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Plug-in Hybrid Electric Vehicle Control Strategy: Comparison between EV and Charge-Depleting Options

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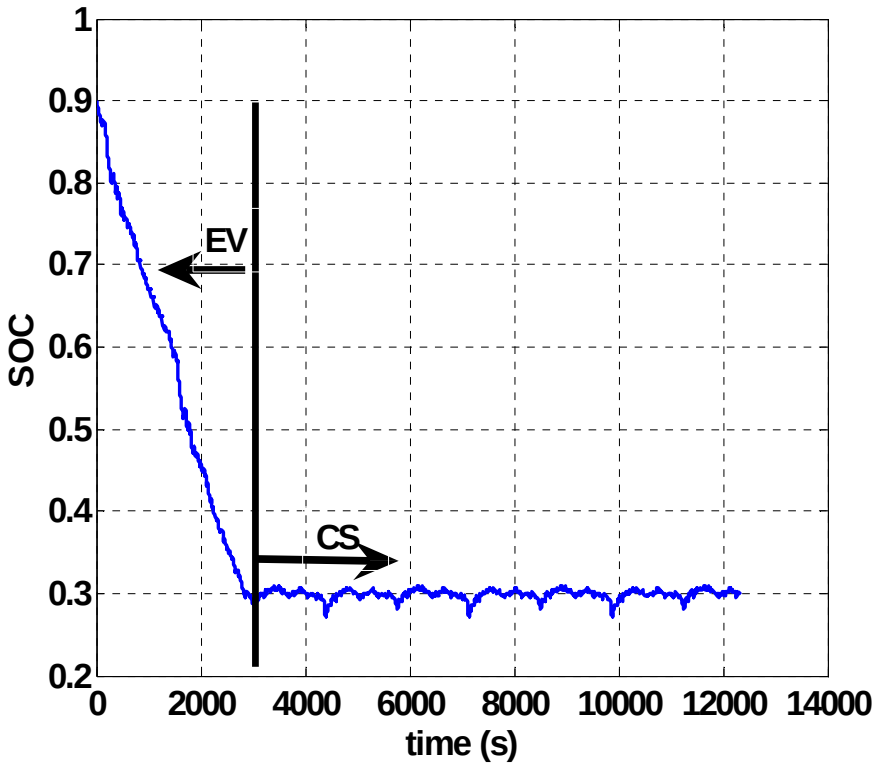
Argonne National Laboratory

