “extended tailpipe” emissions from electrical generation
- **Regional inputs**
  - Vehicle fuel efficiency
  - ISO-NE grid inputs
Experimental Design

- Four technologies:
  - Traditional fleet vehicles: Internal Combustion (ICV), Hybrid (HEV)
  - Electric fleet vehicles: Plug in Hybrid (PHEV), Batter Electric (BEV)

- Vehicle Make/Models
  - HEV: Toyota Prius (2019)
  - PHEV: Toyota Prius Prime (2019)
  - BEV: Nissan Leaf (2019)
  - BEV: Nissan Leaf Plus (2019)

- Data Sources
  - State of New Hampshire (NHDES/NHDAS)
  - University of New Hampshire
  - Peer reviewed literature (93% BEV/PHEV fuel efficiency assumption (Taggart, 2018))
  - Kelly Blue Book

<table>
<thead>
<tr>
<th>NHDES Fleet</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Miles Per Year</td>
<td>Years of Operation</td>
<td>Total Lifetime Miles</td>
</tr>
<tr>
<td></td>
<td>8954</td>
<td>11.6</td>
<td>103866.4</td>
</tr>
</tbody>
</table>

*Final results based on NHDES fleet
Results: Economic

- HEV lowest projected life cycle costs
  - -$1,432.06 compared to ICV
- BEVs more competitive than purchasing price indicates
  - substantial fuel/maintenance reduction compared to ICV
  - Total costs still +$3,733.93
- Leaf Plus not cost competitive
- Effective Price (Purchase – Salvage) most influential on total cost
  - ICV: $14,065.40
  - Leaf: $25,679.95

### Projected Life Cycle Costs

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Purchasing Price</th>
<th>Fuel</th>
<th>Maintenance</th>
<th>Salvage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Focus</td>
<td>$17,950.00</td>
<td>$7,040.80</td>
<td>$9,170.30</td>
<td>$3,884.60</td>
<td>$30,276.49</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>$23,770.00</td>
<td>$4,782.66</td>
<td>$6,113.53</td>
<td>$5,821.76</td>
<td>$28,844.43</td>
</tr>
<tr>
<td>Toyota Prius Prime</td>
<td>$28,300.00</td>
<td>$5,606.13</td>
<td>$6,113.53</td>
<td>$6,931.25</td>
<td>$33,088.41</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>$29,999.00</td>
<td>$4,254.78</td>
<td>$4,075.69</td>
<td>$4,319.05</td>
<td>$34,010.42</td>
</tr>
<tr>
<td>Nissan Leaf Plus</td>
<td>$36,555.00</td>
<td>$4,377.16</td>
<td>$4,075.69</td>
<td>$5,264.52</td>
<td>$39,743.32</td>
</tr>
</tbody>
</table>
Effective Price

- High for BEVs --> Large purchasing price/ comparatively low resale value
- If 44% 5 year resale value assumed
  - Nissan Leaf total costs compared to ICV drops 58%
  - $3,733.93 to $1,562.77
- Federal incentives
  - Full ($7,500) --> Leaf lowest total costs in analysis
  - Half ($3,750) --> Leaf lower total cost than ICV

BEV Fuel Costs

- Full EPA fuel efficiency: only $297.83 cost reduction
- Zero electric: -520.86 compared to ICV

### Resale Value

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Five year resale value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Focus</td>
<td>44%</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>50%</td>
</tr>
<tr>
<td>Prius Prime</td>
<td>50%</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>29%</td>
</tr>
<tr>
<td>Leaf Plus</td>
<td>29%</td>
</tr>
</tbody>
</table>

### Figure 1: Cost Per Mile

- Effective Price
- Fuel
- Maintenance
Results: Environmental

- Function Unit: 1 mile driven
- Large portion of ICV and HEV emissions comes from operations
- BEV emissions greatly impacted by both electrical energy inputs (50% Leaf) and battery production (25% Leaf)
- Nissan Leaf 46% GHG emissions reduction compared to Ford Focus
- Potential Leaf fleet reductions: 650.5 metric tons CO2e
Grid Inputs - Representative of regional differences:

- ISO-NE natural gas/ nuclear heavy
- Coal/oil heavy grids may not provide GHG reductions
- As grid becomes less carbon intensive, BEV impacts will be reduced
- Pairing BEV with renewable energy leads to largest emissions reduction
- The longer a BEV are on the road - the greater the carbon reduction compared to an ICV (embedded carbon from battery production)
## Takeaways

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Total Cost</th>
<th>Cost Per Mile</th>
<th>Lifetime Tons CO2e</th>
<th>kg CO2e Per Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Focus</td>
<td>$30,276.49</td>
<td>$0.29</td>
<td>39.47</td>
<td>0.38</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>$28,844.43</td>
<td>$0.28</td>
<td>27.01</td>
<td>0.26</td>
</tr>
<tr>
<td>Toyota Prius Prime</td>
<td>$33,088.41</td>
<td>$0.32</td>
<td>25.01</td>
<td>0.24</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>$33,712.58</td>
<td>$0.32</td>
<td>21.26</td>
<td>0.20</td>
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<tr>
<td>Nissan Leaf Plus</td>
<td>$39,436.92</td>
<td>$0.38</td>
<td>24.33</td>
<td>0.23</td>
</tr>
</tbody>
</table>

- BEVs are more cost competitive than purchasing price indicates.
- No vehicle has “zero emissions” → Though BEVs in New England can cut emissions by 46%.
- HEVs have lowest total costs and can reduce emissions by 22% compared to ICVs.
Additional Considerations

- EVSE investment dependent on
  - Battery size
  - Driving range
  - Fleet centralization

- Vehicle Reliability
  - BEV range sensitive to very hot/cold temperatures
    - 0 °F: Range may drop up to 36%
    - 105 °F: Range may drop up to 29%
  - Long range fleet must be dynamic, consisting of a variety of vehicle types and EVSE levels
  - Short range fleets can invest in small battery BEVs and Level I EVSE to reduce total costs

### Electric Vehicle Service Equipment (EVSE)

<table>
<thead>
<tr>
<th>EVSE Level</th>
<th>Cost$1</th>
<th>Leaf 80% Charge Time</th>
<th>Leaf Plus 80% Charge Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I$1</td>
<td>$500-$850</td>
<td>30+ hours</td>
<td>50+ hours</td>
</tr>
<tr>
<td>Level II$2</td>
<td>$3,000</td>
<td>8 hours</td>
<td>11.5 hours</td>
</tr>
<tr>
<td>D.C Fast Charging$2</td>
<td>$30,000+</td>
<td>40 minutes</td>
<td>60 minutes</td>
</tr>
</tbody>
</table>


$2. Level II and D.C. Fast Charging data from Nissanusa.com
Questions?

- Email Nathan Peabody at nap2000@wildcats.unh.edu; with
  - Further questions
  - Citations
  - For completed thesis report (Spring 2020)