



U.S. Department of Energy, Vehicle Technologies Program

Advanced Vehicle Testing Activity (AVTA)

Factors that Impact the Fuel Consumption of Plug-In Hybrid Electric Vehicles

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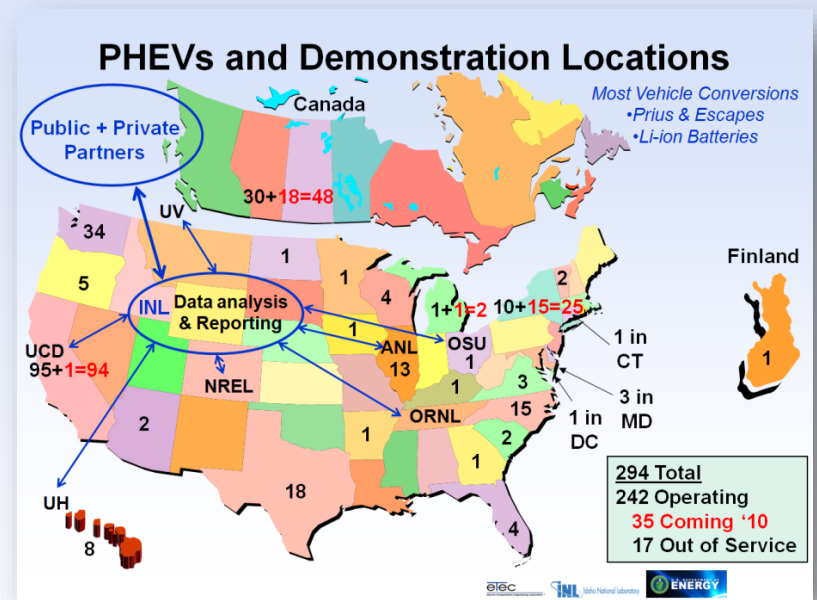
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Six Primary Factor Identified that Impact PHEV Fuel and Elec. Energy Consumption

- 1. Electrical Energy Available for Propulsion**
- 2. Ambient Temperature**
- 3. Accessory Usage (Air Conditioner, Defrost, etc.)**
- 4. Engine Start-up / Warm-up Effect**
- 5. Route Type (urban, highway, mountainous, etc.)**
- 6. Driver Aggressiveness**

Fleet Data Analysis

- Approx. 1.5 Million miles from over 200 PHEV driving and charging data analyzed to identify the six primary factors
- Vehicle
 - Hymotion Prius PHEV
 - Toyota Prius conversion
 - Supplemental battery
 - A123 Li-Ion
 - 5 kWh capacity



