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PHEV Control Strategy

Project ID # vssp_18_rousseau

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Argonne National Laboratory

Sponsored by Lee Slezak

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Project Overview

Timeline

- Start – September 2008
- End – September 2009
- 50% Complete

Barriers

- Develop optimum control strategies to maximize fuel displacement
- Take into account real world driving

Budget

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

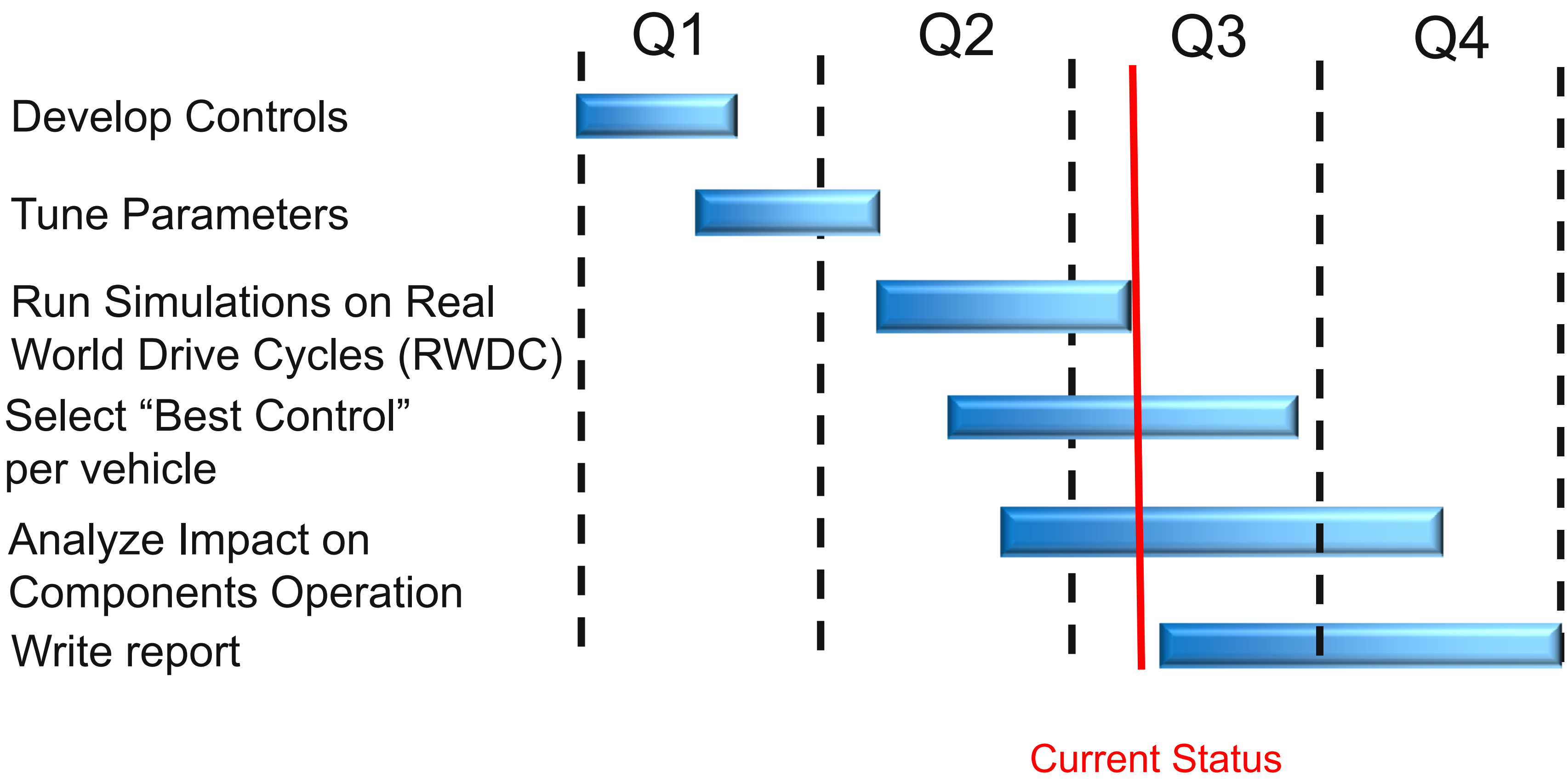
Partners

- U.S EPA

Main Objectives

- Understand impact of different control strategy philosophies on fuel efficiency and component operating conditions.
- Analyze the most appropriate set of control parameter to maximize fuel efficiency while maintaining acceptable drive quality (e.g., engine ON/OFF) and maximizing battery life (e.g., low Irms).
- Evaluate fuel efficiency obtained with different control strategies over Real World Driving Cycles (RWDC's) and compare to the J1711 procedure.

Milestones

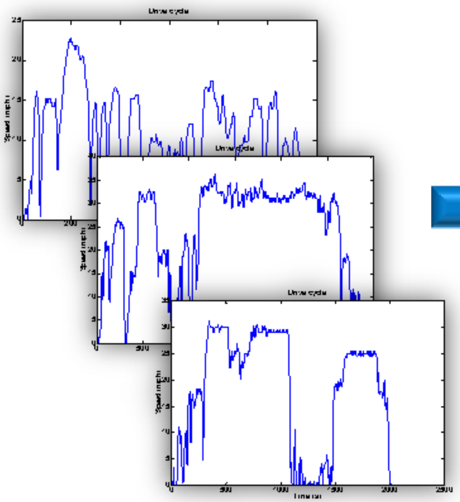

Q1
Q2
Q3
Q4
Develop Controls
Tune Parameters
Run Simulations on Real World Drive Cycles (RWDC)
Select “Best Control” per vehicle
Analyze Impact on Components Operation
Write report
Current Status

