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PHEVs Component Requirements and Efficiencies

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2009 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

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Sponsored by Lee Slezak

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Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project Overview

Timeline

- Start – July 2008
- End – September 2009
- 75% Complete

Barriers

- Set targets for the different technical teams
- Perform cost benefit analysis

Budget

- DOE
  - FY08 $ 200k
  - FY09 $ 400k

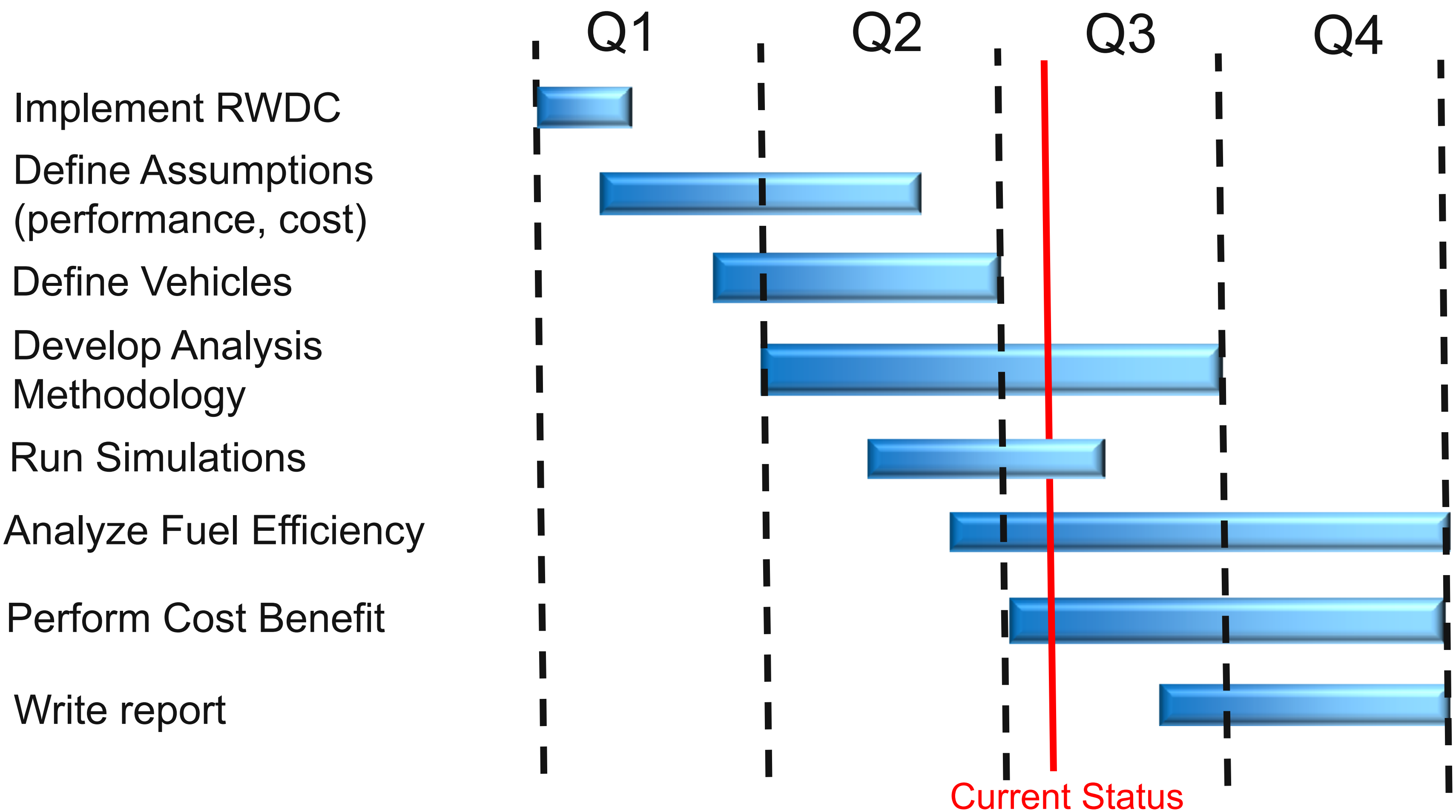
Partners

- U.S. EPA
- ANL Battery's group

Main Objectives

- Define targets for the different technical teams.
- How does each assumption influence the component requirements?
- Can we lower a component requirement without significant fuel economy loss?
- What are the most appropriate battery energy/power to maximize fuel displacement?
- What is the best control strategy philosophy for different battery characteristics?
- What should the cost targets be to have specific payback?

Milestones

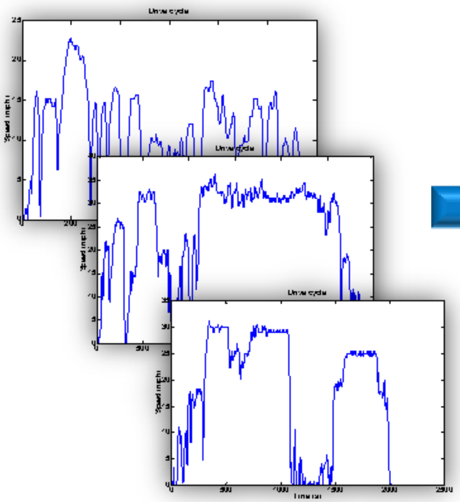

Q1
Q2
Q3
Q4
Implement RWDC
Define Assumptions (performance, cost)
Define Vehicles
Develop Analysis Methodology
Run Simulations
Analyze Fuel Efficiency
Perform Cost Benefit
Write report
Current Status

