Natural Gas for Vehicles (NGV)

Following a decade-long upsurge in the use of natural gas in the energy sector (heating and especially electricity), new outlets for natural gas are being developed in the transport sector. For countries endowed with substantial local resources, development in this sector can help reduce oil dependence. In addition, natural gas is often used to reduce pollution, particularly in cities.

Heterogeneous Situations

Since the early 1990s, natural gas for vehicles (NGV), generally used in compressed form, has attracted renewed interest throughout the world. A number of countries have undertaken large-scale development programs. At the national scale, tax incentives have been implemented to promote the use of this motor fuel. For the time being, the world market of natural gas vehicles remains small and heavily concentrated: over half of the world fleet is located in the Americas, mainly in Argentina and Brazil.

The Situation of NGV Worldwide

A number of countries, including Argentina, Australia, Brazil, Canada, Italy, New Zealand and the United States, launched ambitious natural gas motor fuel programs many years ago.

Latin America

In Latin America, NGV has grown very quickly, boosted by legislation encouraging its development. Currently, Argentina is by far the world leader: with nearly 1.5 million vehicles, it has the largest NGV fleet (nearly 21% of its total fleet). This is the result of an ambitious urban policy to reduce the harmful environmental effects of the automobile. Between 2001 and 2005, Argentina's NGV fleet doubled. Since the country holds substantial gas reserves, large-scale use of NGV helps it reduce oil dependence while exploiting a domestic resource.

Venezuela and Colombia, which both possess large gas reserves, have also launched NGV development programs.

Brazil started to develop NGV in the early 1980s in response to the second oil shock, but the market never really got off the ground until the 1990s, at the same time as the production of domestic natural gas. During this decade, there was a major drive to develop distribution infrastructure. The market expanded from 110 NGV vehicles in 1991 to 293,000 in 2001, totaling nearly 950,000 today. This being said, ethanol and flexible fuel vehicles continue to play a preponderant role in the Brazilian strategy.

Table 1
NGV worldwide in 2005

Country	Vehicle fleet (thousands)	Consumption (Mtoe)	Number of stations
Italy	382	0.36	509
United States	130	0.43	1340
Germany	27.2	not available	558
Japan	24.7	n.a.	288
Canada	20.5	0.04	222
Ireland	9.8	n.a.	10
France	7.4	0.04	105
South Korea	6.5	0.13	170
Sweden	5.3	0.02	65
Argentina	1439.5	1.89	1402
Brazil	948.3	0.91	1080
Pakistan	800	n.a.	740
India	204	n.a.	198
China	97.2	0.07	355
Ukraine	67	n.a.	147
Colombia	60	0.09	90
Egypt	59.4	0.16	90
Iran	48	0.00	72
Venezuela	44.1	0.12	149
Russia	41.8	0.03	213
Armenia	38.1	n.a.	60
Bangladesh	35	n.a.	95
Bolivia	28.8	n.a.	59
Malaysia	14.9	0.03	39
Tadjikistan	10.6	n.a.	53
Indonesia	6.6	0.03	17
Byelorussia	5.5	0.02	24
Chile	5.5	0.03	12
Thailand	5.5	0.01	34
World	**4603**	**4.22**	**8722**

Source : IANGV, AIE.

Europe

In Europe to date, the market has only developed to a very small extent. At the instigation of European authorities, this situation seems about to change. The European Commission has set an indicative target: NGV is to represent 10% of transport energy consumption by 2020.