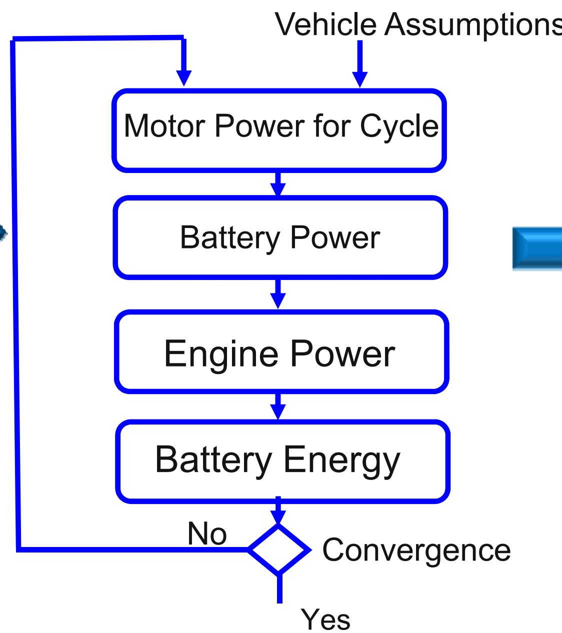
Approach – *Vehicle Definition*

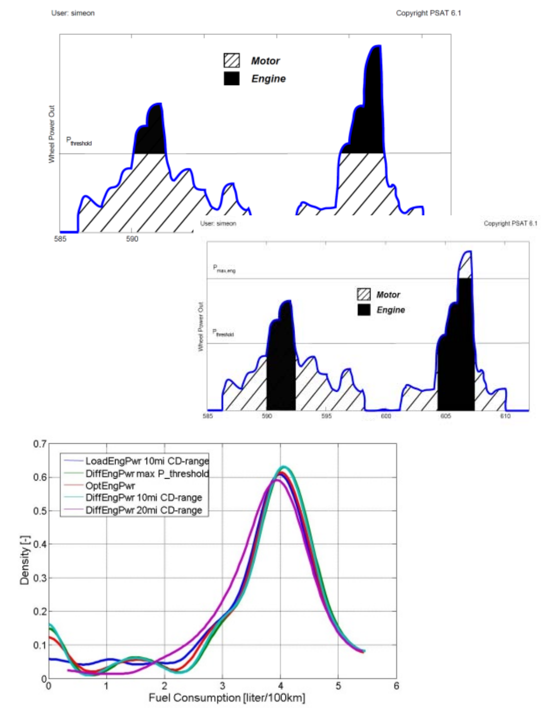
Real World Drive Cycles

Automated Sizing

Control Strategy Analysis





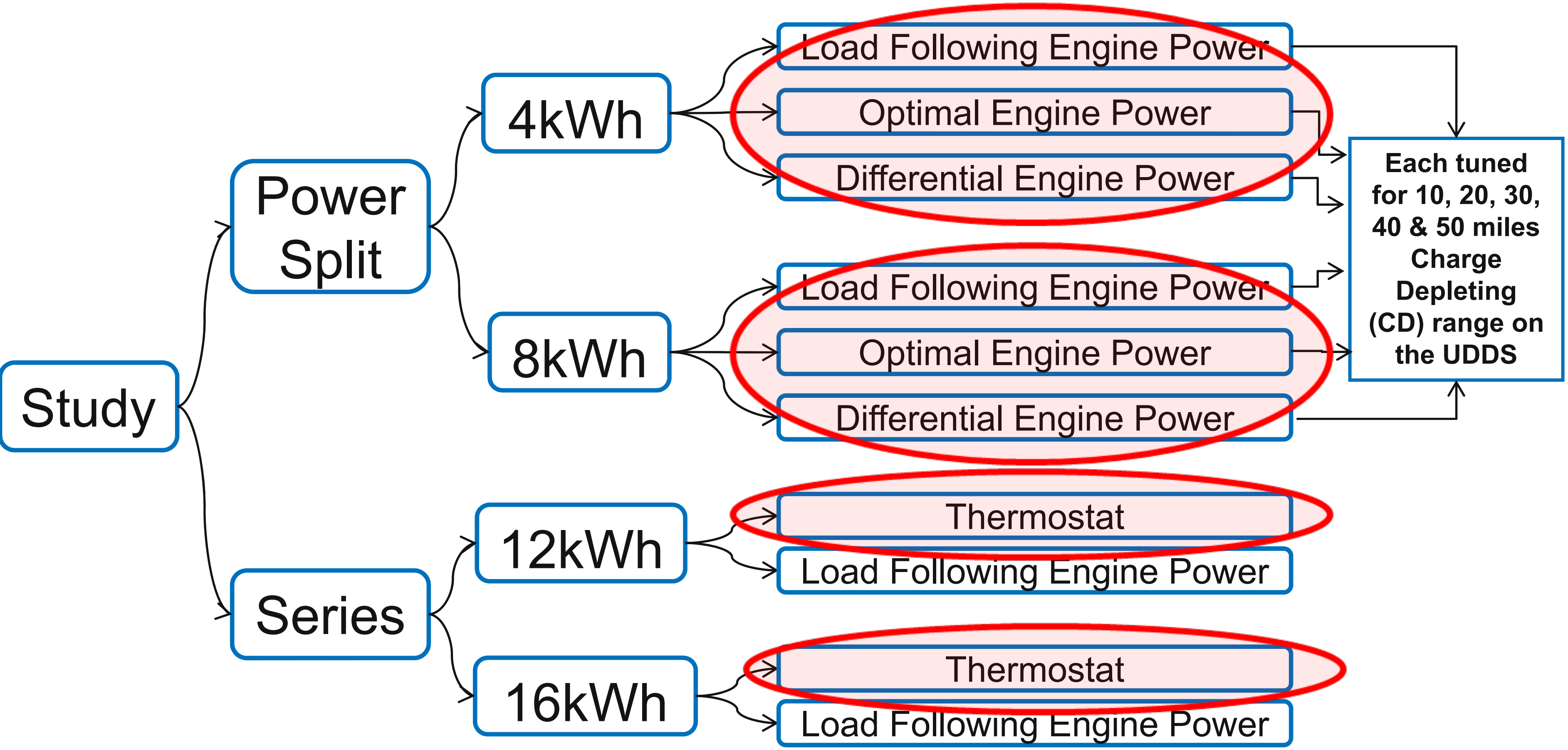


>110 Trips
One day in
Kansas City

Midsize Vehicle

Only Hot Conditions Assumed, no Grade!

