Compressed Natural Gas: A viable transport fuel

Compressed Natural Gas (CNG) is a term used to refer to natural gas when it is compressed and stored in a gaseous state for use as vehicular fuel, replacing petrol or diesel. CNG has several advantages over both petrol and diesel, including significant cost savings, emission reductions and a reduced dependency on oil.

Natural Gas Vehicles (NGVs) are used extensively all over the world, and notably in Europe as CNG buses, trucks and light duty vehicles. According to the Natural Gas Vehicle Association of Europe there are over 12 million Natural Gas Vehicles (NGVs) worldwide (September 2010). The International Association for Natural Gas Vehicles estimates that from 2000 to 2009 the average growth of CNG vehicles has been approximately 28% per year.

Table 1 shows the number of NGVs and refuelling points in various European countries:

Country	Total NGVs	Cars and small commercial vehicles	Buses	Trucks	Others	Total Refuelling points	Public refuelling points	Private refuelling points
Italy	698,500	695,000	2,300	1,200	0	770	725	45
Russia	100,052	72,800	1,400	25,800	52	284	244	40
Germany	88,500	82,815	1,550	3,650	485	900	813	87
Sweden	28,093	26,492	1120	480	1	142	110	32
France	13,307	10,000	2,300	1,000	7	125	15	110
Switzerland	9,279	9,028	135	56	60	126	123	3
Austria	4,983	4,936	41	6	0	216	168	48
Netherlands	3,502	2,800	552	150	0	66	49	17
Spain	2539	506	989	1,001	43	42	2	40
Norway	521	280	198	22	21	9	6	3
United Kingdom	220	20	0	150	50	5	2	3

Source: Data supplied by NGVA Europe and the GVR

Natural Gas Vehicles

Worldwide, approximately 65 manufacturers provide over 300 CNG models, ranging from motorbikes to large heavy goods vehicles. Almost all manufacturers have CNG vehicles, including Volkswagen, Hyundai, Toyota, Audi, Nissan, Mercedes, Opel, Volvo, Mitsubishi, Skoda, Honda, Peugeot, Saab, Suzuki, Ford, Citroen, Renault and Fiat, MAN, Iveco, Scania, Isuzu, Mercedes and Irisbus. There are also a large number of companies worldwide that offer the service of converting conventionally fuelled vehicles to CNG.

CNG is used in dedicated CNG engines. These engines are spark ignited and largely similar to petrol engines. Dedicated CNG engines are used for light or heavy duty applications.

CNG is also used in bi-fuel engines, where the engine can run on either petrol or CNG, and only uses one of the two fuels at any given time. Bi-fuel engines use CNG as a fuel source, but they also have the capability of using petrol. When the CNG supply is depleted the vehicle can automatically change to petrol or the driver can simply switch the fuel source to petrol using a switch in the cab. Bi-fuel systems are generally used for small to medium size vehicles and the main advantage of using petrol as a secondary fuel source is an increase in range of the vehicle.

CNG can also be used in dual fuel engines, where a standard electronically controlled diesel engine is modified so that both CNG and diesel are used. The main modification to the vehicle is the addition of the CNG fuelling, storage and injection equipment, as the compression ratio, cylinder heads and basic operation of the diesel engine generally remain unchanged. The duel fuel engine starts as any normal diesel engine and consumes diesel on start-up and while the engine is idling. As the load on the engine increases diesel is automatically replaced by CNG. Dual fuel engines are generally used for heavy duty applications.

Refuelling

CNG vehicles store CNG at ambient temperature in cylinders located underneath the vehicle, or on the roof in certain bus applications. CNG will need to be replenished using refuelling equipment which essentially comprises of one or more gas compressor(s) with inlet pressures of 4-7 barg and outlet pressures of 200-275 barg. There are two broad refuelling options available; fast-fill or slow-fill. Fast-fill refuelling includes on-site CNG storage adjacent to the compressor. The compressor replenishes the on-site CNG storage as it is depleted therefore ensuring that the required amount of CNG is available at all times and refuelling times are typically 3-5 minutes. Slow-fill compressors can be connected to a domestic natural gas supply, are smaller in size and include little or no CNG storage on site. The compressor is connected, via a hose and nozzle, directly to the CNG cylinder in

the vehicle. This slow-fill refuelling process can refuel a vehicle in four to eight hours and is most suitable where vehicles are stationary overnight.

