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# High Performance Natural Gas Technology for Mining and Rail

Mining Diesel Emissions Council  
Annual Conference

Toronto, Ontario  
October 2010

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## Westport Innovations Inc.

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- Recognized as the leading developer of gaseous fuel engine technology
- Originated from research at the University of British Columbia early '90's
- Public company on the Toronto Stock Exchange (TSX:WPT 1999) and NASDAQ (NAS:WPRT 2008), formed in '95
- Approximately 235 employees
- Revenues of C\$130 million (FY2010)
- Market Cap ~\$700M




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## Westport at a Glance


**Market Focus**

- Transformation of markets for petroleum-fueled engines to alternative fuels




**Position**



- Global leader in medium and heavy-duty commercial vehicle engines operating on alternative fuels



**Strategy**

- Market penetration via OEM partnerships and JV's; All manufacturing outsourced

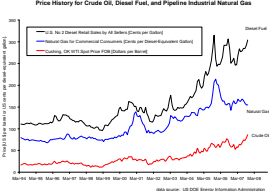



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## Why Alternative Fuels for Transportation?

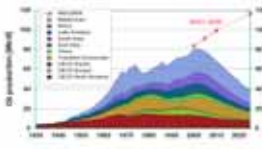
**Energy Prices**

Price History for Crude Oil, Diesel Fuel, and Pipeline Industrial Natural Gas



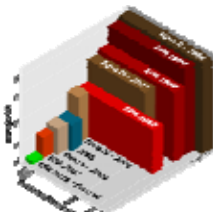
**Energy Security & Supply**

Forecasts of oil supply and demand




Source: Energy Watch Group Oct 2007


**Diesel Emissions Standards**





**Climate Change**



**Urban Emissions**



# Westport Market Interest

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**Mid-Range Truck/Bus**




**Heavy-Duty Truck**




**Light-Duty Industrial**




**Enabling Technologies**




**Off Road Truck**



**Rail**



Potential HHP Development

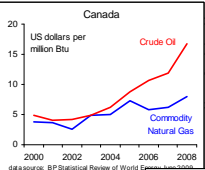


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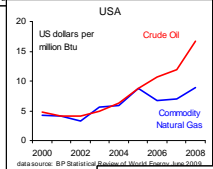
# World Natural Gas Prices

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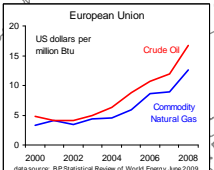
**Canada**



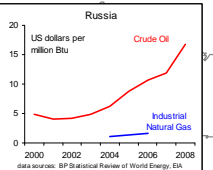
**USA**



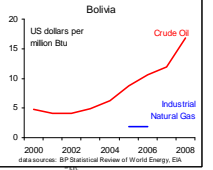
**European Union**



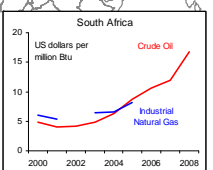
**Russia**




**Bolivia**



**South Africa**



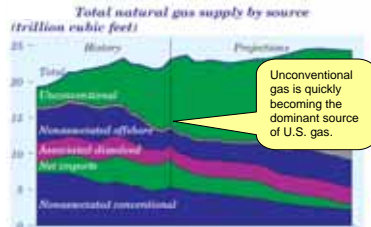
Note: Crude Oil and Natural Gas commodity prices do not include refining or processing costs



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# Energy Security: U.S. Gas Reserves are Rising

- Today
  - There are large supplies of natural gas, about 100 years' worth at current consumption rates
  - Reserves in the U.S. have increased by 27% in the past 3 years as gas shales have come on stream
  - Shale gas basins could contain two to four times the proven gas reserves in the US
  - Indeed, gas producers are concerned about depressed gas prices resulting from this huge new supply—and they are searching for new consumers of their gas, such as transportation
- Medium-term
  - As the techniques for extracting gas from gas shales spreads to other parts of the world, other gas reserves will probably also increase
- Long-term
  - There is a vast amount of gas trapped in methane hydrates in the ocean on the continental shelves, perhaps more than all other known fossil fuels—but no one knows how to extract it economically
  - The world will not run out of natural gas any time soon, and it may become the dominant fossil fuel of the future



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# Technology Review

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## NG Technology Options for Locomotives

- Three combustion technologies for NG:
  - Spark-Ignition (SI)
  - Fumigated Dual-Fuel (DF)
  - High Pressure Direct Injection (HPDI)
- SI and DF have pre-mixed air/fuel mixture during intake and compression stroke, leading to risk of detonation, lower power density, lower efficiency, and increased methane emissions
- HPDI is diesel-cycle engine that retains diesel performance and efficiency with low methane emissions and ~25% GHG reduction vs. diesel