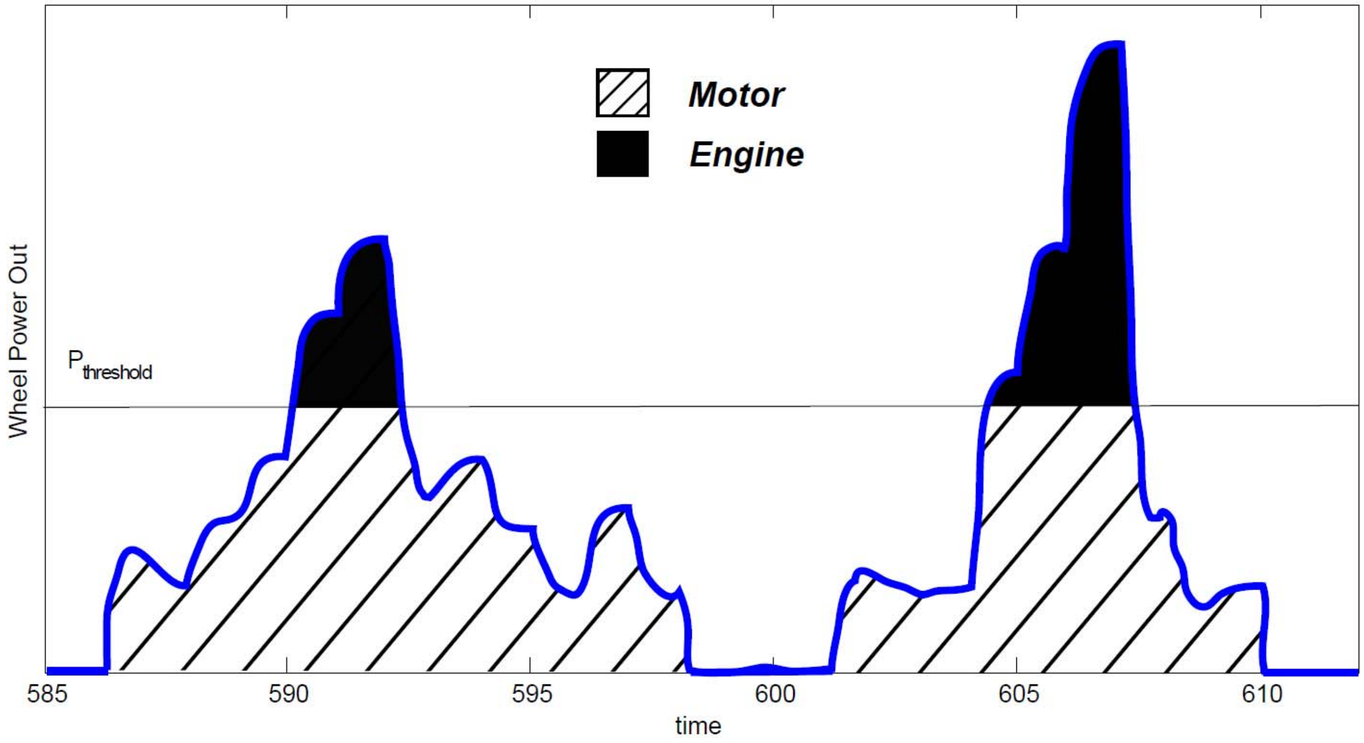
Approach - Control Strategies Considered



All these options were simulated on the RWDCs (source EPA 2005 Kansas City Cycles – 110 trips)

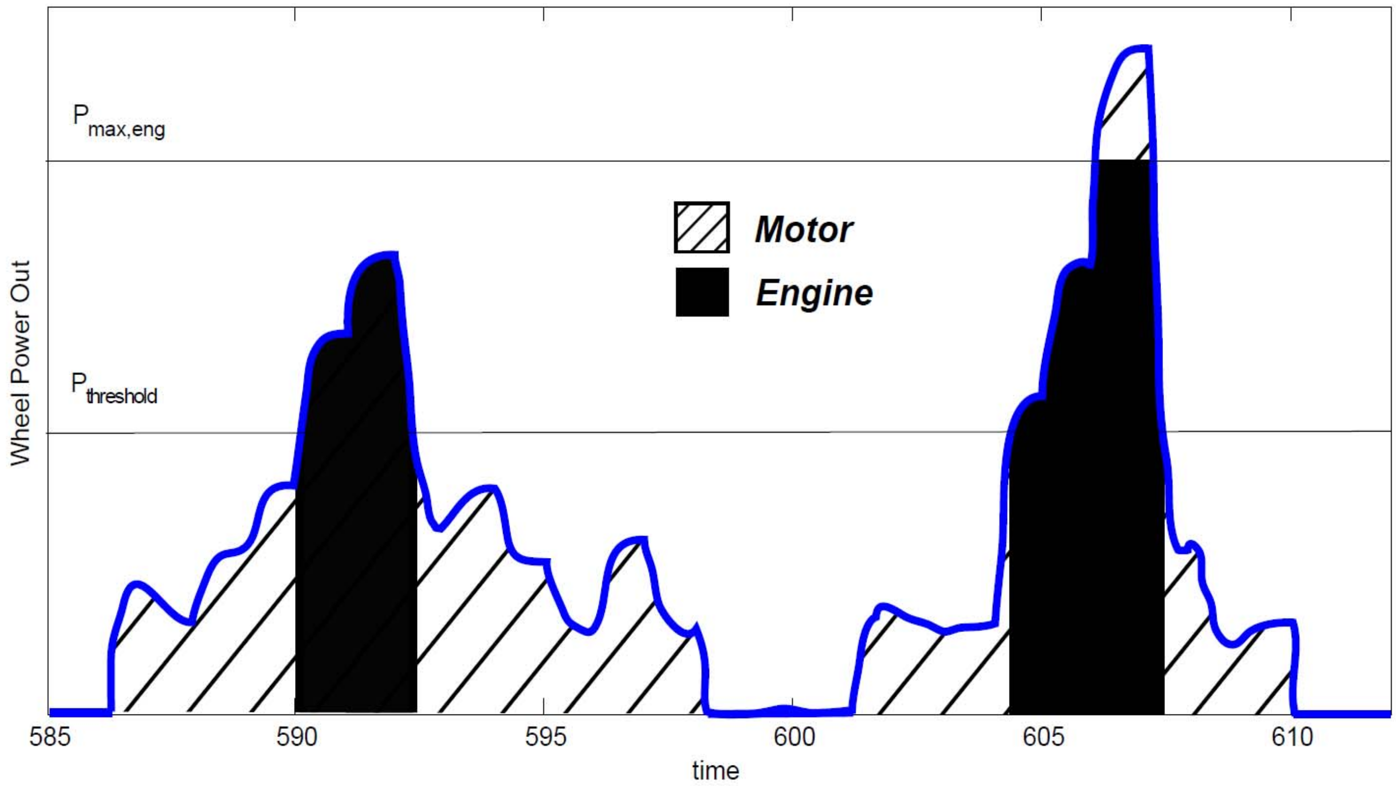
Differential Engine Power Strategy

- The engine is turned on at a certain power threshold. It then provides the difference between the wheel power demand and the power threshold.