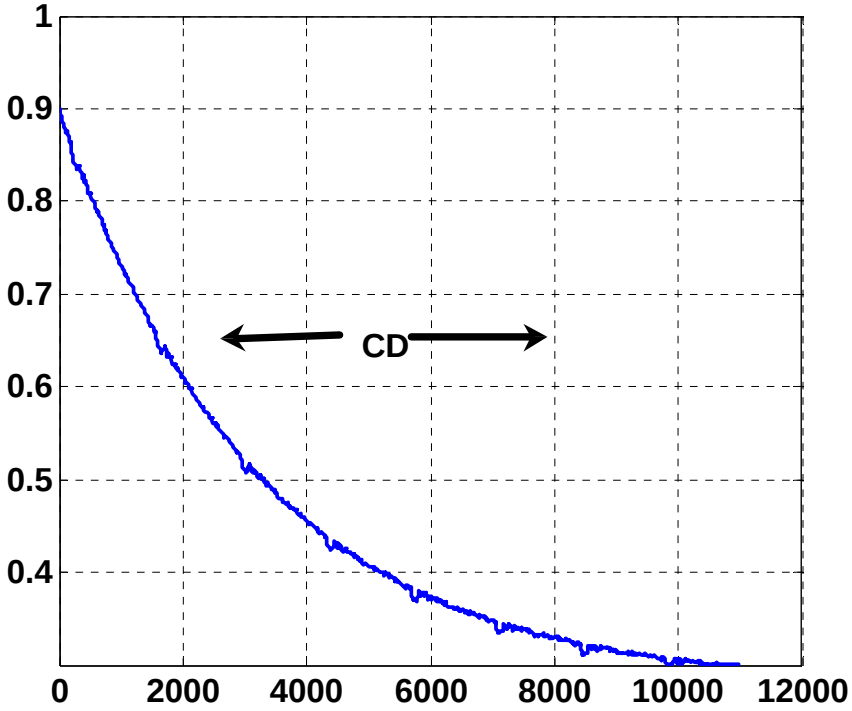
Sponsored by Lee Slezak, U.S. DOE

FreedomCAR & Fuel Partnership

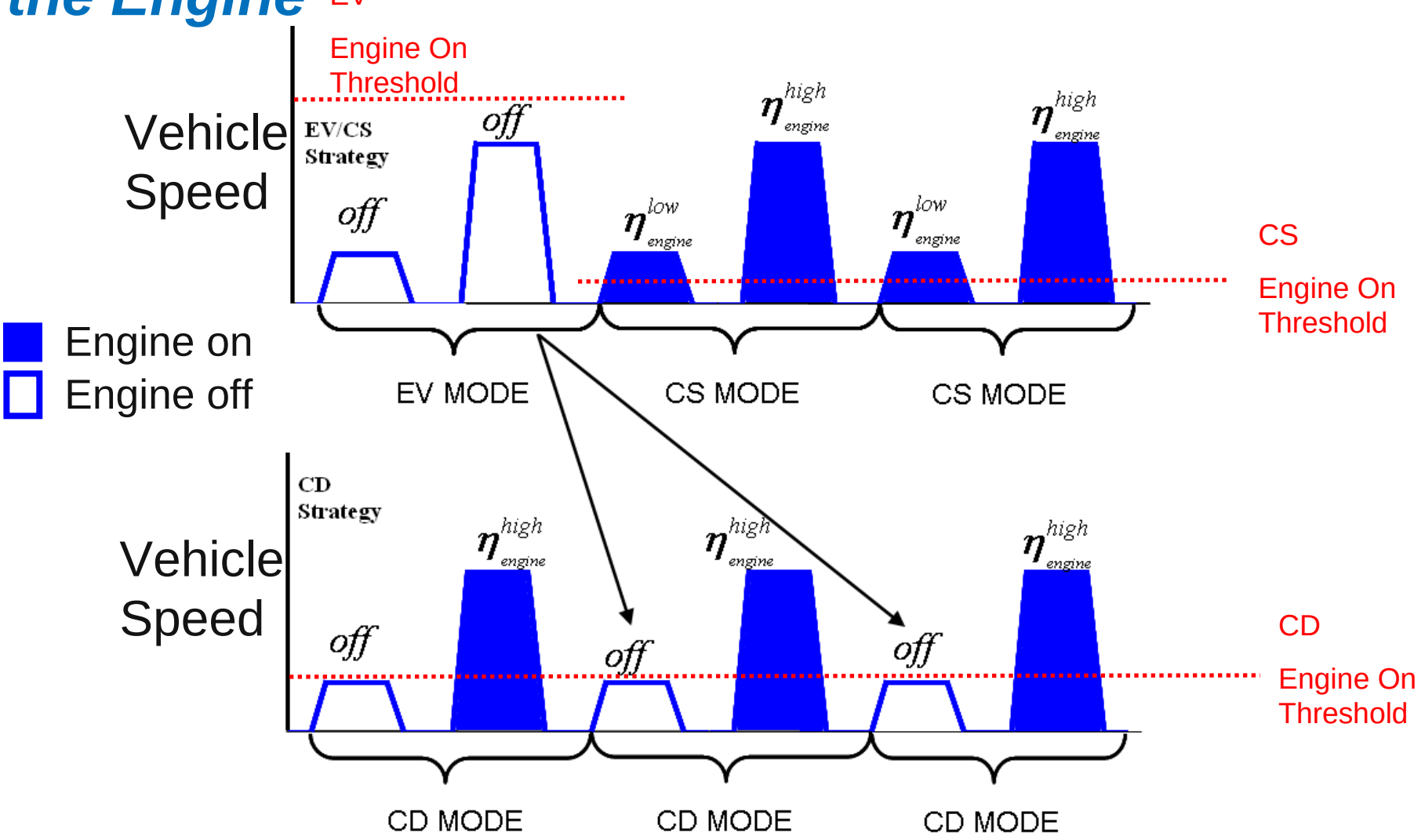
Can Using a Charge Depleting Strategy Further Decrease a PHEV's Fuel Consumption When Trip Distance Exceeds All Electris Range?



V.S.



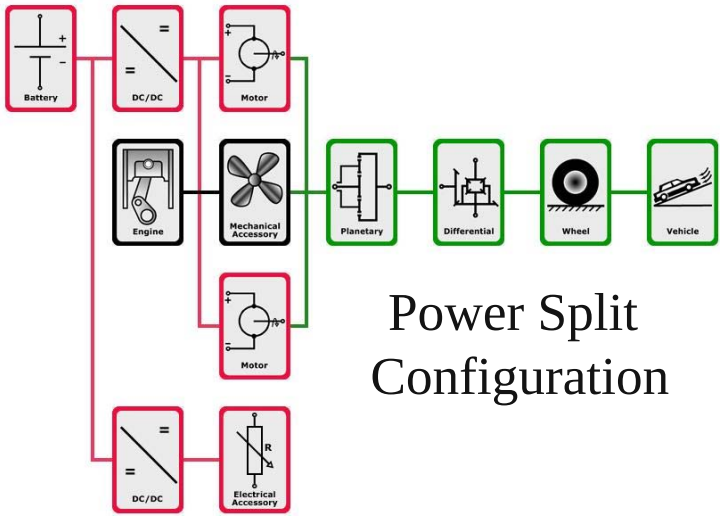
A Charge Depleting Strategy Can Use A Priori Knowledge of Trip Distance to Choose when to Use the Engine



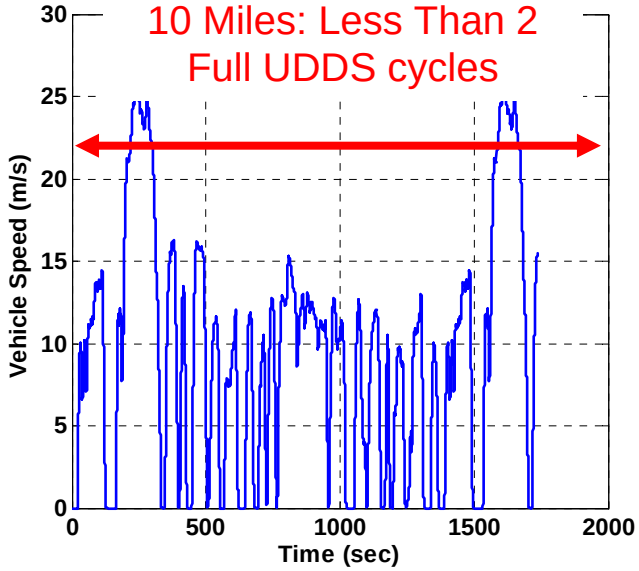
This Is a Specific Case, How Much Can It Be Generalized?

