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# On-Road Evaluation of Advanced Hybrid Electric Vehicles over a Wide Range of Ambient Temperatures



U.S. Department of Energy

UChicago  
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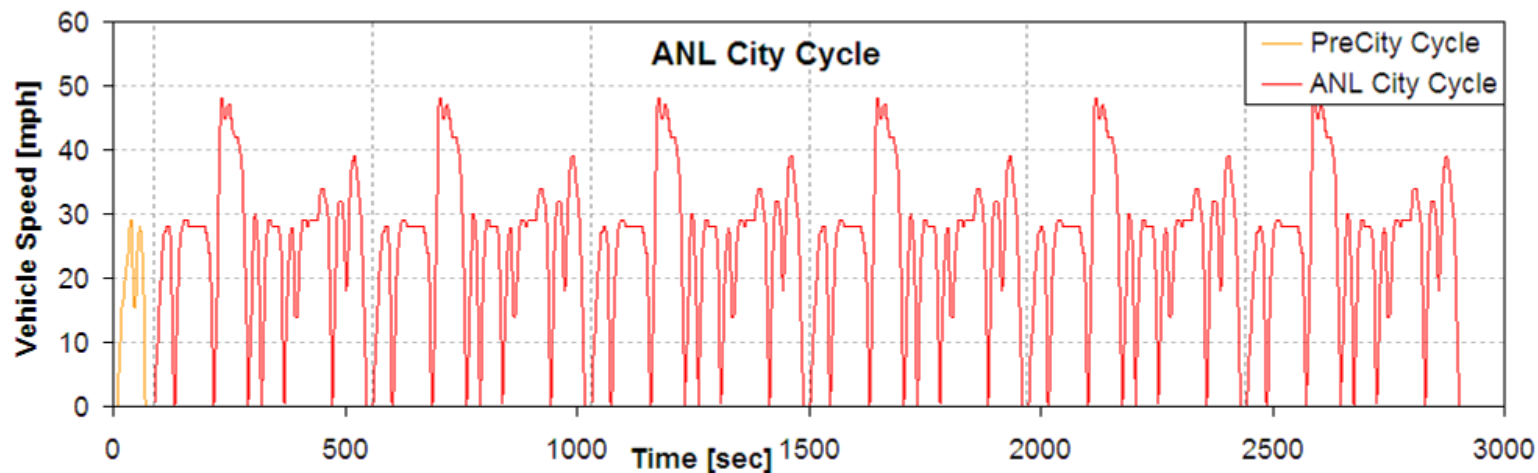
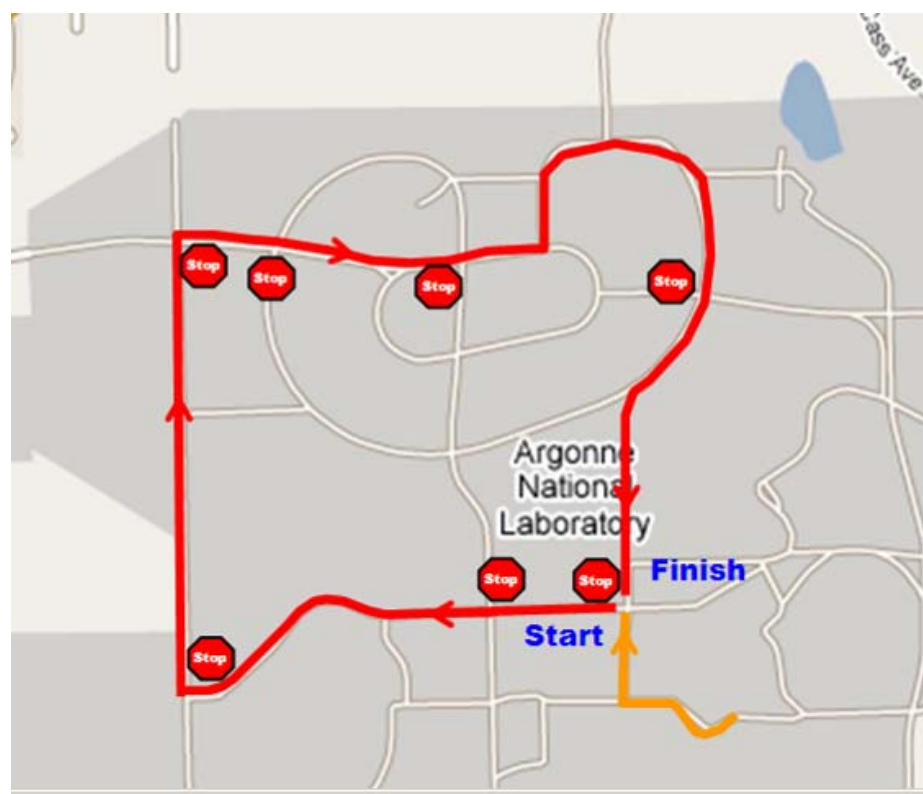
# Vehicle Study Overview

- To evaluate the battery and powertrain utilization and characteristics in extremely varying temperatures
  - Fuel Economy
  - Battery utilization
  - Powertrain control parameters
  - Drivability Characteristics
- Vehicles evaluated
  - 2007 Toyota Camry HEV
  - 2005 Ford Escape HEV
- On-road testing conducted at four temperatures
  - $-15^{\circ}\text{C}$  (cold soak overnight outside, test conducted at 7AM)
  - $0^{\circ}\text{C}$  (cold soak overnight outside, test conducted at 7AM)
  - $15^{\circ}\text{C}$  (cold soak overnight outside, test conducted at 7AM)
  - $30^{\circ}\text{C}$  (hot soak during day in direct sunlight, test conducted at 4PM)
- Dynamometer testing conducted at  $22^{\circ}\text{C}$  for comparison to on-road testing
  - Cold start conducted after overnight soak at  $22^{\circ}\text{C}$