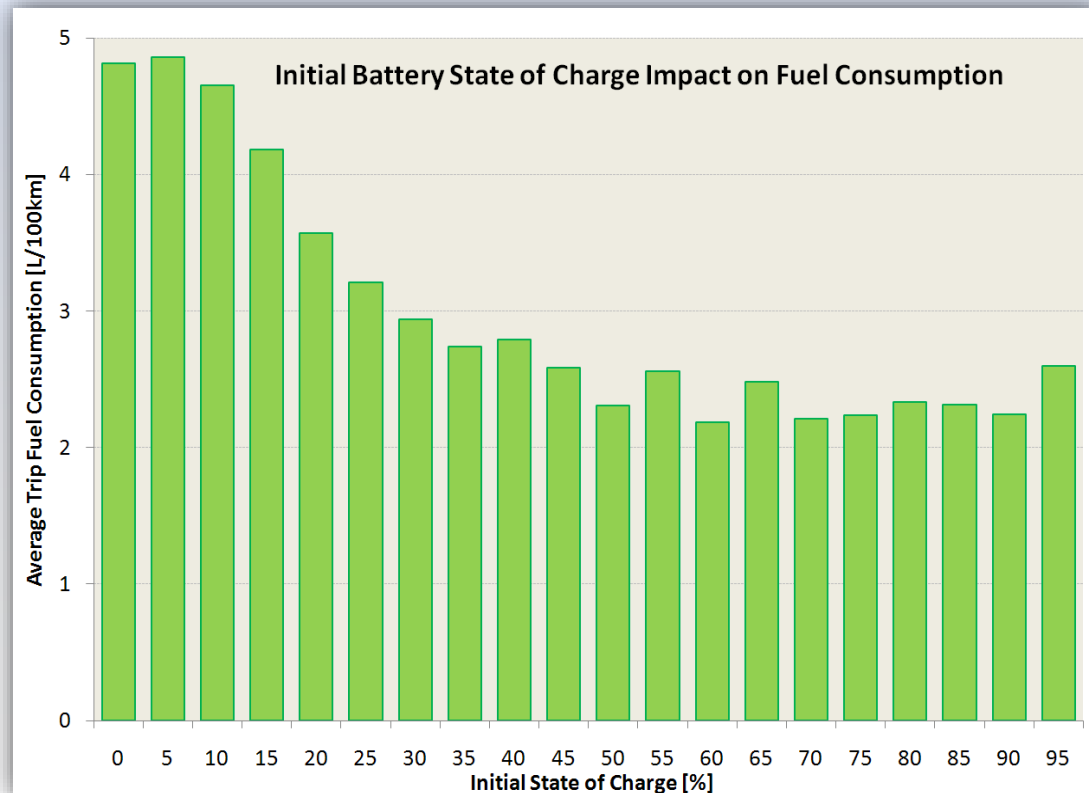
Baseline for Analysis

- To isolate each impact factor, baseline conditions are used for analysis
- Due to random driver and environmental conditions, a normal distribution is assumed with average values representing a majority of the respective data
- Minimum sample size: 50 trips

<u>Primary Factors</u>	<u>Nominal Conditions</u>
Usable Electrical Energy	Trip entirely in charge depletion or in charge sustaining operation, no transitional trips (start CD and end CS)
Vehicle Accessory Utilization	No accessories on (air conditioner, defroster, etc.)
Ambient Temperature	15° C to 30° C
Engine Start-up / Warm-up	Initial engine temp. > 50° C and trip duration > 0.2 hours
Driver Aggressiveness	< 20% of time of the drive with > 40% pedal position
Route Type	Urban driving

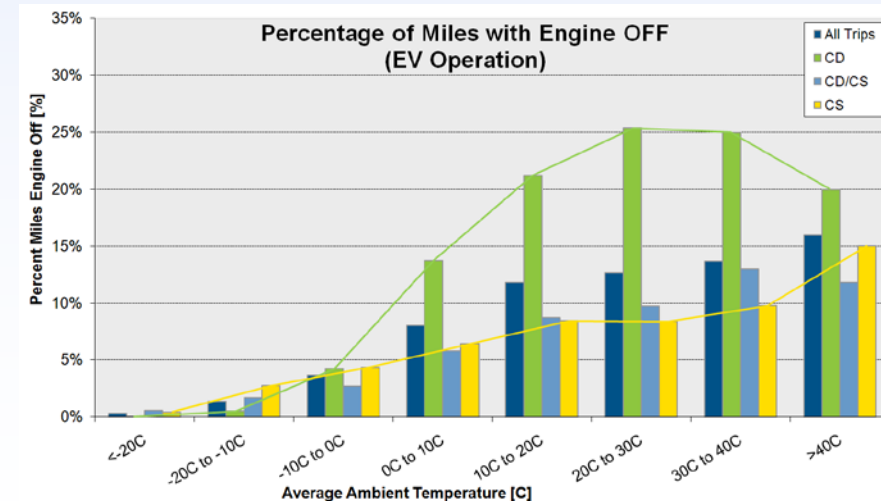
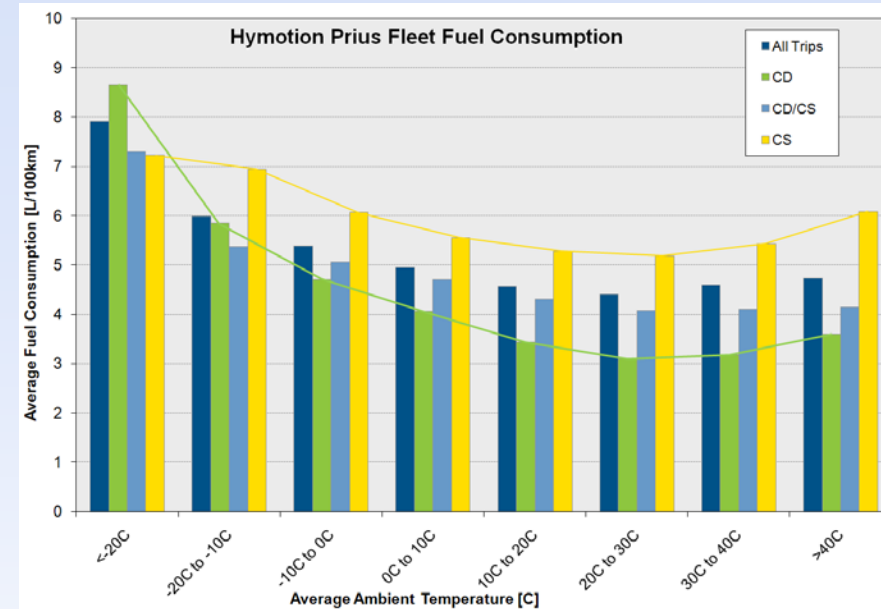
Available Electrical Energy