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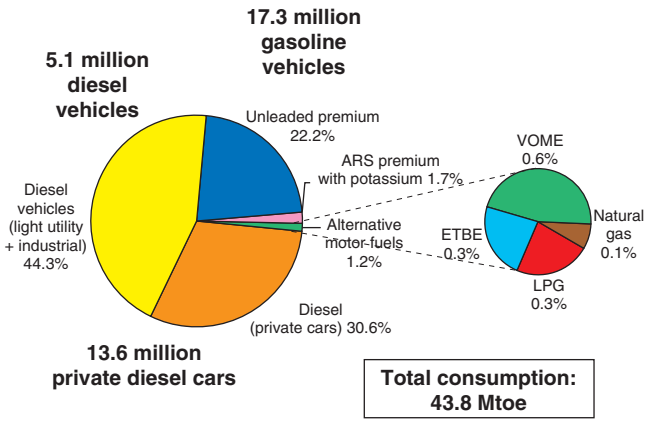
The first country to use NGV to a significant extent, starting in the "Thirties", Italy is currently Europe's largest market and represents more than 380,000 vehicles. Possessing natural gas resources, Italy began building up its fleet long ago. Today, the Italian fleet is aging.

Table 2
European market for natural gas vehicles

Country	Vehicle fleet (thousands)	Consumption (Mtoe)	Number of stations
Italy	382	0.36	509
Germany	27.2	not available	558
Ireland	9.8	n.a.	10
France	7.4	0.04	105
Sweden	5.3	0.02	65
United Kingdom	0.5	0.01	21
Switzerland	0.8	n.a.	58
Spain	0.7	n.a.	28
Europe (total)	**520**	**> 0.6**	**> 1300**

In Germany, where the technology is fairly well developed, 1,000 new stations are scheduled to open between 2003 and 2007. By 2007, 10% of all service stations will be covered.

Fig. 1 Consumption of motor fuel by the French automobile fleet in 2004



Although natural gas had previously been used in the transport sector, NGV technology did not emerge in France until 1998. At that time, the French fleet consisted of about 1,800 light vehicles and a dozen or so buses. In France, the pathway is promoted in a number of ways: tax incentives, subsidies for the purchase of gas-powered vehicles, regulatory constraints that work in its favor and supportive policies.

The French NGV fleet seems to be showing a shift from heavy vehicles to private cars. Out of 8,000 gas-powered vehicles in France, nearly 2,000 are buses and 400 are refuse collection vehicles. Next come company fleets of light vehicles, light utility vehicles and private cars.

NGV still represents only a very small proportion of the French market, but the French Natural Gas Vehicle Association (AFGNV) and the French ministry of the economy, finance and industry recently signed a memorandum of agreement targeting a fleet of 100,000 private cars by 2010.

Key Characteristics of Current Technologies

- *Type of Fleet*

Heavy vehicles as well as light will run on NGV. These vehicles use conventional engine technologies that are well known and immediately available.

Today, most of the heavy gas-powered vehicles are buses and refuse collection vehicles. These applications are especially appropriate for use in urban areas, for a number of reasons. They generate low levels of noise and polluting emissions. In a city, it is not a problem if a vehicle has a limited range or onboard fuel storage capacity. Finally, with respect to logistics, there is a concentration (compressors) at the depot.

In light vehicles, natural gas can be used in bifuel vehicles (gasoline/NGV) or in vehicles running exclusively on natural gas. The intrinsic properties of natural gas are best exploited in dedicated vehicles. The problem is that the motorist needs access to a widespread NGV distribution network. There are few NGV service stations in existence today, which is why carmakers have generally included bifuel (gasoline/NGV) rather than dedicated models in their vehicle range.

- *The Pros and Cons of Using NGV*

There are several advantages to using NGV:

– owing to its low carbon content, it achieves greenhouse gas (GHG) emissions that are 20% lower than for gasoline (basis for comparison: Low Calorific Value[1]);

– there is no need for costly conversion processes;

– it presents a high octane number equivalent (measuring the quality of a motor fuel of the gasoline type);

– like LPG, it obtains energy efficiencies when used to power a dedicated vehicle;

– the use of natural gas, a practically pure compound generating lower levels of polluting emissions, presents clear environmental advantages, especially in urban areas (CO, HC, particles, noise).

(1) Amount of heat released by the complete combustion of a fuel, with the water produced by the combustion remaining as a vapor.