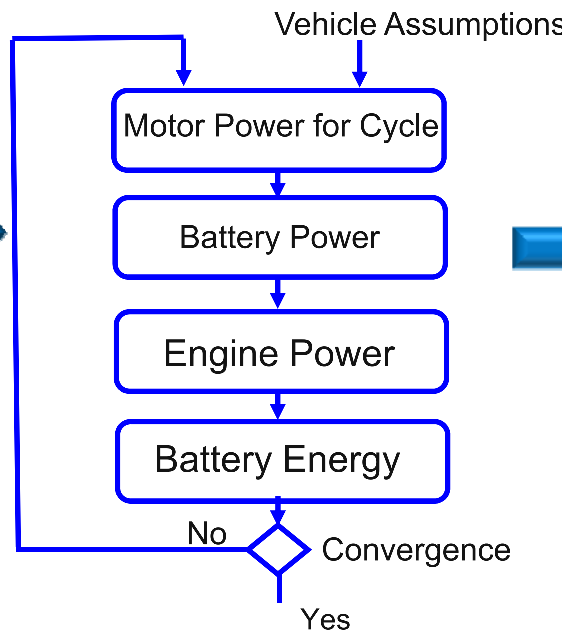
Approach

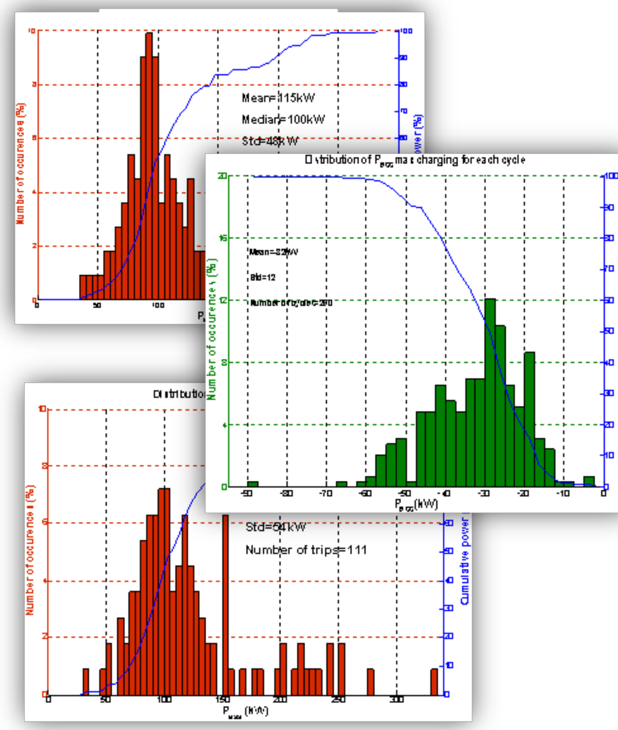
Real World Drive Cycles

Automated Sizing

Analysis (Distribution)





