

# HD Hybrid Test Procedures

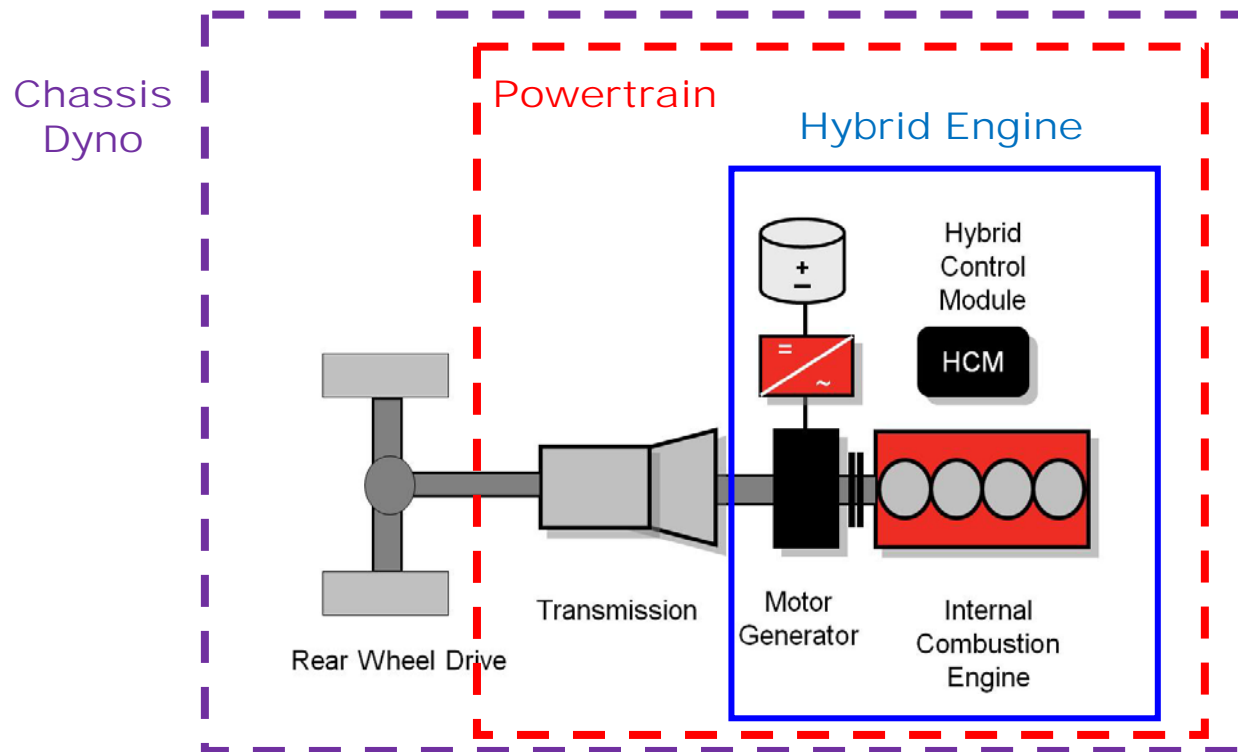
Morgan Andreae  
Cummins Inc

# HD Hybrid Test Procedures

- **Hybrid engine powerpack testing**
- **NPRM to include hybrid criteria emissions**
- **Future Challenges**