The actual process of refuelling is similar to petrol or diesel: park the vehicle adjacent to the refuelling equipment; attach the CNG refuelling nozzle; complete refuelling; disconnect the nozzle and drive away. The only technical difference is that a positive pressure retaining connection is used rather than a pump. As the system is sealed there are no evaporative losses of fuel, which of course has economic and environmental benefits.

How does CNG work?

1. Natural gas is compressed at a refuelling point and enters the vehicle through the natural gas dispenser or fill post.
2. It flows into high-pressure cylinder(s) that are located on the vehicle.
3. When the driver steps on the accelerator, the natural gas leaves the on-board storage cylinder, passes through the high-pressure fuel line and enters the engine compartment.
4. Gas then enters the regulator, which reduces pressure from approximately 250 barg to approximately atmospheric pressure.
5. The natural gas solenoid valve allows natural gas to pass from the regulator into the gas mixer or fuel injectors.
6. Natural gas mixed with air flows down through the fuel injection system and enters the engine's combustion chambers where it is burned producing energy similar to traditional internal combustion engines.

Performance

Dedicated CNG engines are usually designed to deliver a similar power output to comparable diesel and petrol engines.

In bi-fuel applications, the performance is again similar to diesel engines. In these applications the spark is advanced to ignite the fuel while the piston is still travelling up the cylinder. This gives the fuel more time to burn completely and push the piston back down at its most efficient point. The compression ratio is also usually increased. Drivers using the Bord Gáis Networks bi-fuel CNG Mercedes Sprinter van report no perceptible performance difference between the bi-fuel vehicle and current diesel vans.

For dual fuel engines the diesel engines are designed for higher compression ratios and are better suited for CNG/diesel with little modification. Where a diesel engine is converted to dual fuel and not remapped, the power output is increased for engine speeds up to about 3000RPM, and slightly reduced at higher engine speeds. For retro-fitted vehicles the power output is normally mapped to match the diesel performance characteristics.

Proven technology

CNG is not a new technology, and has been continuously adapting for the past 70 years. CNG is a fuel, and like any fuel it must be handled correctly. Numerous studies have proven that CNG vehicle safety is at least equivalent to petrol vehicles. CNG vehicles pass the same international crash and safety standards as petrol or diesel vehicles.

The CNG supply to the engine is isolated using a solenoid valve when the engine is not in use. In the unlikely event of a leak of CNG, the gas disperses quickly in air. The fuel system is hermetic and has no air inside. It is thus impossible for a flammable mixture to develop within the fuel system.

CNG storage cylinders are increasingly manufactured using lightweight composite materials. The design of natural gas cylinders is subjected to a number of tests, such as heat and pressure extremes, gunfire, collisions and fires.

Natural gas has a narrow range of flammability, it will not combust in concentrations below 5% or above 15% gas in air. Natural gas also has a high autoignition temperature of approximately 650^{o}C, compared to petrol which is approximately 260^{o}C.

Although it is difficult to compare NGVs with existing petrol and diesel vehicles, a survey in the USA of 8,331 natural gas vehicles that had travelled 178.3 million miles found that the CNG fleet injury rate was 37% lower than the petrol fleet vehicle rate. There were no fatalities compared with 1.28 deaths per 100 million miles for petrol fleet vehicles and the collision rate for CNG vehicles was 31% lower than the rate for petrol vehicles.

Cost and Savings

The cost of the fuel itself is significantly less than conventional fuels. A 675 vehicle refuse truck fleet study in Madrid showed that the fuel costs were in the region of 30% lower than the diesel alternative. The same study showed that during the complete truck life, including investments for CNG refuelling equipment and the trucks extra costs, an overall saving of 15% was achieved when compared to the diesel alternative.