- Charge Depletion Operation is known to reduce fuel consumption
- At high initial SOC, there is a greater amount of charge depletion operation, hence lower fuel consumption



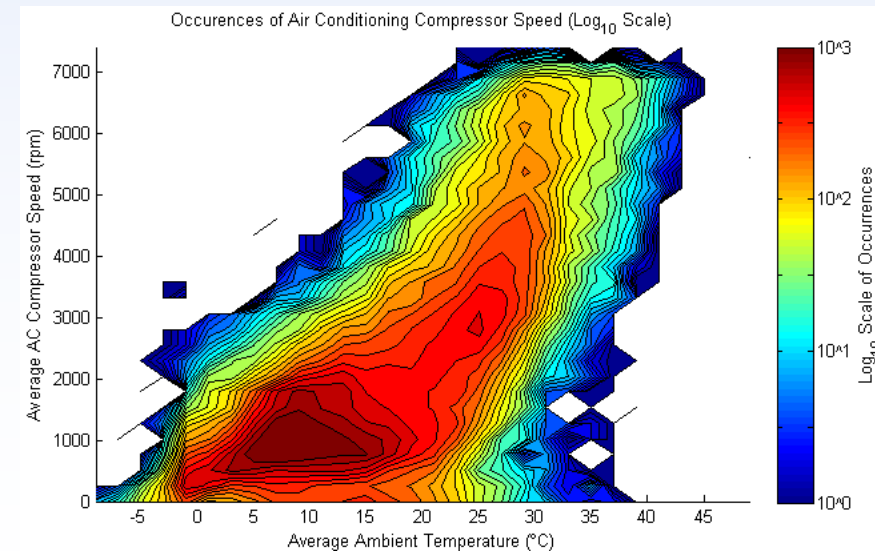
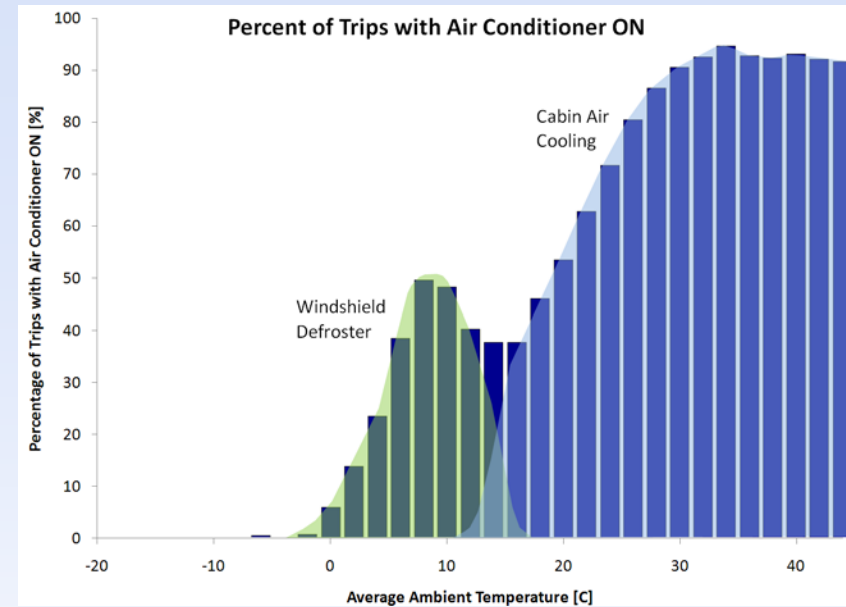
Ambient Temperature

- Fuel consumption increases at colder ambient temperatures
- Change in fuel consumption effect is more dramatic for charge depletion operation
- Engine is on nearly 100% of miles at cold ambient temperatures
- Approx 25% of miles is all-electric operation near 25°C