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Environmental Aspects

The replacement of today's gasoline vehicles with light vehicles running on NGV would lead to a drop in total GHG emissions "from well to wheel" of about 15%. This would be due mainly (in a proportion of about 80 to 90%) to a decrease in emissions during vehicle use. However, the share of CO_2 emissions generated at each stage of the supply chain (from extraction to compression in the fuel tank) depends heavily on the amounts of energy consumed and methane leaked during transport. This is a very important point. Natural gas has a global warming potential that is more than 20 times that of CO_2. As a result, efforts to minimize methane leakage should be integral to the development of NGV technology and infrastructure.

During the stage of vehicle use alone, natural gas can reduce CO_2 emissions by more than 20% compared to a gasoline vehicle. Bifuel vehicles (gasoline/NGV) obtain similar results. Dedicated engines can be optimized to run on natural gas and thus deliver better performance levels. For users, the difficulty is that this motor fuel is not easily available. On markets where NGV infrastructure has not yet been developed to any significant extent, bifuel vehicles make a better choice than dedicated ones: they enable the motorist to drive longer or farther between tank refills. A case in point is Europe, where the NGV fleet consists mostly of bifuel vehicles. The most recent models have been optimized to run on natural gas to the detriment of the gasoline operating mode.

With the development of this type of optimized engine, substantial gains are expected as regards air polluting emissions with a local and/or regional impact, e.g.:

– they do not generate any odor, soot, particle, grime or loss through evaporation;

– an engine optimized to run on natural gas produces CO_2 emissions that can be 5 to 10% lower than for a diesel engine.

Comparable levels of performance are obtained for Euro IV gasoline and NGV vehicles. These results can be further improved by exploiting the properties of natural gas. For instance, when the engine is adjusted for cold-start or heavy-load conditions (operating zones difficult for the after-treatment system), natural gas has the advantage.

Economic Aspects

Unlike for many other alternative motor fuels, the total extra cost of implementing NGV technology is low. The largest component of this extra cost is the installation of refueling stations and onboard storage systems.

For individuals, it is apparently more economical to use NGV than gasoline, considering the existing vehicle purchase subsidies and the relatively low cost of the motor fuel (taxed at a low rate). This being said, the prices recently announced in France seem to be higher than those to be found in other European countries, including Germany and Italy.

Table 3
Prices of motor fuels, all tax included, on an equivalent energy content basis, according to the DIREM prices (October 31, 2005) for the petroleum-based motor fuels and ENGVA for natural gas

€/GJ	France	Italy	Germany
Unleaded premium 95	38.2	40.1	40.3
Diesel	30.7	33.6	32.0
LPG motor fuel	27.3	24.3	22.5
NGV motor fuel	20.6	15.5	15.5

Taxes on gas-based motor fuels have been lowered significantly. Since 1997, successive French appropriations bills (the annual "Loi de Finance") have decreased the TICGN and TIPP taxes on LPG and NGV motor fuels. In this way, considered on an equivalent energy content basis, the reduction in the TIPP tax on LPG and NGV motor fuels comes to nearly 80% compared to the diesel taxation.

Based on the motor fuel costs and consumption levels in Table 4 (average consumption being for a C3 type vehicle), and without considering tax breaks or purchase subsidies, an extra cost of €1,800[(2)] at purchase would be amortized after 51,000 km due to the low cost of this motor fuel.

Table 4
Cost of using motor fuels
(not included: vehicle purchase price, insurance or maintenance)

€/100 km	France	Italy	Germany
Unleaded premium 95	8.0	8.6	8.6
Diesel	4.9	5.4	5.2
LPG motor fuel	5.9	5.3	4.9
NGV motor fuel	4.5	3.4	3.4

Table 5
Return on investment for a vehicle running on natural gas compared to gasoline

Motor fuel	Gasoline	Natural gas	Difference
Extra cost at purchase compared to gasoline	0	1,800	1,800
Average consumption (MJ/km)	2.1	2.2	
Cost of motor fuel (all tax included)	1.29 €/l	0.80 €/m^3	
Cost (€ per 100 km)	8.0	4.5	– 3.5
Distance that the natural gas vehicle must travel to get a return on investment compared to gasoline	–	51,430 km	

(2) Source: EUCAR/JRC/CONCAWE.