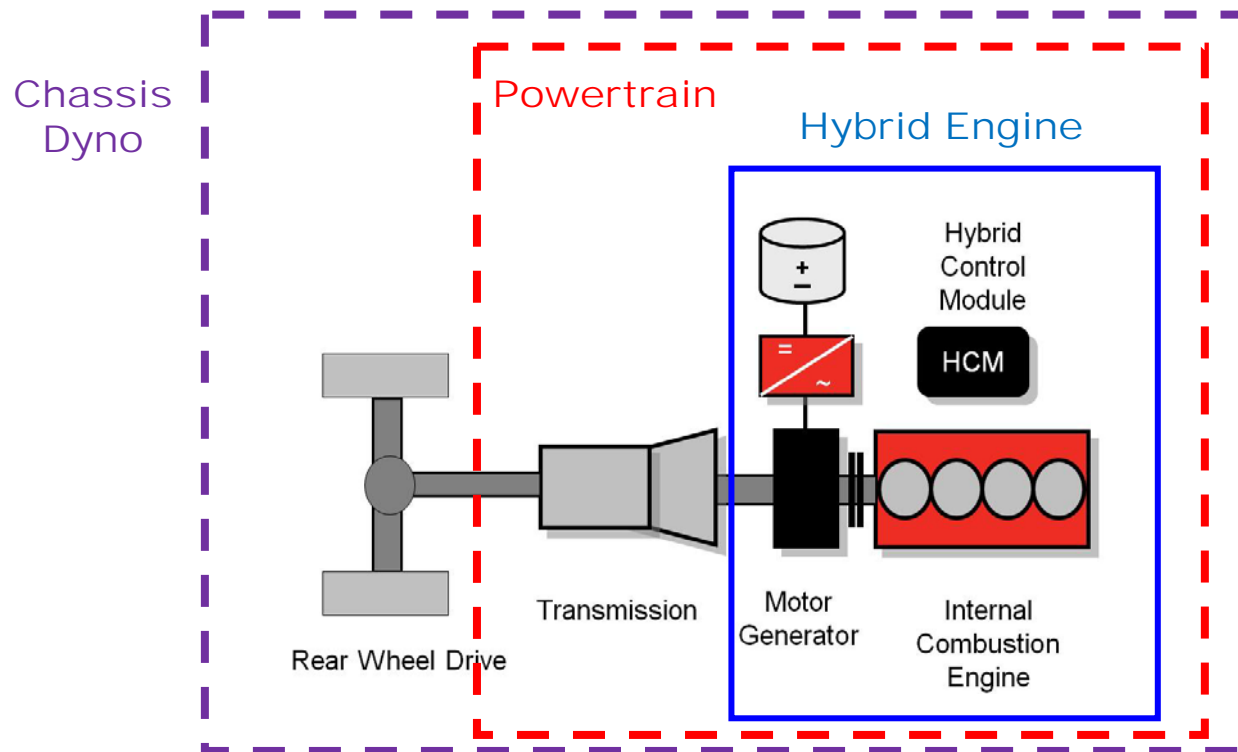
# US EPA GHG Rule

- Three options for hybrid certification
  - Hybrid engine
  - Hybrid Vehicle
    - Chassis Dyno (full vehicle)
    - Powertrain Dyno (engine + transmission & simulated vehicle)



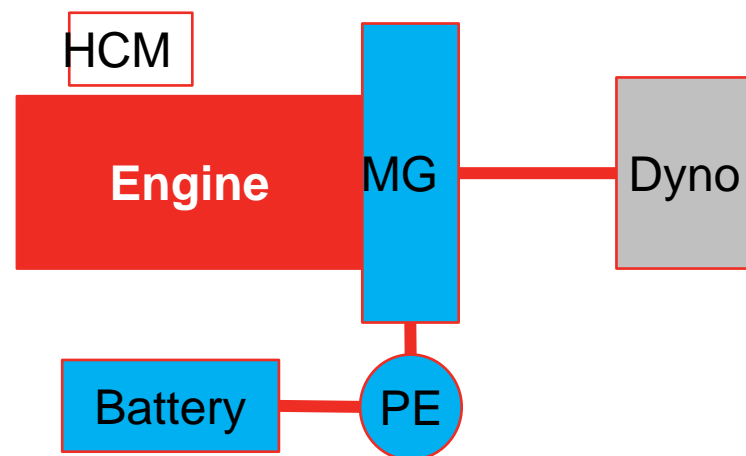
# US EPA GHG Rule

- Hybrid engine option is vehicle independent
  - Aligns with conventional criteria emissions strategy (allows use of engine standards)
  - Provides way to avoid proliferation
  - Practical approach for commercial vehicle market

