PACCAR - Eaton Hybrid Collaboration

Taking HD Hybrid from Concept to Commercialization

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Heavy Duty Hybrid: Building on MD Success

- 20-60% impr. In fuel cost
- 50% reduction in NOx
- Utility Truck-High Value
- Partnerships are Key!
  - Fedex, UPS
  - DOE, HTUF, Others

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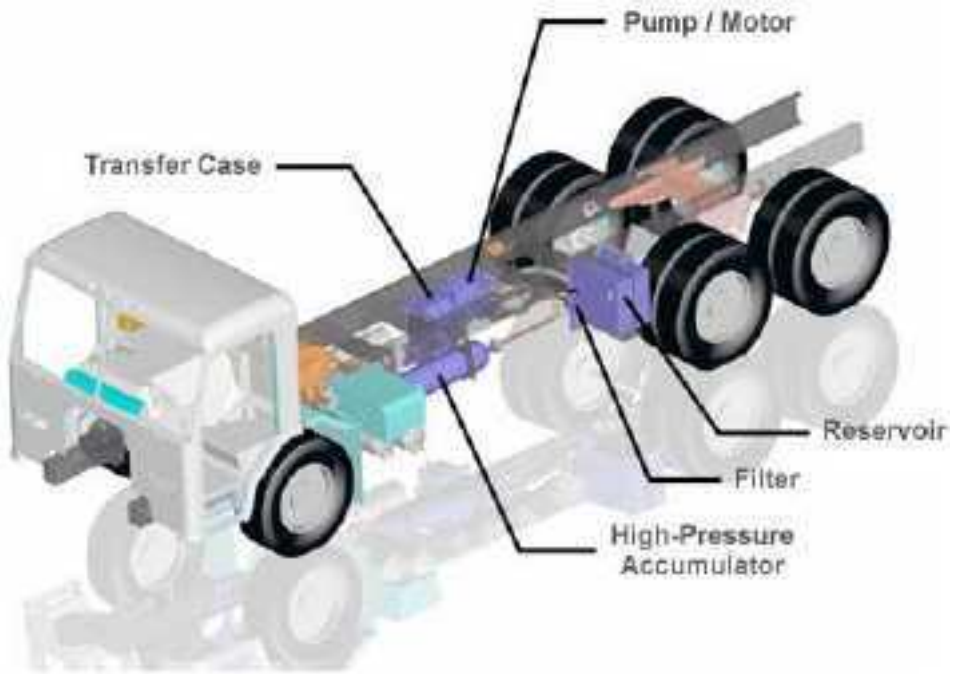
Heavy Duty Hybrid: Multiple Paths

Hydraulic Launch Assist:

Start/Stop Assist, generally municipal applications, charges accumulator during deceleration, then releases energy back during acceleration.



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Heavy Duty Hybrid: Multiple Paths

Diesel Electric Hybrid:

2004 Concept vehicle has matured beyond "Show Truck" status with 2009 Production Launch

Common technology with MD Diesel Electric, with added anti-idle during hotel-mode.

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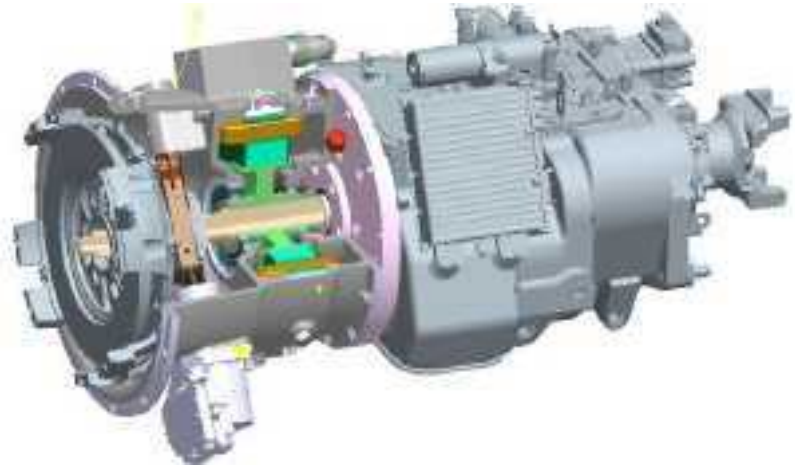
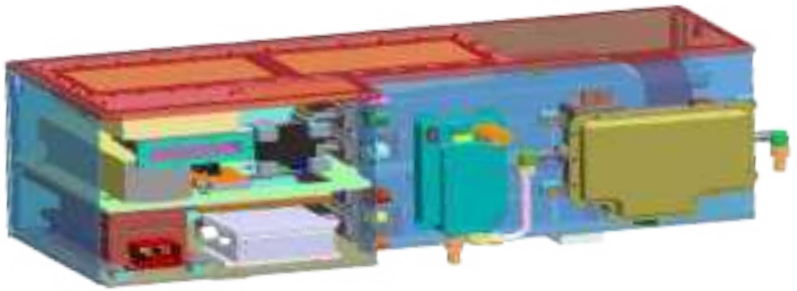
Diesel Electric Product Description:

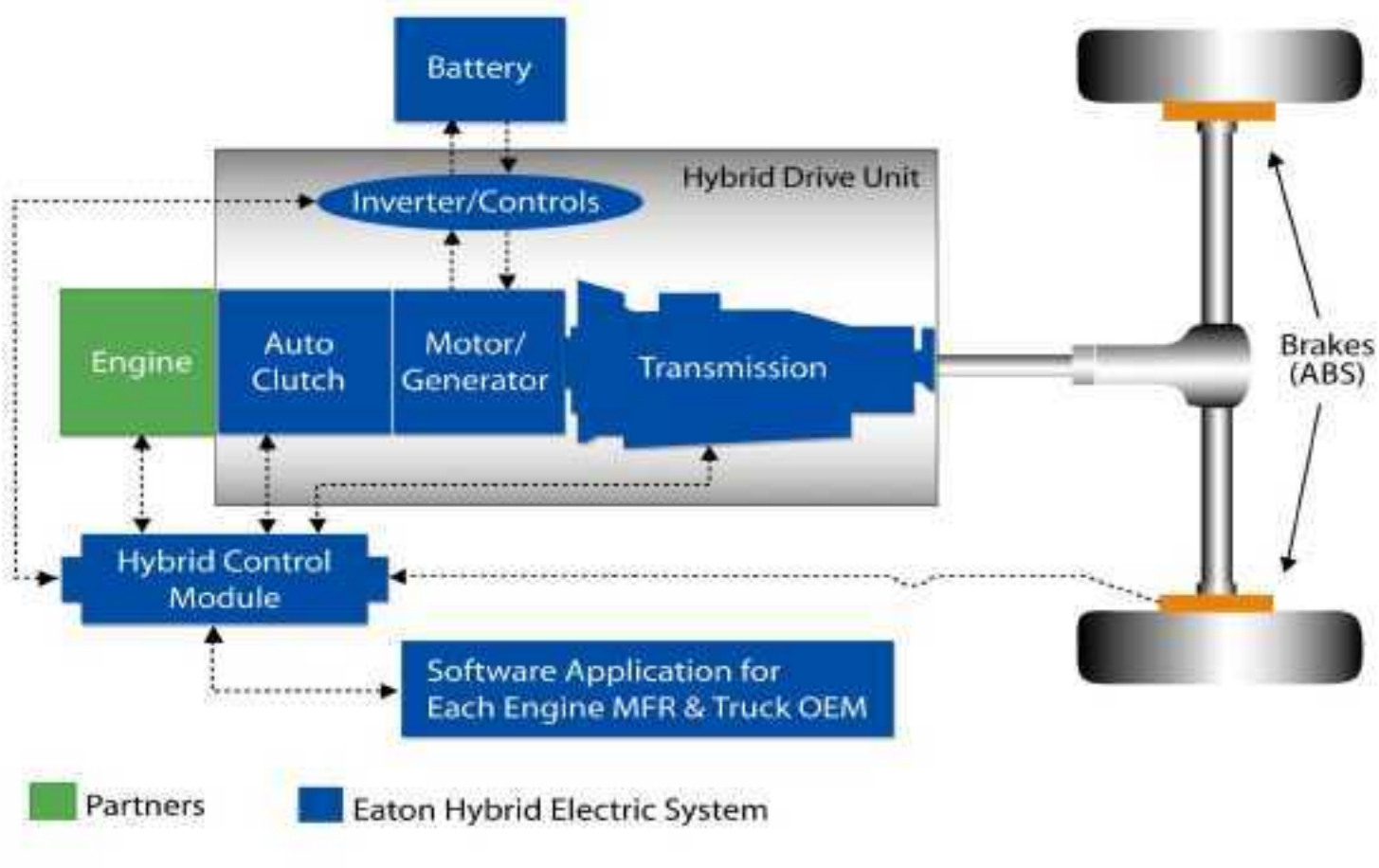
Hybrid Drive Unit (HDU) and Power Electronics Carrier (PEC)