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## HPDI Technology

- Pilot diesel injected just prior to natural gas to provide energy for auto-ignition of gas injection
- Natural gas injected at high pressure at end of compression stroke (no pre-mixed air/fuel)
- Low diesel usage under all conditions
  - Average of 4-6% diesel over vehicle operating cycle
- Diesel Engine Performance remains
  - Same high power and torque
  - Same or higher efficiency
- Robust combustion over wide range of fuel composition (no premixed air/fuel so no chance of detonation)



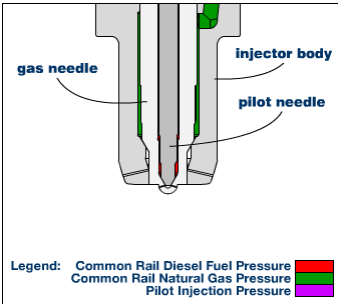
<b>Typical Emissions</b> (vs. base diesel)			
	NOx	PM	GHG
N. America	-33%	-	-20%
Australia	-	-45%	-25%

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# High Pressure Direct Injection

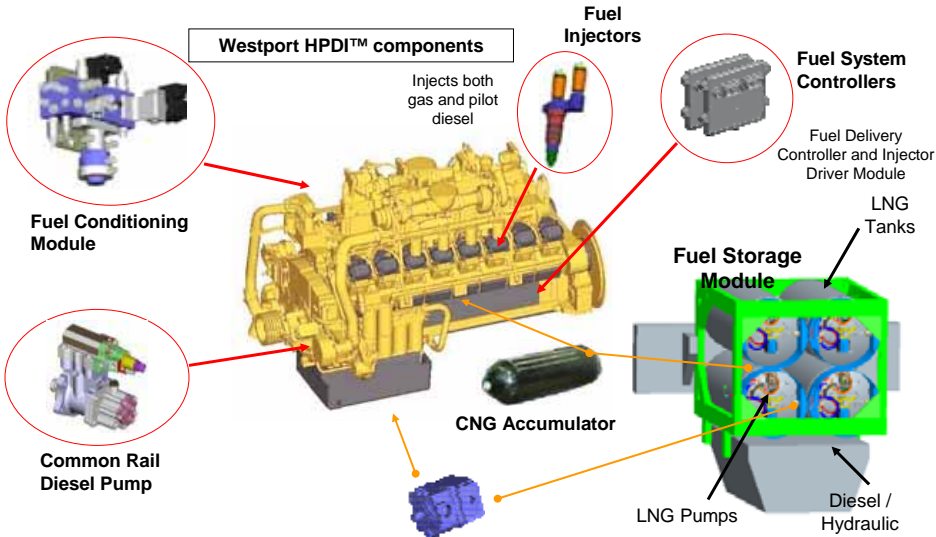
- Common-rail style injector
- Directly replaces diesel injector
- Capable of independently injecting diesel and gas at up to 30 MPa injection pressure
- Diesel used as an ignition source, actuation fluid, lubricant, and coolant



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# HPDI Fuel System



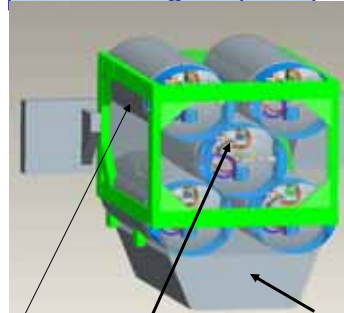
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## Range of an LNG Mine Truck

- LNG has ~ 60% of the energy of diesel fuel on a volume basis
- LNG has ~ 115% of the energy of diesel fuel on a mass basis
- HPDI uses about 5% diesel fuel over an operating cycle
- Conceptual designs with one or multiple-tanks
- Design targets:
  - 12-15 hours between refuel
  - <20 min refuel time

*1.7 gal LNG will enable the same range as 1.0 gal diesel, but fuel will weigh 13% less (not including tank)*



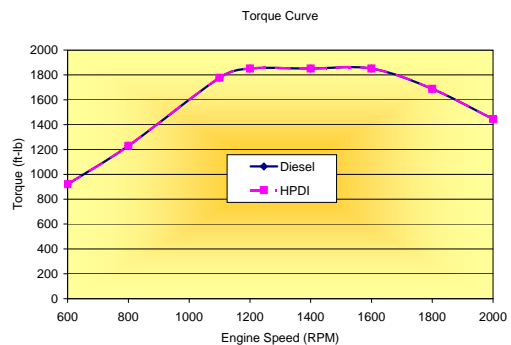
LNG Tank      LNG Pump      Diesel Tank

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## Performance – Power & Torque