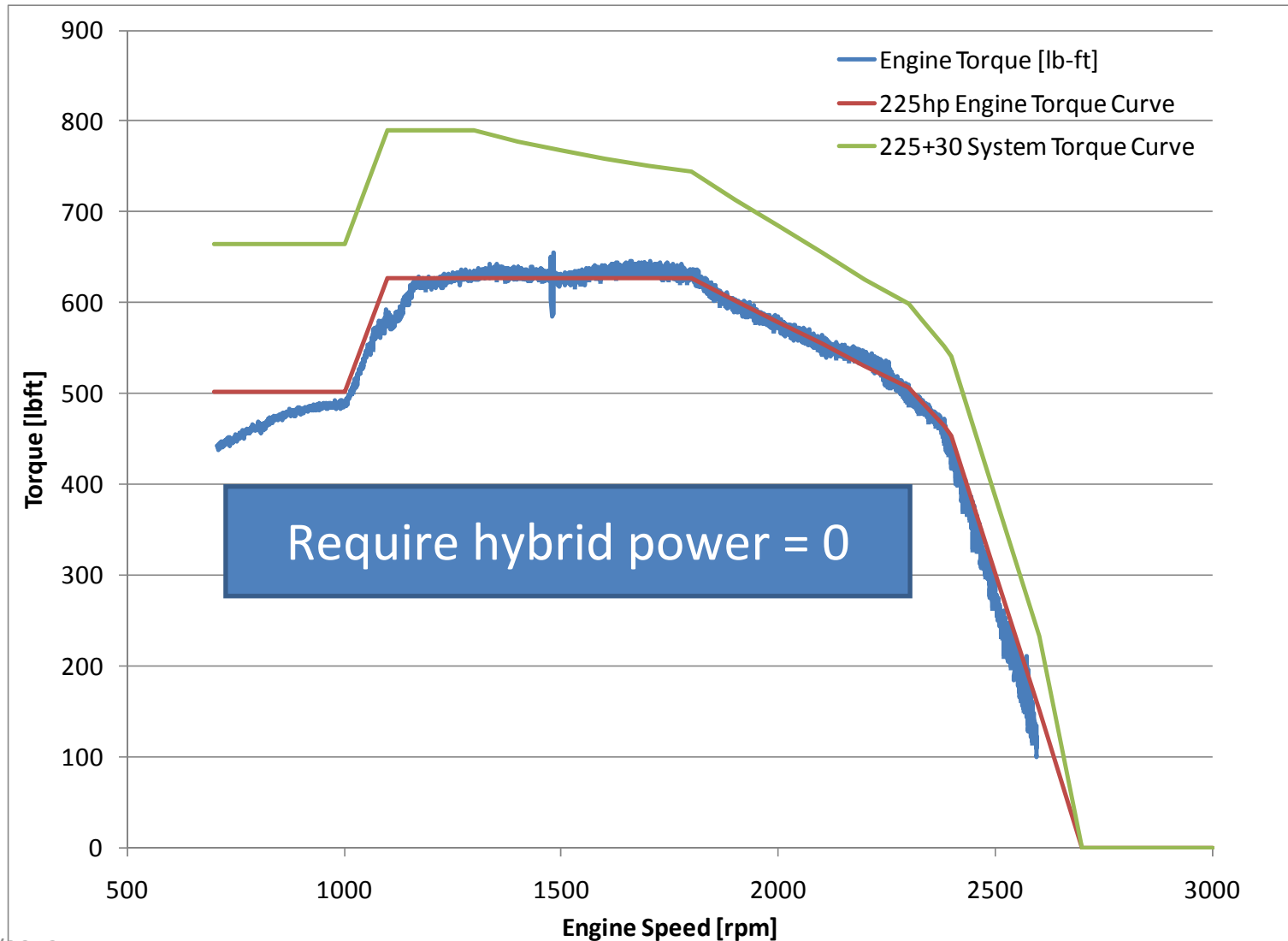


# Hybrid Engine: Vehicle Independent Hybrid Certification

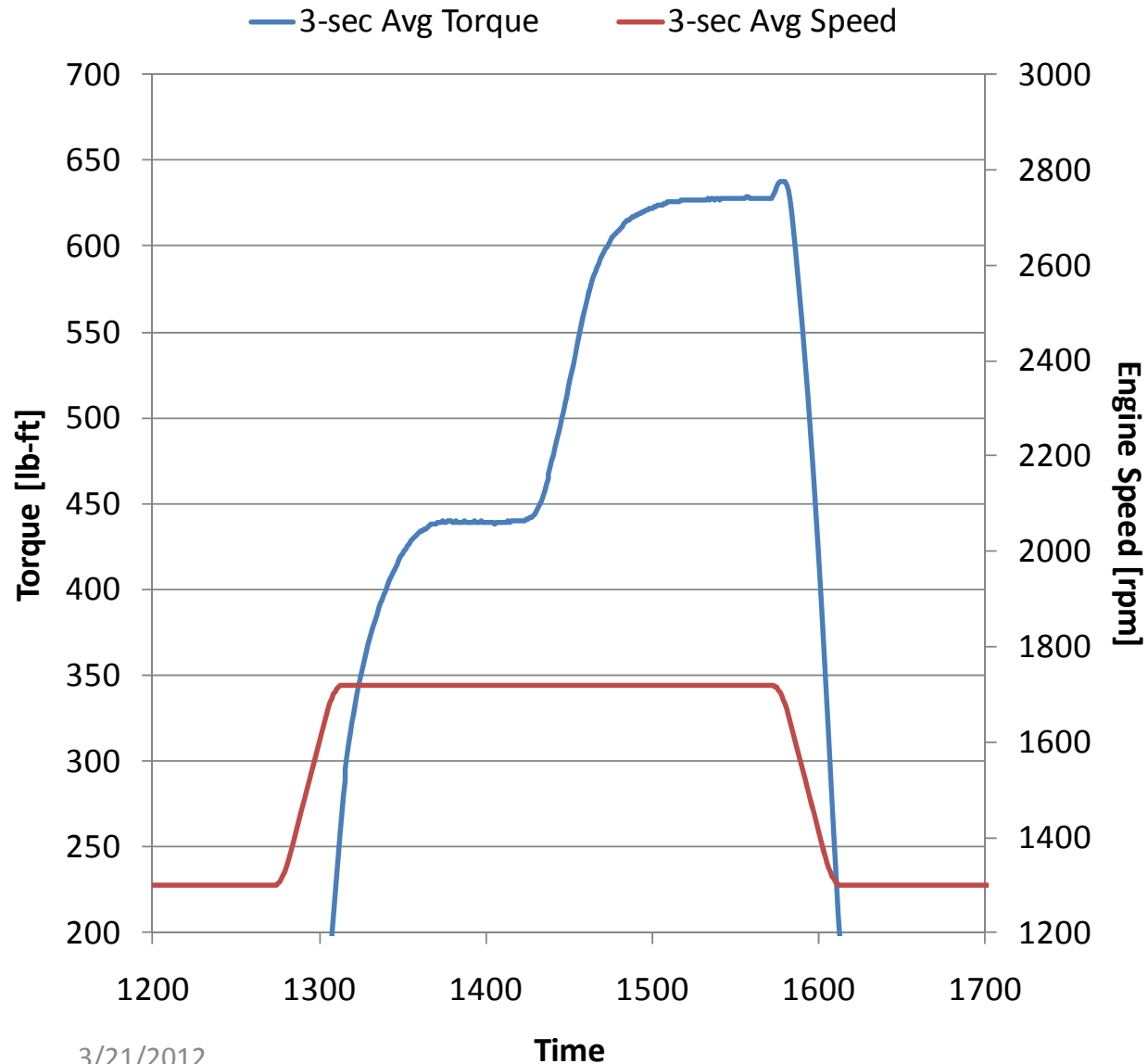
- Hybrid engine testing builds on existing procedures
  - Limit “brake” energy capture in realistic way
  - Apply same energy storage management criteria as for other hybrid test procedures
- Key challenge: Torque curve definition for hybrid
  - Torque curve may depend on energy storage system state
  - Define steady state & transient torque curve procedures



