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# CERI Commodity Report - Natural Gas

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## Natural Gas – A Niche Solution for Heavy Vehicles in Canada

Heavy diesel vehicles use a significant amount of energy. Defined as trucks and buses weighing more than 4.5 tonnes, heavy diesel vehicles make up less than 4 percent of on-road vehicles in Canada, yet they consumed nearly one-third of vehicle fuel, or 16 billion litres of diesel fuel in 2006. Typically travelling three times the distance of a passenger vehicle, heavy vehicles may use half a litre of fuel per kilometer, for an annual energy consumption that is thirty times greater than that of a passenger vehicle. Trucks, buses, street sweepers, and highway tractor trailers are all examples of heavy diesel vehicles.

| Typical Annual Fuel Consumption | |
|---|---|
| Passenger vehicle | 2,400 m3 |
| Refuse truck | 24,000 m3 |
| Transit bus | 39,000 m3 |
| Tractor trailer | 58,000 m3 |

Heavy diesel vehicles are responsible for a large part of the growth in greenhouse gas emissions from on-road transportation sources in Canada since 1990. According to Canada's National Greenhouse Gas Inventory, emissions from heavy diesel vehicles have increased nearly 19 Mt $CO_2e$ since 1990, representing almost half of the growth in carbon emissions from on-road vehicles since 1990. Heavy diesel vehicles are also expected to be one of the fastest growing sources of carbon emissions through to 2020, according to Natural Resources Canada.

Increasingly stringent tailpipe standards, the introduction of ultra low sulphur diesel fuel and changes to diesel technology, including the addition of diesel particulate filters (2007), and the use of selective catalytic reduction, involving spraying urea into vehicle exhaust to neutralize nitrogen oxide (NOx) emissions (2010), have no impact on carbon emissions from heavy diesel vehicles.

### Heavy Natural Gas Vehicle Technology

There are two types of engine technologies currently in use for heavy natural gas vehicles in North America: spark-ignited stoichiometric engines from Cummins Westport, and compression cycle high pressure direct injection (HPDI) engines from Westport Innovations. Both of these engine

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Editor-in-Chief: Mellisa Mei **(mmei@ceri.ca)**

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suppliers are Canadian companies, with Cummins Westport formed as a joint venture between Westport Innovations and US-based engine manufacturer Cummins in 2001.

**Spark-Ignited ISL G Engine for Buses and Trucks**
(Cummins Westport)
The first spark-ignited internal combustion engine for heavy vehicles was developed in the mid-1980s in Ontario. Seven Hamilton Street Railway diesel transit buses with Cummins engines were modified to operate on compressed natural gas (CNG). This work led to the development of the L10 natural gas engine, which was used in first generation natural gas transit buses that were sold to municipalities in North America. This early generation technology had performance and reliability issues which resulted in a mixed experience for early adopters.

Subsequent generation of spark-ignited natural gas engines have had significantly improved performance, reliability, and fuel efficiency. The current fourth generation natural gas engine, the ISL G, met EPA 2010 diesel emission standards three years early, and was the only engine to do so. This engine also meets other stringent standards, including the California Air Resources Board (CARB) 2010 standards, and the European Euro V EEV standards. The 8.9 litre engine is available in 250 to 320 horsepower ratings, and provides power and torque comparable to a diesel engine.

Cummins Westport now has more than 20,000 engines in service around the world in transit bus, refuse, school bus, and vocational truck applications. The fuel source for these engines may be either CNG or liquefied natural gas (LNG).

**HPDI Engine for Highway Tractor Trailers**
(Westport Innovations)
On an entirely separate research and development path were the efforts of Professor Philip Hill at the University of British Columbia's Mechanical Engineering Department. During the 1980s, Professor Hill was interested in reducing harmful NOx and particulate matter emissions, while preserving the performance and efficiency of heavy diesel engines. His laboratory work focused on injecting a small amount of diesel fuel into a heavy diesel engine to trigger combustion, followed by a main injection of natural gas. The development of a unique two phase injector was part of this work and represented a key breakthrough.

In 1995, Westport Innovations was formed in Vancouver, with the HPDI technology as its principle asset. In 1999, Westport signed a memorandum of understanding with Cummins to explore the development of the HPDI system in Cummins 15 L ISX engine for highway tractor trailers.

Following successful technology demonstrations in both California and Ontario from 2005 to 2006, Westport secured EPA and CARB certifications for the HPDI system, and began commercial product sales in 2007. There are currently about 200 highway tractor trailers operating with the HPDI system in the US and in Australia. The fuel source for the HPDI system is LNG.

**Increasing Availability of OEM Vehicles**

Natural gas engine technology for heavy vehicles is a mature and commercial technology. There are an increasing number of original equipment manufacturers (OEMs) that offer factory-direct heavy natural gas trucks and buses.

All major refuse truck manufacturers sell natural gas trucks including Peterbilt, Autocar, American LaFrance, Mack, and Crane Carrier. Similarly, most major transit bus OEMs produce natural gas buses including New Flyer Industries, Daimler Bus North America, North American Bus Industries, and El Dorado. Freightliner recently announced natural gas availability in its M2 112 vocational truck series, with six LNG and CNG truck configurations. Natural gas highway tractor trailers are manufactured by Kenworth and Peterbilt.

As heavy diesel vehicles increase in cost and complexity, heavy natural gas vehicles provide an increasingly cost competitive, lower emission alternative for public and private fleets. In offering natural gas products, heavy vehicle OEMs are seeking to capitalize on growing market and government interest in reducing the emissions impact of transportation.