- Identical torque curve as selected diesel ratings
- Provides compatibility with diesel drive train components
- No change in cooling requirements vs. base diesel
- Ratings of 400-475hp (1,450-1,750 lb-ft) in NA being certified to EPA 2010
- Ratings of 500-580hp (1,650-1,850 lb-ft) in Australia certified to ADR 80/02
- Similar BMEP as HHP engines

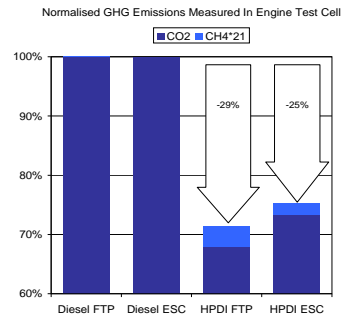


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## Australian HPDI Emissions Results

- Australian HPDI engine certified to ADR 80/02 (December 2007)
- 25% GHG reduction on ESC test and 29% reduction on FTP
- PM at 50% of base diesel engine



	CO <sub>2</sub> g/bhp-hr	CH <sub>4</sub> g/bhp-hr	NOx+NMHC g/bhp-hr	CO g/bhp-hr	PM g/bhp-hr
ADR 80/02 Limit	N/A	N/A	2.5	15.5	0.10
FTP Composite	413	1.0	2.1	3.0	0.04
ESC 13-Mode	368	0.5	2.1	2.2	0.04

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## HPDI Key Benefits

- Fully preserve base diesel engine's performance characteristics without physical changes to the base engine
- Matches or exceeds diesel engine efficiency
- Operates at all times with high gas substitution, average of ~95% energy consumption is natural gas
- Engine out emissions are typically reduced by 30% for NOx, 50% for PM, and >20% for GHG
- Low methane emissions
- No pre-mixed air/fuel so HPDI is not limited by knock
- Robust combustion with wide fuel composition allowance
- Architecture compatibility with base diesel engines (EGR, DPF, SCR compatible)
- Proven technology in HD on-road applications
- Speed-to-market through collaboration with Westport

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## Westport HHP Activities

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### High Horsepower Applications for Natural Gas

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- HHP applications, such as mine trucks and locomotives, consume large quantities of fuel which offers significant economic and emission reduction opportunities
- Minimal fuel infrastructure needed to support concentrated HHP applications
- LNG production infrastructure scale is compatible with HHP applications
- Considerable interest by HHP operators and OEM's in natural gas for economics, emissions, and greenhouse gases
- Westport has organized to pursue HHP opportunities



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## LNG Mine Truck Interest - History

- Westport involvement in mining applications:
  - 2000 – Consortium including Placer Dome/Kennecot, Komatsu, and Cummins investigate feasibility of LNG mine truck for Cortez
  - 2001 – HazOp review completed for Cortez with no identified obstacles
  - 2004-2006 – EDL and Westport prepare feasibility study of LNG MHT (Australia and global). EDL financial challenges prevented further funding of project.
  - 2006-2008 – Engage mining company interest and various truck/engine OEM's
  - 2007 – Risk Assessment performed with an Australia mining customer and truck/engine OEM
  - Sept 2008 – Global Financial Crisis
  - 2009 - Feb 2010 – Building mining customer and fuel-provider interest

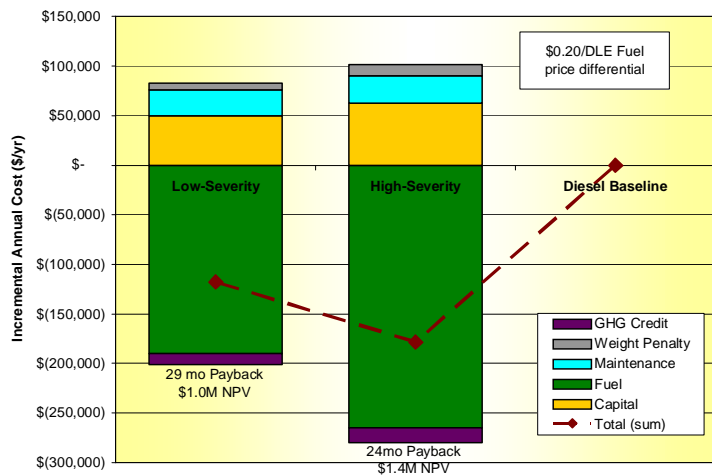
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## Lifecycle Cost Example