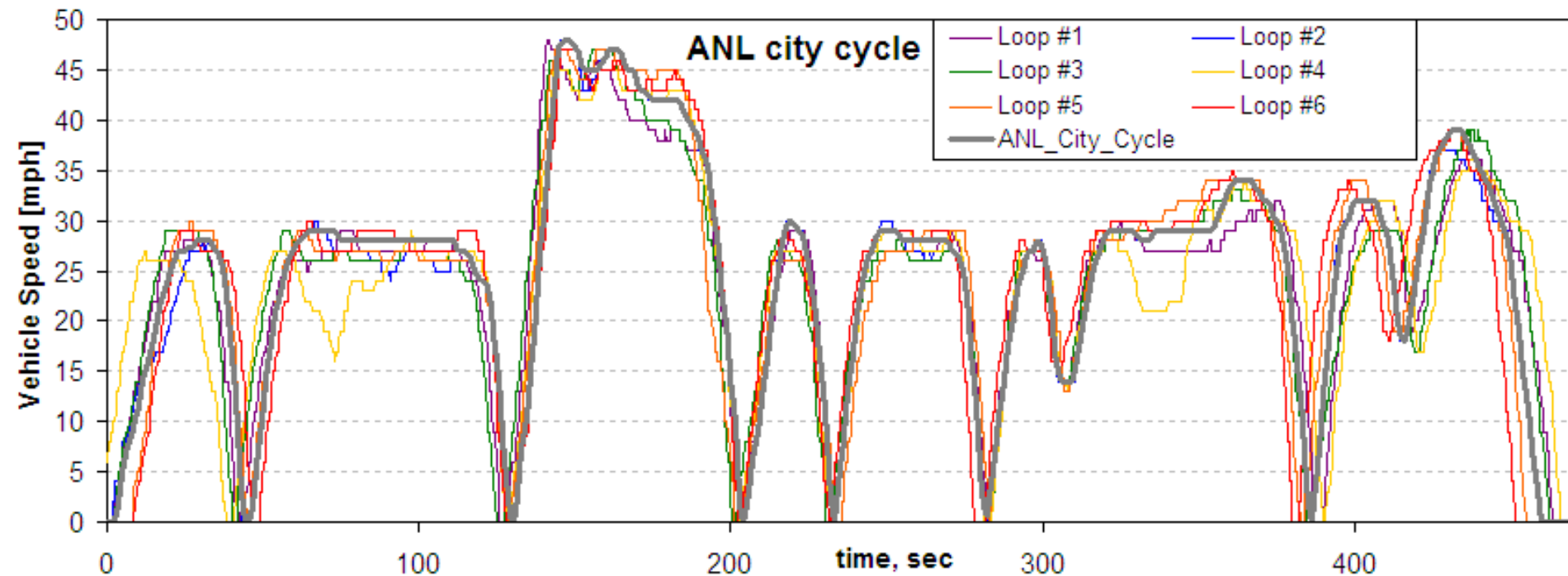
## On Road “ANL City Cycle”

- The testing is conducted from a ‘Cold Start’
  - parked outside for > 12 hours
- The **Pre-City Cycle** is the test section from the parking lot to the test loop
- The **ANL City Cycle** is conducted six times consecutively with 15 seconds between cycles
- The **ANL City Cycle** test loop is 3.35 miles long



## On-Road Driving Repeatability

- Six consecutive real on-road driving loops are shown
  - Fairly good repeatability
  - Most variations due to traffic
- The ANL City Cycle driver's trace for dynamometer operation is derived from averaged vehicle speeds recorded during the on-road evaluations



# On Road Testing Data Acquisition

- Data is recorded at approx 3Hz from the vehicle CAN bus by a Scan tool to a laptop
- At the end of each loop data is manually recorded
  - Fuel Economy from the vehicle dashboard displayed Fuel Economy
  - Distance traveled from the dashboard displayed Trip Odometer