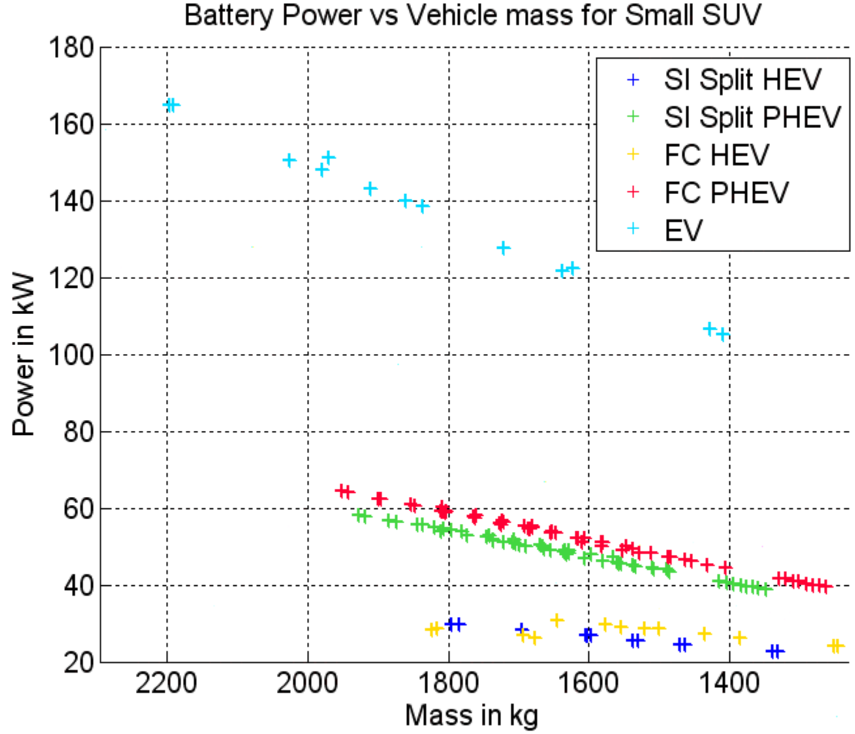


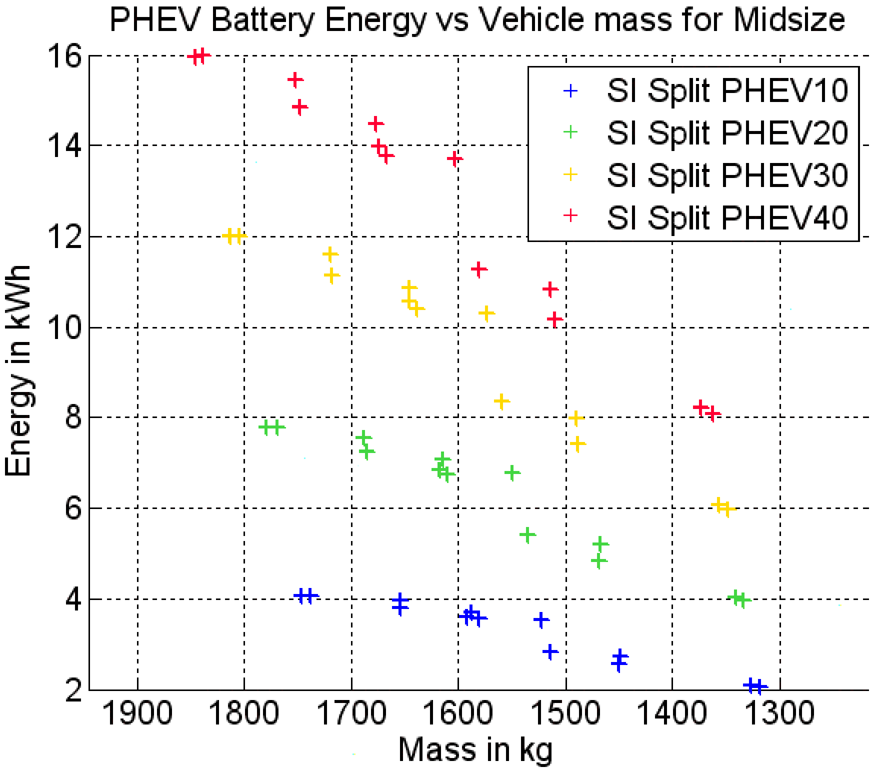
>110 Trips
One day in
Kansas City

Midsize Vehicle

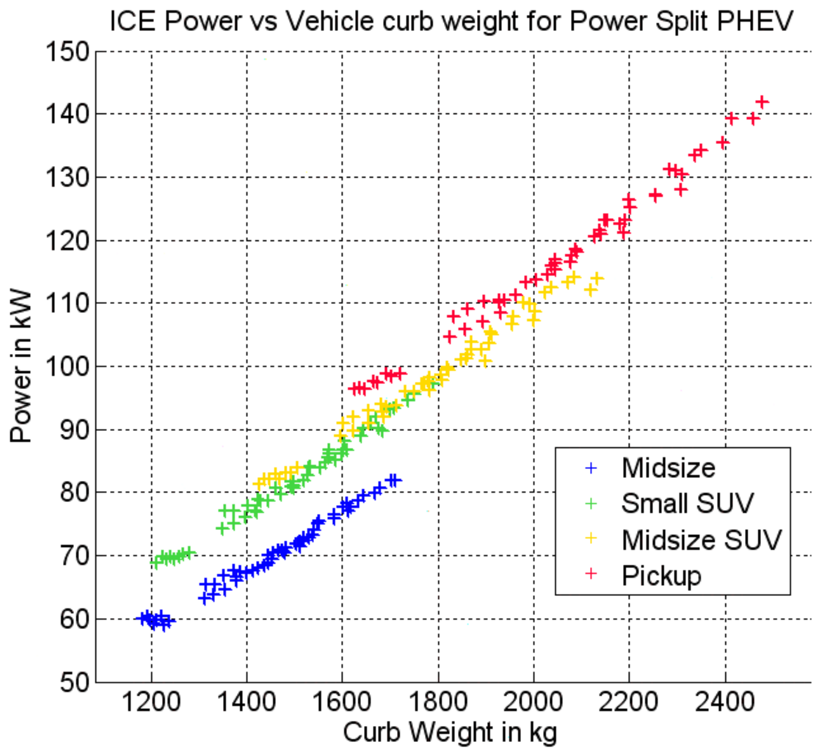
Only Hot Conditions Assumed, no Grade!