- Hybrid Drive Unit Assembly
  - 10speed Automated Transmission
  - Clutch Actuation System
  - Electric Traction Motor / Generator
    - (Motor is common to HD and MD Hybrid)
- PEC Assembly
  - Batteries
  - Traction Inverter
  - 12vDC/DC Converter
  - System Controller
  - 120vAC Inverter





HEV System Diagram



Modes of Operation:

- Engine Starting Mode (Start-Stop)
  - Battery Starts / stops engine through Motor inverter auto clutch
- Diesel Engine Only Mode (Back up)
  - Diesel Engine Charges Batteries Through Motor Inverter
- Regenerative Braking Mode
  - Assist on full stop and or downhill retardation while capturing power
- Electric Only Mode
  - Idle Power for “Hotel Mode” with Engine Off
- Diesel Engine & Hybrid Motor (Motor Boost)
  - Uses Battery Power to assist on launch, grades, and acceleration

Eaton's System: Unique Benefits

- World's first true production parallel MD Hybrid system
  - **Proven customer uptime** based on >1,000,000 field test miles
- Based on proven high-volume AMT, Autoclutch and controls components
- **Single-Motor/Single-Clutch design** vs. Dual-Mode systems
  - Eaton's Direct Hybrid achieves lowest possible operating cost
- Direct Hybrid architecture provides highest degree of Integrated **Functionality**
  - APG, ePTO, Anti-Idle, EV mode, etc.

Challenges to Commercialization

- Battery Technology
  - Power Density / Life constraints, ie, ability to use all potential energy
  - Battery Weight / Size / Packaging (especially with SCR adds)
  - Sustainability / Recycle / Reuse infrastructure for Batteries
- Capital Spending Cycle
  - System incremental cost
  - “Show Me” approach of major fleet purchase decisions
  - Residual Valuation / Payback Cycle
  - ~6-7% fuel savings typically required to develop interest of fleets
  - Clarifying the “Value of Green”
- Duty Cycle variation and savings demonstration

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Class 8 Hybrid Truck Fuel Economy Improvement Potential

by

Aaron Brooker and Michael O'Keefe

National Renewable Energy Laboratory

Dean Edwards and Johney Green Jr., Ph.D.