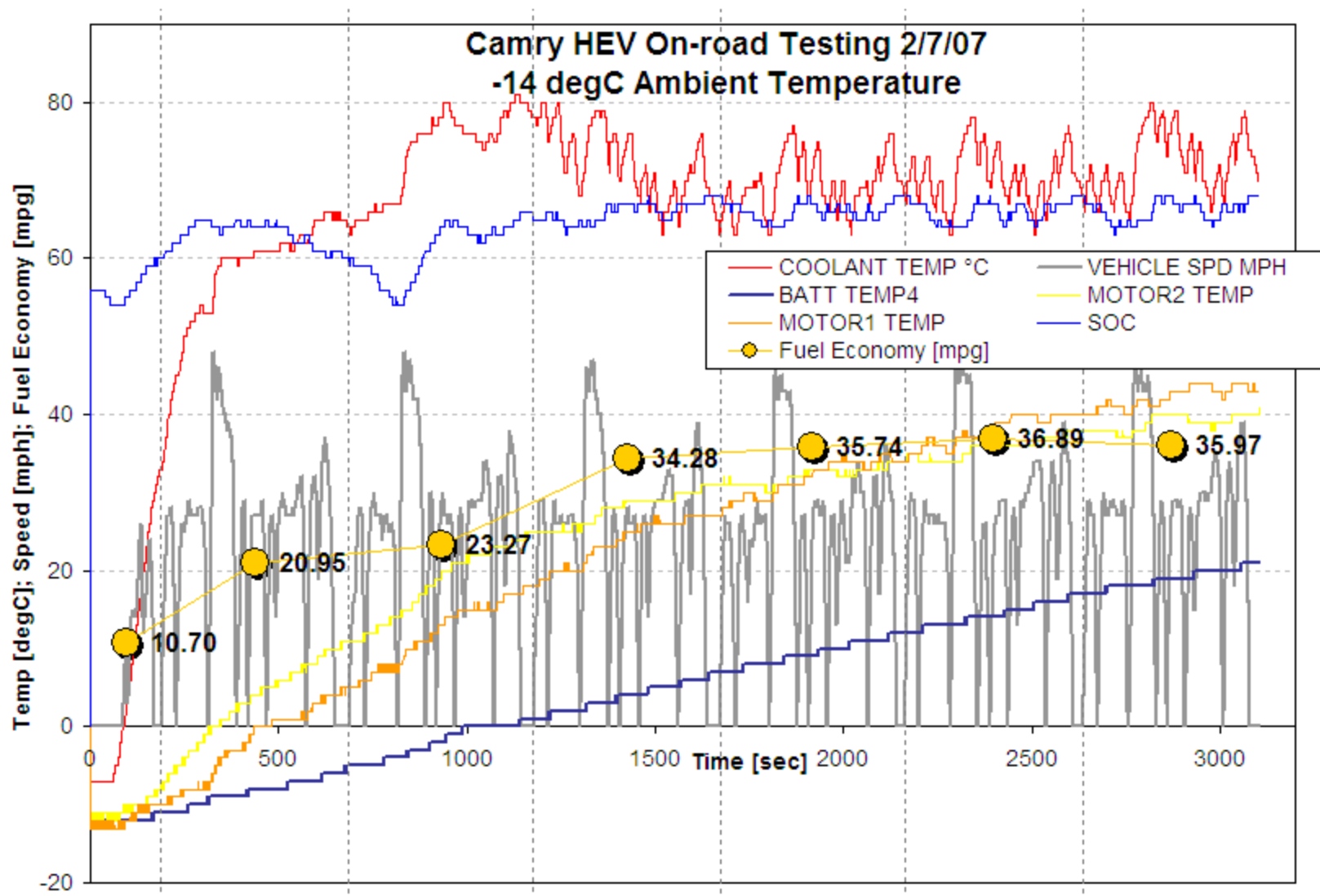


# *Camry HEV*

## *On-Road Evaluation and Analysis*

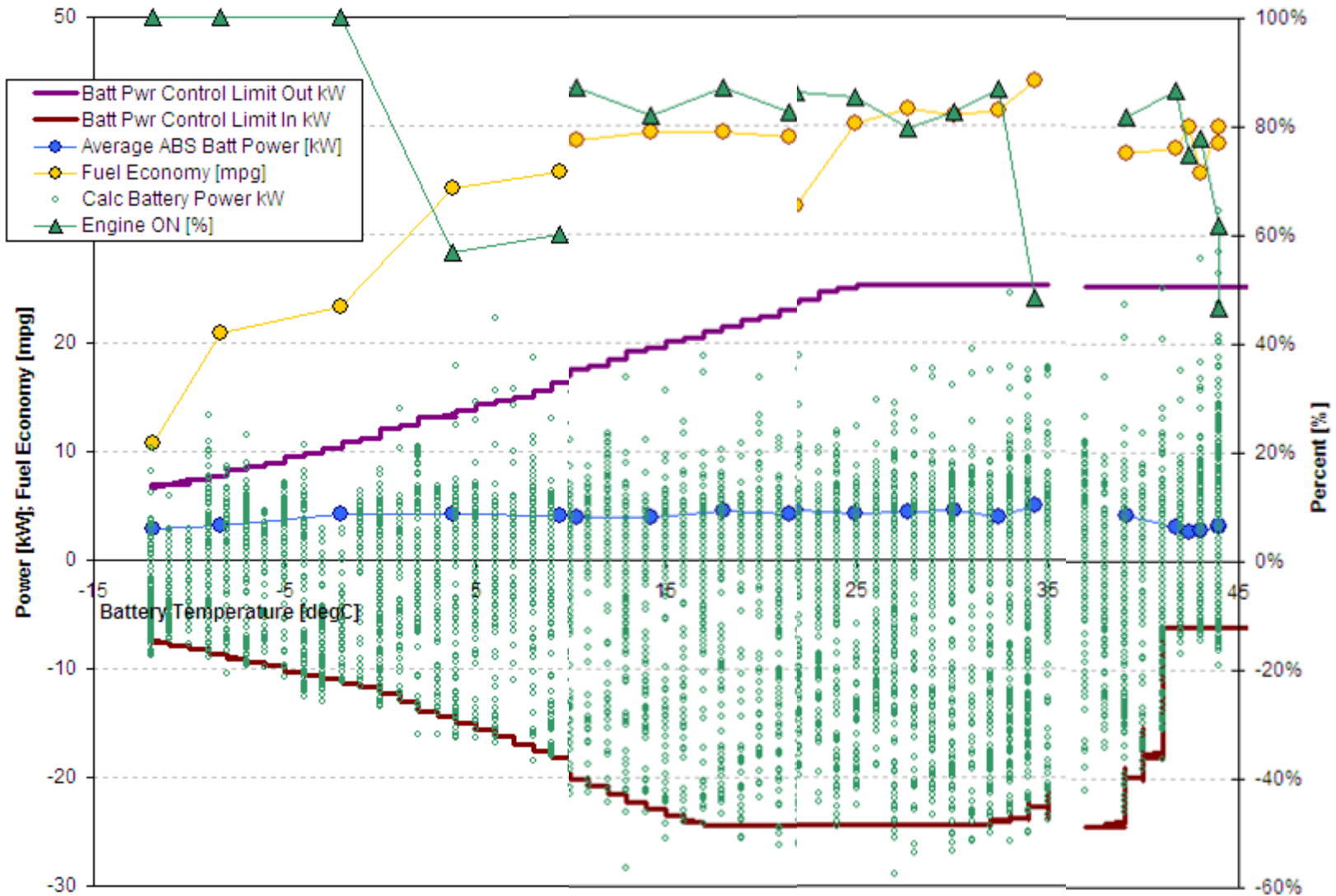


# Camry HEV On Road Testing at -14°C Ambient