Battery Power and Usable Energy Requirement as a Function of Vehicle Mass



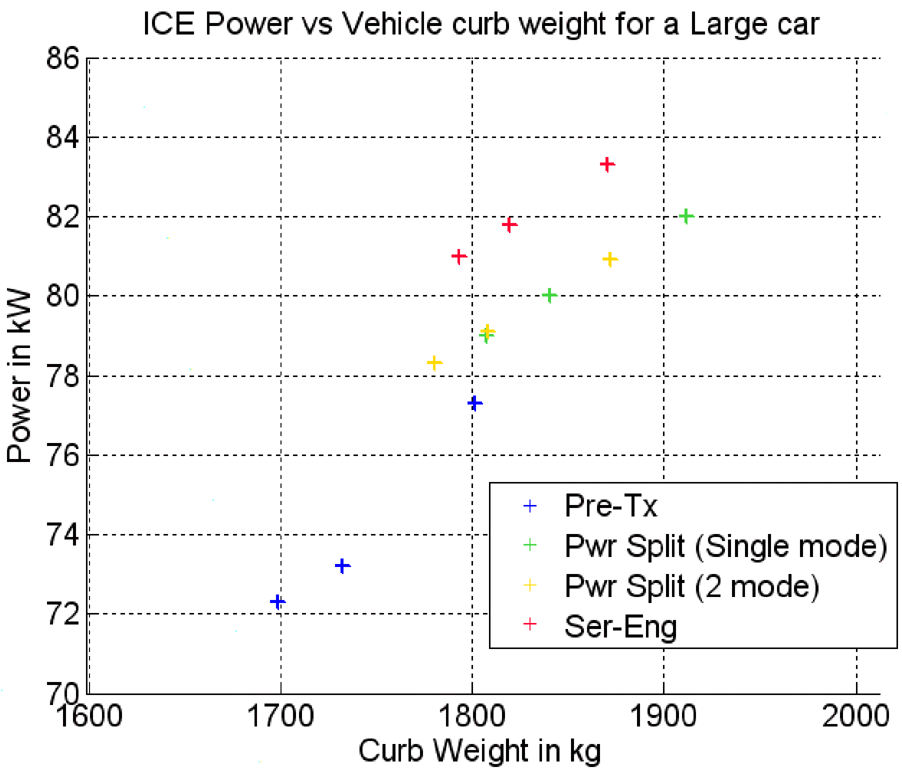


Engine Power Requirements Provided to the Engine Tech. Team

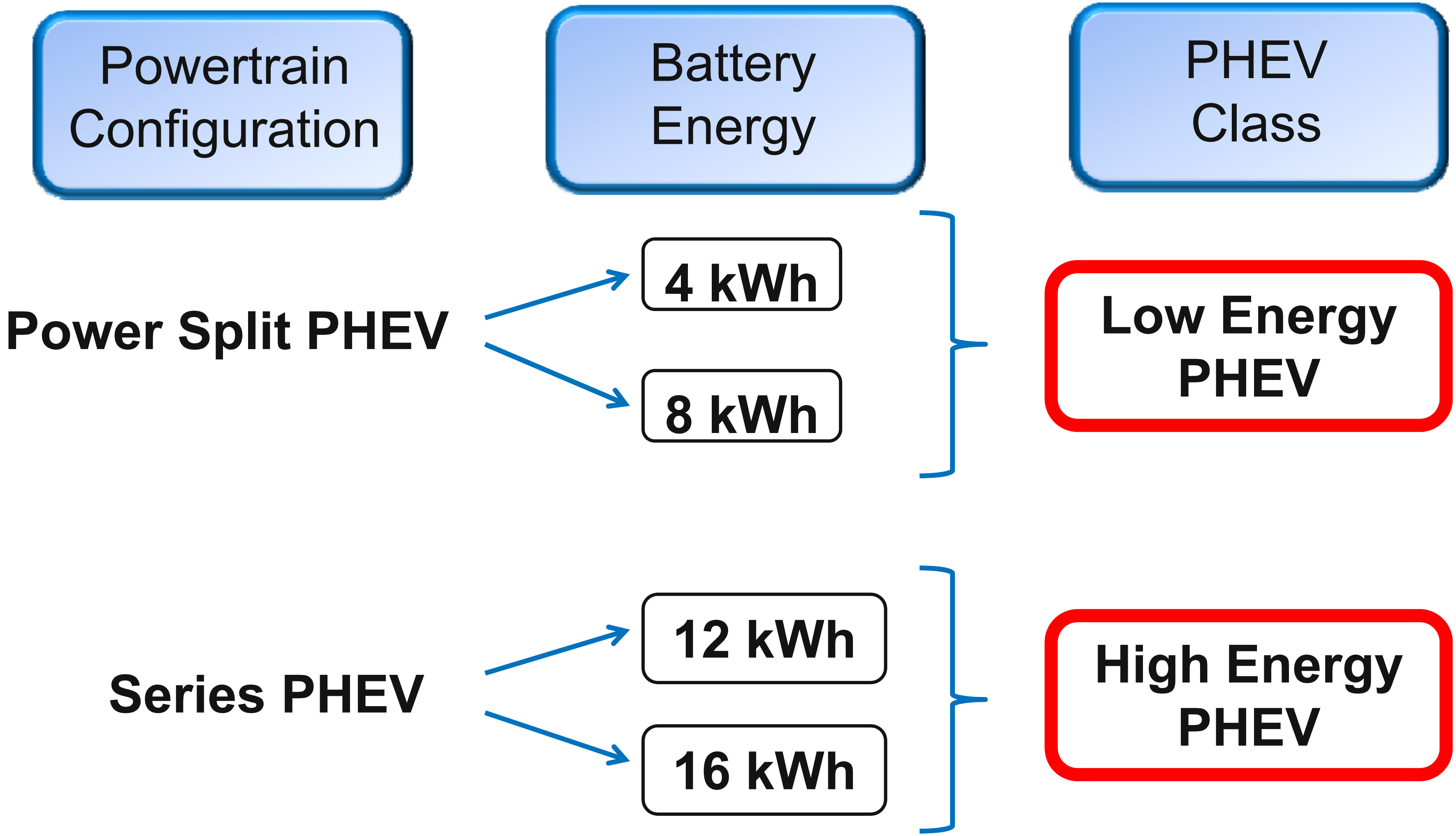


Engine Power
per vehicle classes

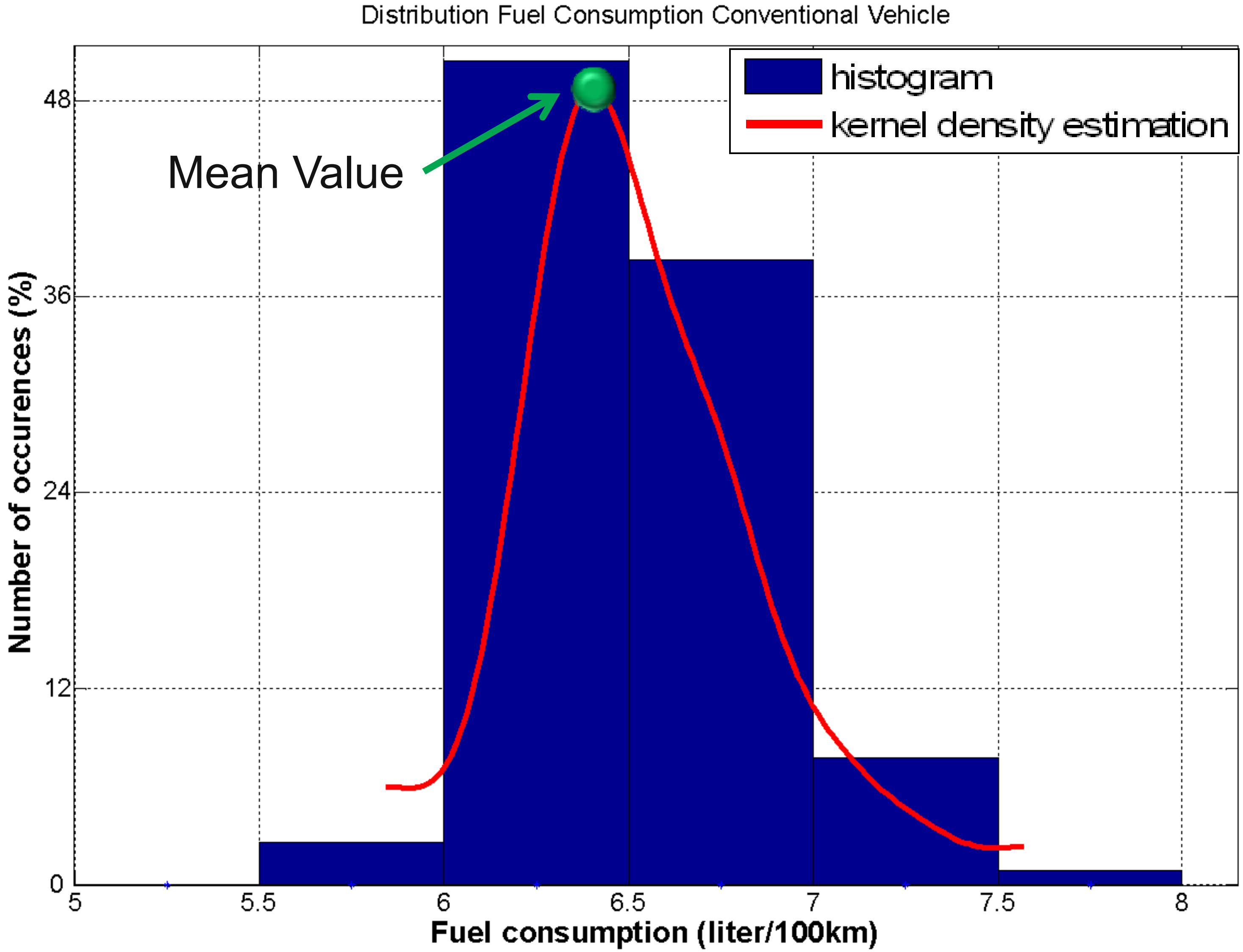
Engine Power
