# 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 $CO_2e$ 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 $CO_2e$ 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)

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

**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
  - ICV: Ford Focus (2018)
  - 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

| NHDES Fleet | | |
|---|---|---|
| Average Miles Per Year | Years of Operation | Total Lifetime Miles |
| 8954 | 11.6 | 103866.4 |

**Final results based on NHDES fleet*

# Results: Economic

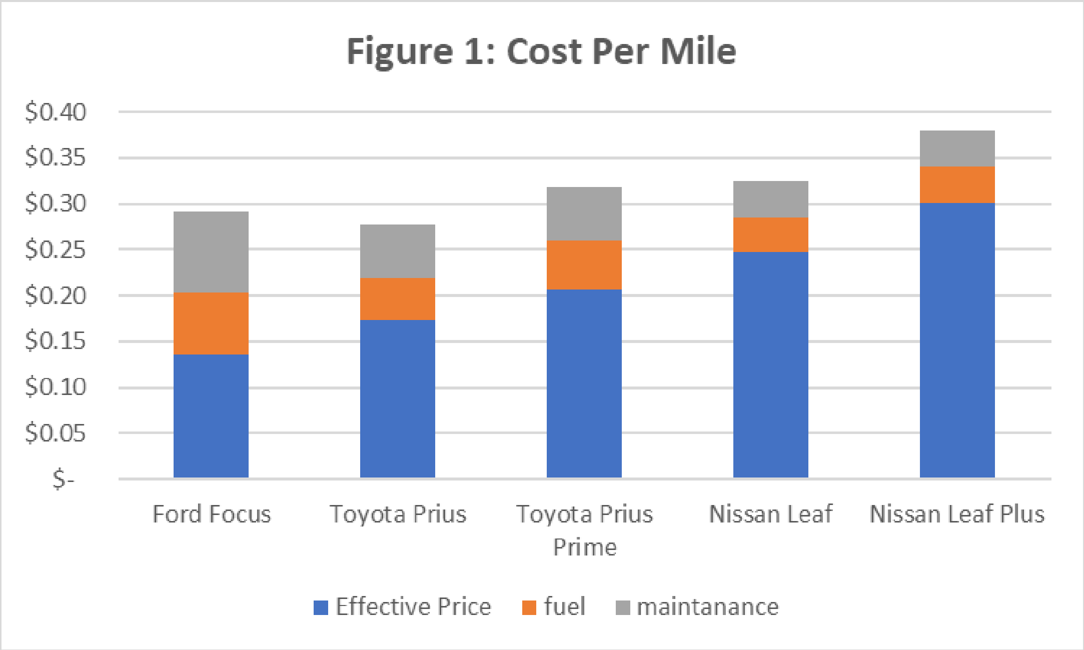
- HEV lowest projected life cycle costs
  - -$1,432.06 compared to ICV
- BEVs more competitive than purchasing price indicates
  - substantial fuel/ maintenance reduction compared to ICV
  - Total costs still +$3,733.93
  - Leaf Plus not cost competitive
- Effective Price (Purchase – Salvage) most influential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