- 1 Configuration – Power Split
- PHEV with 10 mile Range on the UDDS
- Trip Distances - 10, 20, 30, 40, 60 miles on the UDDS
- 3 Control Strategies
- 1 Control Parameter was adjusted (Engine On Power Threshold)
- Did Not Include
  - Temperature Effects – Cold or Hot Battery
  - Emisssions

PSAT Modeling Assumptions



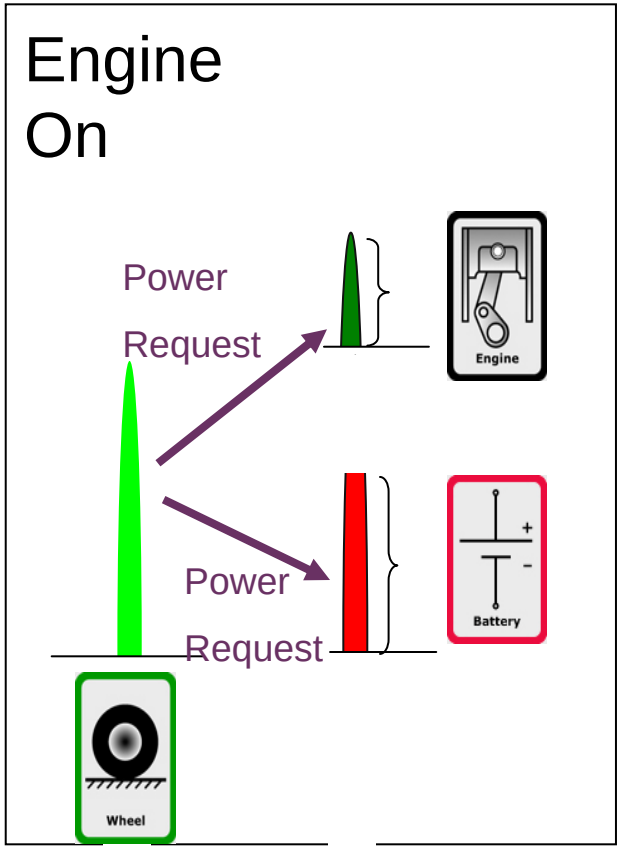
Power Split Configuration



Class	Midsize
Curb Weight	1432 kg
Battery Type	Li-Ion JCS - Saft 19 Ah
0 to 60 mph	9 sec
Grade	6% at 65 mph
Range	10 miles on UDDS
Delta SOC	90% to 30% SOC
Charge Sustaining at	30%

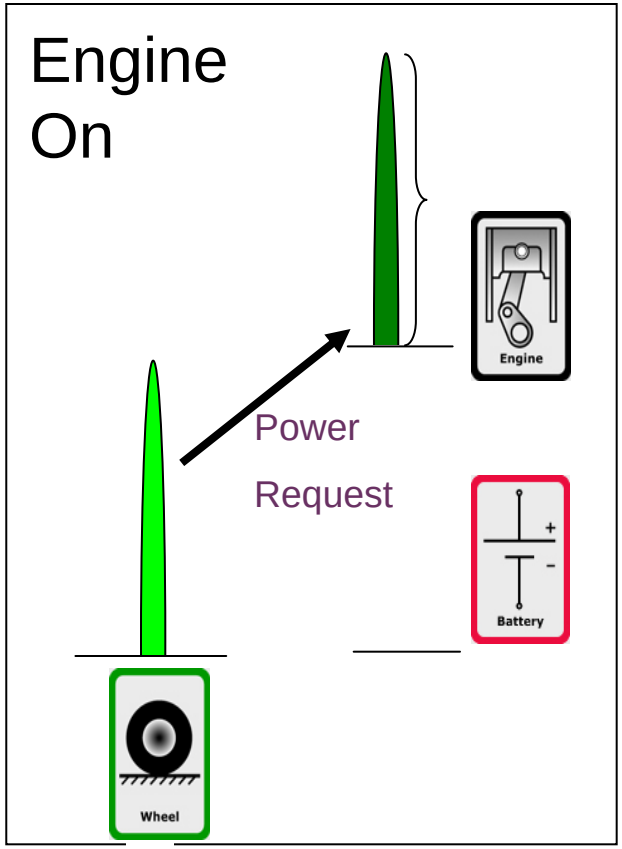
Each of the Three Control Strategies Partitions the Demanded Road Load between the Engine and Battery Differently