per vehicle configuration



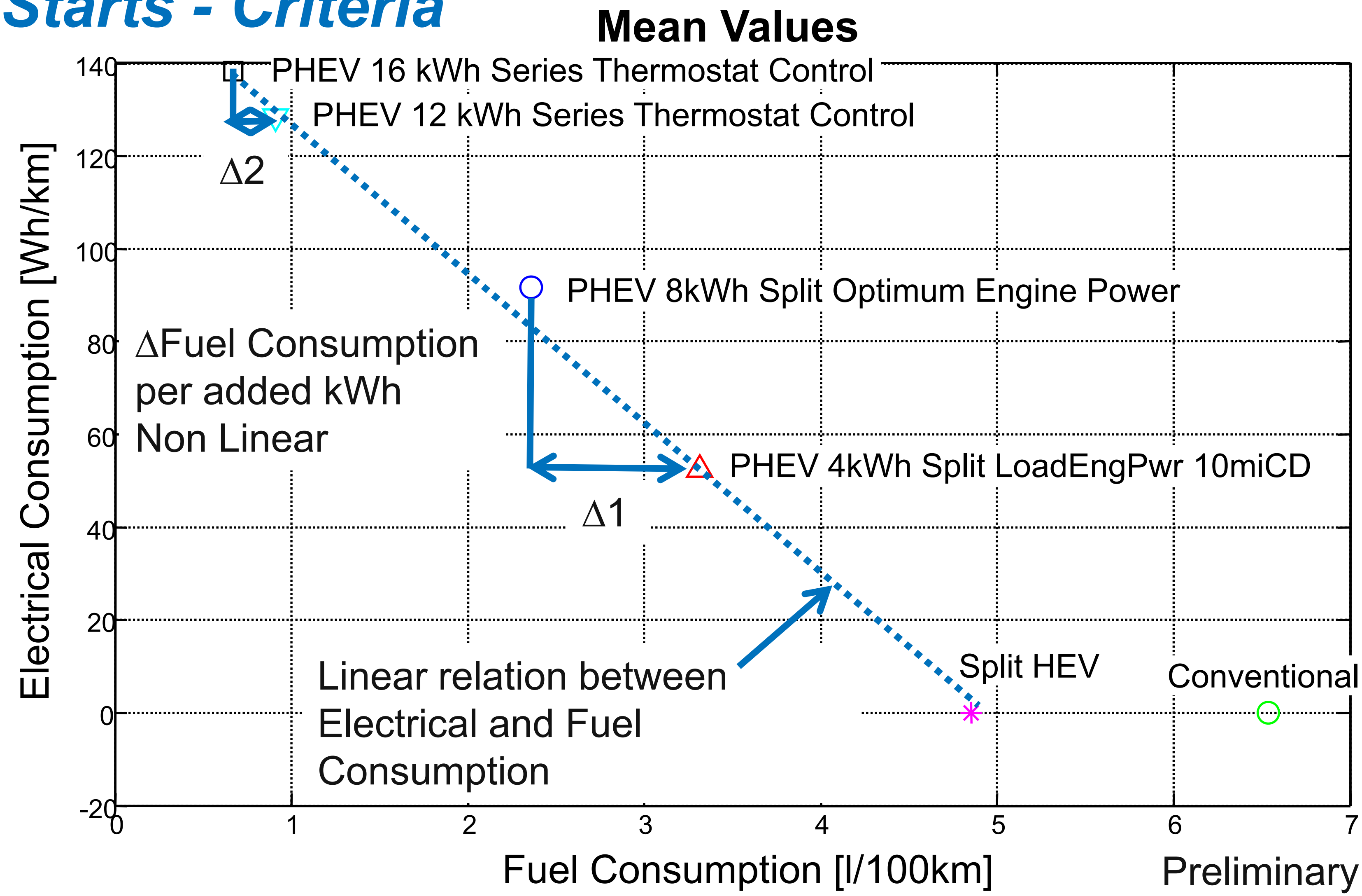
Different PHEV Powertrains and Battery Sizes



Kernel Density Used to Compare Options

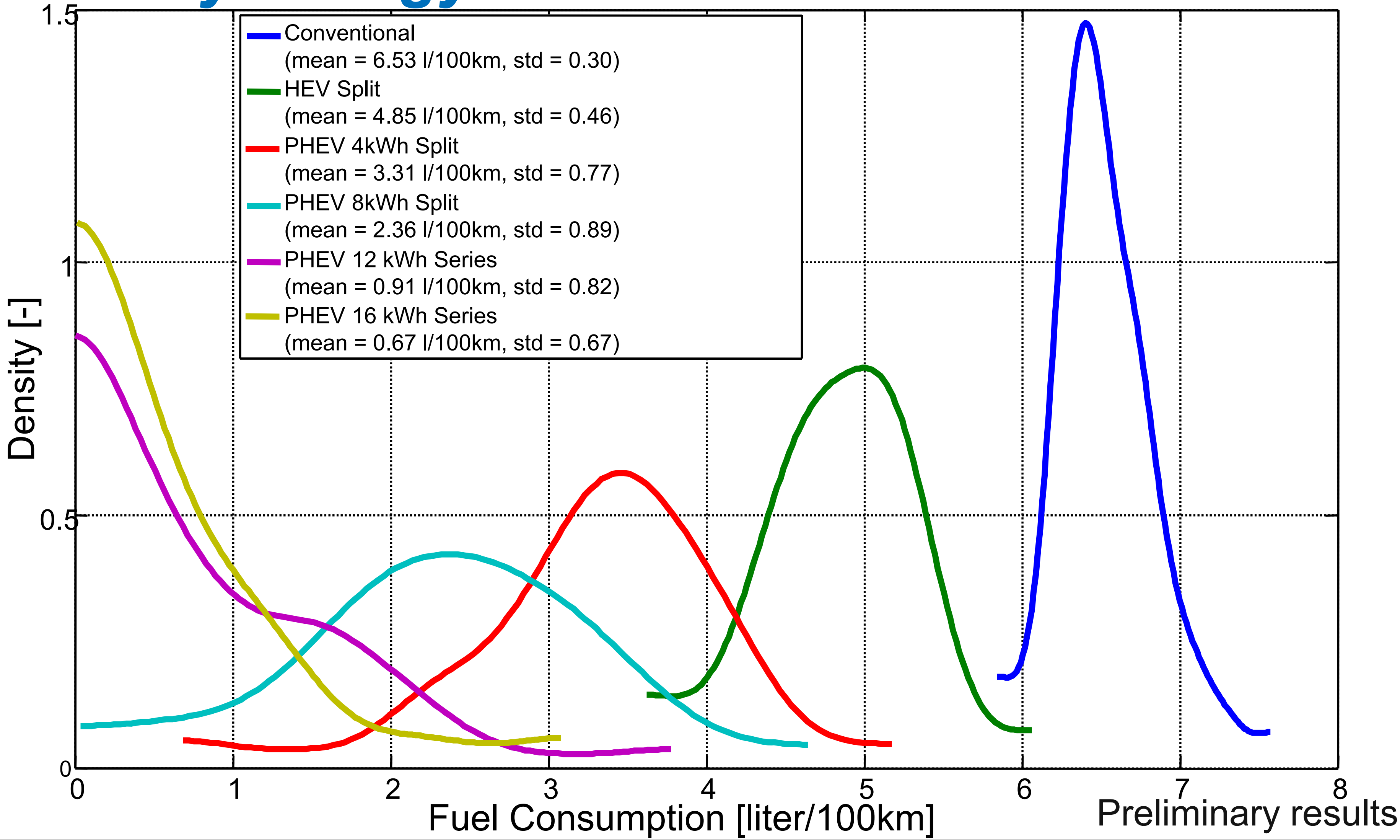


One Control per Configuration was Selected Based on a Fuel Economy and Number of Engine Starts - Criteria

