

Vehicle Conversion to Natural Gas or Biogas

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Factsheet

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INTRODUCTION

This Factsheet provides information on the opportunities and limitations associated with using natural gas, biogas or biomethane as a vehicle fuel. It discusses the different types and forms of fuels, the process of converting a vehicle and the refuelling options in Ontario.

Fuelling a Vehicle With Natural Gas or Biogas

Using this type of fuel in a vehicle has several benefits over using conventional fuels:

- lower emissions
- lower fuel costs
- use of self-produced fuel

Natural gas vehicles (NGVs) produce less smog-related emission and reduce greenhouse gas emissions compared to conventional vehicles. Several company owners who have switched their fleets to NGVs have saved, on average, 40%–60% compared to the price of gasoline. For farms with a natural gas well or a biogas system, fuelling can come from fuel generated on the farm. Figure 1 shows a tractor designed to operate on a biogas/diesel blend.



Figure 1. This Valtra tractor can operate for 3–4 hours on biogas between fill-ups. Photo courtesy of AGCO Valtra.

NATURAL GAS

Natural gas (NG) is a gaseous fuel made up of more than 95% methane (CH_4). Natural gas is most commonly used in Ontario in agricultural and industrial applications for process and space heating, as a home heating or cooking fuel, and as a fuel for electricity generation.

Biogas and Biomethane

Biogas is produced from the breakdown of organic materials such as manure, food waste or sewage in an anaerobic digester in the absence of oxygen. In its non-refined state, biogas consists of 50%–60% methane (CH_4), 40%–50% carbon dioxide (CO_2) and some trace amounts of impurities. Biogas that has been refined or “upgraded” to higher CH_4 levels and lower CO_2 levels is called biomethane or renewable natural gas. Once biogas is cleaned and upgraded to biomethane, it is (chemically) virtually the same as NG. The gas collected from sealed landfills is also a form of biogas and may have similar characteristics to agricultural or sewage biogas.

Because biogas has a lower energy density than NG, due to the high CO_2 content, in some circumstances, changes to an NGV’s fuel injection system are required to use the biogas effectively. Before putting biogas directly in a vehicle, ensure that it is warranted for biogas use.

GHGenius, a life-cycle emissions model from Natural Resources Canada, can be used to compare natural gas /biogas greenhouse gas emissions to conventional liquid fuels for vehicles.

FORMS OF NATURAL GAS AND BIOMETHANE

Compressed Natural Gas

Compressed natural gas (CNG) is natural gas that is stored under high pressure. Normally, CNG is stored in high pressure tanks at 21–25 kPa (3,000–3,600 psi). CNG is the form of natural gas most commonly used in vehicles. If moisture is eliminated from the gas, biogas is stored in the same pressure range.

Liquefied Natural Gas

Liquefied natural gas (LNG) is stored in small volume tanks by purifying NG and condensing it into a liquid by cooling it to below -162°C . Under normal conditions, LNG occupies $\frac{1}{600}$ of the volume of NG. It must be kept at very cold temperatures to remain in liquid form, so it is typically stored in a double-wall vacuum-insulated pressurized tank. Because of the difficulties of storing and managing LNG, it is only used as a vehicle fuel in heavy-duty, high fuel-demanding vehicles such as highway trucks and construction equipment.

This Factsheet focuses on fuel pressurized to CNG levels, as CNG is the most common gas form used for vehicles.

NGV WORLD MARKETPLACE

NGV on the Global Stage

According to a recent industry study, Canada's NGV population is currently 12,000 vehicles. In the 1980s and 1990s, NGV use was higher, but demand for NGVs in Canada declined for a number of reasons, including decreased vehicle choices on the market and the elimination of federal and provincial vehicle and station investment incentives.

Pakistan is currently the leading country in the world for NGV use, with 52% of vehicles (2,400,000 vehicles) using CNG. Argentina is second, with 1,800,000 vehicles, and Brazil is third with 1,600,000 vehicles.

Buying an NGV

All the major auto manufacturers are planning to introduce factory-built NGVs into the North American market. Visit NGV Ontario (www.ngvontario.com) for current availability. Currently more than 50 models of factory-produced medium and heavy-duty trucks and buses can be purchased as new vehicles with natural gas fuel systems.

CONVERTING A VEHICLE

Converting from Gasoline to NG

Many vehicles can be converted to operate on both conventional liquid fuels and natural gas. This includes conversions from gasoline to natural gas/gasoline operation and from diesel to natural gas/diesel operation. An NGV that can operate on either gasoline or NG (or diesel or NG) is called a bi-fuel NGV. An NGV that operates only on NG is called a dedicated NGV.

To convert a vehicle from gasoline to bi-fuel operation, install fuel storage cylinders on the vehicle — usually underneath the vehicle or in the trunk. Other required components include stainless steel fuel lines, a regulator to reduce the pressure and a special fuel-air mixer.