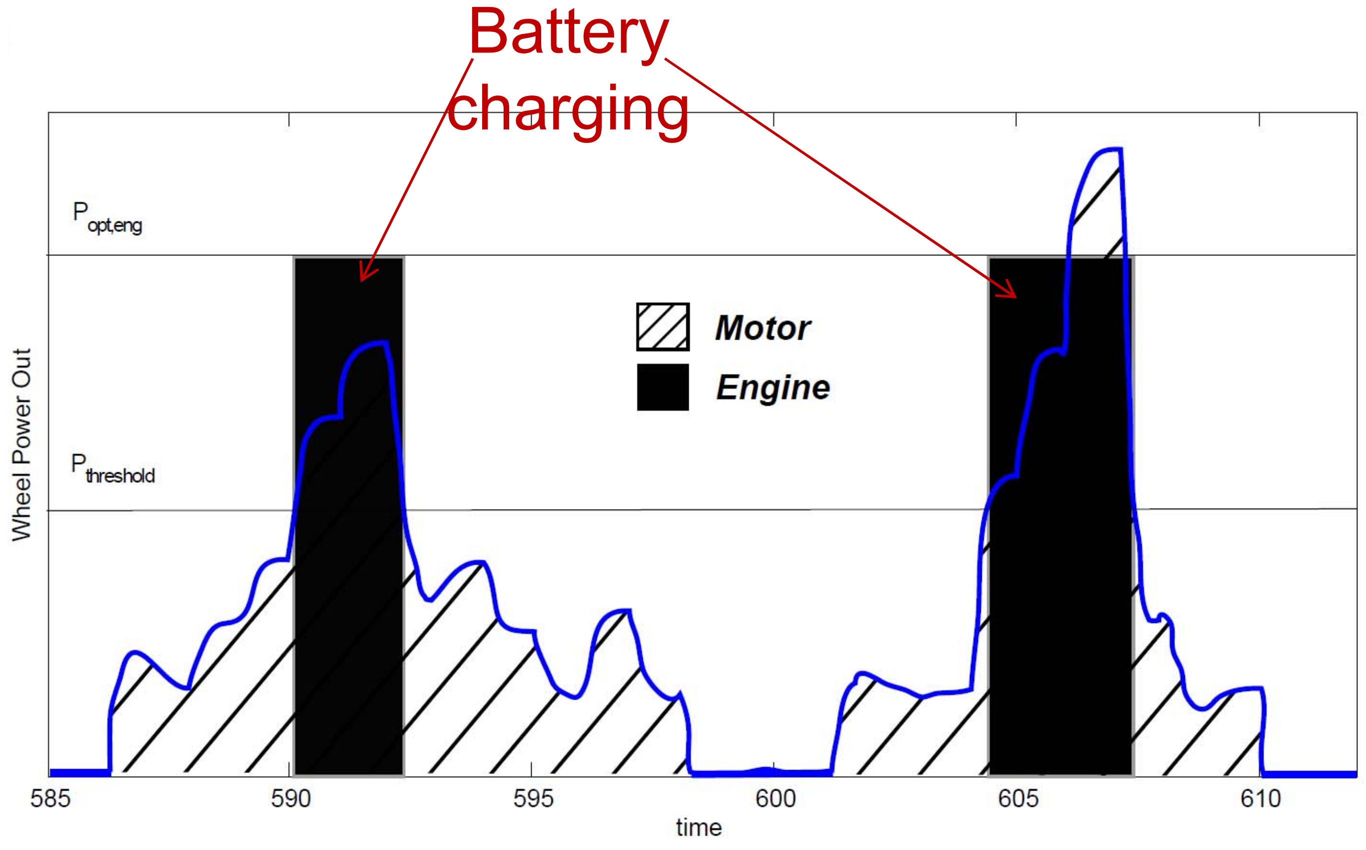
Load Following Strategy

- The engine is turned on at a certain power threshold. It then provides the full wheel power, i.e. it is load following

