Alternative Fuels and Systems for Refuse Trucks

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March 23, 2005
Purpose: Overview of alternative fuel and advanced propulsion technologies for refuse applications, which reduce regulated emissions and potentially lower O&M costs

• Alternative fuels
  – Natural gas
    • Natural gas engine and vehicle R&D
    • Landfill gas to LNG
  – Biodiesel blends

• Hybrid propulsion systems
  – Hydraulic hybrids
  – Hybrid electrics
Natural Gas

New Jersey EcoComplex, Burlington Co., NJ
Natural Gas Engines

• Benefits
  – Petroleum displacement
  – Meet EPA emissions requirements ahead of schedule
  – Less noise than conventional diesel
  – No diesel smell
  – Lower fuel cost
    • NG – Roughly $1.50/diesel gallon equivalent
    • Diesel – Over $2/gallon
  – O&M costs are becoming equivalent to diesel
  – Carl Moyer credits

• Issues
  – Fueling station cost
  – Limited range with CNG; less of an issue with LNG
Next Generation Natural Gas Vehicle Activity

• DOE, NREL, SCAQMD, CEC started Next Generation Natural Gas Vehicle activity in 2000
  – Focused on developing natural gas engines and platforms for medium- and heavy-duty applications
  – Meet or beat EPA standards
    • 2007 - 1.2g/bhp-hr NOx; 0.01g/bhp-hr PM
    • 2010 - 0.2g/bhp-hr NOx; 0.01g/bhp-hr PM
  – Conducted workshops involving engine and vehicle OEMs and other stakeholders to gather their input
Next Generation Natural Gas Vehicle Activity

• Market assessment indicated refuse trucks and transit buses best applications of NG engines

• Vocation profile data included
  – Annual mileage
  – Range
  – Power requirement
  – Fuel economy
  – Refueling practices
  – Trade cycles

• End users surveyed to assess decision factors
  – Reliability
  – Maintenance cost
  – Vehicle purchase cost

• Lifecycle cost analysis indicated vehicle cost and annual mileage/fuel use are most critical to refuse collection

• Less critical – fuel cost, fuel station cost, annual maintenance cost
Natural Gas Engine Development

• Current or near-term availability
  – Cummins Westport (1.5g NOx + NMHC)
    • B Gas Plus; 5.9L; 195 hp; 420–500 lb-ft torque
    • C Gas Plus; 8.3L; 250–280 hp; 660–850 lb-ft torque
    • L Gas Plus; 8.9L; 320 hp; 1000 lb-ft torque
  – John Deere (1.2g NOx)
    • 6081H; 8.1L; 250–280 hp; 735–900 lb-ft torque
  – Mack (aiming for 2010 EPA compliance)
    • E7G; 12L; 325hp; 1250 lb-ft torque
  – Clean Air Power (2007-2010 EPA compliance)
    • C-13 Caterpillar; 13L; 425hp; 1450 lb-ft torque

• 2010 EPA compliant engines are being developed for MY2007 production
Natural Gas Engines

• NREL has performed in-service evaluations of natural gas refuse trucks
  – Waste Management; Washington, PA
  – Norcal Waste System; San Francisco, CA
  – Los Angeles Bureau of Sanitation

• Evaluations available on Advanced Vehicle Testing website

• Results
  – Start-up problems were experienced but were overcome
  – Drivers reported that the performance of the natural gas trucks was as good or better than diesel
  – Fuel economy for natural gas engines is improving
  – Maintenance costs are higher, but should improve
  – LNG cost was a major component of operational costs
Landfill Gas to LNG

• DOE/Brookhaven National Lab working on LFG to LNG process

• Benefits
  – Greenhouse gas reduction
  – Co-production of food-grade liquid CO\textsubscript{2}
  – Imported petroleum displacement

• Sites
  – Arden Landfill in Washington, PA
    • Waste Management; Applied LNG Technology; Mack Truck
  – Burlington County Landfill, NJ
    • Acrion; Mack Truck; Air Products

• Enabling technologies
  – Gas cleanup
  – Liquefiers for LNG (-259\degree F)
Landfill Gas to LNG