# Testing Process – Steady state torque curve



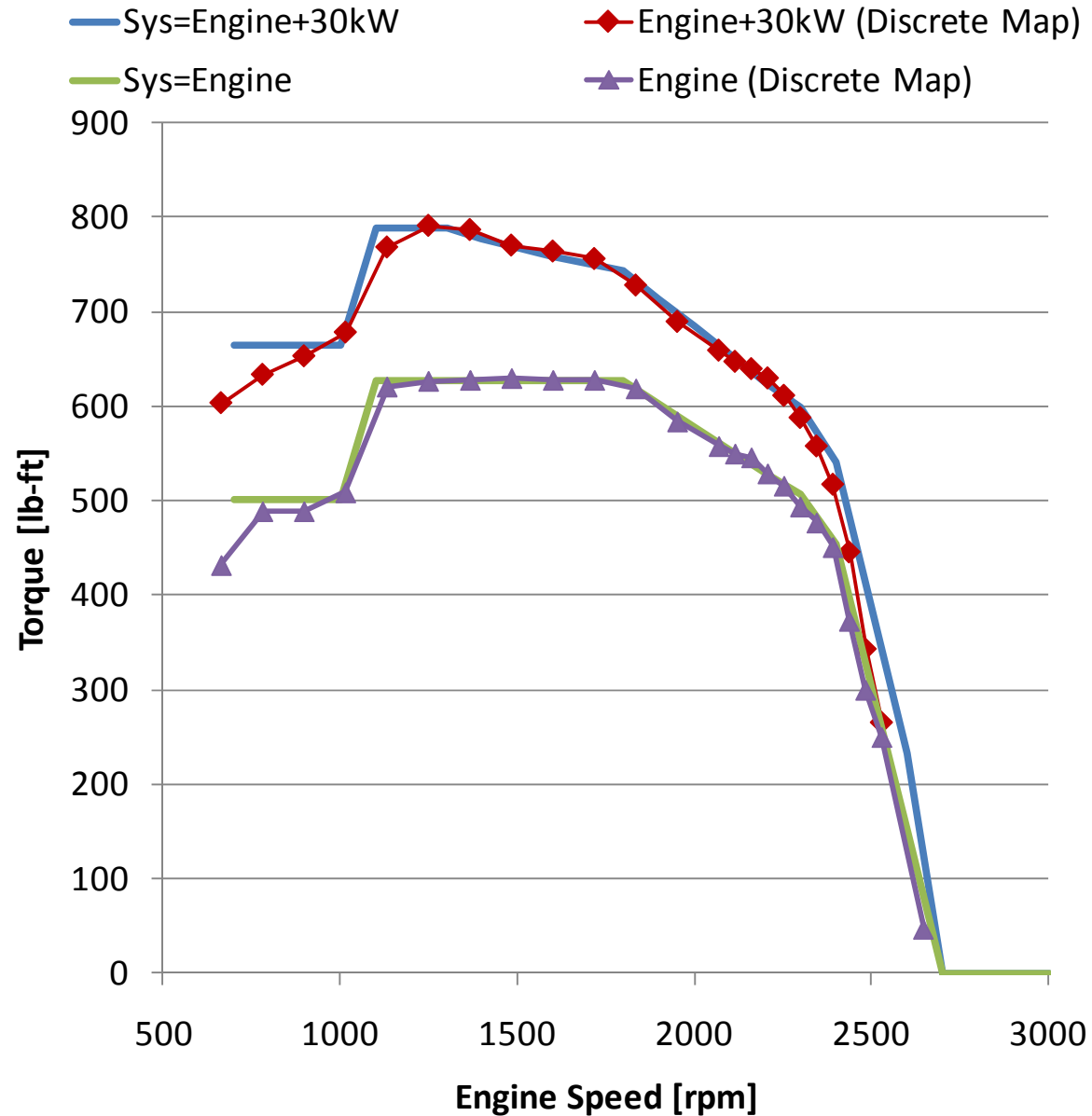
# Transient Torque Curve Mapping



- Evaluate peak torque at discrete points
- Allow energy storage level to return to target levels in between peaks
- Measure peak 3-second average torque

# Discrete Torque Curve Mapping Result

(Transient system torque curve)