#1 Differential Engine Power



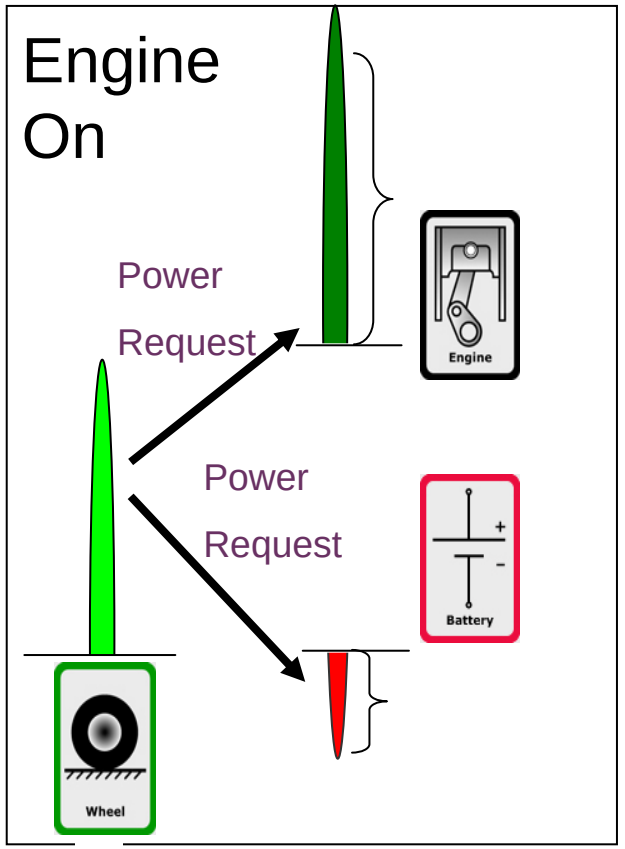
Eng power < Road Load

#2 Full Engine Power



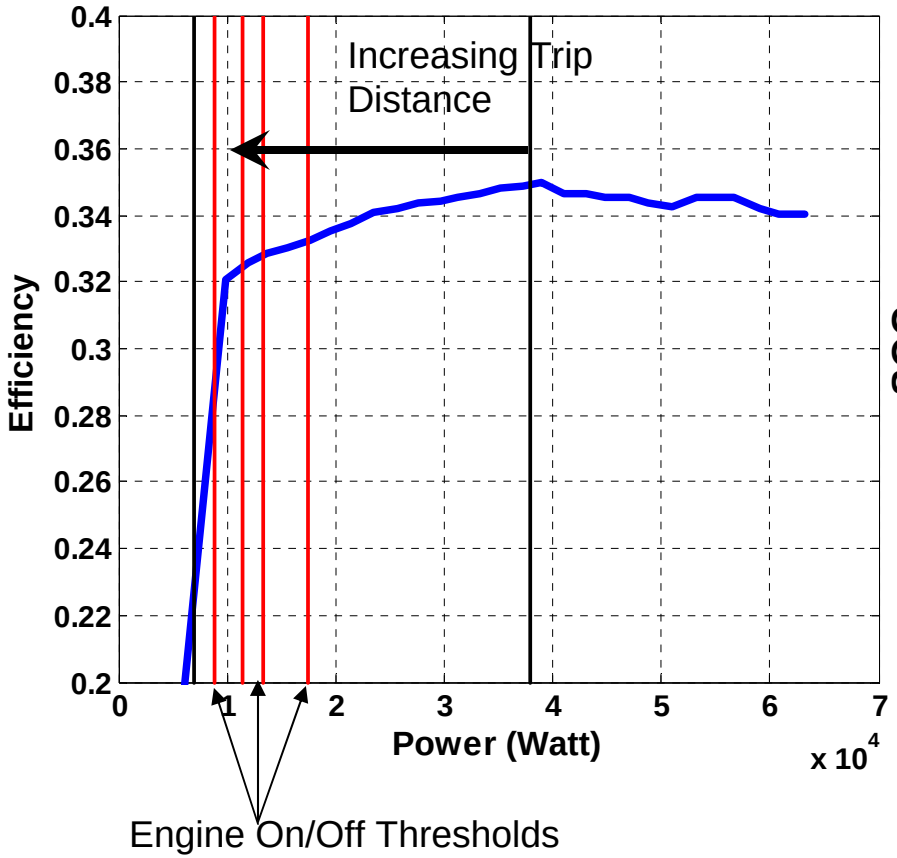
Eng power = Road Load

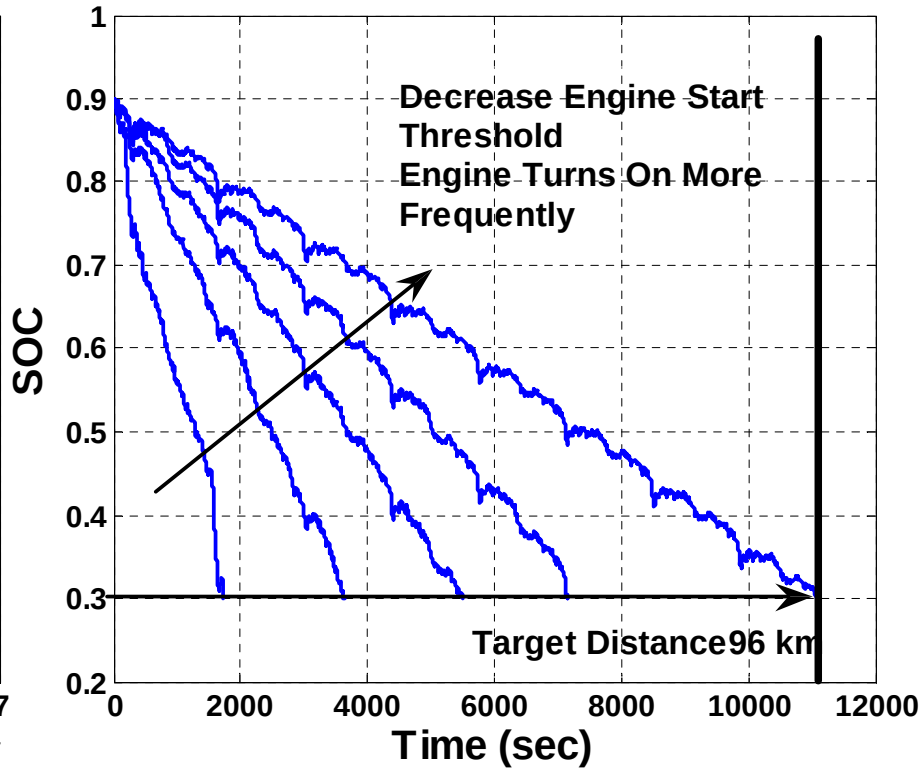
#3 Optimal Engine Power



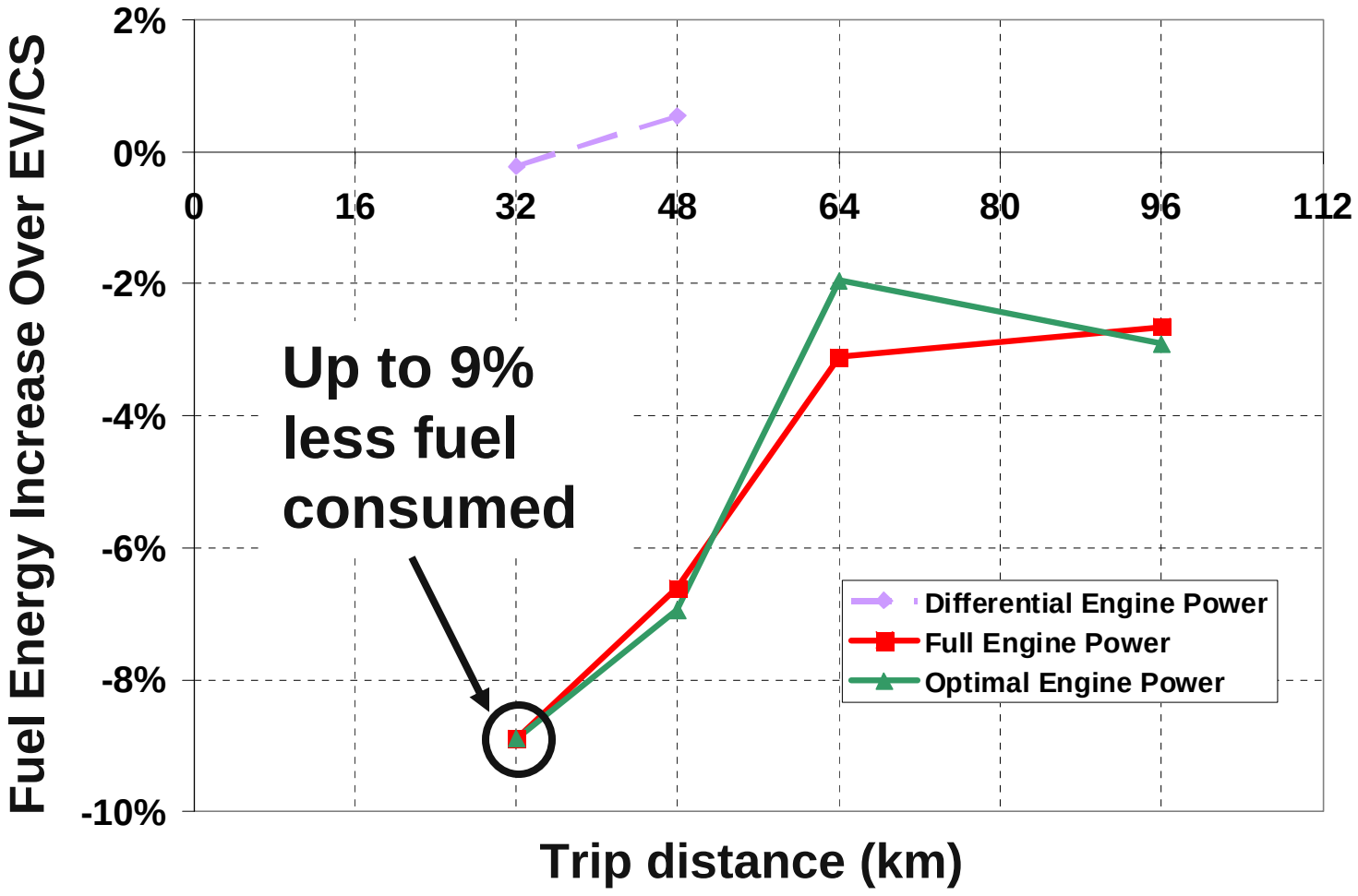
Engine Power > Road Load