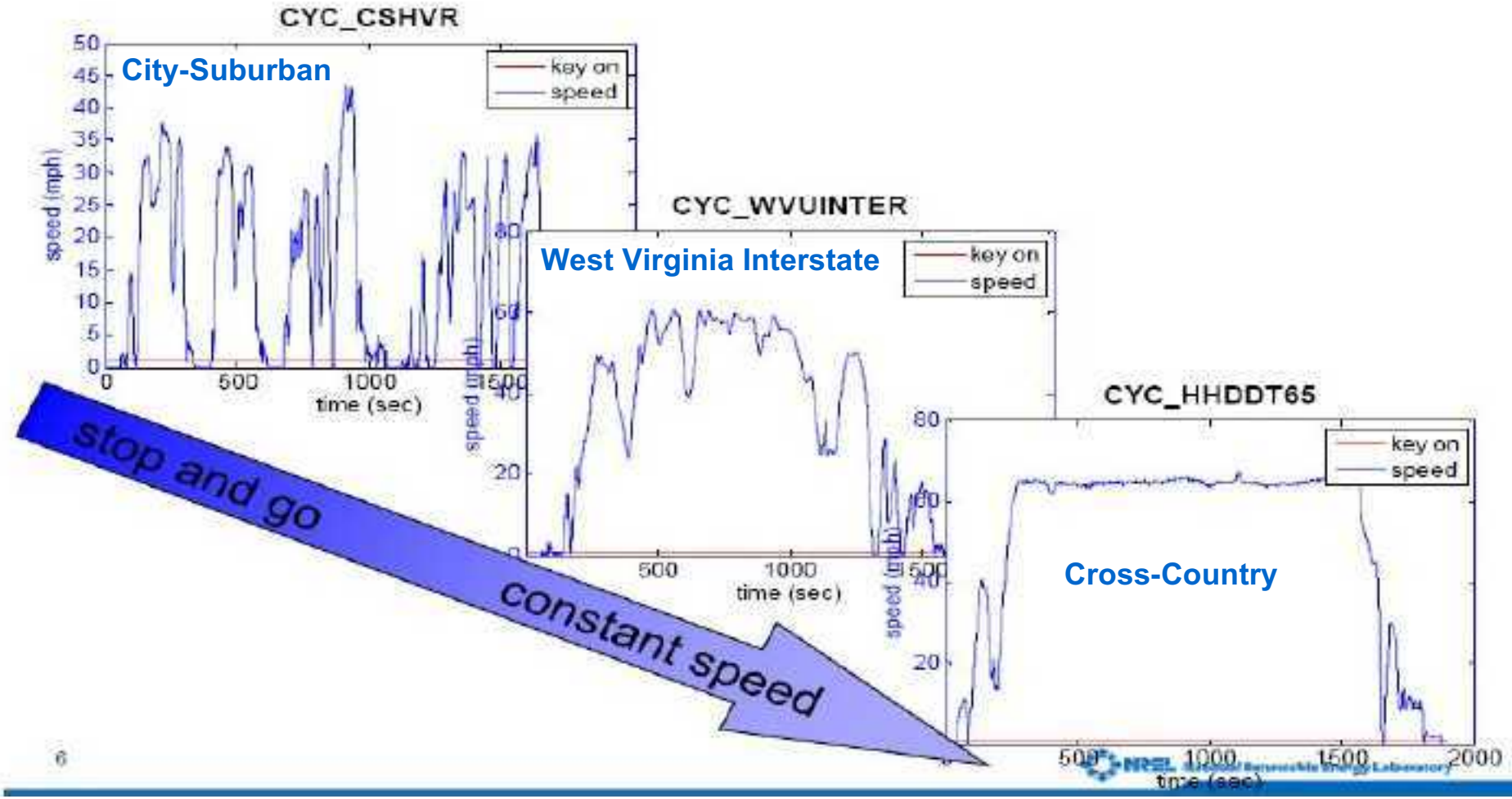
Oak Ridge National Laboratory

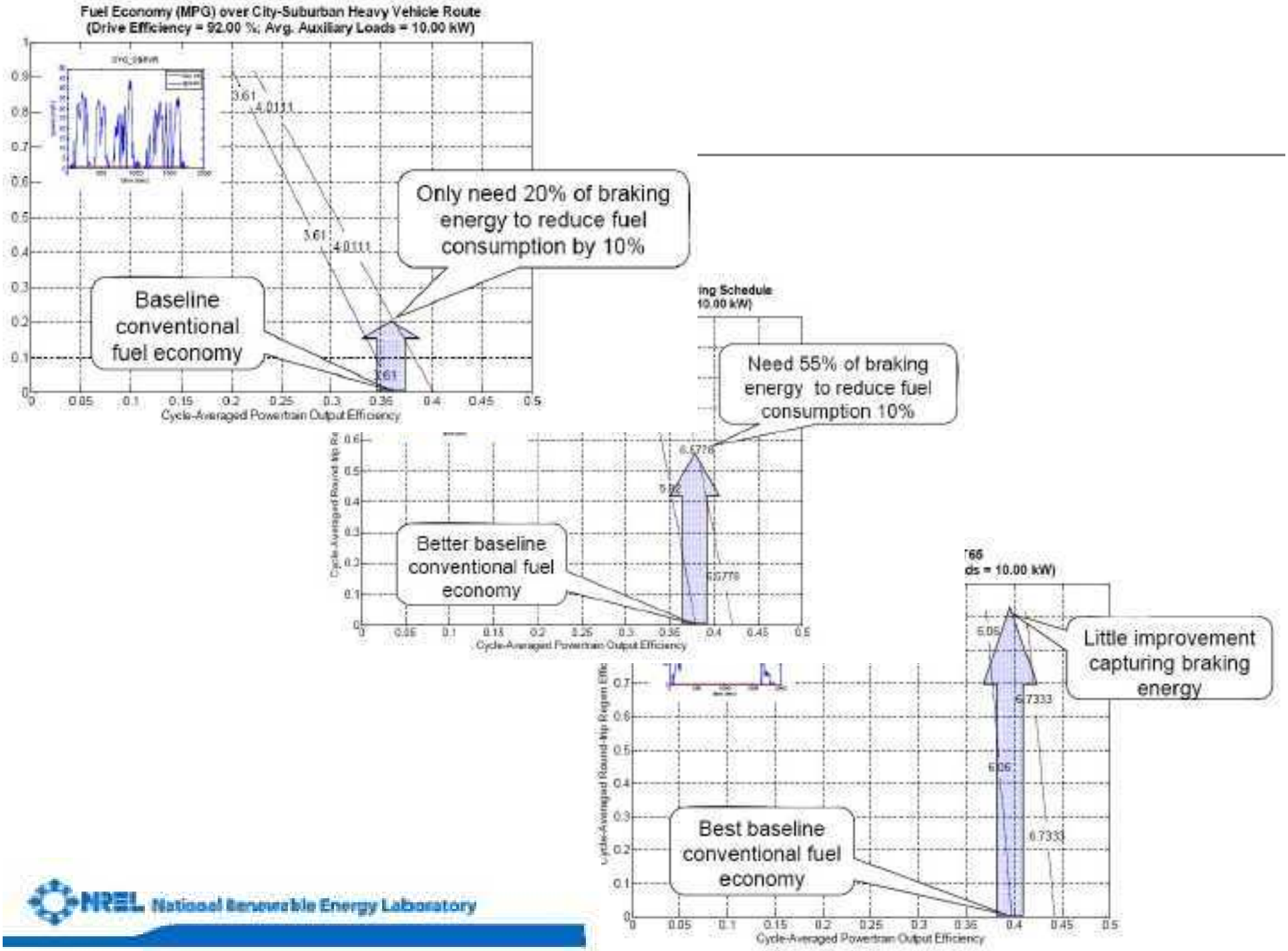
October, 2007

MPO2

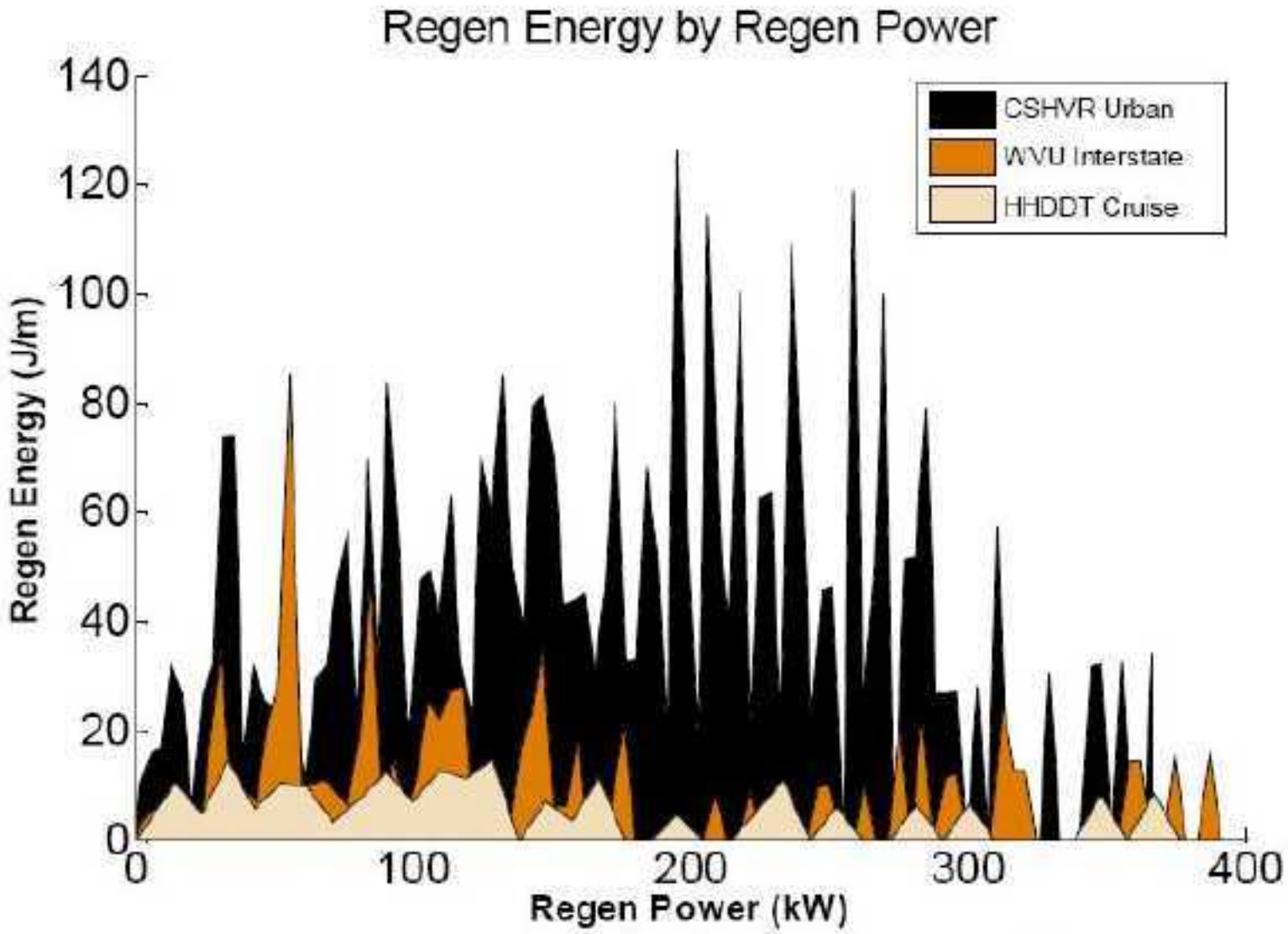
Question of Interest

- Can a significant fuel economy benefit be obtained through hybridization of class 8 over-the-road line-haul tractor trailers?




Fuel Economy (MPG) over City-Suburban Heavy Vehicle Route
(Drive Efficiency = 92.00 %; Avg. Auxiliary Loads = 10.00 kW)
3.61
4.0111
3.61
4.0111
3.61
Only need 20% of braking energy to reduce fuel consumption by 10%
Baseline conventional fuel economy
Cycle-Averaged Powertrain Output Efficiency
Need 55% of braking energy to reduce fuel consumption 10%
Better baseline conventional fuel economy
Cycle-Averaged Powertrain Output Efficiency
Little improvement capturing braking energy
6.05
6.7333
6.05
6.7333
Best baseline conventional fuel economy
Cycle-Averaged Powertrain Output Efficiency

Much less regen available for line-haul driving



Key Enablers to Successful HD Hybrid Commercialization

- Diesel Fuel Price increases and taxation
- Simplification of Tax Credit Regimes nationwide
- Legislation & Regulation
- Taxation / Tolls
- Penalties for Carbon Emissions in city centres (Madrid, Paris, Los Angeles,…)
- Environmental Pressure and increased valuation of “Green” by owners and shareholders of HD Vehicle operators
- Support for technology development to reduce battery cost & packaging

Thank You !

Questions ?