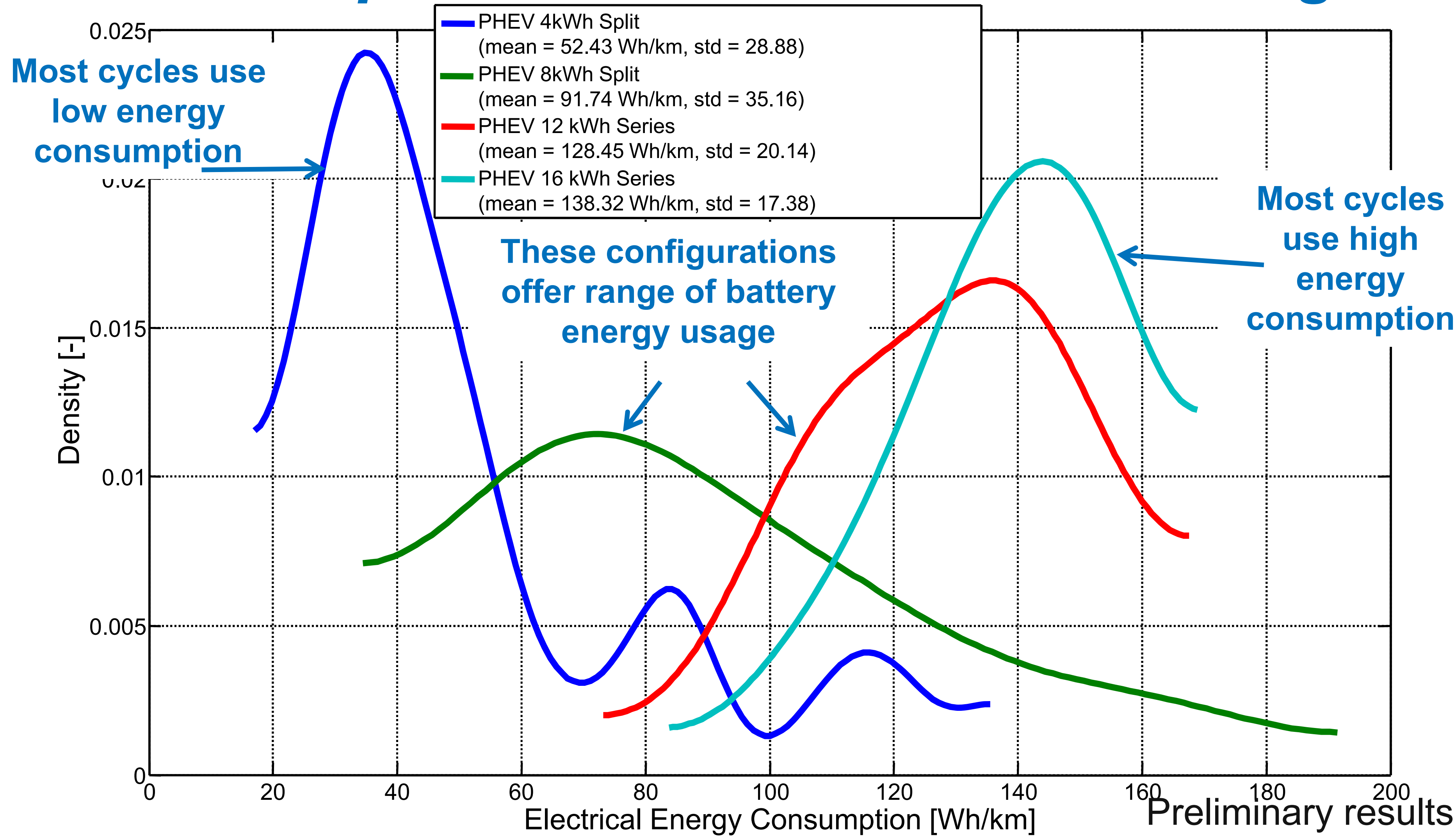


Preliminary results

Fuel Consumption Lowers with Increasing Battery Energy

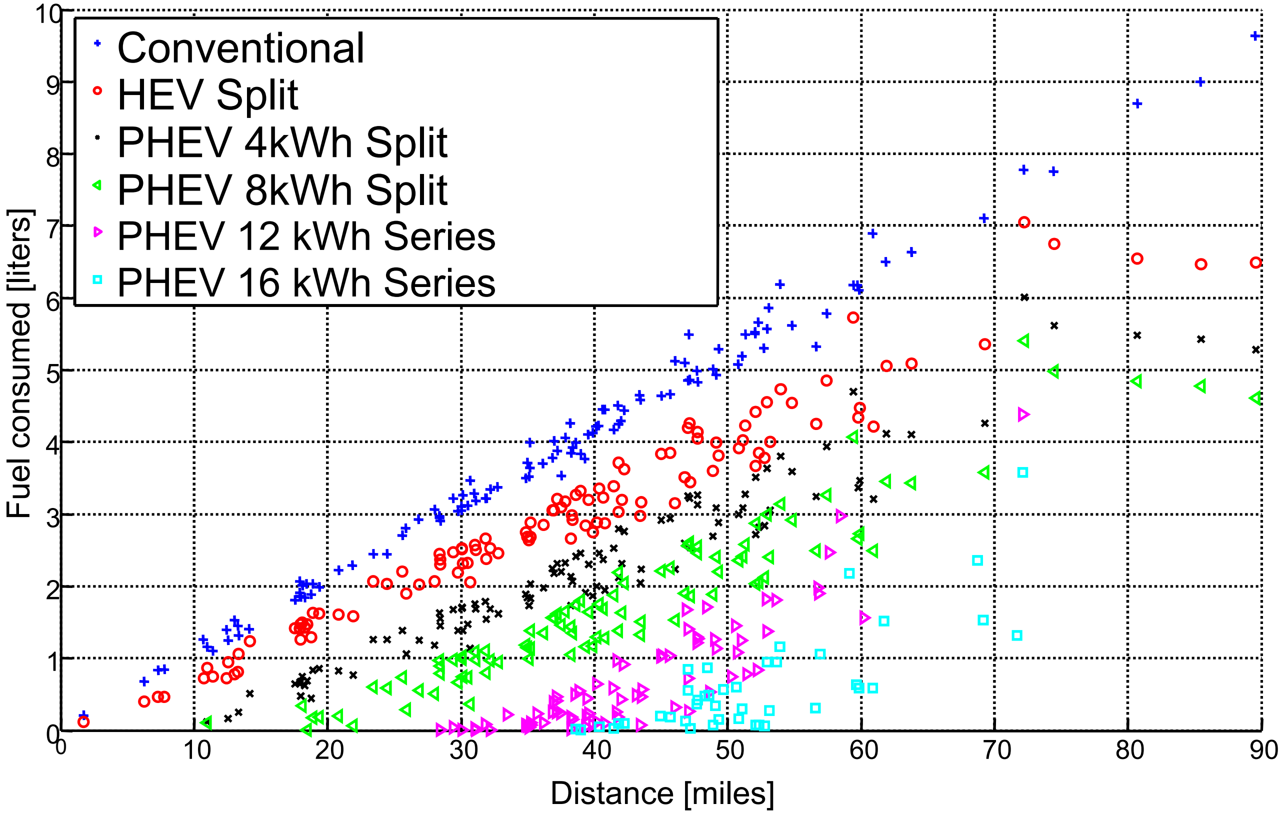


Battery Usage Linked to Usable Energy -> Different Impact on Life for Different Energies