**Projected Life Cycle Costs**

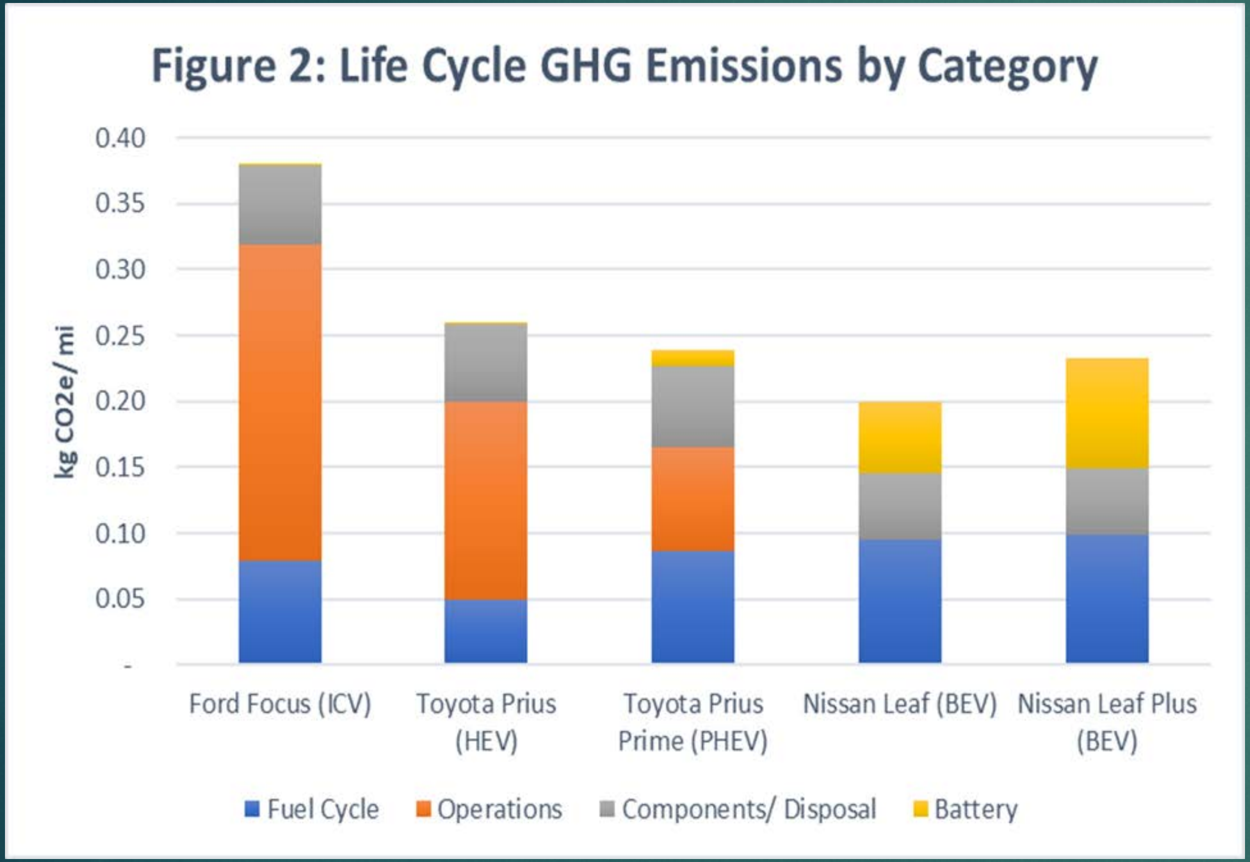
| Vehicle | Purchasing Price | Fuel | Maintenance | Salvage | Total |
|---|---|---|---|---|---|
| Ford Focus | $17,950.00 | $7,040.80 | $9,170.30 | $3,884.60 | **$30,276.49** |
| Toyota Prius | $23,770.00 | $4,782.66 | $6,113.53 | $5,821.76 | **$28,844.43** |
| Toyota Prius Prime | $28,300.00 | $5,606.13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

- 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 | |
|---|---|
| Vehicle | Five year resale value (%) |
| Ford Focus | 44% |
| Toyota Prius | 50% |
| Prius Prime | 50% |
| Nissan Leaf | 29% |
| Leaf Plus | 29% |