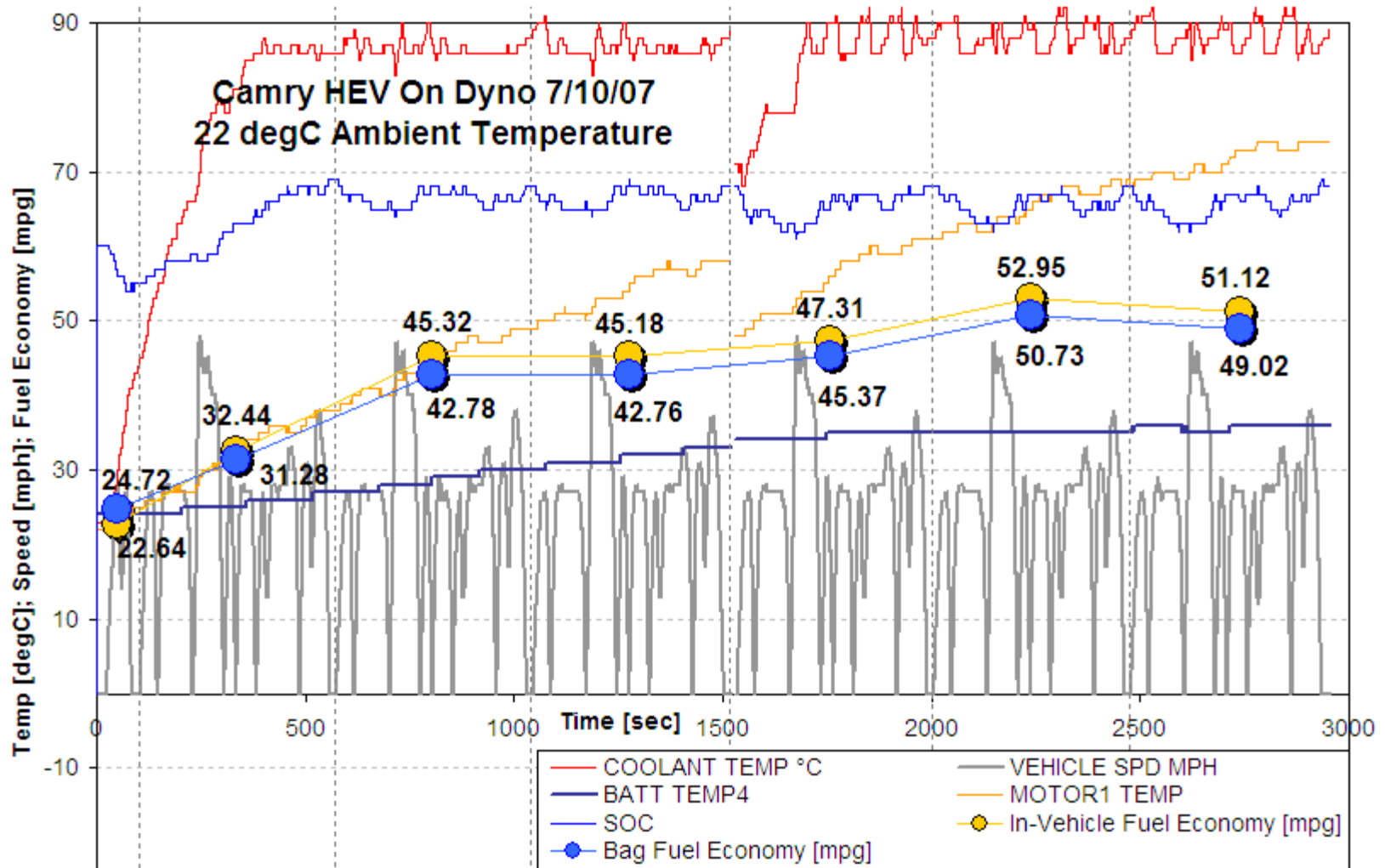


# Camry HEV

## Effect of Battery Temperature on Powertrain Operation

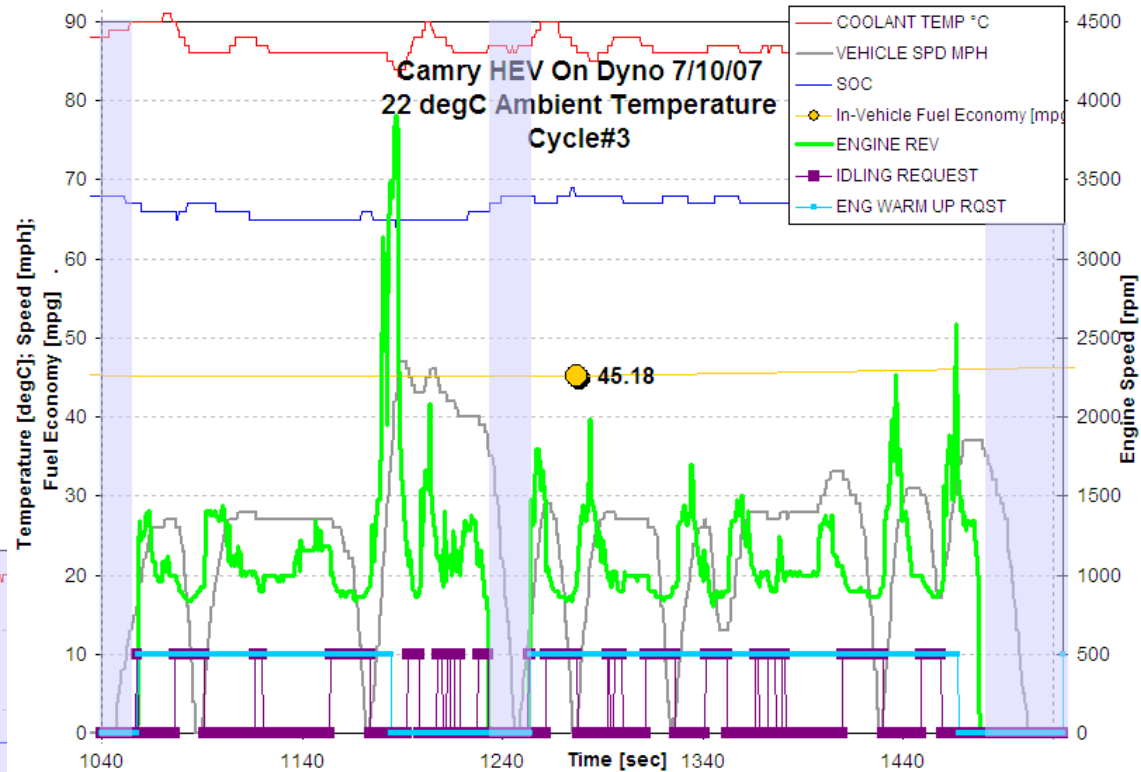
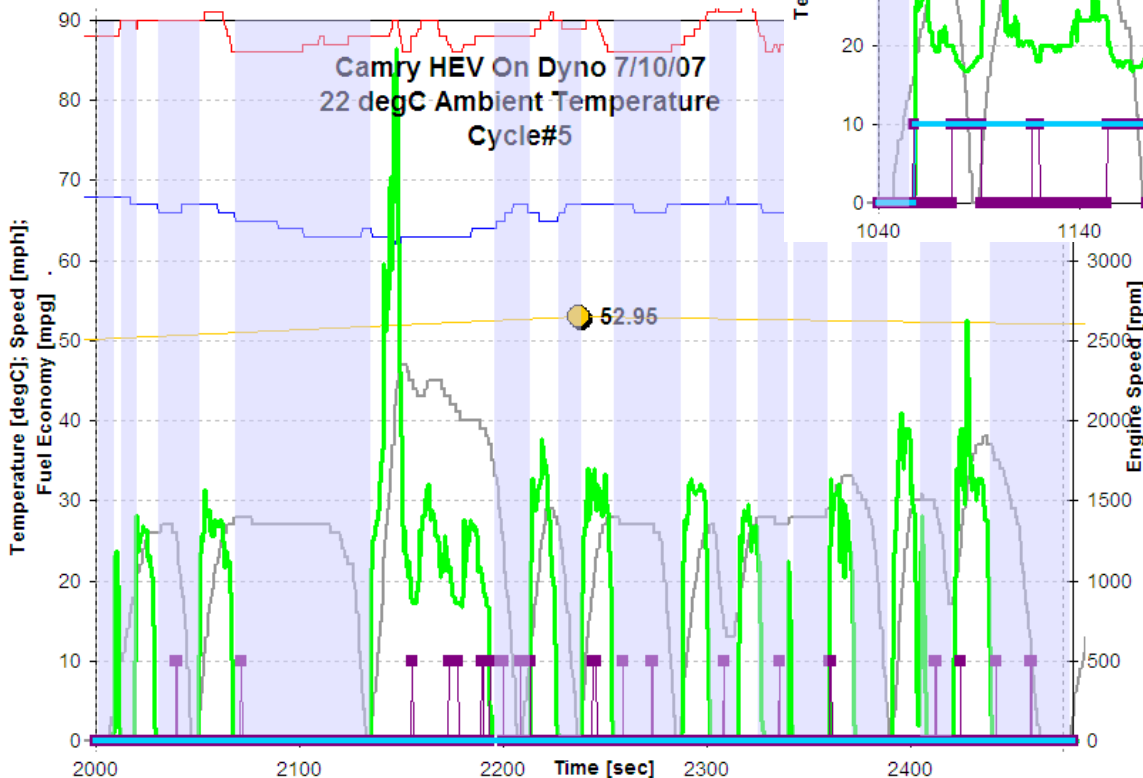