# Transient Cycle Results

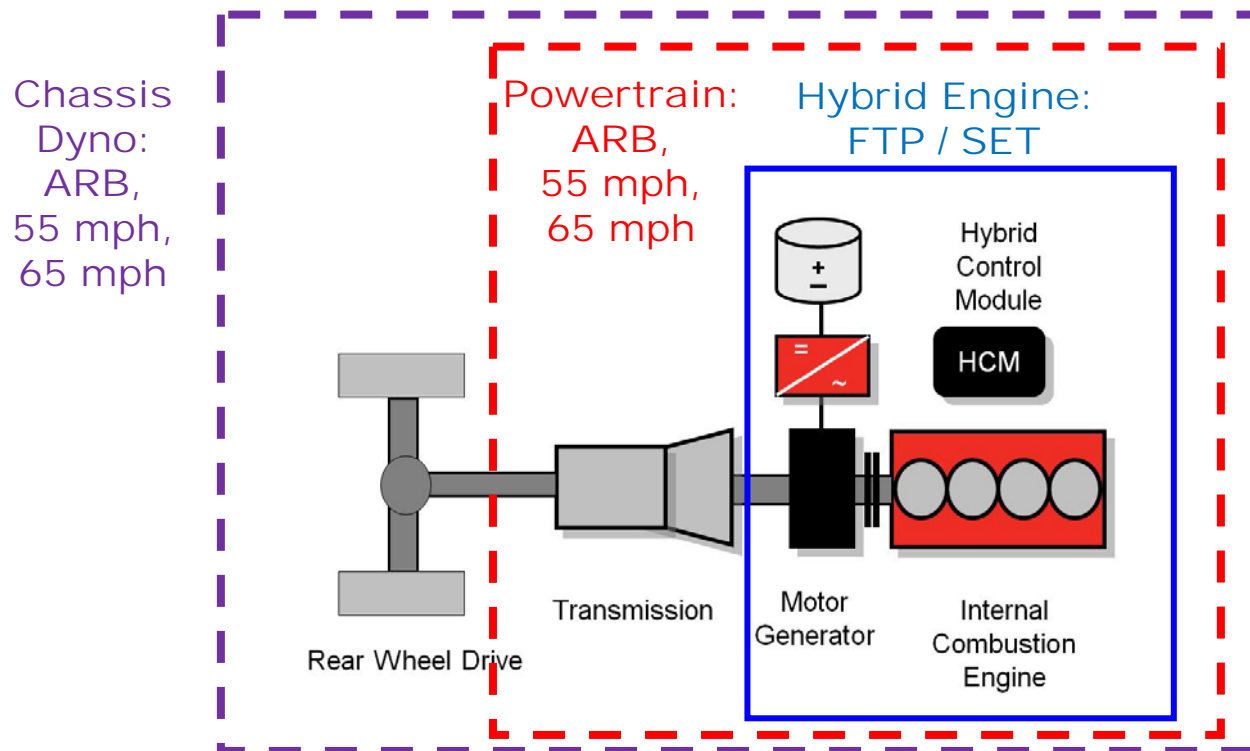
Cycle	Fuel Used	Cycle Work	Battery Energy Change
	Mean (Std Dev)	Mean (Std Dev)	Mean (Std Dev)
	[g]	[hp-hr]	[%fuel energy]
225/30 FTP, 30kW regen limit	2528.0 (19.7)	16.17 (0.12)	0.03 (0.29)
225/30 FTP, vFTP regen limit	2643.1 (11.0)	16.64 (0.03)	-0.20 (0.14)
225 FTP, 30kW regen limit	2139.1 (13.1)	13.47 (0.01)	0.21 (0.21)

# 2012 NPRM

- EPA has announced that 2012 NPRM will include content to provide hybrid criteria emission certification option
  - Encourage system optimization by allowing evaluation of criteria performance using hybrid system
  - Avoid higher “real world” criteria emissions from hybrids
- Build on existing GHG hybrid certification options
  - Hybrid engine: FTP + SET
  - Hybrid vehicle: chassis & simulated chassis A to B comparison using vehicle cycles