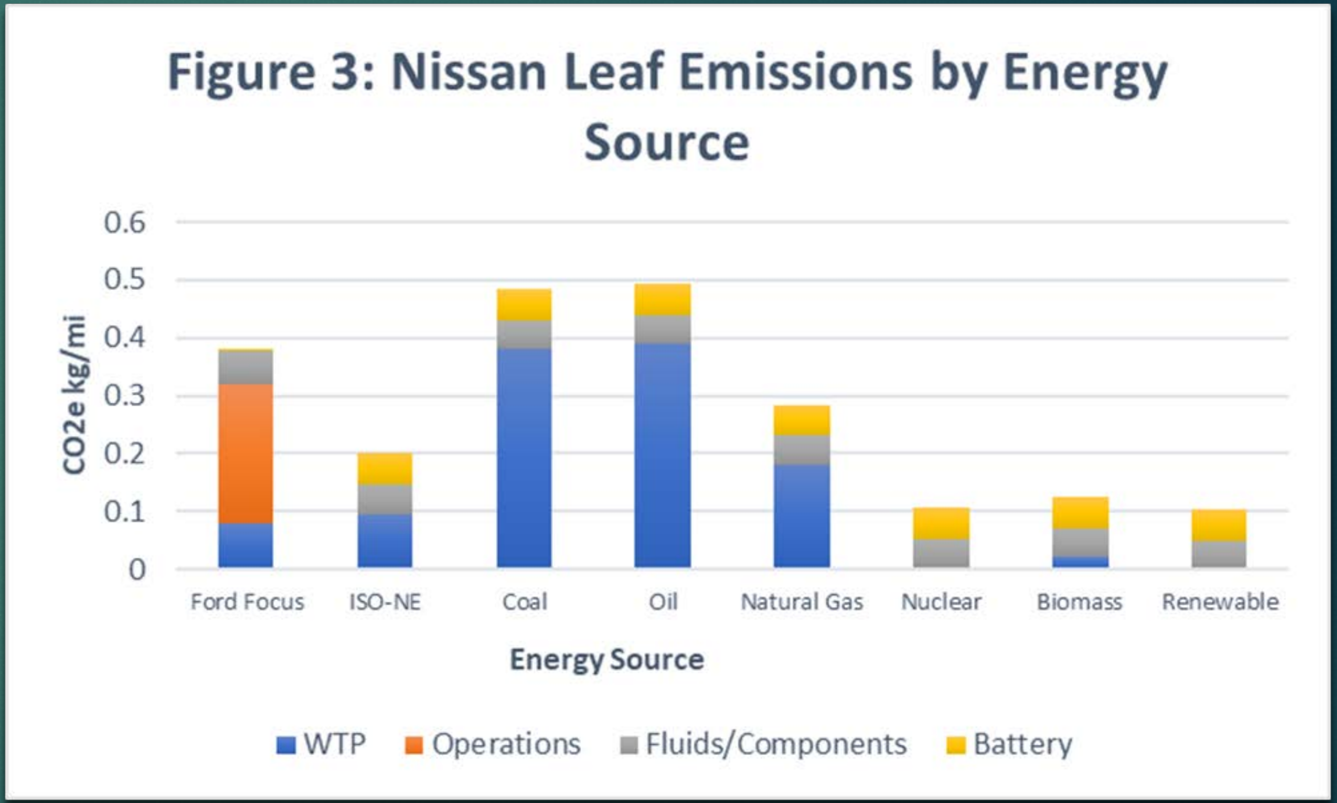


# Results: Environmental




- 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

| Final Results | | | | |
|---|---|---|---|---|
| **Vehicle** | **Total Cost** | **Cost Per Mile** | **Lifetime Tons CO2e** | **kg CO2e Per Mile** |
| **Ford Focus** | $30,276.49 | $0.29 | 39.47 | 0.38 |
| **Toyota Prius** | $28,844.43 | $0.28 | 27.01 | 0.26 |
| **Toyota Prius Prime** | $33,088.41 | $0.32 | 25.01 | 0.24 |
| **Nissan Leaf** | $33,712.58 | $0.32 | 21.26 | 0.20 |
| **Nissan Leaf Plus** | $39,436.92 | $0.38 | 24.33 | 0.23 |

- BEVs 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

| Electric Vehicle Service Equipment (EVSE) | | | |
|---|---|---|---|
| **EVSE Level** | **Cost[1]** | **Leaf 80% Charge Time** | **Leaf Plus 80% Charge Time** |
| **Level I[1]** | \$500-\$850 | 30+ hours | 50+ hours |
| **Level II[2]** | \$3,000 | 8 hours | 11.5 hours |
| **D.C Fast Charging[2]** | \$30,000+ | 40 minutes | 60 minutes |
| [1]. Costs and Level I charge times from (Howell, et al. 2017) | | | |
| [2]. Level II and D.C. Fast Charging data from Nissanusa.com | | | |

- 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

# Questions?

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