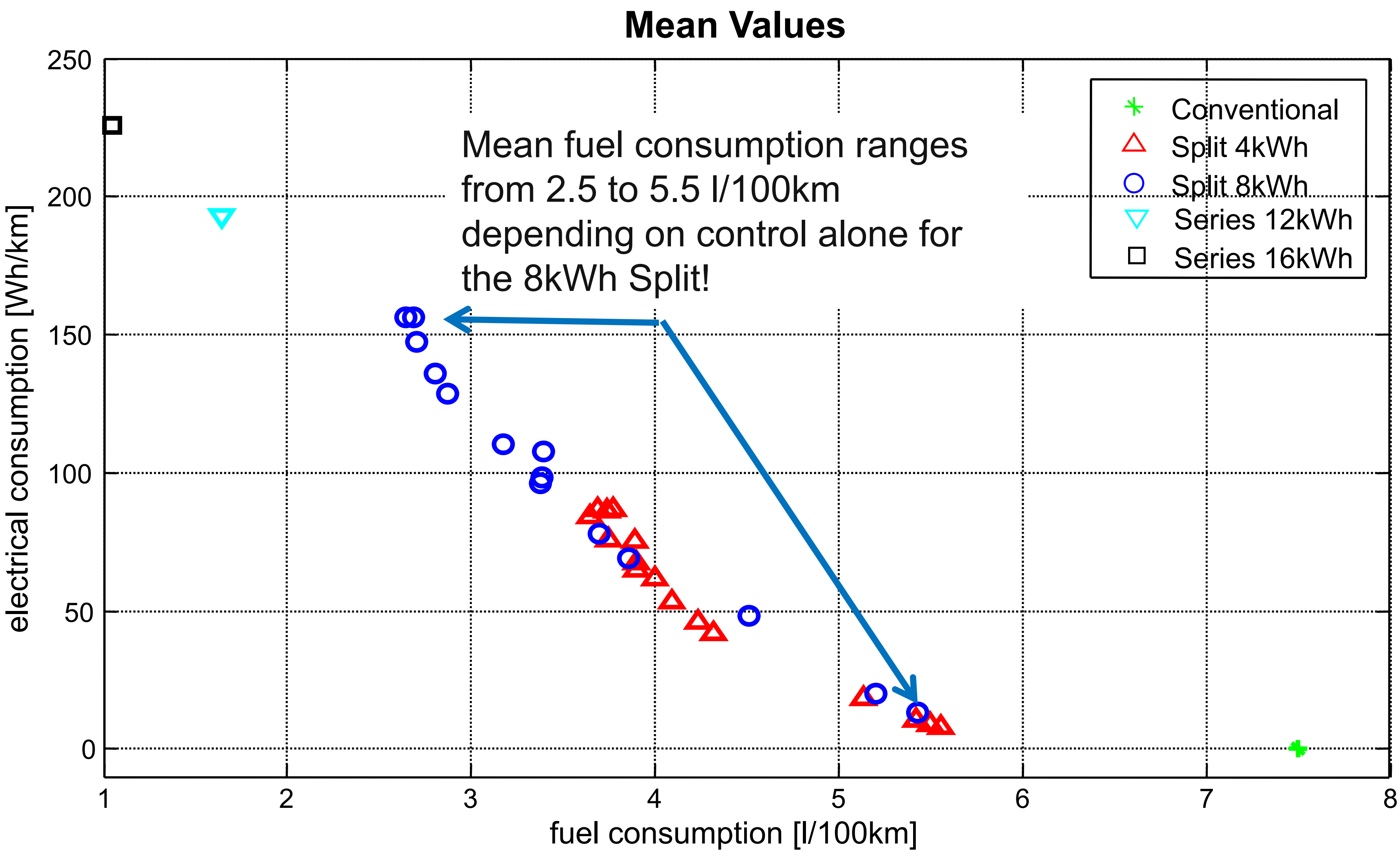


Constant Optimal Engine Strategy

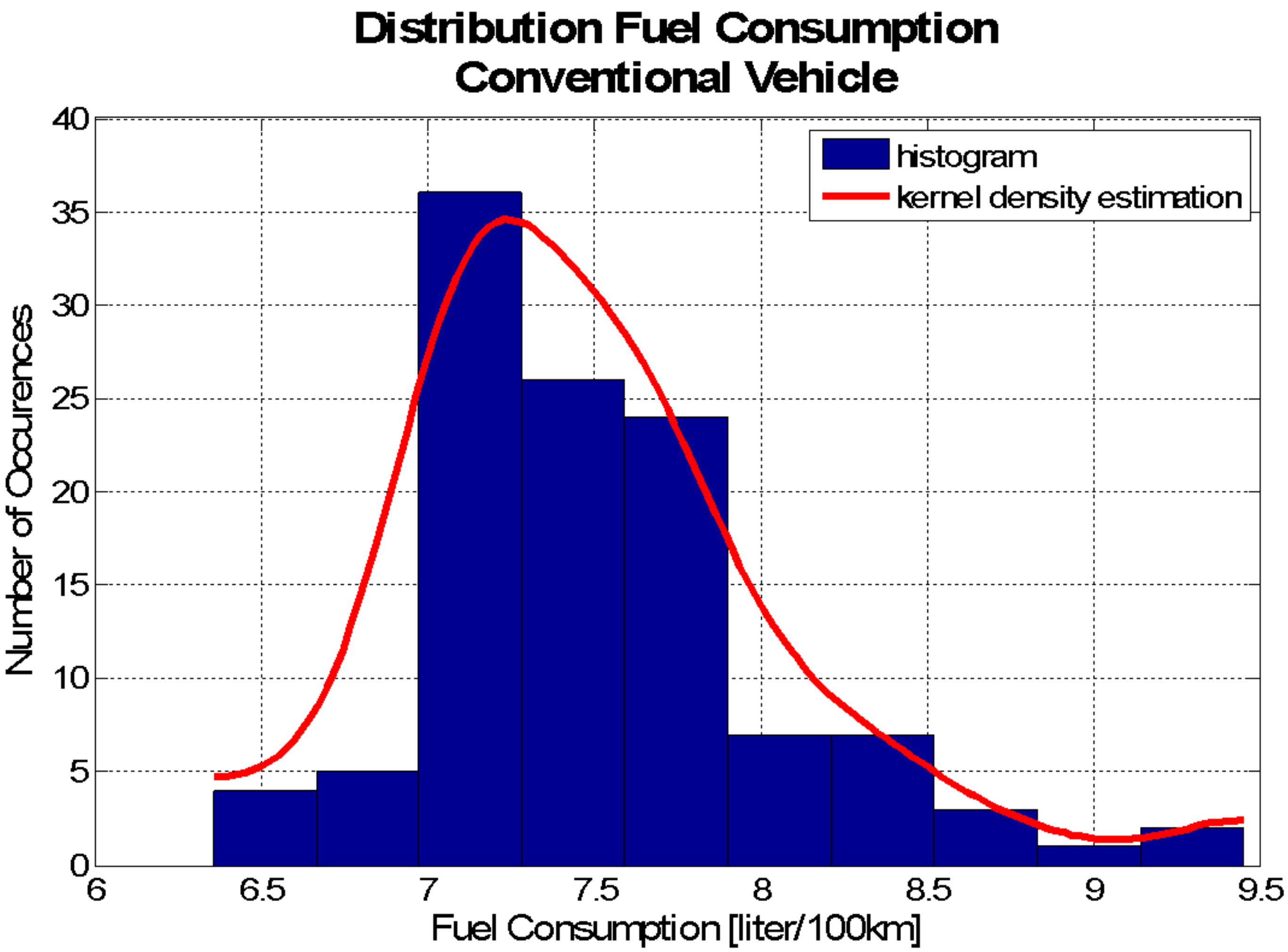
- The engine is turned on at a certain power threshold. It then operates at its optimal power. If the engine power is bigger than the wheel power demand, the battery will be charged.