**Benefits of Heavy Natural Gas Trucks & Buses**

Many heavy vehicles operate in a return-to-base mode, where vehicles return to the yard at the end of the shift. This fleet model offers a particularly good fit for natural gas since refuelling infrastructure investment can be minimized. In addition, heavy vehicles are typically bought on specification, so customer fuel and range requirements can be met as with a diesel vehicle.

Heavy natural gas vehicles offer several benefits compared to heavy diesel vehicles:

1. Lower cost fuel – Fleets can reduce their operating costs per kilometer with natural gas. Natural gas is typically 20 percent to 40 percent less expensive than diesel fuel. Current estimated fuel savings are $8,000 per year for a transit bus, and $12,000 per year for a tractor trailer.

2. Lower carbon fuel – Natural gas is the lowest carbon fossil fuel. Natural gas already exceeds proposed low carbon fuel standard goals of a 10 percent reduction in carbon compared to conventional transportation fuels. The well-to-wheel lifecycle greenhouse gas benefits of heavy natural gas vehicles range from 17 percent to 25 percent, or about 8 to 40 tonnes less $CO_2e$ per heavy vehicle per year, according to Natural Resources Canada's *GHGenius* lifecycle emissions model.

3. Reductions in criteria air contaminants – Heavy natural gas vehicles also reduce criteria air contaminants which affect local air quality, producing lower levels of NOx, volatile organic compounds, carbon monoxide, and sulphur dioxide compared with diesel vehicles.

4. Heavy natural gas vehicles are capable of operating on up to 100 percent renewable natural gas, produced by upgrading biogas from waste sources to pipeline grade gas. Biogas from municipal landfill and wastewater treatment plants, or from the anaerobic digestion of agricultural or forestry residue may be used. The use of renewable natural gas in heavy vehicles reduces life cycle emissions by more than 85 percent, or 40 to 120 tonnes of $CO_2e$ per heavy vehicle per year.

**Challenges Associated with Heavy Natural Gas Vehicles**

The greatest barrier to market adoption of heavy natural gas vehicles is the upfront capital cost associated with vehicles and refuelling infrastructure. A natural gas transit bus or refuse truck has an estimated 10 percent to 15 percent capital cost premium, relative to a comparable diesel bus or truck. Natural gas highway tractor trailers are 50 percent to 60 percent more expensive than diesel tractor trailers. While there is the potential to significantly lower these premiums through production economies of scale, the challenge is to build market demand in order to reach this scale.

High initial capital costs are associated with building refuelling infrastructure. However, financing models are available for private, onsite refuelling, through some of the regulated utilities in Canada, and through private sector companies that finance the capital cost of infrastructure over a long-term fuel supply contract.

**Public Policy Considerations to Encourage Adoption**

Despite being a technology leader in the natural gas vehicle sector, Canada lags other jurisdictions when it comes to market adoption of heavy natural gas vehicles. Transit use of natural gas in Canada is approximately 2 percent, compared with 20 percent in the U.S. Currently, there are no natural gas refuse trucks or highway tractor trailers in Canada.

A perceived lack of long-term natural gas supply has constrained public policy thinking in this area. Yet, the increasingly abundant natural gas supply outlook, attributable to both shale gas developments, as well as the potential for increased LNG imports, is now changing the entire North American supply picture. Given this context, it would be of value to consider the use of natural gas for heavy vehicles as a niche opportunity to reduce emissions from transportation sources in Canada.

Assuming 20 percent of heavy vehicles in Canada operated on natural gas, the total gas demand for this sector would be 109 Bcf (equivalent to 3.2 billion diesel litres) per year. This represents less than 5 percent of current Canadian domestic natural gas consumption.

Measures that would encourage the use of natural gas in heavy vehicles include:

1. Tie government funding for transportation to emissions performance. For example, Southern California regulates public and private fleets operating 15 vehicles or more, and requires the procurement of the "best available commercial technology." Natural gas is the technology of choice in this environment.

2. Fund profile demonstrations to support awareness building, education, and outreach to heavy vehicle fleets. To initiate its Clean Air Action Plan, the ports of Los Angeles and Long Beach established a program to fund lower emission drayage trucks. Westport LNG trucks were the first trucks to be funded. The program aims to replace more than 16,000 diesel trucks, by 2012, with half of the replacement trucks to operate on alternative fuels.

3. Establish consistent, long term funding or other fiscal measures that create market stability, and that reward the purchase of lower emission heavy vehicles. Lower emission vehicles, whether natural gas, hybrid electric or other technologies, are more expensive vehicles. Consistent and predictable funding, that fleets could count on accessing, is a major factor in the purchase decision. Successful measures in the US have included long-term vehicle tax credits, ranging from US$2,500 for passenger vehicles to US$32,000 for heavy vehicles, and a US$0.50 per gallon tax credit on natural gas sold as for vehicle fuel.

The use of CNG and LNG for heavy vehicles can provide a targeted solution to reduce carbon emissions, and lessen the air quality impact of heavy vehicles. Canada has strong technology capabilities in the area of heavy natural gas vehicles and station infrastructure, which could be leveraged for both economic and environmental gain.

**For more information, please contact:**

Alicia Milner
President, Canadian Natural Gas Vehicles Alliance
350 Sparks Street, Suite 809
Ottawa, ON K1R 7S8
Office: (613) 564-0181
E-mail: Alicia.Milner@cngva.org
**www.cngva.org**