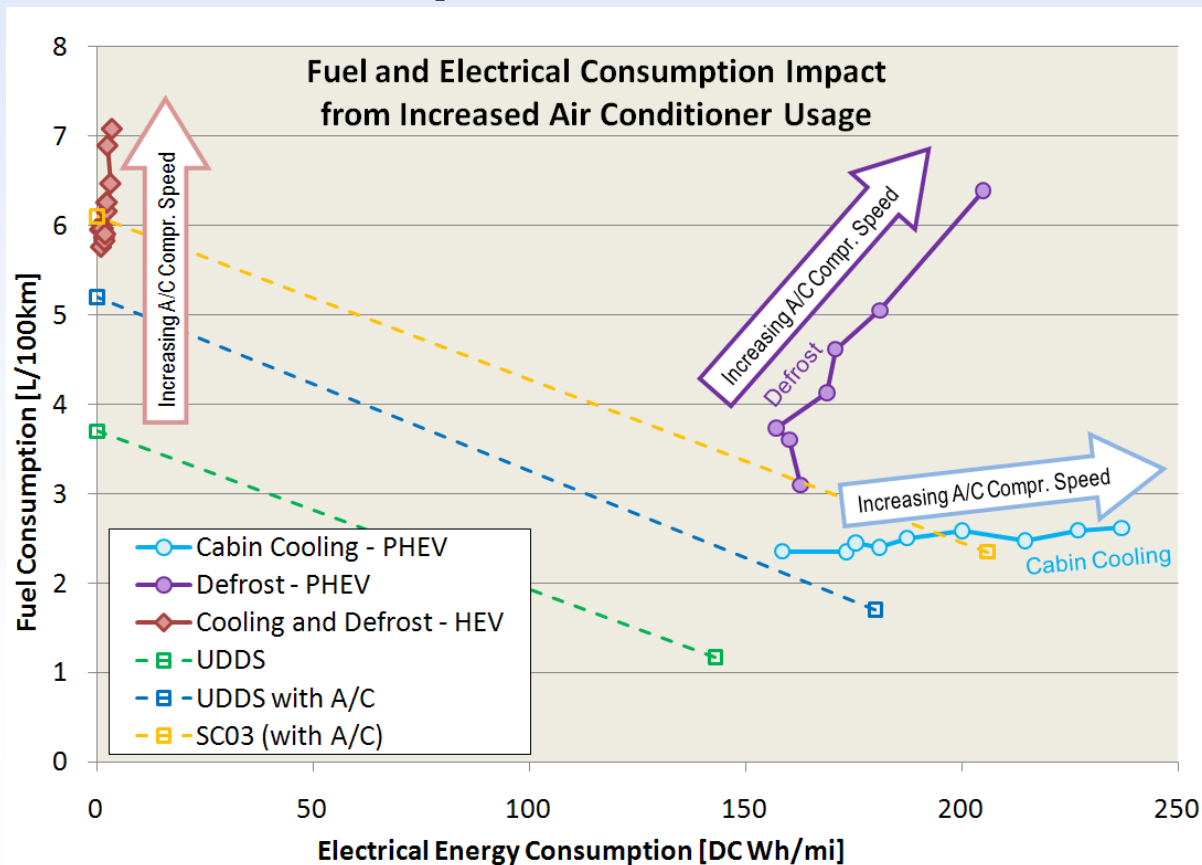
Accessory Utilization – Air Conditioner

- Most trips (>90%) above 30°C use the Air Conditioner
- Between 15°C and 0°C significant Defrost usage
- A/C power consumption is relative to A/C compressor speed
- Many trips near 10°C with Defrost but at low compressor speed (power)
- Cooling above 25°C requires high compressor speed (power)