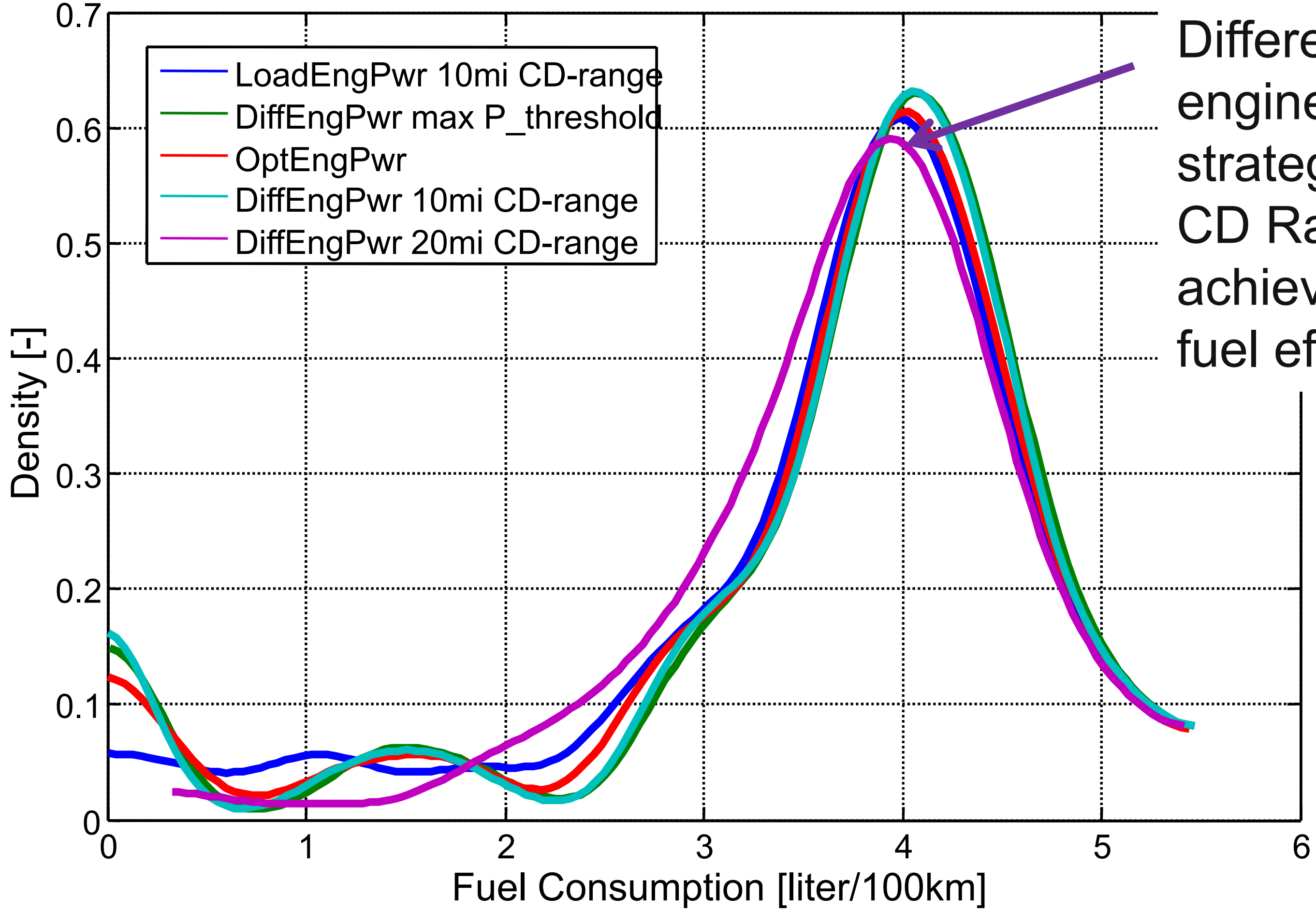
Different Strategies Influence Energy Tradeoff – How Do We Select The "Best" Control?



Kernel Density Will be Used to Compare Control Options



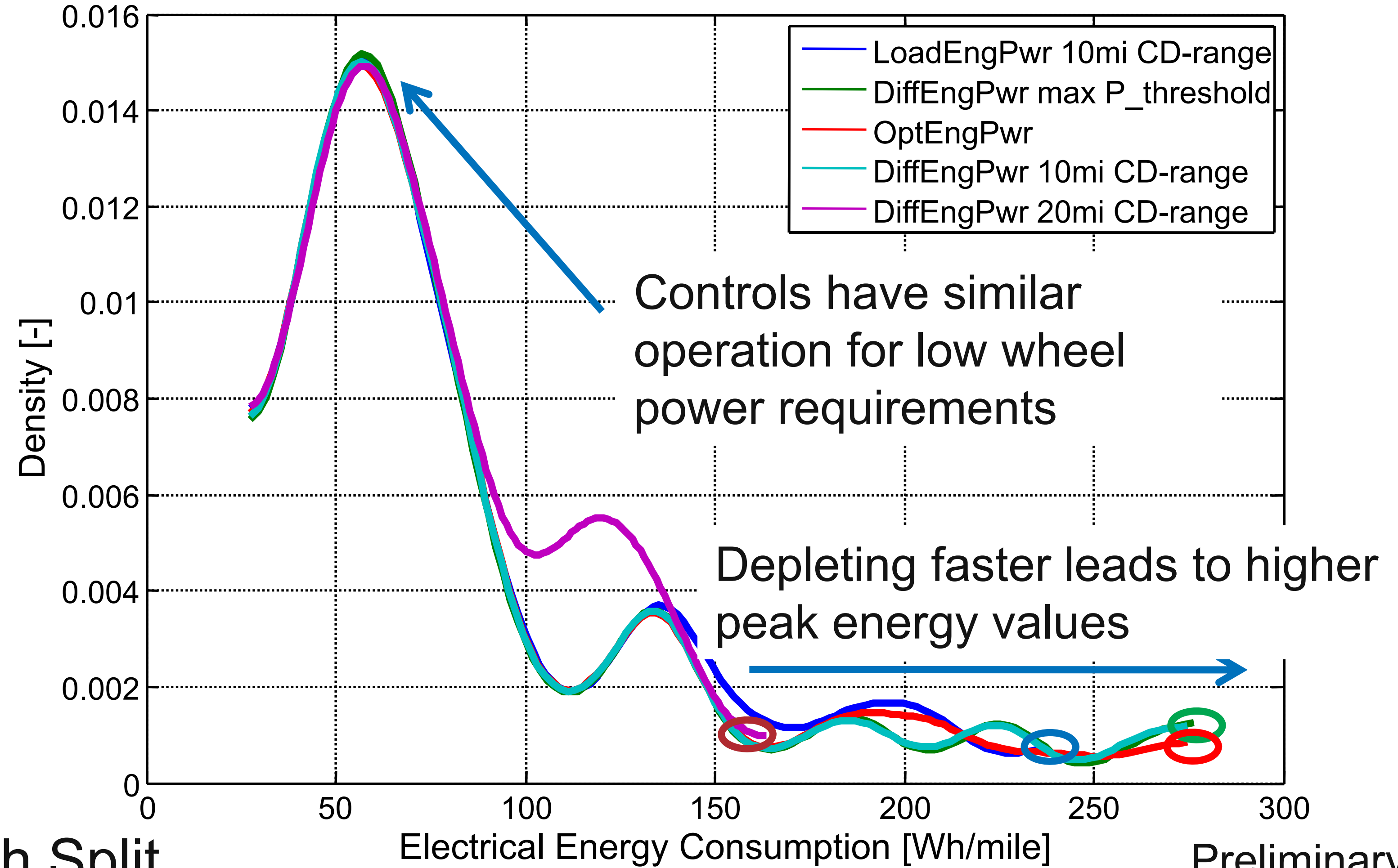
Best Fuel Economy with "Differential Engine Power" Strategy for the 4kWh Power Split



Differential engine power strategy (20 mi CD Range) achieves highest fuel efficiency