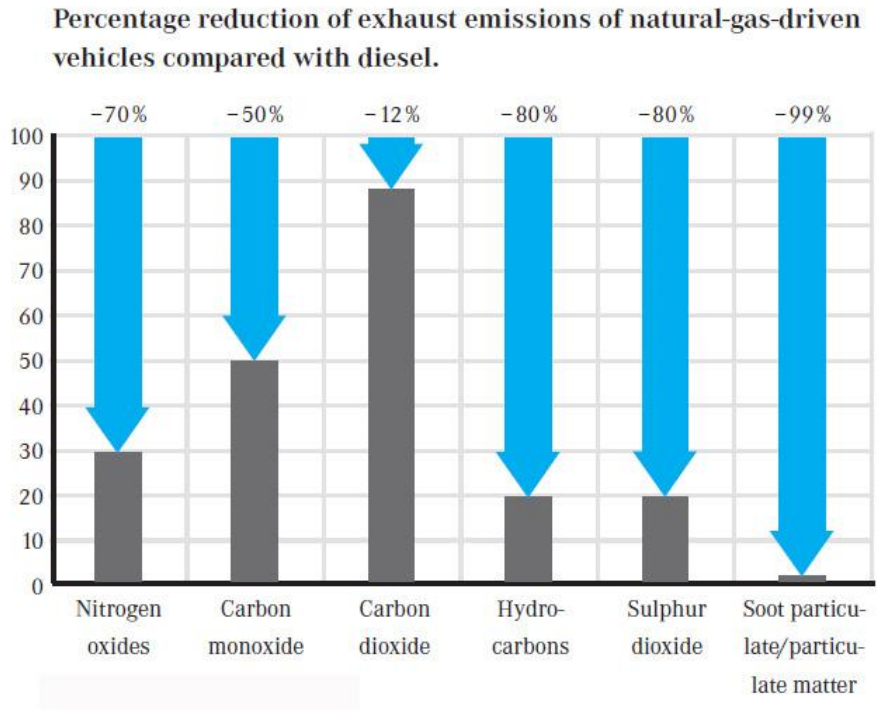
CNG vehicles have numerous components that are similar to those of a traditional vehicle; so much of the maintenance costs will be similar to diesel or petrol vehicles. The main differences are engine

oil and spark plugs, which are changed less often as natural gas is a clean burning fuel and produces comparatively little by-products of combustion.

Reduced Emissions

Of all hydrocarbons, methane (the main component of natural gas) has the lowest carbon to hydrogen ratio and is a much cleaner fuel than petrol or diesel. The actual emissions reduction will, amongst other factors, depend on whether the engine is dedicated CNG, bi-fuel or dual fuel, the use the vehicle is put to, the size of the vehicle and the average and maximum and minimum RPM of the vehicle. Research on CNG emission reduction is detailed and varied but, with minor exceptions, significant reductions in emissions of nitrogen oxides, carbon monoxide, carbon dioxide, sulphur dioxide and particulate matter are achieved when using CNG in all of the three applications. Dual-fuel engines show significant reductions in emissions of nitrogen oxides, carbon monoxide, carbon dioxide, sulphur dioxide and particulate matter over the range of engine speeds.

Bord Gáis Networks recently purchased a bi-fuel Mercedes Sprinter van with the reported emission reductions as follows (when using CNG as fuel versus an equivalent diesel fuelled van):



The reduction in nitrogen oxides and particulate matter is of particular importance, as the Euro VI limits due to be introduced in 2013 for certain vehicle categories will require a reduction in nitrogen Oxides of 80% and a reduction in particulate matter of 66% compared to the Euro V stage limits. Noise emissions are also significantly reduced when using CNG vehicles.

Summary

The important challenge of overcoming the refuelling infrastructure needs to be addressed and in doing so Ireland, and especially fleet managers, can benefit from using Natural Gas as a transport fuel. The main advantages of CNG are reduced fuel costs, reduced dependency on oil, significantly reduced emissions, reduced fuel price volatility, reduced noise, reduced fuel costs, reduced total lifetime vehicle costs, enhanced corporate image and EU compliance with Euro VI and beyond.

Photographs:

Bord Gáis Networks Natural Gas Vehicle in Cork

The environmental and economic benefits of NGVs include reduced emissions and lower costs

Madrid currently benefits from 480 CNG buses and 700 CNG refuse collection trucks.