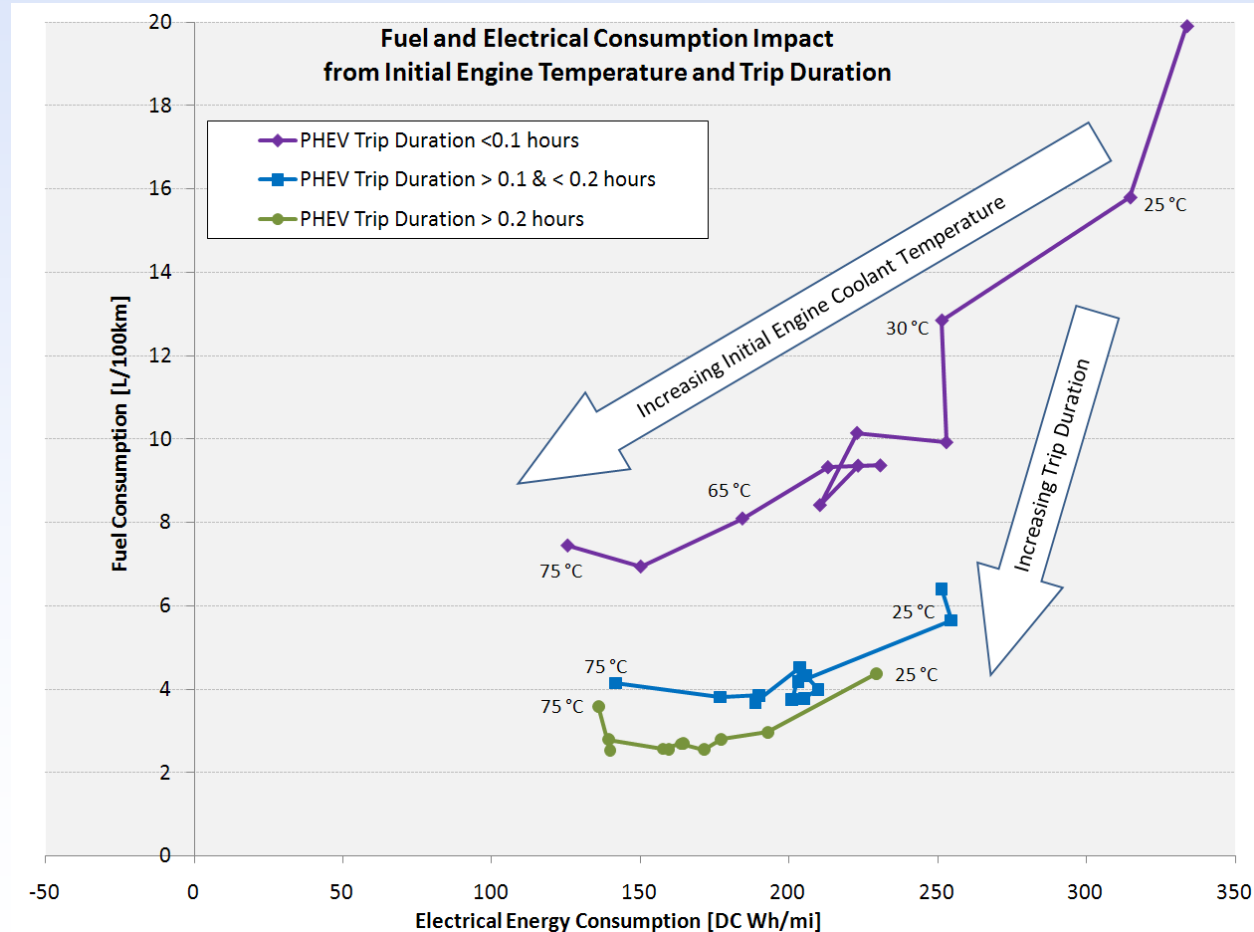
Accessory Utilization – Air Conditioner

- As A/C compressor speed (and load) increases
 - CD: Wh/mi increases, and change in fuel consumption
 - CS: Fuel consumption increases