# Comparison of On-Road to Dynamometer Test Results



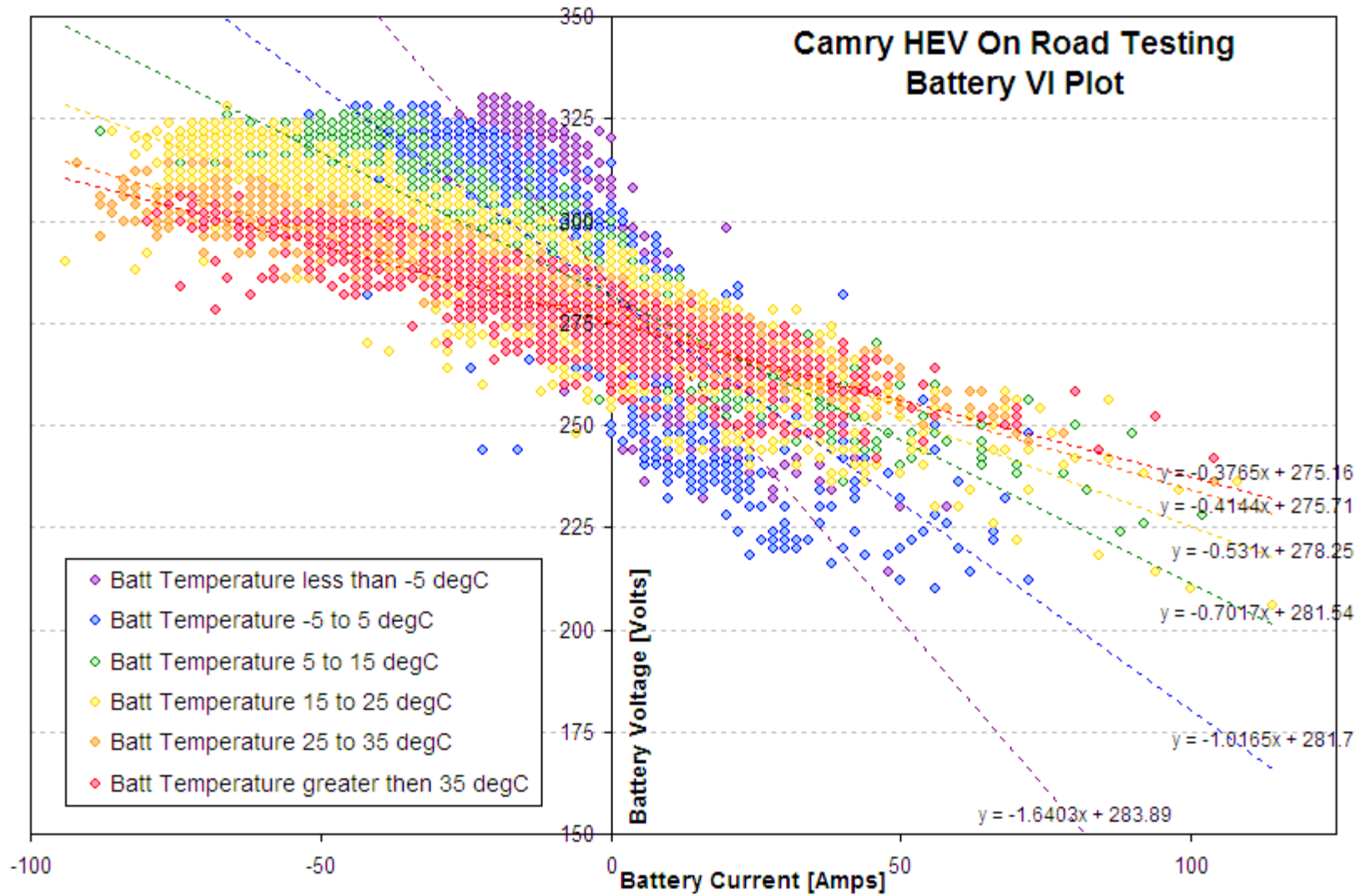
# Engine is Utilized Less in 5<sup>th</sup> Cycle (22°C dyno testing)

- “Engine Warm Up Request” keeps engine ON through more of the 3<sup>rd</sup> cycle as compared to the 5<sup>th</sup> cycle