The conversion for biogas use is the same as for natural gas use, although due to the lower energy density, consumers may want to install additional fuel cylinders to extend their driving range. Licensed NG conversion companies can provide conversion services. A listing of conversion companies is found at the end of this Factsheet.

With a bi-fuel conversion, a switch installed on the dashboard allows the driver to easily switch between NG/biogas back over to gasoline or diesel at any time, including while driving, idling or in park. In general, bi-fuel vehicles automatically switch to the reserve tank of conventional fuel when the NG tank is empty.

Conversion Cost

The price for a bi-fuel conversion varies from approximately \$6,000–\$12,000. The difference in price depends on the vehicle model, engine type, engine size, type of conversion and the number of fuel storage cylinders.

For example, converting a gasoline-fuelled Ford F150 5.4 L to bi-fuel operation costs approximately \$6,600. Installation includes the fuel train, brackets and two 70-L cylinders. The annual fuel savings, estimated by Enbridge Gas Distribution, is approximately \$3,500 (based on \$1.30/L gas and \$0.75/L compressed natural gas).

Bi-Fuel vs. Dedicated NG

Fuelling a bi-fuel vehicle is easier than fuelling a dedicated NGV, as there are only a limited number of public NG refuelling stations in Ontario. A bi-fuel vehicle can always be run on the more available fuel (gasoline or diesel) until it's convenient to refuel at an NG station.

A bi-fuel conversion also allows the vehicle to start on gasoline or diesel and then switch to running on NG once the engine reaches a certain temperature. A bi-fuel NGV has the additional advantage of having a back-up fuel tank in case the NG tank runs empty.

Dual-Fuel Biogas/Diesel Blend Conversions

It is possible to run a diesel vehicle on a biogas/diesel blend (e.g., 90% biogas, 10% diesel) using a modified diesel engine. The engine runs by injecting biogas into the engine on the air intake stroke (since the methane does not ignite upon compression). The diesel is injected and ignited, which then ignites the biogas, effectively acting like a spark plug. The modifications needed for dual-fuel operation include two fuel injection systems (for the biogas and the diesel), a second fuel line and a tank to hold the biogas.

In a dual-fuel configuration, the engine starts on 100% diesel, and the fuel injection technology increases the biogas ratio as high as the drive cycle will allow (to a maximum of 90%). This technology has several advantages over spark ignition, as it maintains the overall efficiency found with compression ignition, and when the biogas runs out, the engine continues to run purely on diesel.

The diesel/biogas dual-fuel model has been demonstrated at farm-based biogas systems with systems running on a 95%/5% biogas/diesel blend. In such cases, the biogas still contains 40% carbon dioxide and has not been upgraded to NG quality. Figure 2 shows AGCO's Valtra tractor, a biogas/diesel dual-fuel tractor.

A trial performed in the U.K. in July 2010 demonstrated a dual-fuel garbage truck operating with a 90%/10% blend of upgrade biomethane/diesel from a landfill site.



Figure 2. Dual-fuel tractor running on either diesel fuel or biogas. Photo courtesy of AGCO Valtra.

Refuelling Range

Without extra gas storage tanks, a typical NGV car can drive approximately 175 km on one tank of NG (compared to approximately 400 km for a conventional car). This value was calculated assuming a fuel storage volume equal to a normal gas tank. In most cases, larger volume tanks or multiple tanks are installed in NGVs to allow for further distances between refuelling.

Because of the storage space required, conversion to an NGV may make more sense for a truck, van or tractor where additional space is available for extra fuel tanks. If a vehicle runs on non-upgraded biogas (i.e., still containing 40% CO₂ by volume), range is further reduced because of the lower energy density of the fuel.

Kettering University found that their 2009 Chevrolet 2500 HD gasoline/CNG bi-fuel truck had a range of approximately 1,175 km (730 highway miles) — 385 km (240 miles) on biomethane and 790 km (490 miles) on gasoline.

The City of Guelph biogas bi-fuel 2007 Dodge Ram 5.7 L Hemi truck has a range of roughly 200 km when both 70-L biogas tanks are full, and 500 km on gasoline. A full refuelling takes 5–8 hours and typically occurs overnight. The raw biogas contains 60% methane and 40% carbon dioxide. Guelph boosts the gas quality to 86% methane by adding natural gas to meet regulatory safety requirements for having odourant in the gas. By comparison, pure natural gas has approximately 95% methane. Guelph does not remove any carbon dioxide from the biogas.



Figure 3. A commercial van being refuelled with natural gas. Photo courtesy of M.O.T Construction.



Figure 4. A VRA unit filling a City of Guelph pick-up with a blend of biogas and natural gas.

REFUELLING

Refuelling Stations

Public refuelling stations are Fast-Fill systems whereby most vehicles are refuelled in just 2–3 minutes. In Ontario, there are a number of public natural gas refuelling stations operated by Enbridge Gas Distribution, Shell Canada, Pioneer, Sunoco and Canadian Tire. For a current list of NG refuelling stations in your area, visit Natural Gas Vehicles Ontario, www.ngvontario.com. For stations across Canada, visit the Canadian Natural Gas Vehicle Alliance (CNGVA) website, www.cngva.org.

