The Right Technology Matters
The Importance of Public-Private Partnerships for Engine Technology Development

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August 3, 2009
- Diesels in broader energy context
- Technology and Application
- Alternative fuels
- Personal example of benefits from DOE partnership
Energy Source

- Solar
- Gas
- Coal
- Oil
- Renewable HC
- Bio-derived
- Bio-produced
- Nuclear
- Wind
- Water (Gravity)
- Geothermal

* “Not to scale”
Power Conversion

**ΔP → “motive force”**

Heat a gas
- Combustion
- Nuclear
- Geothermal
- Solar
- Gravity
  - Dams
  - Waves
  - Wind

Shaft Work Machines
- Reciprocating
  - Spark Ignition (Otto)
  - Compression Ignited (Diesel)
- Stirling
- Turbine

Direct Electric
- Fuel cells
- Photovoltaic Electric

Combined cycle
- CHP
  - “Hybrids”
  - Waste Heat Recovery

“Fossil”
- Coal
- Oil

Renewable HC
- Bio-derived

Efficiency, Conservation

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Energy Efficiency
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Improving Efficiency / Reducing CO₂ Footprint

- Idle Reduction
- Hybrids
- High Efficiency Clean Combustion
- Low Temp Aftertreatment
- Waste Energy Recovery

CO₂ ↔ Energy Efficiency
Partitioning the System

- **Fuels**
  - Reduced carbon intensity
  - Improved combustion

- **Engines**
  - Efficiency improvements
  - Reduced Carbon Fuels
  - Hybrids / Waste Heat Recovery

- **Vehicles**
  - Transmissions / Axles / Tires
  - Aerodynamics
  - Tractor & Trailer

- **Fleets / Operators**
  - Duty cycles
  - Operator behavior

- **Highways / Infrastructure**
  - Highway Construction / Congestion
  - Speed limits
  - GVW
Potential Efficiency Improvement / CO₂ Reduction

Line-Haul Applications

Vocational Applications

Refuse Truck
Waste Energy Recovery

- *Engine* Waste Heat Recovery
- *Vehicle* Kinetic Energy Recovery (Hybrids)
Waste Heat Recovery vs. Hybrid

- Waste Heat Recovery
- Hybrid

Customer Benefit

Frequent Start/Stop vs. Seldom Start/Stop
Waste Heat Recovery vs. Hybrid

Customer Benefit

Vocational

Linehaul

Waste Heat Recovery

Hybrid
Business Domain
- Context
- Application
- Value

Technology Domain
- Innovation

The Right Technology DOES Matter!
Alternative (Diesel) Fuels
Alternative Fuels in general...

- My personal view:
  - Installed base of consumer vehicles
    + sunk investment in delivery infrastructure
    = alternative fuel → like conventional gasoline or diesel fuel
  - Boutique engines for boutique fuels (or vice versa)
    make no business sense (just lab entertainment)

- Why I might be wrong:
  - If a reformulated fuel enables a significant fuel economy improvement at low emissions, it could get more interesting to adapt special engine and fuel technology for each other.
Alternative Fuels

- “Fossil” source
  - Coal
  - Natural gas

- Renewable -- Derived from biological sources
  - Ethanol (corn, sugar cane, switchgrass / cellulose, …) = “biogasoline”
  - Biodiesel (soy, canola, jatropha, sugar cane …)
  - Biomass gasification (cellulose, animal waste, landfill gas)
  - Used cooking oil / animal fat … too little volume
“Fossil Alternative Fuels”

- Synthetic liquids – Fischer-Tropsch
  - Natural gas to liquid (GTL)
  - Coal (to gas) to liquid (CTL)
- Requires lots of water for coal to liquid
- Excellent fuel properties, especially diesel
  - Zero aromatics
  - Zero sulfur
- Lower emissions – but not low enough
Other Alternative Fuels from Coal

- **Methanol**
  - Poor autoignition quality
  - Toxic, soluble in water

- **Di-Methyl Ether (DME)**
  - Gaseous at normal atmospheric pressure and temperature – requires pressure to liquefy
  - Good for cooking and for potato guns

- Neither is a good diesel fuel
Renewable Diesel Fuels

- Bio-derived diesel
  - Soy, Canola / Rapeseed, Jatropha
  - Fatty Acid Methyl Ester (FAME)
  - Molecule generally heavier than average diesel
  - Quality is crucial -- Glycerin impurity is a filter killer

- Bio-produced diesel
  - Genetically engineered yeast produce diesel-range hydrocarbon from sugar (Amyris)
  - Algae
Producer-Gas 1 MW Power Generation Plant Coimbatore, India
Coconut Shells to Electricity and…

... Activated Charcoal
Personal Example of the Benefits of DOE Public-Private Partnerships

2007 Dodge Ram
- Cummins 6.7 l Diesel
- Met 2010 emissions 3 years ahead of schedule
- First commercial introduction of NOx adsorber for diesel emission control
- 50% reduction in noise
- Higher power and torque
- Up to 30% better efficiency than gasoline
- Evolved directly from DOE LDD technology program

Thanks!
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