# Camry HEV

## Battery Voltage vs. Current over a wide Temperature Range

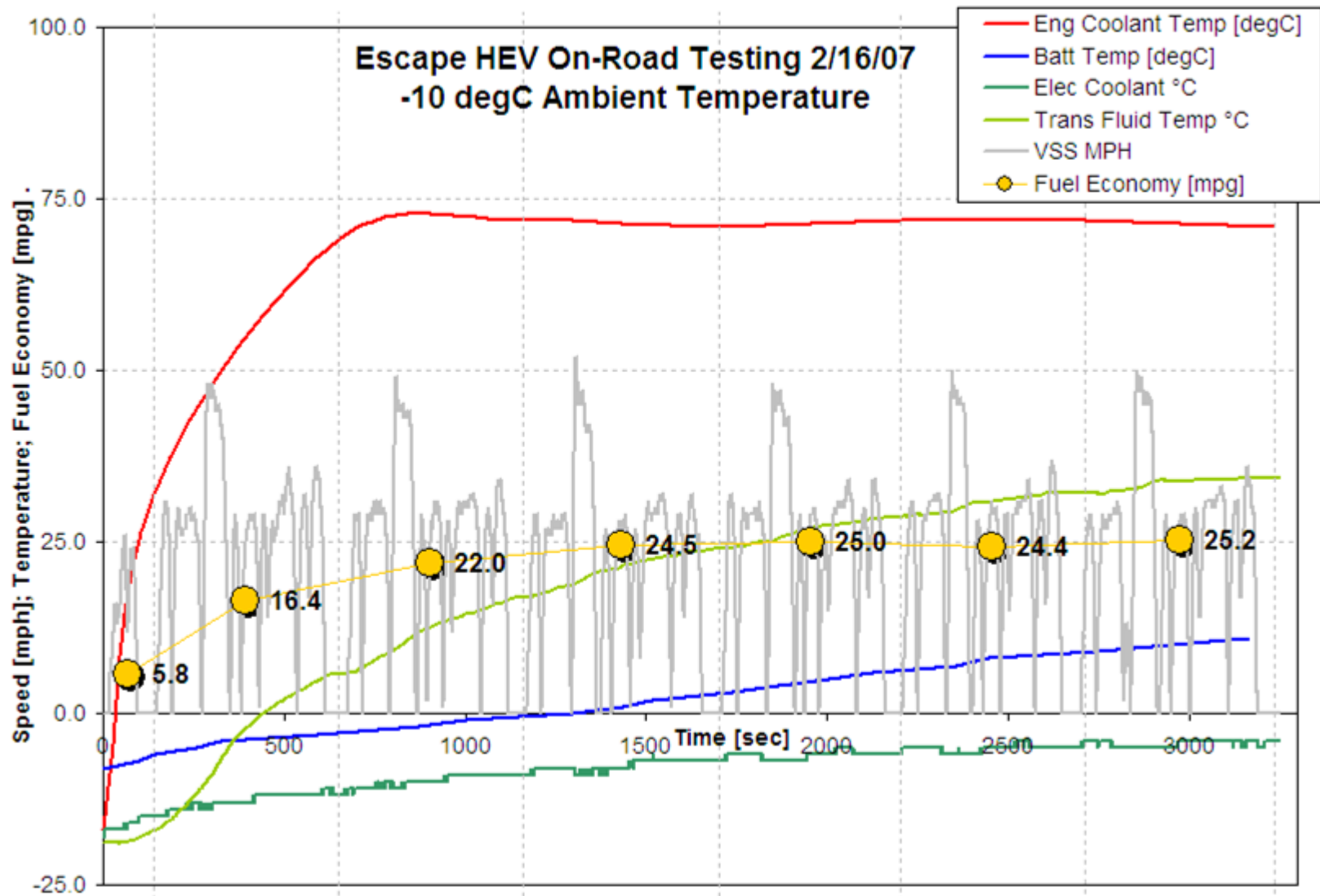


# *Escape HEV*

## *On-Road Evaluation and Analysis*

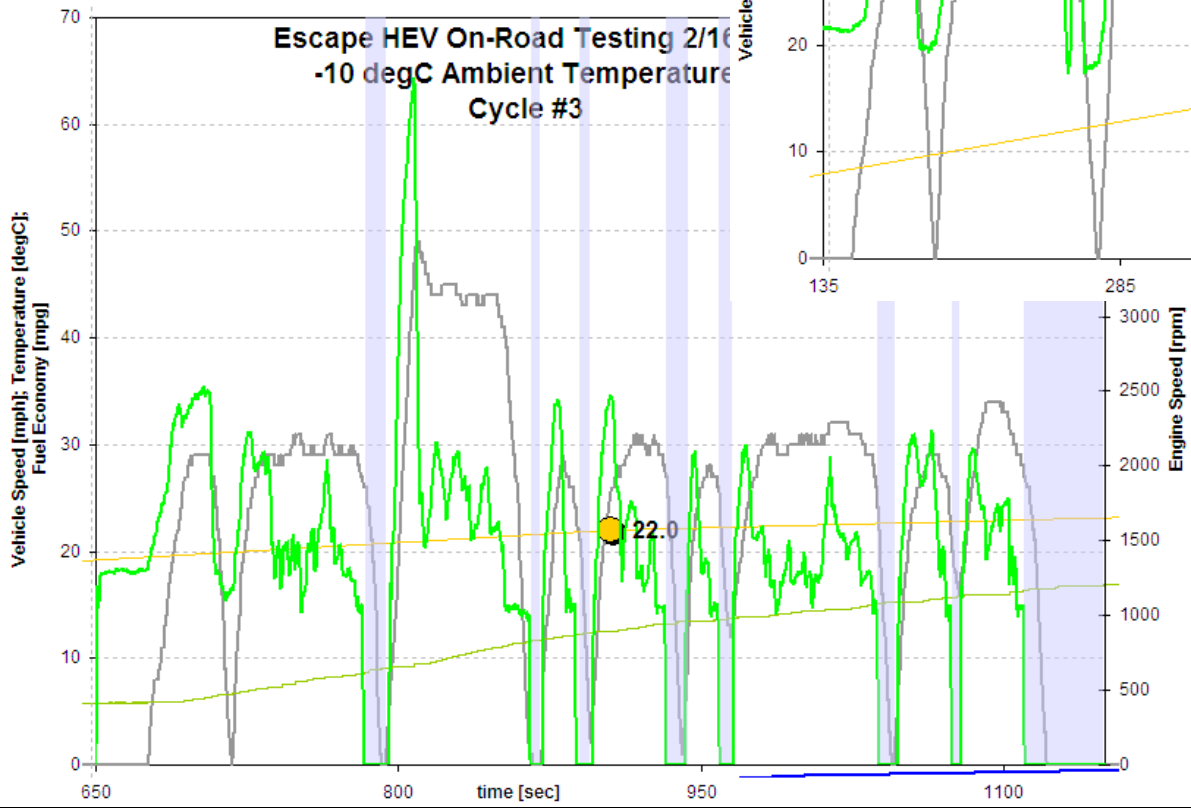
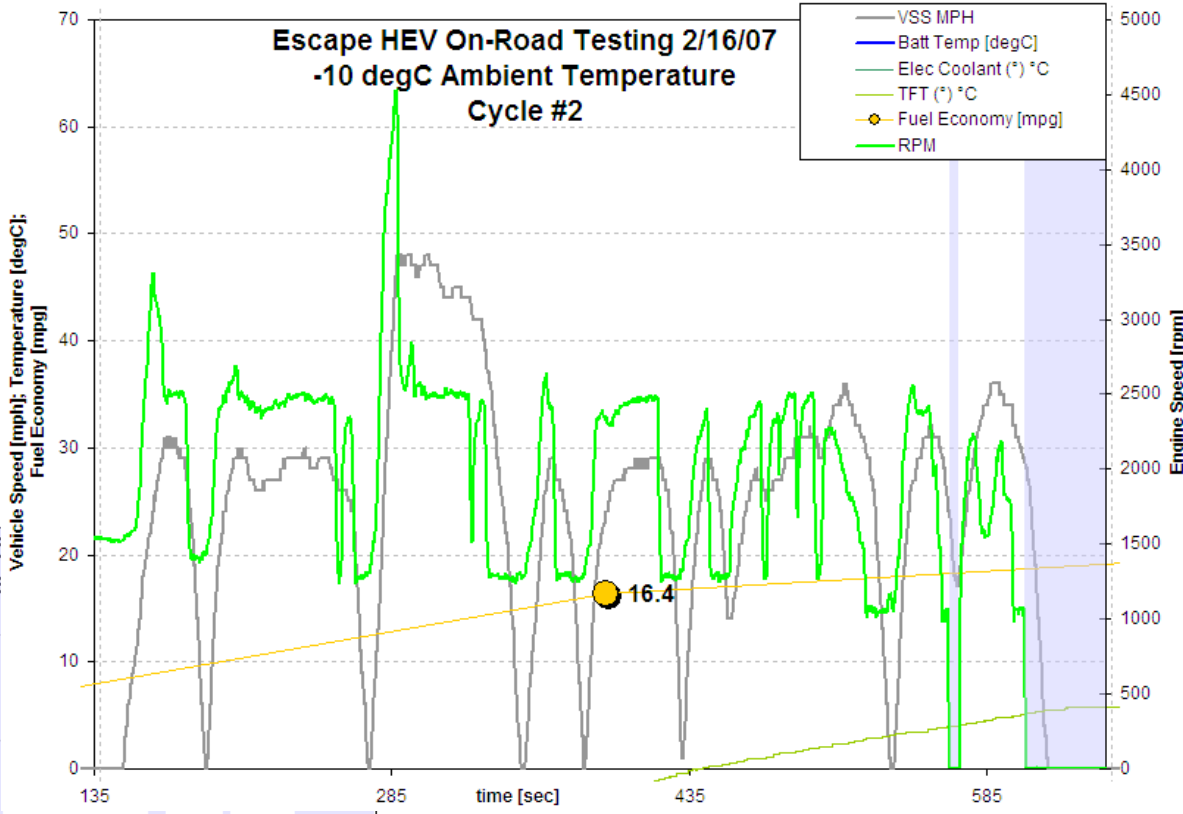