Preliminary results

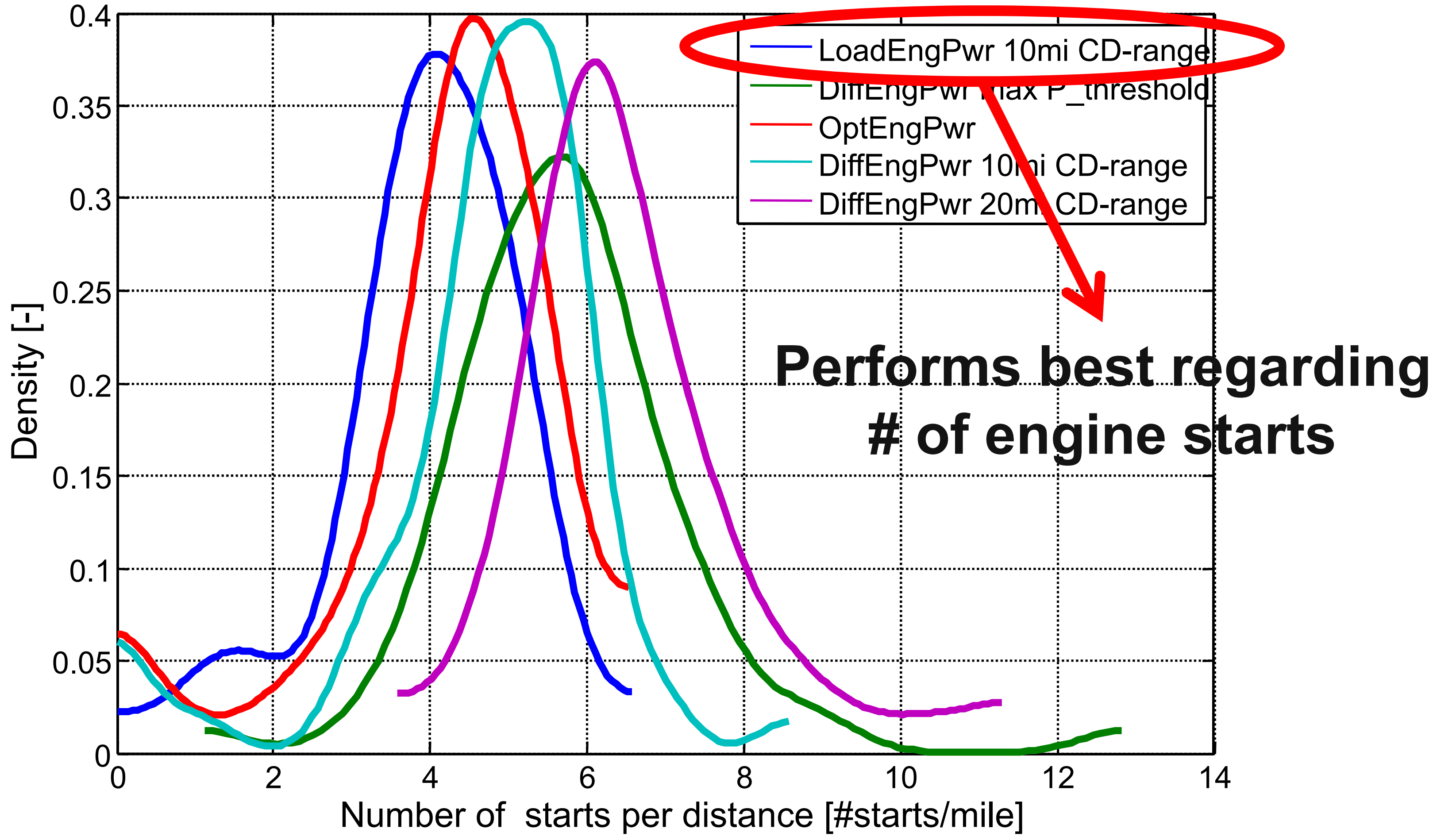
All Controls Share Same Peak Density, Favoring Electrical Energy Leads to Lower Energy Consumption Maximum Values



4kWh Split

Preliminary results

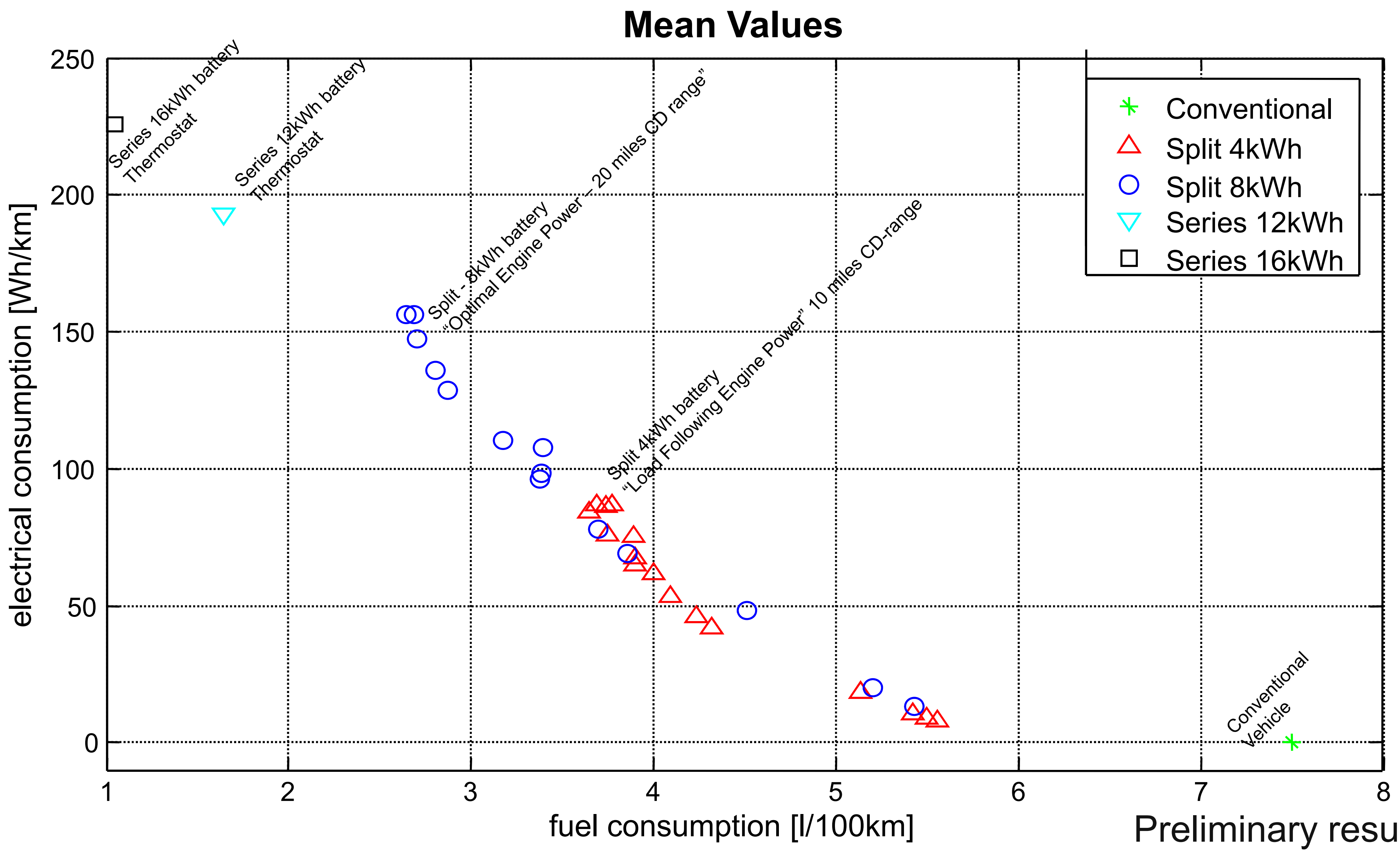
Number of Engine Starts Clearly Distinguishes Control Strategies