• Gas cleanup
  – Typical LFG composition: 50% methane, 40% carbon dioxide, and 10% nitrogen, oxygen, volatile organic compounds
  – Challenge is removal of CO$_2$
  – Acrion CO$_2$ wash technology looks promising

• Liquefiers
  – Small-scale liquefiers (10,000 gal/day) typically operate at lower efficiency, but adequate using low cost/no cost fuel
  – Design requirements
    • Low initial cost
    • Reliable performance
    • Robust refrigeration system
    • Residual CO$_2$ removal
Landfill Gas to LNG

- Process energy efficiency roughly 80%
- 1MMBtu methane = 2,000 SCF of LFG = ~10 gal LNG
- System cost effectiveness a function of equipment investment expense, operational cost, available gas volume, and LNG price
- 10K gallon/day process ~ $4M initial cost
Biodiesel

Harvesting rapeseed, a biodiesel feedstock
Biodiesel Blends

• Most diesel engine manufacturers approve B5 (5% biodiesel) blends
• B20 blend is becoming socially acceptable, but not fully supported by engine manufacturers
Biodiesel Blends

• Benefits
  – Petroleum displacement
  – Greenhouse gas emission reduction
  – Increased lubricity
  – No engine or infrastructure modifications required
  – Less PM emissions, diesel odor and smoke (B20)
  – Domestic, “homegrown” fuel

• Issues
  – Slightly higher NOx emissions
  – Fuel quality has been inconsistent
  – Higher cost (may be offset by a tax credit)
Heavy Hybrids
Hydraulic Hybrids

- Pressurized hydraulic fluid captures braking energy
- Reversible hydraulic pump/motor coupled to the driveshaft
  - Braking pumps fluid from low pressure to high pressure accumulator
  - During acceleration, high pressure fluid flows through hydraulic motor to low pressure accumulator to provide torque to the driveshaft
- Peterbilt and Eaton are developing a Model 320 using Hydraulic Launch Assist™
Hydraulic Hybrids

• Benefits
  – Higher fuel economy
  – Reduced vehicle emissions
  – Reduced brake and drivetrain wear
  – Equal or improved vehicle acceleration
  – Lower cost than electric hybrids

• Issues
  – Unproven technology
Hybrid Electric Vehicles

• Hybrid electric systems manipulate electrical energy
  – Generator operates during coasting, braking, idling
  – Energy stored in batteries and/or ultracapacitors for use by electric motor during acceleration
  – Electric motor and ICE can operate together (parallel) or ICE can function as a generator (series)

• Benefits
  – Improved fuel efficiency
  – Reduced emissions
  – Lower operational costs due to decreased brake wear
  – Improved acceleration

• Issues
  – High cost
  – O&M costs could be high
DOE Advanced Heavy Hybrid Propulsion Systems (AH\textsuperscript{2}PS) Project

- AH\textsuperscript{2}PS goal is to commercialize vehicles by 2010
  - Increase powertrain efficiency 100%
  - Meet 2007-2010 EPA emissions standards
  - Increase component reliability and durability
- Project teams
  - Eaton/International/Ricardo
  - Oshkosh/Rockwell/Ohio State U.
  - General Motors/Allison transmission
  - Caterpillar Inc.
Advanced Heavy Hybrid Propulsion Systems Project

- Next-generation technologies
  - Propulsion systems
  - Engine technologies
  - Motor/generator technologies and motor control
  - Energy storage architectures/systems
  - Power electronics & control systems
  - Auxiliary load electrification
  - Advanced vehicle systems modeling & optimization
  - Waste heat recovery systems
  - Heavy hybrid testing development

- Hybrid electric transit buses are starting to emerge; no commercial product on the horizon for trash haulers
Summary

• Emerging alternative technologies reduce regulated emissions and are targeted to provide lower O&M costs
• Some technologies are ready-to-go
  – Natural gas
  – Biodiesel
• Others are near term
  – Landfill gas
  – Hydraulic hybrid
• Longer term
  – Hybrid electrics
  – Fuel cell