Preliminary results

4kWh Battery Energy Provides 50% of the Gains Achieved with 16 kWh Battery



$\sum_{conv}$ 449.16 Liters

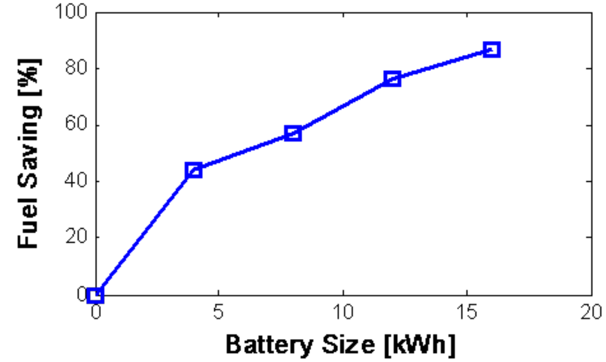
$\sum_{HEV}$ 339 Liters (24.5%)

$\sum_{split4kWh}$ 239.7 Liters (−46.6%)

$\sum_{split8kWh}$ 169.8 Liters (−62.2%)

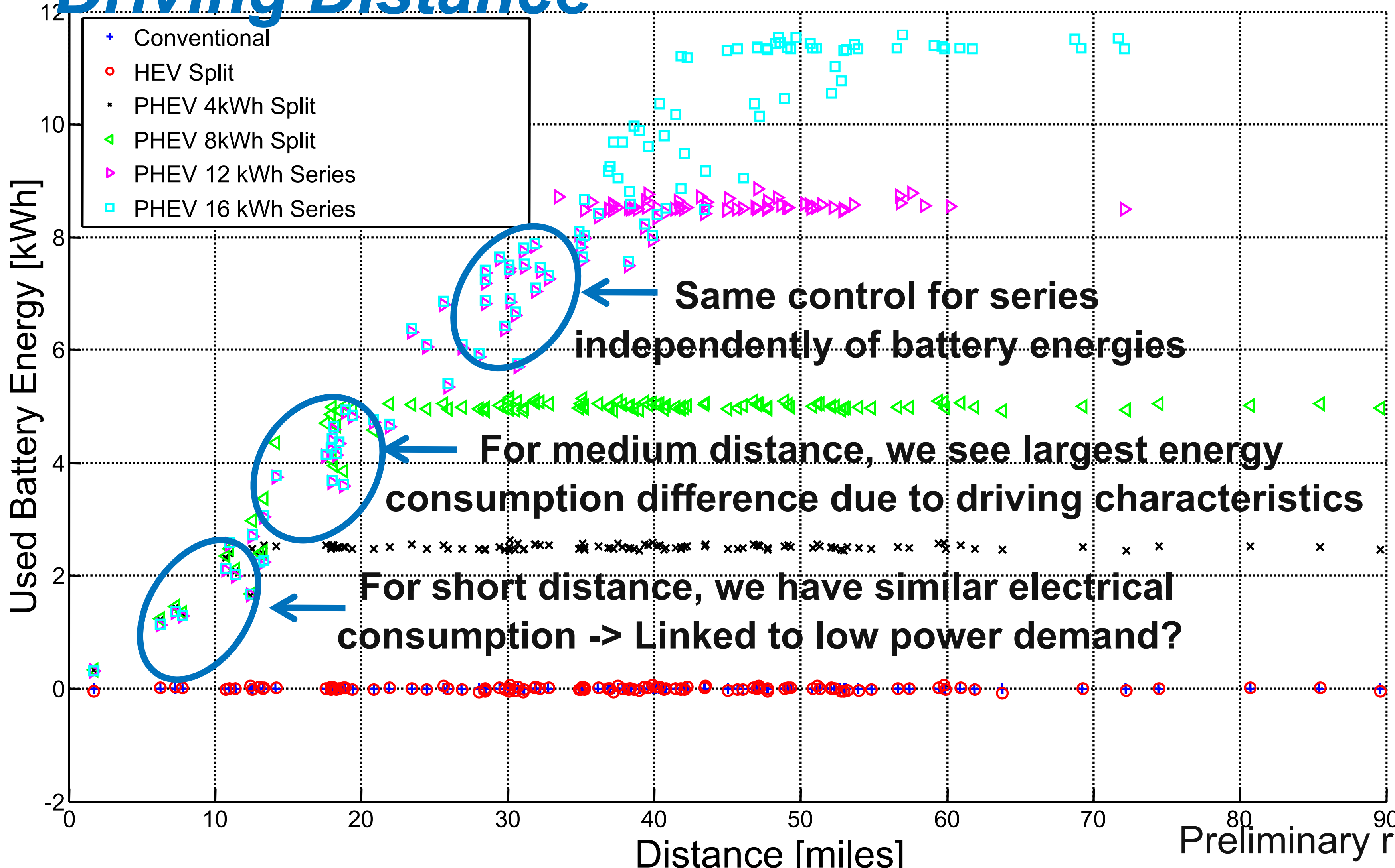
$\sum_{series12kWh}$ 53.5 Liters (−88%)

$\sum_{series16kWh}$ 26.2 Liters (−94.1%)