4kWh Split

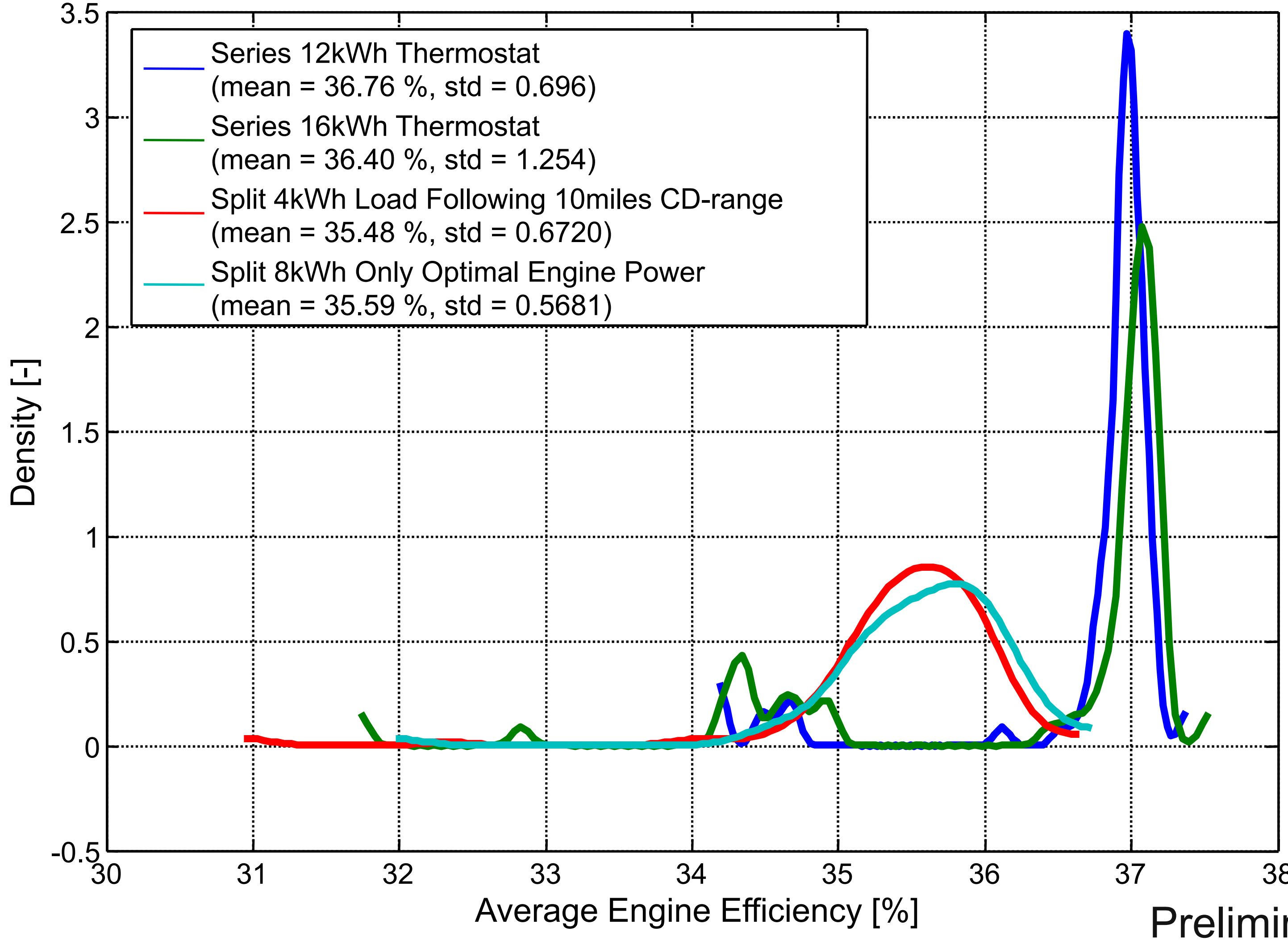
Preliminary results

Best Control Selected for Each Configuration Based on Criteria of Fuel Consumption & Number of Engine Start



Preliminary results

Higher Average Engine Efficiency (at its maximum) for the Series Configuration



Preliminary results

Future Activities

- Expand study to other Real World Drive Cycles (RWDC) – Source INL
- Develop and test control strategies with trip recognition
- Implement controls on hardware (if possible)
- Understand differences with J1711 fuel efficiency results

Summary

- The analysis is only valid for the specific set of RWDC.
- Several control strategies and set of parameters were evaluated on Real World Drive Cycles.
- Different controls were selected based on fuel efficiency and drive quality.
- Control selected varies depending on the battery energy.
  - Load Following for 4kWh battery
  - Optimum Engine for 8kWh battery
  - Thermostat for 12 and 16 kWh battery
- Impact of component operating conditions assessed
- Preliminary comparison with J1711 shows fuel economy under evaluated

References

- D. Karbowski, “Fair Comparison of Powertrain Configurations for Plug-In Hybrid Operation using Global Optimization”, SAE 2009-01-1334, SAE World Congress, April 2009
- Rousseau, A. Pagerit, S., Gao, D. (Tennessee Tech University) , "Plug-in hybrid electric vehicle control strategy parameter optimization", Journal of Asian Electric Vehicles, Volume 6 Number 2 December 2008, ISSN 1348-3927
- P. Sharer, A. Rousseau, D. Karbowski, S. Pagerit, “Plug-in Hybrid Electric Vehicle Control Strategy: Comparison between EV and Charge-Depleting Options”, SAE paper 2008-01-0460, SAE World Congress, Detroit (April 2008).