Decreasing the Control Parameter (Engine On Power Threshold) Increases the Trip Distance





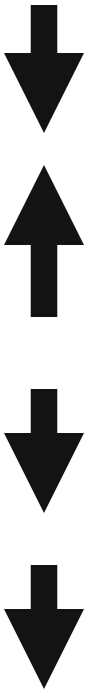
Driving 32 km with a PHEV 10 in Blended Mode Would Save 9% More Fuel Than in EV Mode!



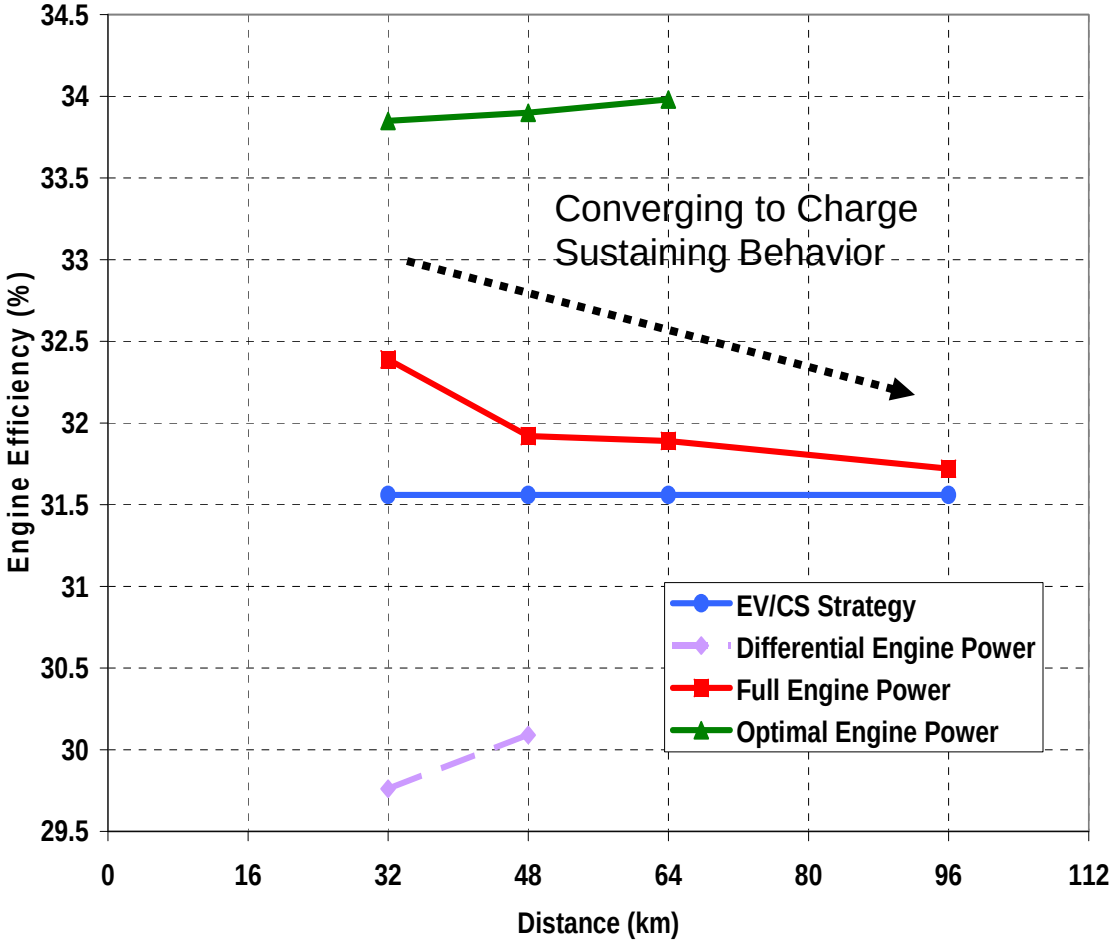
10 miles AER vehicle run on several UDDS cycles

