(HD Diesel) Engine Technologies for the Future

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Our Products Must Meet Customer Requirements

- High Performance
- Low Noise and Emissions
- Reliable
- Low Initial Cost
- Fuel Efficient
- Durable
- Low Maintenance
- Connected and Integrated Systems
Cummins Engines
109 to 3,500 HP
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109 to 3,500 HP
“Fuel Economy” isn’t “BSFC” and it isn’t at a “point” - Duty Cycle Matters
Ultra-Low Emission HD Diesels
It’s ALL about Technology Integration

Air Handling & EGR

Combustion

Fuel Systems

Aftertreatment

Electronic Controls

Innovation You Can Depend On™
Evolution of HD Diesel Technology

1990

Aftercooling

500 ppm S

Electronic Fuel Systems

1990-2000

15 ppm S

Diesel Particulate Filter

1990-2000

Cooled Exhaust Gas Recirculation

1990-2010

Selective Catalytic Reduction

1990-2020

500 ppm S
Evolution of HD Diesel Technology

- **98% Reduction in NOx and Particulate**
- Diesel Particulate Filter
- Selective Catalytic Reduction
- Cooled Exhaust Gas Recirculation
- 15 ppm S
- 500 ppm S
- Electronic Fuel Systems
- Aftercooling

**Combustion Development**

- 1990
- 2000
- 2010
- 2020

**Total Cost of Ownership**

**Fuel Efficiency**

**Reliability**
Stable Product Architecture

- Cost
- Quality
- Reliability
- Customer acceptance

- Requires a long-term view
Evolution of Cummins Heavy-Duty Product Architecture

- **2010**
- **System Integration**

Diagram showing the evolution of Cummins heavy-duty product architecture, including fuel injection, particulate filters, SCR systems, and Urea dosers, with emphasis on system integration.
Heavy Duty Engine Efficiency

Brake Thermal Efficiency (%)


SCR

EGR
Evolution of Diesel Technology

- CO₂
- NOx, PM
  - Selective Catalytic Reduction
  - Diesel Particulate Filter
  - Cooled Exhaust Gas Recirculation
  - Electronic Fuel Systems
  - Aftercooling

Timeline:
- 1990
- 2000
- 2010
- 2020
Reducing CO₂

- Idle Reduction
- Low "Net Carbon" Fuels
- Hybrids
- High Efficiency Clean Combustion
- Waste Heat Recovery
- Low Temp Aftertreatment
Energy Source

* “Not to scale”
Reducing CO₂

- Idle Reduction
- Low Carbon Fuels
- Hybrids
- High Efficiency Clean Combustion
- Low Temp Aftertreatment
- Waste Heat Recovery

CO₂ ↔ Fuel Efficiency
2010 HD Engine Energy Balance

Fuel Energy 100%

Indicated Power 50%

Heat Transfer 26%

Exhaust 24%

Gas Exchange 4%

Friction 1.5%

Accessories 2.5%

Brake Power 42%
Enabling Technology for Efficiency Improvement

Advanced Combustion (Mixed Mode)
- Stoichiometric
- Early PCCI
- Lifted Flame

- Indicated Power 55.5%
- Heat Transfer 23.5%
- Exhaust 21%
- Gas Exchange 2%
- Friction 1.0%
- Accessories 2.5%
- Brake Power 50%

Fuel Energy 100%
Enabling Technology for Efficiency Improvement

Advanced Combustion
- Higher Inj. Pressure, Multiple Inj
  - Cooled EGR
  - Flexible Air Handling
  - High Cylinder Pressure
- Closed Loop Combustion Control

Indicated Power 55.5%

Fuel Energy 100%
- Heat Transfer 23.5%
- Exhaust 21%

Gas Exchange 2%
Friction 1.0%
Accessories 2.5%
Brake Power 50%

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Enabling Technology for Efficiency Improvement

- **Fuel Energy**: 100%
- **Indicated Power**: 55.5%
- **Heat Transfer**: 23.5%
- **Exhaust**: 21%

  - **Gas Exchange**: 2%
  - **Friction**: 1.0%
  - **Accessories**: 2.5%
  - **Brake Power**: 50%

- **Low Temperature Aftertreatment**
  - lower soot loading
  - low pressure drop
  - regeneration controls/strategy
Enabling Technology for Efficiency Improvement

Fuel Energy 100%

Indicated Power 55.5%
Heat Transfer 23.5%
Exhaust 21%

Gas Exchange 2%

- Electrically assisted turbo
- EGR pump
- Variable valve actuation

Friction 1.0%
Accessories 2.5%
Brake Power 50%
Enabling Technology for Efficiency Improvement

Fuel Energy 100%

- Indicated Power 55.5%
- Heat Transfer 23.5%
- Exhaust 21%

- Gas Exchange 2%
- Friction 1.0%
- Accessories 2.5%
- Brake Power 50%

Friction Reduction
- Piston and rings
- Bearings
- Surface treatment

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Enabling Technology for Efficiency Improvement

Fuel Energy 100%

Indicated Power 55.5% (+5.5%)

Heat Transfer 23.5% (-2.5%)

Exhaust 21% (-3%)

Gas Exchange 2% (-2%)

Friction 1.0% (-0.5%)

Accessories 2.5%

Brake Power 50% (+8%)
Reducing CO₂

- Idle Reduction
- Low Carbon Fuels
- Hybrids
- High Efficiency Clean Combustion
- Low Temp Aftertreatment
- Waste Heat Recovery

CO₂ ↔ Fuel Efficiency
Waste Heat Recovery vs. Hybrid

- Hybrid
- Waste Heat Recovery
- Heavy Duty
- High Horsepower

Fuel Economy Benefit

Frequent Start/Stop vs. Seldom Start/Stop

Duty Cycle
Waste Heat Recovery

Fuel Energy 100%

Indicated Power 55.5%

Heat Transfer 23.5%

Exhaust 21%

Waste Heat Recovery

Gas Exchange 2%
Friction 1.0%
Accessories 2.5%
Brake Power 50%
Waste Heat Recovery

- Engine
- Power Turbine
- Condenser
- Boiler
- Pump
- Waste Heat
- Additional Power
ISX Engine with EGR
ISX Engine with WHR

- Preserve EGR Control System
- WHR Power Turbine
- Boiler replaces EGR Cooler and integrates with EGR system
Energy Balance for Waste Heat Recovery and Electric Accessories

Fuel Energy 100%

- Indicated Power 55.5%
- Heat Transfer 19.5%
- Exhaust 19.5%

Gas Exchange 2%
Friction 1.0%
Accessories 1.0%
Brake Power 57% (+ 15%)
EGR Source (ORC) 4%
EGR + Exhaust Source 1.5%

Electric Accessory Drive

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Heavy Duty Engine Efficiency

- Advanced Combustion
- Waste Heat Recovery
- And
- Vehicle Electrification

+25% Fuel Economy

Waste Heat Recovery

Brake Thermal Efficiency (%)

Reducing CO$_2$

- Idle Reduction
- Low "Net Carbon" Fuels
- Hybrids
- High Efficiency Clean Combustion
- Waste Heat Recovery
- Low Temp Aftertreatment
Producer-Gas 1 MW Power Generation Plant Coimbatore, India
Innovation You Can Depend On™

- 您可信赖的创新
- L’innovation Sur Laquelle Vous Pouvez Compter
- 期待に答える技術革新
- Innovación En La Que Usted Puede Confiar
- 신뢰할 수 있는 혁신
- Inovação Que Você Pode Confiar
- नवयुक्ति जिस पर आप निर्भर कर सकें