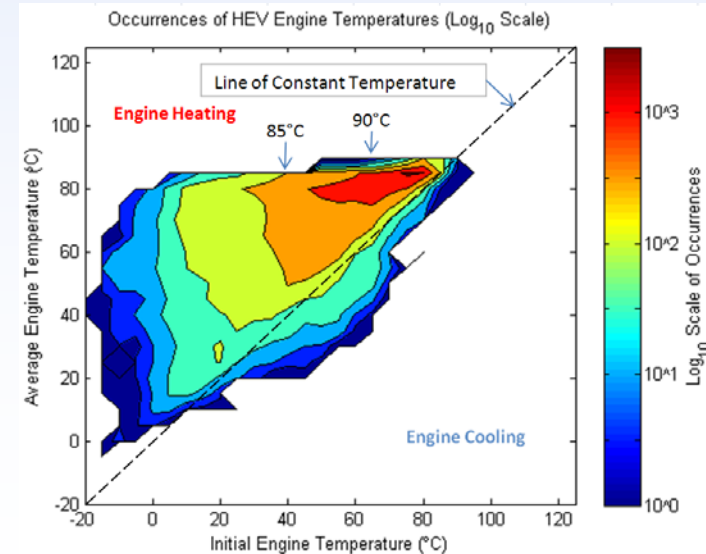
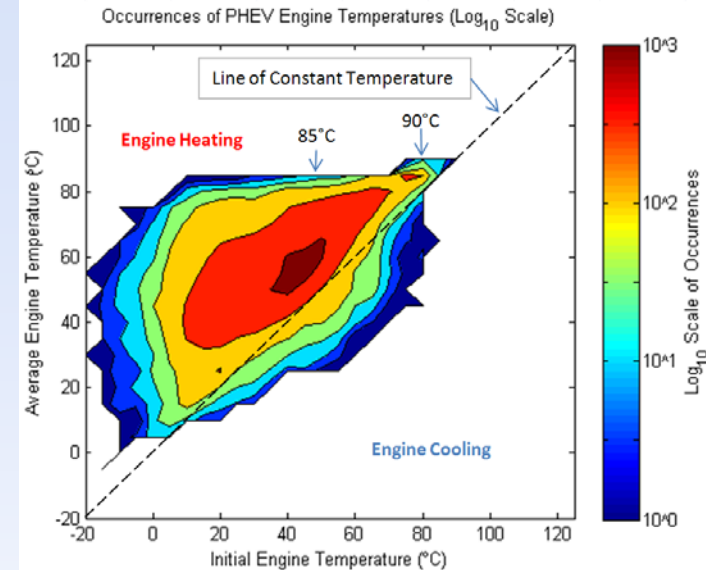
Engine Warm-up / Start-up

- Total energy consumption dramatically decreases as initial engine temperature increases
- Increasing trip duration reduces fuel consumption due to greater time driving with warm engine (less impact of start-up effect)