Four Factors Affecting Consumption

- Increased Engine Efficiency
- Increased Excess Battery Charging
- Increased Transmission Efficiency
- Increased Regenerative Braking



Changing the Engine On Power Threshold to Get a Longer Trip Has a Great Effect on the Differential Engine Power Strategy

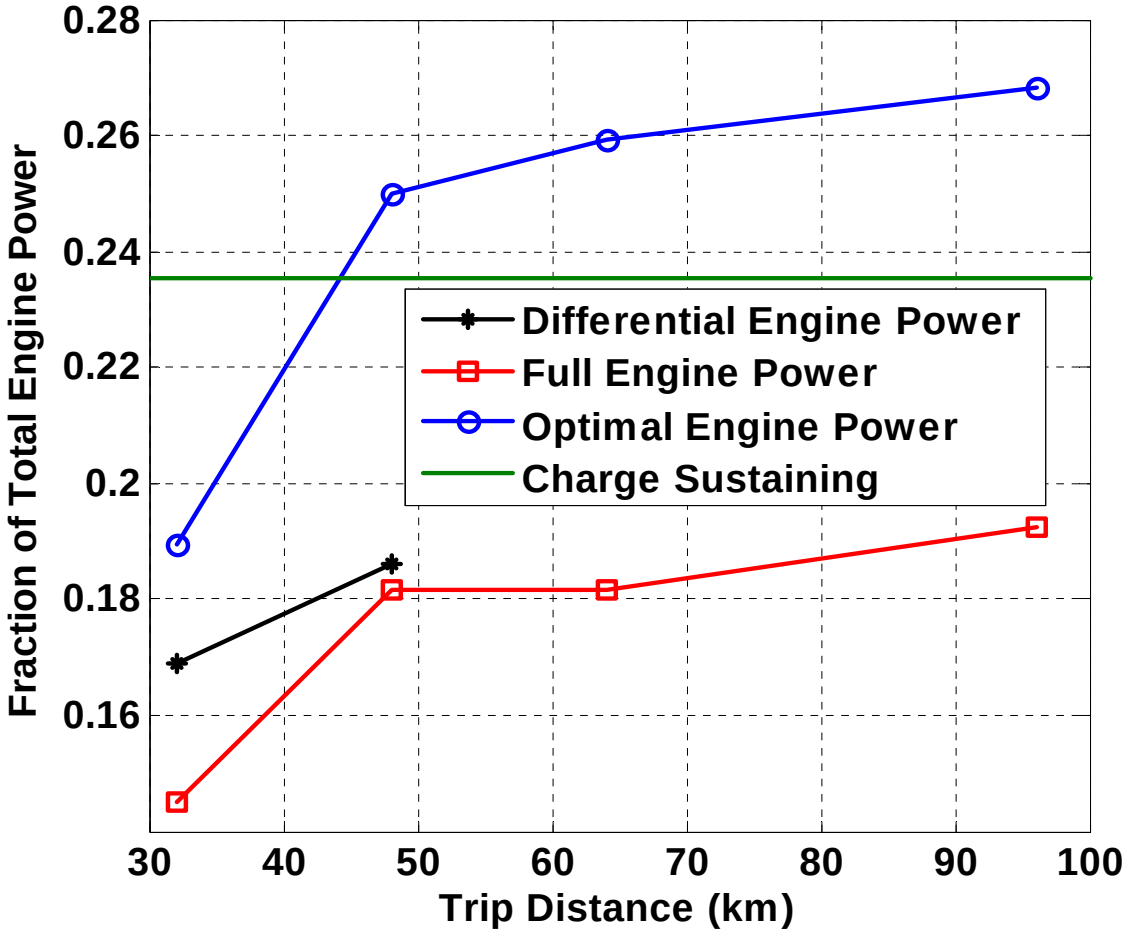


Engine Peak Efficiency = 35%

Effect on Consumption PHEV32

	ICE Eff	X-chg	Trans Eff	Regen
Diff	↑			
Full	↓			