# Escape HEV On Road Testing at -10°C Ambient



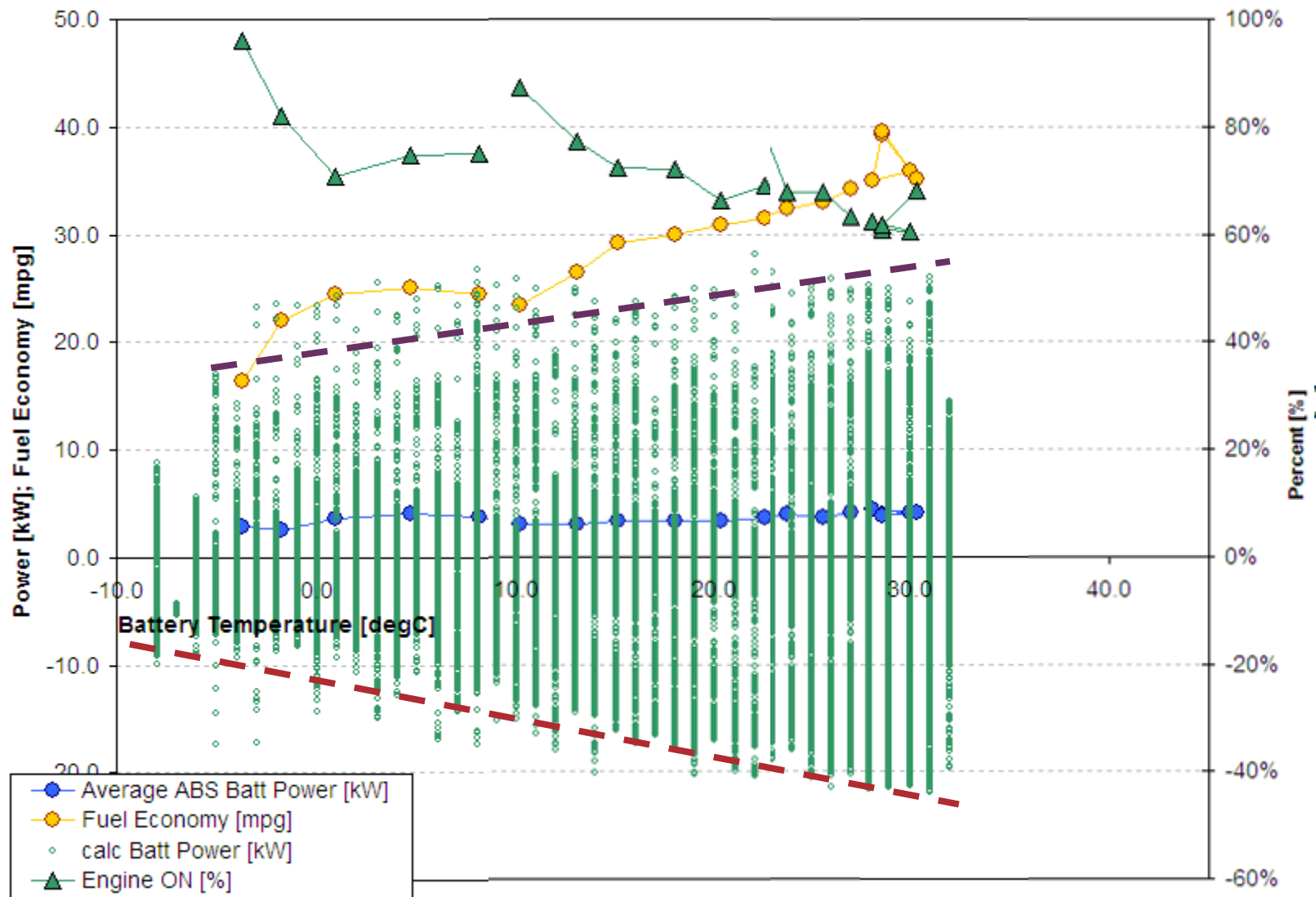
# Escape HEV On Road Testing at -10°C Ambient