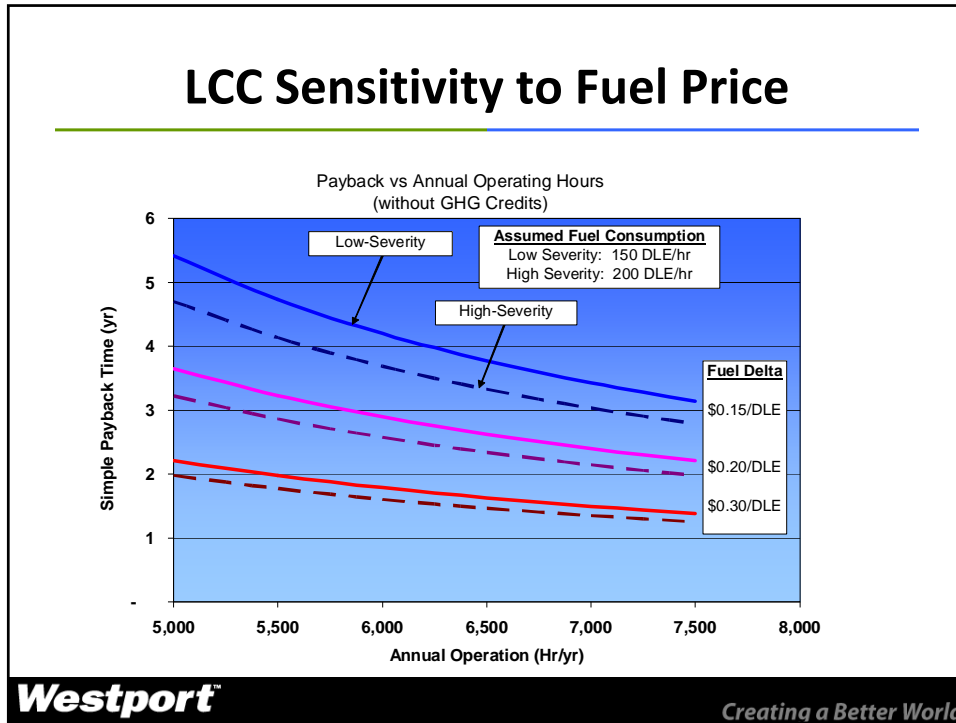
Key Assumptions:	Low-Severity	High-Severity	Units
Incremental System Cost	\$400,000	\$488,000	USD
Annual Operation	6,500	6,800	hr/yr
Engine Life	75,000	75,000	Hours
Base Fuel Consumption	150.0	200.0	DLE/hr
Incremental Maintenance	\$4.00	\$4.00	\$/hr
GHG Value	-\$20	-\$20	\$/Tonne

HPDI Mine Truck LCC Components



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### Market Opportunity

- Strong correlation between mining activity and regions with attractive natural gas fundamentals (price, availability)
 

<u>Region</u>	<u>Key Drivers</u>
- Australia	Fuel Price, GHG
- South America	Fuel Price
- North America	Fuel Price, Emissions, GHG
- Eastern Europe	Fuel Price
- Corporate image concerning GHG emissions and the potential for more substantial returns from carbon trading factors into this discussion in all regions
- Over 75% of mining operations are in locations that have inexpensive access to gas
  - Based on current fuel pricing, in such locations we have estimated a payback time for the incremental cost of a repower or new product to be less than 3 years

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## LNG Supply

- For most mines, a new LNG production facility will need to be constructed to provide sufficient fuel volume
- While some mining companies may be willing to take on the fuel production, there are many experienced energy companies interested in investing in this infrastructure with recovery through fuel sales
- The fuel consumption of one or two mines is an ideal scale for underpinning an efficient LNG production facility
- LNG can use a variety of feedstock sources:
  - Pipeline natural gas
  - Stranded gas wells near mine sites
  - Coal mine methane (CMM) or coal seam methane (CSM)
  - Bio-methane from a wide range of sources (waste)
- Natural gas at the mine site can also be used for power generation, process heat, and LNG off-sales to support on-road transportation

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## The Westport Carbon Project

- Supports the economic and environmental value proposition we offer to customers
- Demonstrates the rigorously verifiable GHG emission reductions of Westport HD and Cummins Westport ISLG engines:
  1. Vehicles from global fleets “bundled” into the WCP
  2. Customers required to sign emission transfer agreements transferring ownership of emissions to Westport
  3. Westport verifies emissions data via annual survey
  4. Carbon is monetized and rebate cheques are issued to customers annually



HD Trucks - 40 tonnes per year x \$20 per tonne = ~\$800 per vehicle/yr\*

Locomotives – 200-800 tonnes per year x \$20 per tonne = ~\$4k-\$16k per loco/yr\*

*\* Carbon rebate per vehicle dependent on carbon price per tonne and vehicle operating data collected via annual survey*

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**Thank You**

[www.westport.com](http://www.westport.com)

Bruce Hodgins

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