Opt	↓			

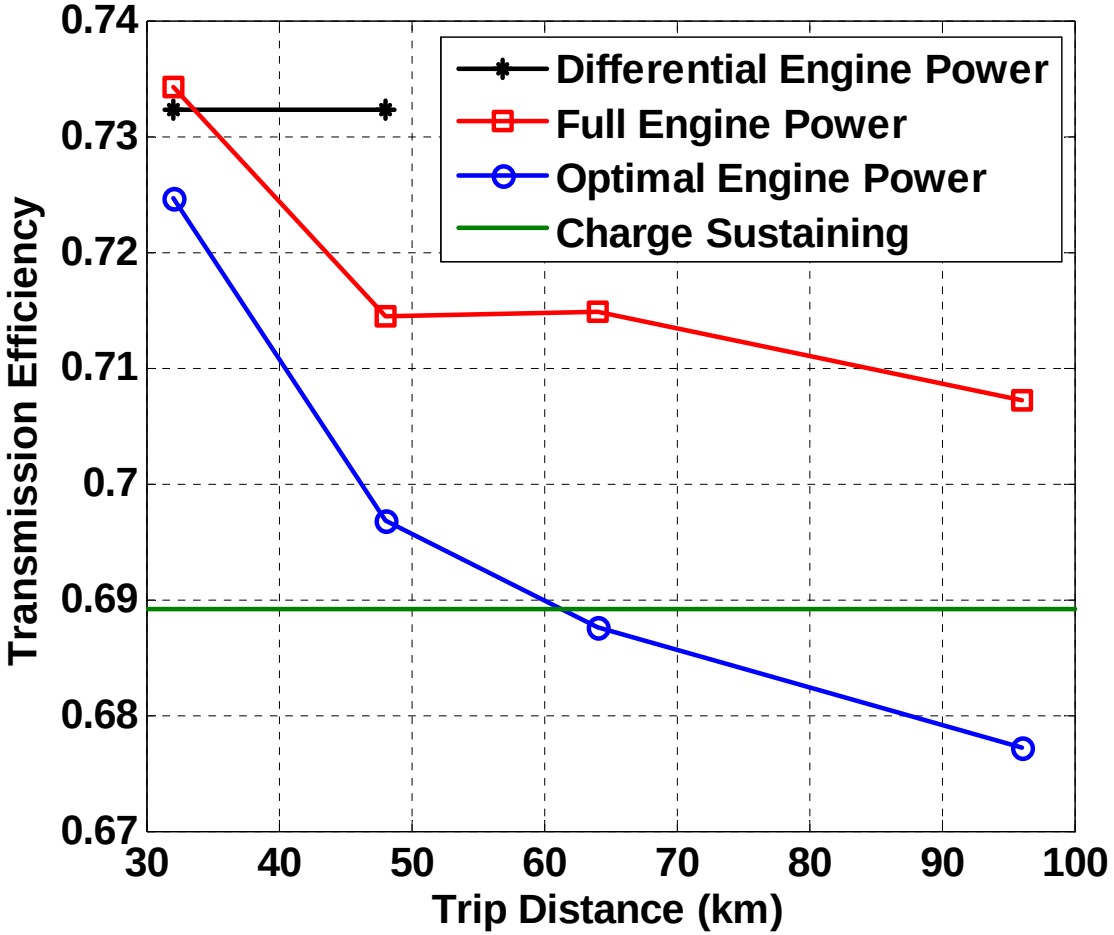
Even Though the Optimal Engine Strategy Has the Highest Average Efficiency, Its Greater Excess Charging Reduces This Advantage



Effect on Consumption PHEV32

	ICE Eff	X-chg	Trans Eff	Regen
Diff	↑	↓		
Full	↓	↓		
Opt	↓	↑		

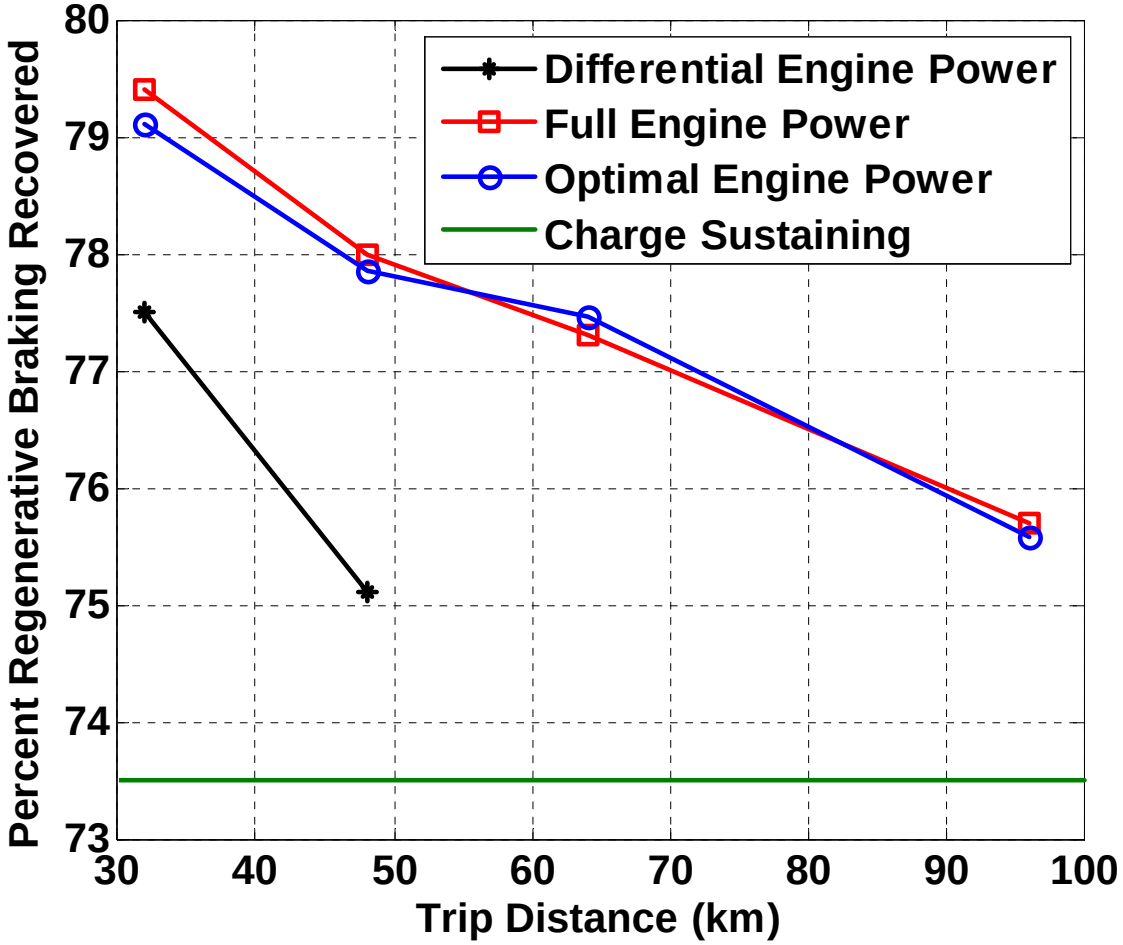
As Trip Distance Increases, the Transmission Efficiency for the Optimal Engine Strategy Drops below the CS Strategy Transmission Efficiency