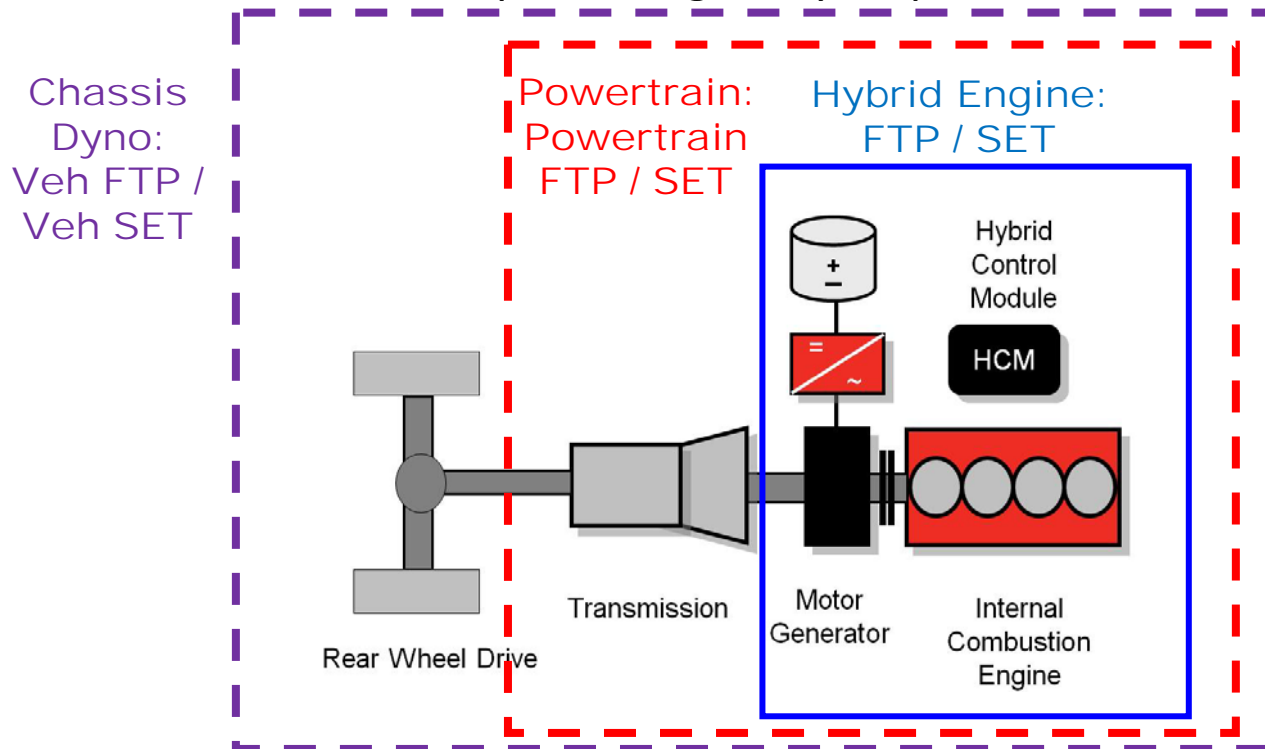
# Future Challenges for EPA: Align Cycles

- Currently engine and vehicle options use different cycles
- Preserve flexibility of multiple options, but align cycles
  - Ensure equivalent evaluation between methods
  - Allow comparison with existing standards – and comparison to conventional performance



# Future Challenges

- Align cycles for different test procedures
  - Hybrid Engine: FTP + SET
  - Chassis: vFTP & vSET (SAE 2012-01-0878)
  - Powertrain: normalized cycle based on engine & vehicle cycles (ptFTP SAE ComVehC)
    - Vehicle speed, engine cycle power



# US EPA Hybrid Rules & GTR Development

- EPA rulemaking is facing many of the same challenges as have been raised in the HD hybrid GTR development
- GTR development has the advantage of an engine cycle and a vehicle cycle that are already aligned (WHTC & WHVC)
  - Allows equivalent evaluation to conventional powertrains
- Vehicle independent hybrid certification option is practical solution for HD market
  - Equivalent to conventional vehicles
  - Reduce proliferation
  - Provide practical framework for off-highway hybrids
  - Definition of normalized powertrain cycle aligned with engine cycle is feasible