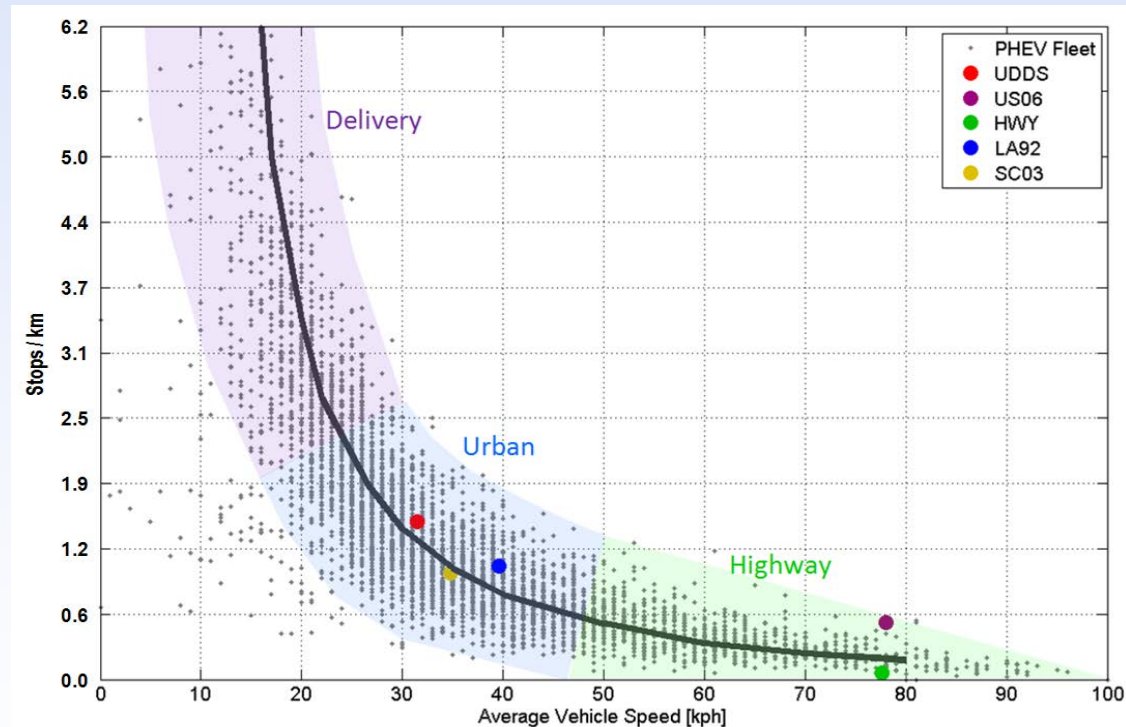
Engine Warm-up / Start-up

- Charge Depletion Operation
 - Lower initial coolant temp
 - Typical CD driving after being parked (plugged in)
 - Lower average coolant temp
 - Less engine operation due to more electric operation
- Charge Sustaining Operation
 - Higher initial coolant temp
 - CS operation after CD trips
 - Higher average coolant temp
 - More engine operations since all propulsion relies upon fuel energy



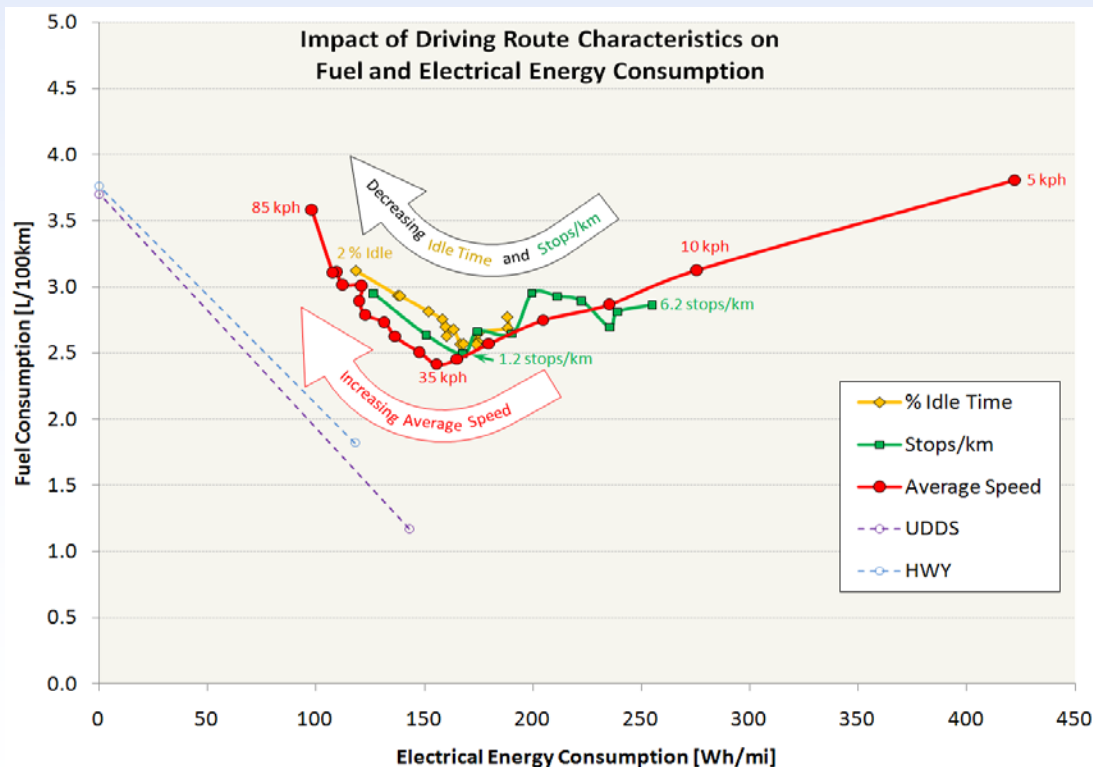
Route Type

- Discernable by
 - Average Vehicle Speed
 - Stops per km
 - % time stopped
- For typical driving
 - Strong correlation between average speed and stops per mile