Effect on Consumption PHEV32

	ICE Eff	X-chg	Trans Eff	Regen
Diff	↑	↓	↓	
Full	↓	↓	↓	
Opt	↓	↑	↓	

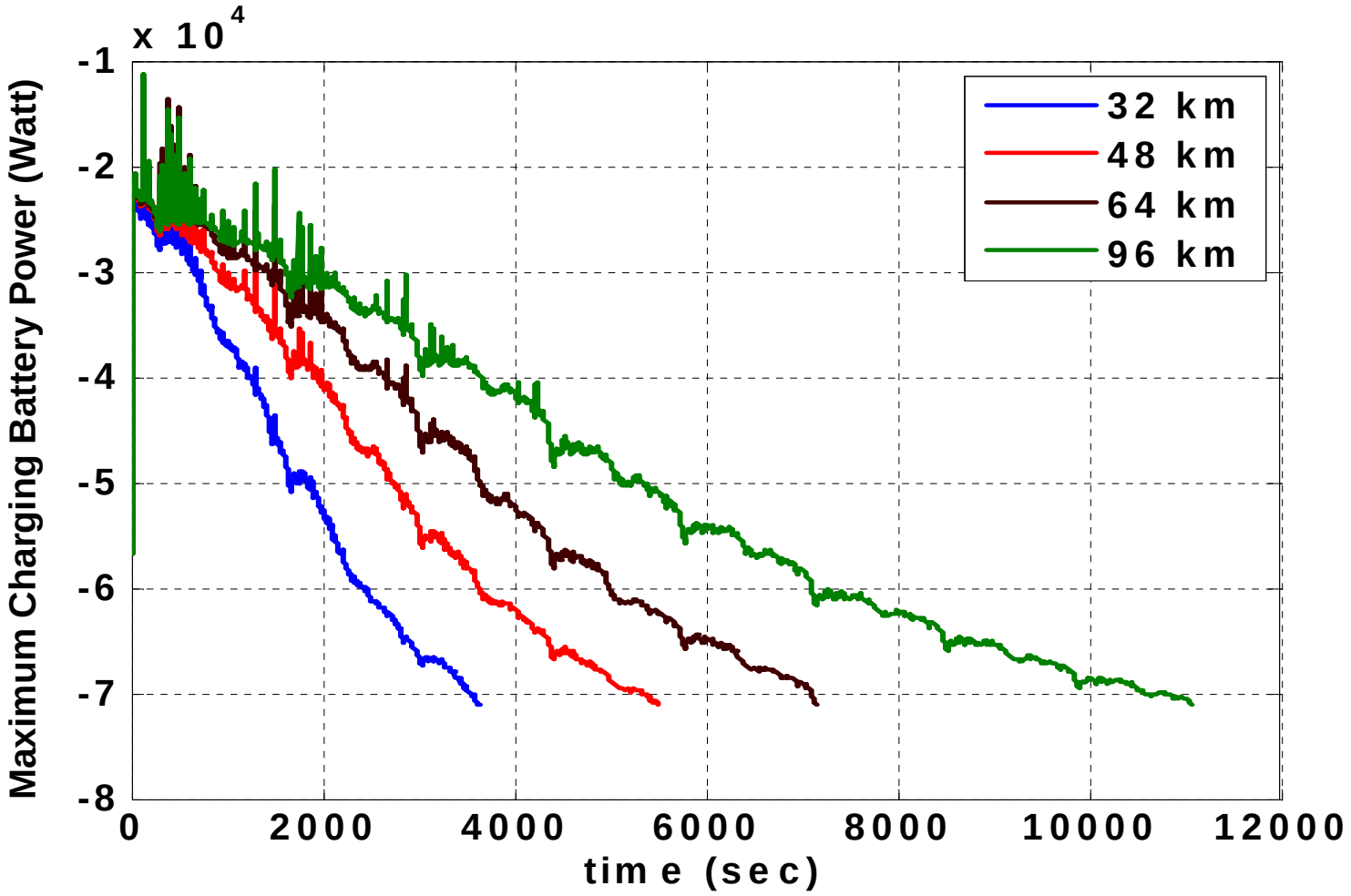
As Trip Distance Increases Regenerative Braking over the Cycle Decreases



Effect on Consumption PHEV32

	ICE Eff	X-chg	Trans Eff	Regen
Diff	↑	↓	↓	↓
Full	↓	↓	↓	↓
Opt	↓	↑	↓	↓

Regenerative Braking Decreases Because the Battery Discharges Slower



Conclusion

- A Charge Depleting strategy can improve a PHEV's fuel economy by up to 9% for a power split configuration
- Most of the gain is from operating the engine more efficiently
- The full engine strategy showed the most benefit as a charge depleting strategy
- Engine benefits are cancelled by excess charging, decreased transmission efficiency and decreased regenerative braking
- The Optimal engine strategy suffered the most from excess charging
- The Differential engine strategy suffered from low engine efficiency