■ Engine start / stop functionality improves Fuel Economy in cycle #3

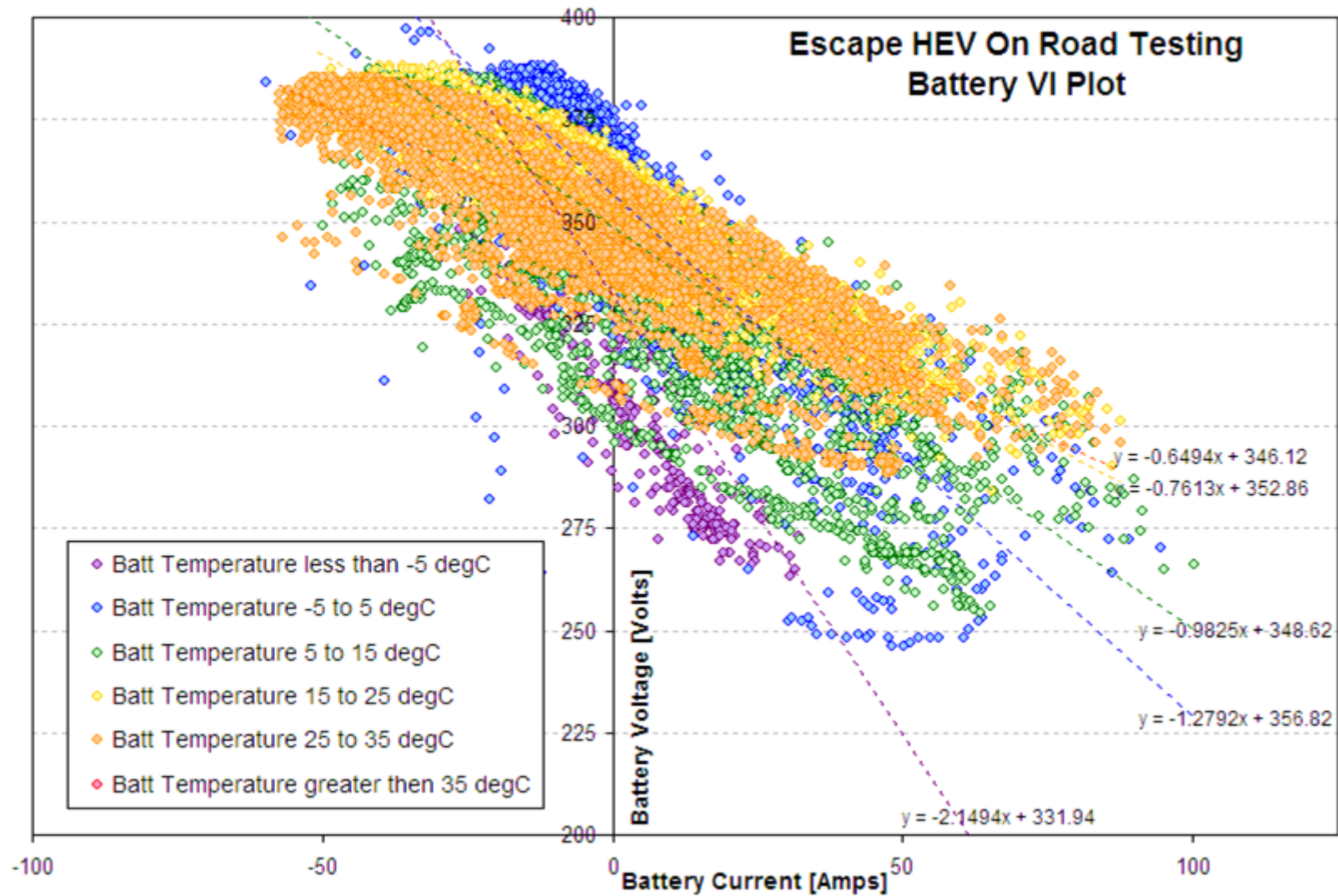


# Escape HEV

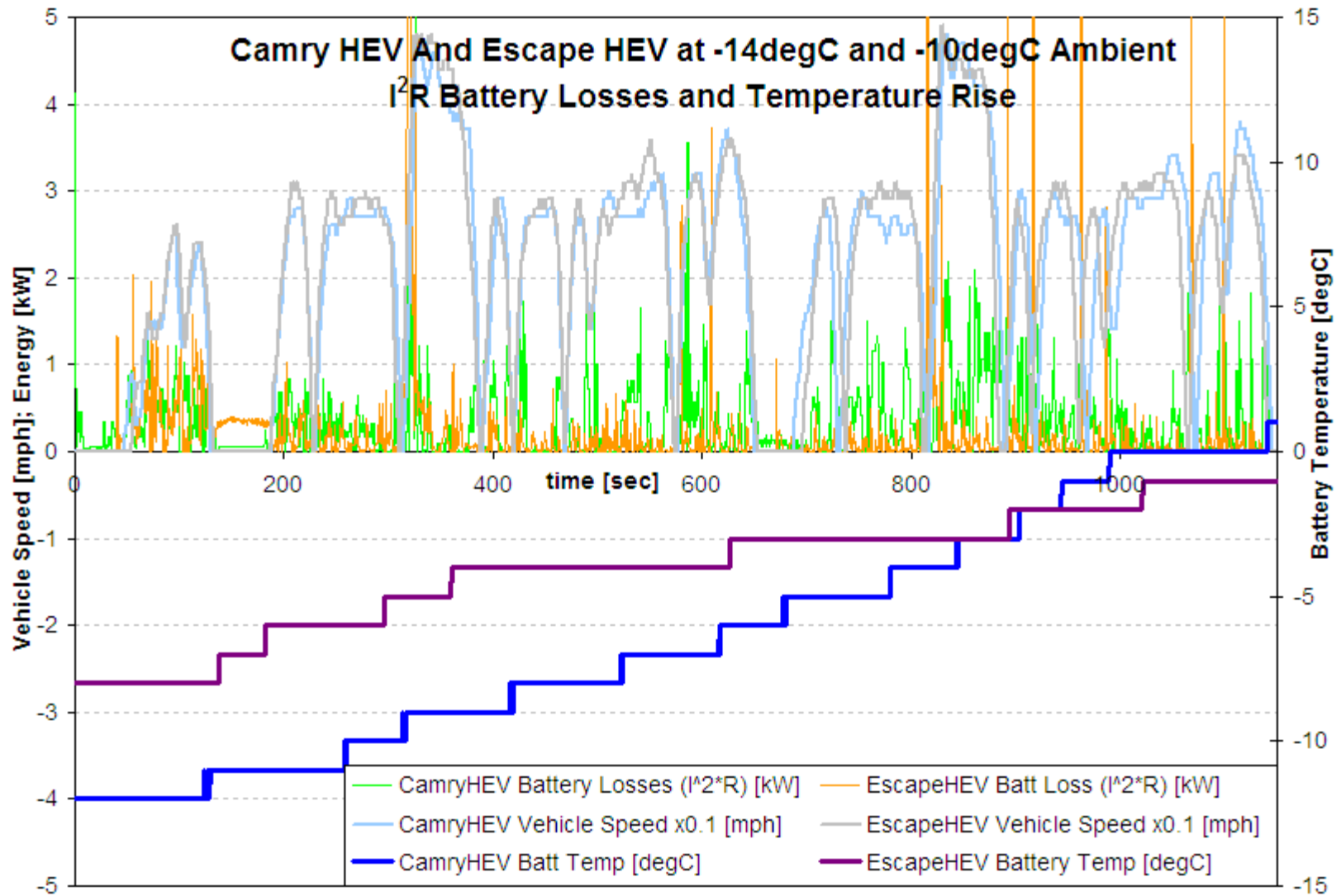
## Effect of Battery Temperature on Powertrain Operation



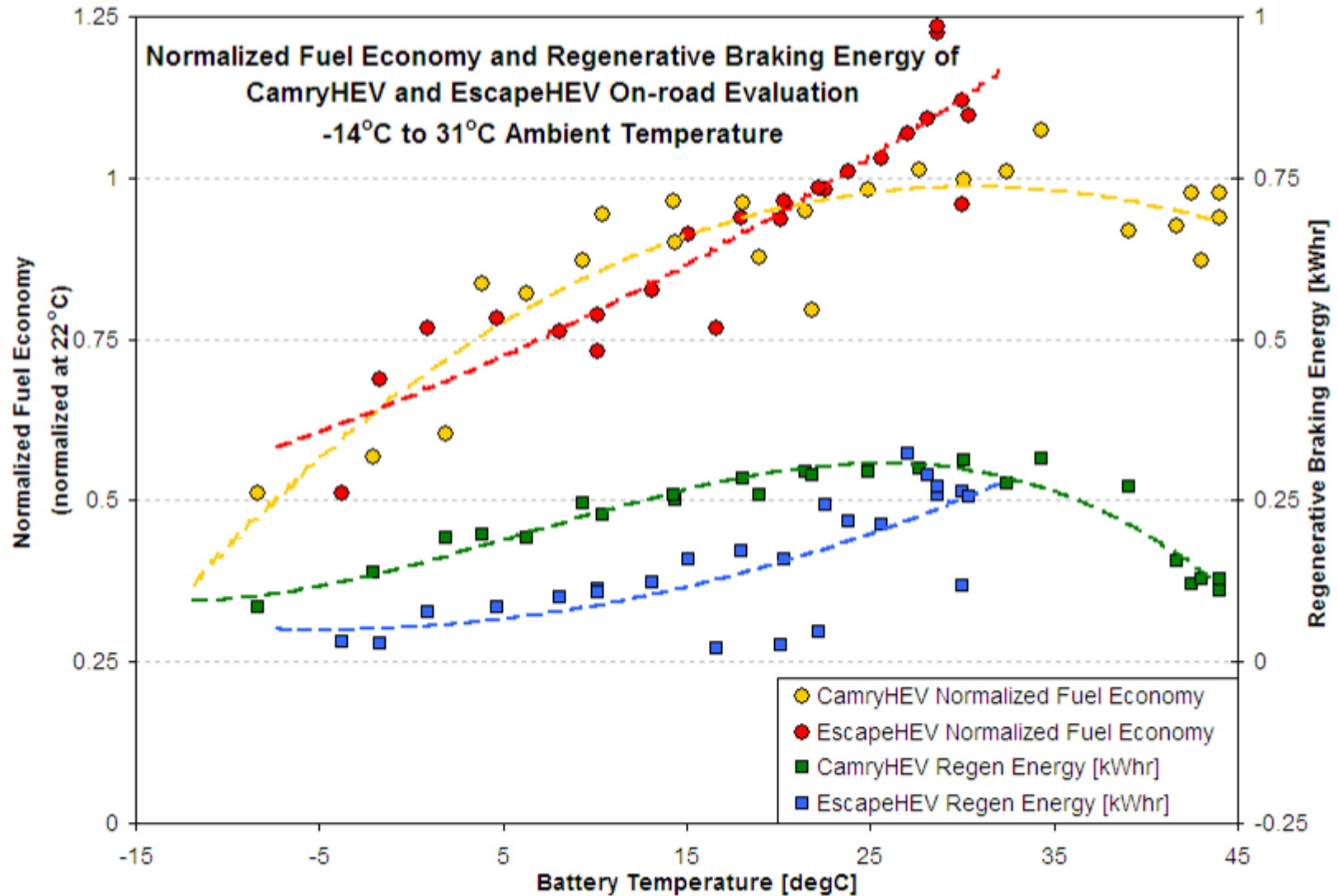
# Escape HEV Battery Voltage vs. Current over a wide Temperature Range



# Battery Temperature Rise



# Fuel Economy Trends and Regenerative Braking Energy



# Summary - On-Road Evaluation of Advanced Hybrid Electric Vehicles over a Wide Range of Ambient Temperatures

- Both vehicles
  - Battery power is limited at very low temperatures
  - Dramatic change in fuel economy (nearly 2X) from - 15°C to 20°C
- Camry HEV
  - Limits the negative battery power (regenerative braking) at battery temperatures above 40°C
  - Uses cabin air to cool the battery
  - Start / stop engine operation began after approx 7 miles
- Escape HEV
  - Air conditioner is used to control battery temperature to less than 33°C
  - Start / stop engine operation began after approx 3 miles