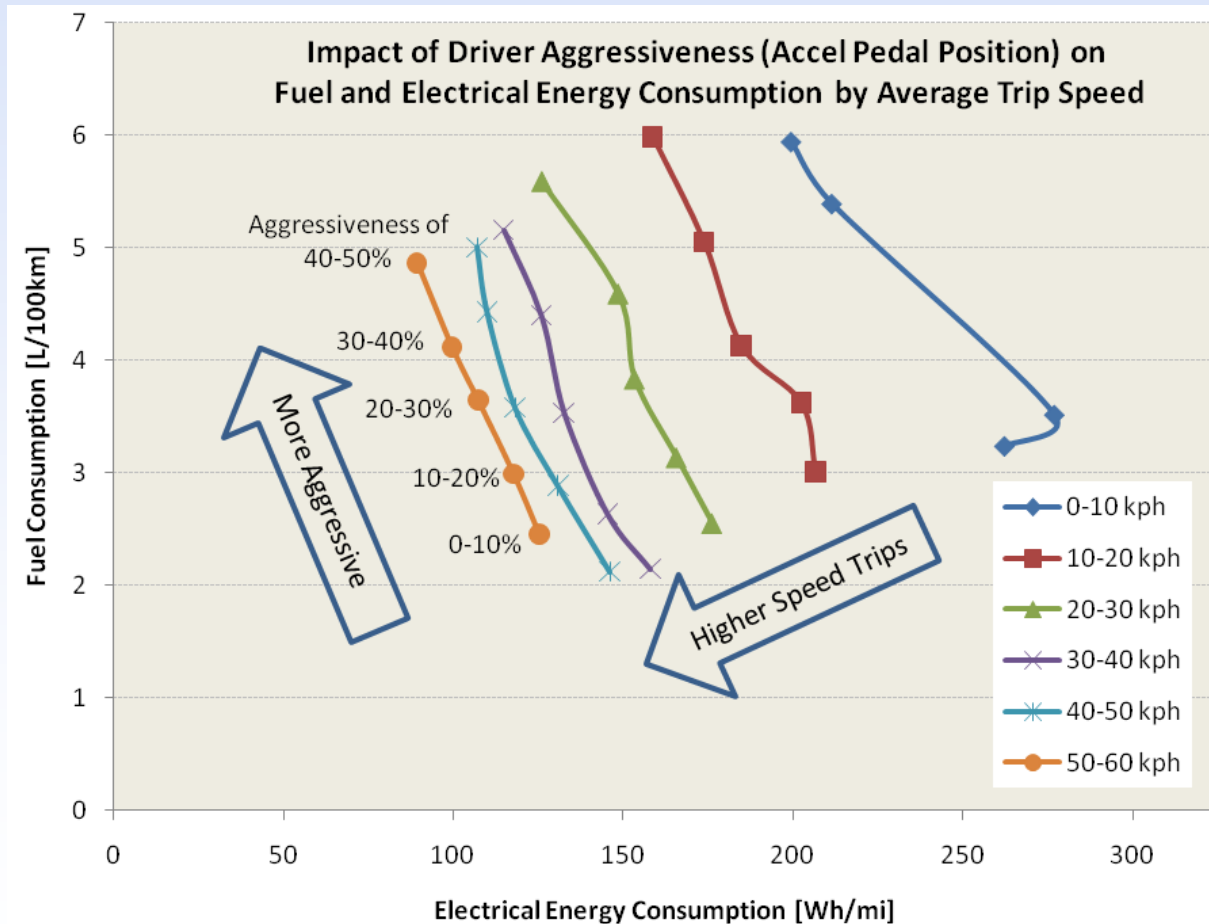
Route Type

- Inflection point around 35 kph and 1.2 stops/km
- Lower average speed results in higher fuel consumption and higher electrical consumption
- Higher average speed also results in higher fuel consumption BUT lower electrical consumption



Driver Aggressiveness

- With increase in driver aggressiveness
 - Fuel consumption increases
 - Wh/mi slightly decreases



Summary

- **Six primary factors are identified that impact the fuel and electrical energy consumption of the Hymotion Prius PHEV**
- **Driving at moderate speeds (~35 kph), in an urban environment without the Air Conditioner, in a non-aggressive manner, at ambient temperature near 25°C, after plugging in the vehicle often, will result in very low fuel consumption**
- **But no one *really* drives like that so continued development in advanced technology vehicles is needed to continue improvements in petroleum displacement**

Acknowledgement

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Additional Information

<http://avt.inl.gov>

or

<http://www1.eere.energy.gov/vehiclesandfuels/avta/>

Backup Slides

Accessory Utilization – Air Conditioner

- Charge Depletion
 - Cooling A/C:
 - ~45 Wh/mi increase &
 - ~0.5 L/100km increase
 - Defrost A/C:
 - ~12 Wh/mi increase &
 - ~1.2 L/100km increase
- Charge Sustaining
 - Cooling A/C:
 - ~1.1 L/100km increase
 - Defrost A/C:
 - ~0.5 L/100km increase

