Near Zero Emissions
Engine Technologies
For Heavy Duty Transportation

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LA Basin and San Joaquin Valley Need More Emission Reductions, Sooner

SCAQMD carrying capacity for 80 ppb ozone standard = 160 tpd NOx

SCAQMD 642 TPD in 2010

SJVAPCD carrying capacity for 80 ppb ozone standard = 115 tpd NOx

SJVAPCD 560 (?) TPD in 2012

Carrying capacity for 75 ppb ozone standard = 80 tpd NOx

NOx...
Mobile Sources with Good Potential for Conversion to NG (in red)

(298 tons/day out of total 319 tons/day)
Five Strategies for Emission Reductions

**Goals**
- NOx: Reduce to ZE-equivalent ~ 90% below EPA 2010/Tier 4
- GHGs: Reduce to 2050 goals ~ 80% below current levels

**Advanced Engines and Drivelines**
- GHG and NOx reduction through combustion optimization and increased efficiency

**Advanced after-treatment**
- NOx Reduction through Advanced After-treatment
- GHG and NOx reduction through increased efficiency

**Hybridization**
- GHG and NOx reduction through increased efficiency

**Vehicle Integration**
- GHG and NOx reduction through increased efficiency and low-carbon fuels

**Fuels, Storage & Infrastructure**
- GHG and NOx reduction through efficiency and low-carbon fuels
Technology Advancements to Reduce Emissions and Increase Engine Efficiency

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| NOx: Reduce from 0.2 Gr/Bhp-Hr to 0.02 Gr/Bhp-Hr | • New or enhanced combustion strategies  
• Optimized Compression Ratios  
• On Board Diagnostics  
• Advanced Sensors/Controls  
• Innovative and Advanced Cycles  
• Waste Heat Recovery  
• Camless Engine & HCCI  
• Multi Port Injection  
| • Enhanced 3-way Catalyst  
• Lean burn + SCR  
• Rich burn + NSCR + EGR  
• Lean burn + SCR + Oxidation Catalyst  
• Lean burn + Lean NOx Trap (LNT)  
• Advanced control  
| • Various drive-train configurations to capture waste energy to “assist” the primary drive  
• Hydraulic hybrid  
• Battery-Electric  
• Advanced Plug-in range extender (FC, turbines)  
• Dual Mode Catenary hybrid  
| • Incremental improvements to known strategies  
| | • RNG from organic waste, dedicated crops or sunlight  
| | • Aerodynamics  
| | • Weight reduction  
| | • Tire rolling resistance reduction  
| | • Friction & Parasitic reduction  
| | • Improved compression technology  
| | • Low pressure storage  

Increase Thermal Engine Efficiency From ~35 to 50%
Multiple Strategies to Address NOx Emission Reductions

- Advanced combustion and after-treatment for CNG/LNG engines
- Next generation after-treatment
- Hybridization
- CNG/H₂ blends

“Power plant equivalent” Goal (0.02 g/bhp-hr)
Similar Technology Strategies Can Reduce GHG Emissions

Efficiency Improvements and Renewables Availability Increase Over Time

- Petroleum Fuels
- CNG/LNG
- Efficiency Improvements
- Renewable Blends / H2

2050 Goal

GHG emissions (from 1990 levels)
Engine Technology Advancements

- Advanced Combustion – IC Engine
  - Spark Ignition
  - Compression Ignition
  - Homogeneous Charge Compression Ignition (HCCI)
  - Direct Injection (DI)
  - Low Peak Temperature Combustion (LPTC)
  - Camless Engine (Electronic Valve Timing)
  - Sensors & Controls
- Advanced Turbines
Various Types of Engine Ignitions

- **Diesel Engine** (compression ignition)
  - Fuel injector
  - Hot flame region: NOx + smoke

- **Gasoline Engine** (spark ignition)
  - Spark plug
  - Hot flame region: NOx

- **HCCI Engine** (Homogeneous Charge Compression Ignition)
  - Low temperature combustion: ultra low emissions

- **Direct Injection**
Engine Controls and Exhaust Treatment

- Stoichiometric Engine + NSCR (TWC) + EGR
- Lean Burn + SCR + Ammonia/Urea
Other Technology Advancements

• Advanced After Treatment
  – Selective Catalytic Reduction (SCR)
  – Non-Selective Catalytic Reduction (NSCR)
  – Lean NOx Catalyst (LNC)
• Waste Heat Recovery
  – Bottoming Cycle
• Hybridization
• Renewable Natural Gas
Next Generation Refuse/Transit

**Project Overview**

- Develop dedicated natural gas engine with near zero emissions without sacrificing performance or efficiency compared to 2010 engine standards
- Doosan and SWRI are the technical leads
- On-road testing to begin late 2014 – plan to test 3 vehicles

**Potential Benefits:**

- 75%+ reduction in NOx emissions
- Similar efficiency and cost to diesel alternatives

**Goals & Targets**

- Modify 11L 340hp Doosan engine (conversion from lean burn w/SCR)
- Stoichiometric operation, TWC, Cool EGR
- Advanced ignition system for highly dilute mixtures
- Optimized in-cylinder turbulence & High efficiency turbo matching
- Advanced control for knock and misfire detection

**Partners**

- CEC, DOE, SCAQMD and SWRI
Low Emission Turbine Drive

**Project Overview**
- Demonstrate near-zero emissions dual liquid/natural gas combustor for existing 350 kW gas turbine engine designed for Class-8 trucks
- Brayton Energy, Kenworth & FedEx -- develop a Class 8 MT dual fuel truck

**Potential Benefits**
- Near-zero emissions (75% NOx improvement)
  NOx < 0.05 g/bhp/hr, CO< 0.02 g/bhp/hr
- Fuel flexibility
- Improved efficiency from advanced turbine design

**Goals & Targets**
- Testing of turbine in truck chassis is schedule for late 2013
- First chassis dynamometer runs expected in July 2013
- FedEx will receive the CNG-only truck (made by Kenworth) in late 2013 and operate in 2014 in CA

**Partners**
- CEC, DOE and Brayton Energy
US Hybrid: Plug-in Hybrid Natural Gas Drayage Truck Demonstration

**Project Overview**
- Demo of 80,000 GVWR Nat Gas Plug-in Hybrid Truck
- Utilizes ISL-G (8.9 L) CARB certified engine and 100 kWh Li-Ion Battery-Pack

**Potential Benefits**
- Eliminates frequent periods of idling typical at Port facilities where drayage trucks often queue for long periods.
- Hybrid truck will operate in electric mode (EV mode) around 25% of time (30 miles) in charge depletion mode, then in hybrid mode with sustaining charge.
- No limitation of the range and usage and will have higher number of operating hours than a diesel truck.

**Goals & Targets**
- Target of 30% fuel reduction due to HEV operation
- Out-perform strict CARB emission standards

**Partners**
- CEC, US Hybrid, GTI and Freightliner
RFP to Develop & Demonstrate Near Zero Emissions HD Engines

• SoCalGas, CEC, SCAQMD and SJVAPCD are partnering to fund On-Road Heavy-Duty Development, Integration, and Demonstration of Ultra-Low Emission Natural Gas Engines.

• The RFP emissions targets are:
  – 0.02 grams per brake horsepower-hr (g/bhp-hr) NOx
  – 0.01 g/bhp-hr particulate matter (PM)
  – 0.14 g/bhp-hr hydrocarbon (HC)
  – 15.5 g/bhp-hr carbon monoxide (CO)

• Proposal are due July 24, 2013

• http://www.aqmd.gov/rfp/index.html (RFP P2013-22)
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