Home or Farm Refuelling with a Vehicle Refuelling Appliance

A vehicle refuelling appliance (VRA) allows operators to refuel the vehicle at home or at the farm, as shown in Figures 3 and 4. The VRA compresses the gas and pumps it into the vehicle fuel tank. A VRA is configured for NG or for biogas. While regulations make it difficult to have a commercial gasoline refuelling station anywhere other than the retail stations, NG refuelling stations have fewer constraints.

Different-sized VRAs offer different filling rates. In 2011, the cost of a small VRA capable of refuelling 3–5 m³ per hour was approximately \$7,500. Designed to refuel a vehicle overnight, this type of slow-fill system can also be fitted with a quick-fill attachment via a storage tank. The VRA slowly fills the storage tank, and the vehicle is quickly filled from the storage tank. Large VRAs with a flow rate of up to 17 m³/hr are also available. Enbridge Gas rents VRA systems from approximately \$90 a month.

Farms that have a natural gas well or a biogas system may need to clean and cool/dehydrate the gas prior to feeding it through a VRA. Eliminating moisture and corrosive elements such as hydrogen sulphide is the first step. Depending on the vehicle design, upgrading the biogas by eliminating CO₂ may also be required.

Energy Value of Fuels

Fuels have a range of energy values. Operators using lower-value fuels can either refuel more often or install a larger fuel tank (Table 1).

Table 1. Approximate energy value range for various fuels

Fuel	Approximate Energy Value MJ/unit (BTU/unit)
Gasoline ¹	32.6–34.6 MJ/L (30,900–32,900 BTU/L)
No. 2 diesel ¹	36.0–38 MJ/L (34,000–36,000 BTU/L)
Propane (LPG) ^{1,2}	23.4–26.9 MJ/L (22,200–25,000 BTU/L)
Natural gas or biomethane ²	35.3–40.6 MJ/m ³ (33,500–38,500 BTU/m ³)
CNG (at 3,600 psi) ¹	10.6–12.2 GJ/m ³ (10,040,000–11,600,000 BTU/m ³)
LNG ¹	20.4–23.6 MJ/L (19,400–22,400 BTU/L)
Biogas ^{2,3}	22–27 MJ/m ³ (20,800–26,000 BTU/m ³)

Note: 1 m³ = 1,000 L 1 BTU = 1.055055853 kJ
1 MJ = 1,000 kJ = 0.001 GJ

¹ U.S. Dept. of Energy: www.afdc.energy.gov/afdc/pdfs/afv_info.pdf

² OMAFRA personal correspondence with Union Gas; OMAFRA Factsheet *Burning Shelled Corn as a Heating Fuel*, Order No. 11-021

³ www.biomotion-tour.eu/biofuels

CONCLUSIONS

The knowledge and technology exist to fuel vehicles using natural gas or biogas. The economics appear to be quite attractive. Rediscovering this approach to vehicle fuelling may provide cost savings to farmers and allow them to produce their own fuels locally.

RESOURCES

The following resources are available to support the conversion of vehicles to natural gas or biogas use. This list is not comprehensive.

Ontario Conversion Garages

www.ngvontario.com/Vehicle_Conversions.aspx

Vehicle Conversion Kits

ECO Fuel Systems

Tel: 604-888-8384

E-mail: andre@ecofuel.com

Fuel Stations

Natural Gas Vehicles Ontario

Website: www.ngvontario.com

Home/Commercial Refuelling Systems

Compression Technology Corporation

(BRC Fuelmaker & Phill)

P.O. Box 545

Milton, ON L9T 4Z1

Tel: 905-699-1564

Fax: 905-636-1387

Attn: Tim Sanford

E-mail: tsanford.ctc@bellnet.ca

Website: www.compression-technology.ca

CNG Canada

1765 Trafalgar St.

London, ON N5W 1X7

Tel: 519 301 8451

Attn: John Wilkinson

E-mail: jwilkinson@cngcanada.ca

Website: www.cngcanada.ca

NG Dryers and Biogas Upgraders

Flotech Greenlane

Tel: 604-568-9042

E-mail: sales@flotech.com

Website: www.flotech.com

Xebec Inc.

Tel: 1-877-GO-XEBEC

E-mail: sales@xebecinc.com

Website: www.xebecinc.com

Natural Resources Canada

Office of Energy Efficiency

Website: <http://oee.nrcan.gc.ca>

Click on *Alternative Fuels*

GHGenius

Website: www.ghgenius.ca

NG Engines

Westport

Tel: 604-718-2000

Website: www.westport.com

Additional Resources

AGCO Corporation

www.agcocorp.com

Biomotion Biofuels

www.biomotion-tour.eu

Canadian Natural Gas Vehicle Alliance

www.cngva.org

Clean Energy Fuels

www.cleanenergyfuels.com

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- U.S. Dept. of Energy. www.afdc.energy.gov/afdc/pdfs/afv_info.pdf

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