Preliminary results

Used Battery Energy as a Function of Driving Distance

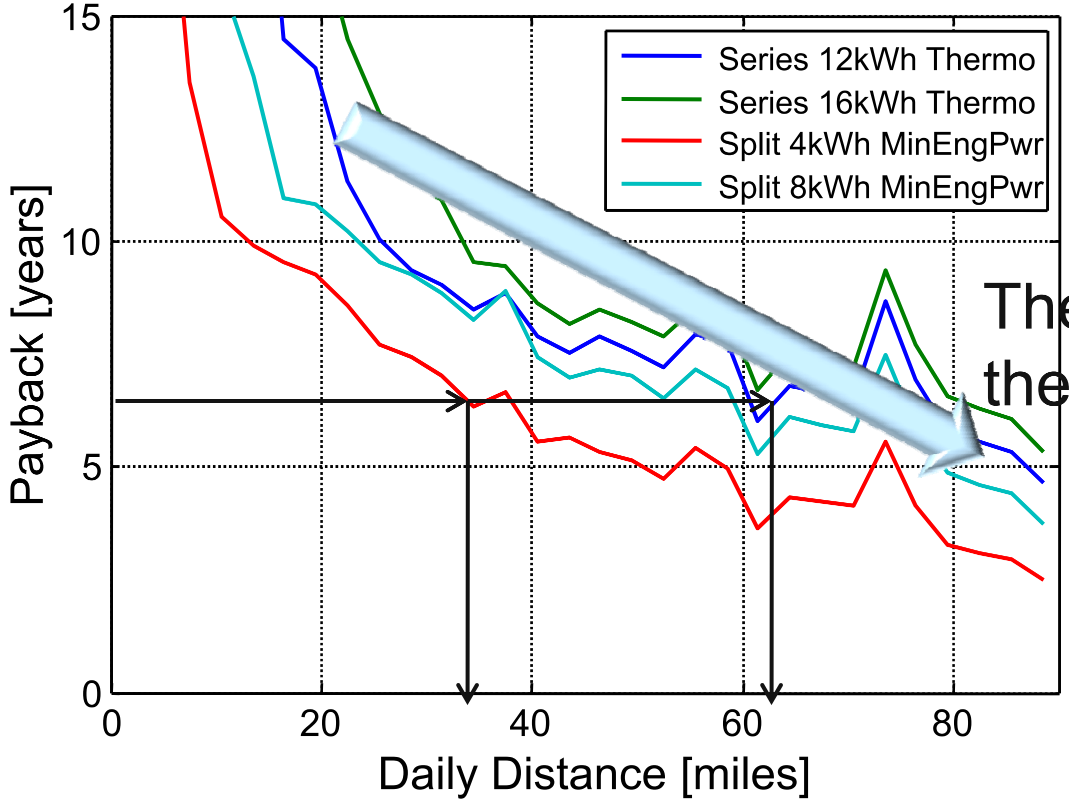


Preliminary results

Constant Payback Period Requires Longer Driving Distances for Bigger Battery Packs

- Equation for break even lines with conventional vehicle:

$$t_{breakeven} = \frac{C_{Veh2} - C_{Veh1}}{C_{fuel} * [Cons_{fuel,Veh1}(d) - Cons_{fuel,Veh2}(d)] + C_{elec} * [Cons_{elec,Veh1}(d) - Cons_{elec,Veh2}(d)]}$$



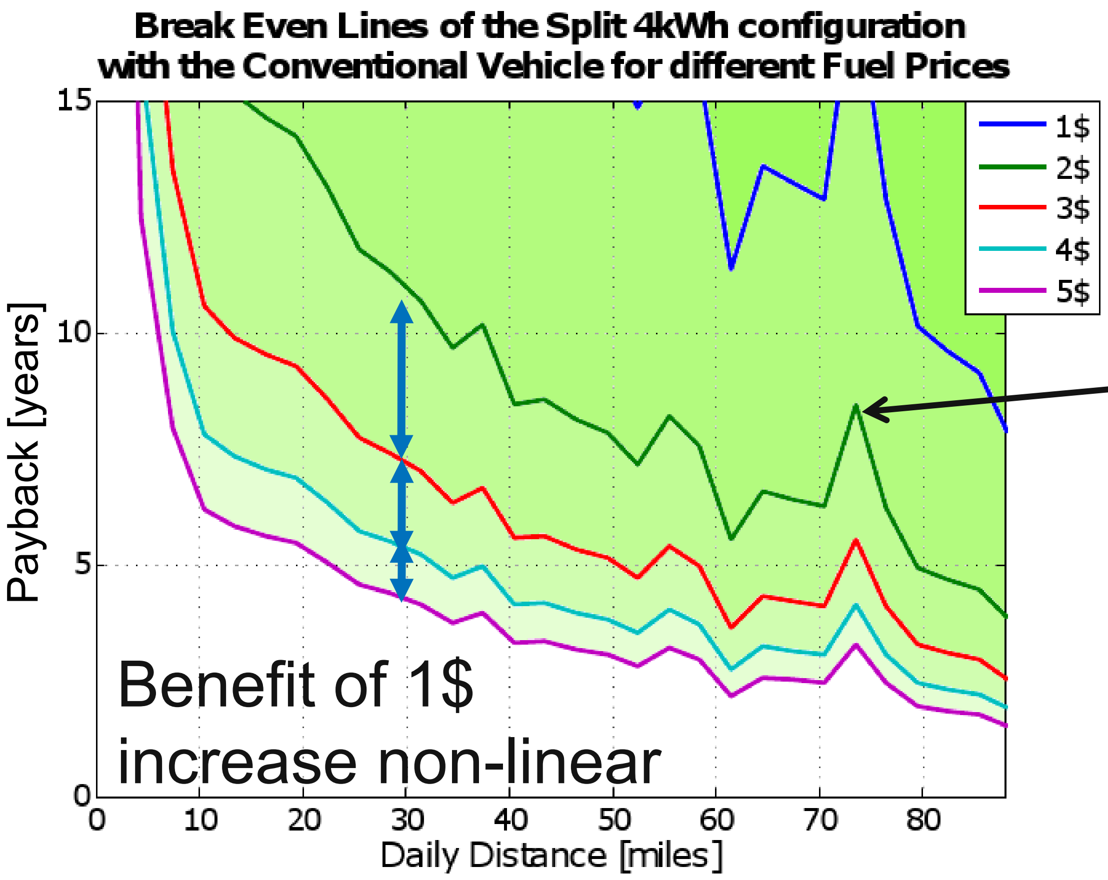
The further you drive, the better the payback

C_{elec} = 0.07 $/kWh

C_{fuel} = 3$/gallon

Preliminary results

Fuel Price Significantly Influences Payback Period



Spikes due to small number of data points for long distances

C_{elec} = 0.07 $/kWh

$C_{battery}$ = 4128 $ (1000$/kWh)

C_{base} = 30791 $

Preliminary results

Future Activities

- Update the cost assumptions based on litterature search and expert discussions (D. Santini & A. Vyas).
- Complete fuel efficiency and cost analysis
- Add HEV vehicle
- Perform cost benefit analysis based on several scenarios to define the most approriate vehicle for different options (i.e., battery energy, battery cost, distance, fuel cost...).
- What is the impact of assuming the vehicle can be charged during the day?
- How does the results based on the RDWC compare with the latest J1711 Procedure (using both National and RWDC Utility Factors).
- Perform MonteCarlo analysis on the control strategy parameters to provide an uncertainty value.

Summary

- **Impact of RWDC on Fuel Efficiency**
  - Several vehicles with different powertrain configurations and battery energies were simulated.
  - A single control strategy was selected for each option based on a combination of fuel efficiency and engine ON/OFF criteria.
  - The fuel efficiency was compared with a conventional vehicle to assess the potential fuel displacement over the Kansas City RWDC.
- **Impact of RWDC on Cost Benefit Analysis**
  - With current pricing, long payback period due to high battery cost
  - Increasing fuel price significantly influences payback period and is a major factor for the rentability of a PHEV
  - Benefits of price reduction on payback nonlinear
  - You should regularly drive longer than what your AER theoritically allows

References

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- A. Rousseau, "Impact of Real-World Drive Cycles on PHEV Battery Requirements", SAE 2009-01-1383, World Congress, April 2009
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