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In actual fact, the tax credit granted for the purchase of an NGV vehicle (as much as €2,300) covers this extra cost.

Constraints inherent to the NGV technology

Today, especially in France, NGV technology is at a disadvantage in that it lacks a network of stations to ensure large-scale distribution of NGV motor fuel. Furthermore, the prospective car buyer only has a limited number of models to choose from, although manufacturers are starting to extend their selection.

In addition to legislative measures to promote the use of NGV (e.g. creating standards for storage on board the vehicle and at stations), a number of technological advances are required. One example of potential progress: the use of composite materials or other advanced technologies could be generalized to lessen the constraints associated with onboard gas storage relative to volume, range and, to a lesser extent, weight.

There is also another obstacle to overcome: this technology will have to be made acceptable to the public at large, which questions its safety.

Outlook for Development

- *Protocol in France*

On July 4, 2005, a memorandum of agreement was signed in France by the French ministry of the economy, finance and industry and by industrial partners: Gaz de France, Carrefour, Total, PSA Peugeot Citroën, Renault and Renault Trucks, which are all members of the French Natural Gas Vehicle Association (AFGNV). Its purpose is to ensure the success of NGV by 2010.

This agreement breaks down into two main parts:

– The first calls for further developing the current uses of NGV in heavy vehicles. The goal is to double the bus rolling stock, triple the fleet of refuse collection vehicles and extend its use to urban freight transport.

– The second part aims to make natural gas an attractive alternative motor fuel for private cars by 2010, by making the following available:
  . vehicles that can run on natural gas and perform as well as other vehicles (fleet of 100,000 light vehicles by 2010);
  . two types of distribution: home distribution (compressor) and NGV station at conventional service stations (300 by 2010).

- *Pilot Sites in France*

In parallel, the French agency for the environment and the management of energy (ADEME), the French Natural Gas Vehicle Association (AFGNV), the French association of transport authorities (GART) and Gaz de France teamed up at the end of 2004 to establish NGV vehicle pilot sites. The idea was to attract a diversified range of users and set up real dynamics between players in the NGV sector. There are pilot sites in Bourges, Colmar, Montpellier, Orsay, Poitiers and Strasbourg. Eventually, the partners hope to have ten sites. This 2-year program will provide technical and economic credentials that will be useful in marketing natural gas vehicles to different types of operator. ADEME will provide the pilot sites with financial support. In addition to subsidies for buses and refuse collection vehicles, it will cover 30% of the financing for freight transport vehicles whose authorized maximum weight exceeds 3.5 tons. It will also subsidize the purchase of light NGV vehicles by local authorities and business enterprises, in an amount not to exceed €1,500. Finally, for compression stations servicing a fleet of at least 5 vehicles, a subsidy will be granted to cover up to 20% of the cost (ceiling: €20,000).

In Toulouse, another pilot site, a home natural gas compression system will made available.

- *Manufacturers Extend their Range*

Four manufacturers make NGV buses: Irisbus, Evobus, Van Hool and Volvo. For NGV refuse collection vehicles, there are three: Iveco, Mercedes and Renault Trucks/PVI. When it comes to private cars, the offering has been relatively limited until now. However, major motor companies are starting to offer bifuel models (gasoline/NGV), including PSA Peugeot Citroën with its “C3 GNV”, Renault and Fiat as well as German automakers like Volkswagen, Mercedes and Opel. The optimization of NGV utilization (engine/motor fuel configuration and tank integration) should enable deployment of these models. IFP has been or still is involved in several optimization projects, including the Smart NGV demo-car and the Amoga research project concerning engine/motor fuel configuration. Optimization — of the vehicle offering, of maintenance at the dealership and, as we already noted, of motor fuel distribution — is key to the development of this technology.

Conclusions

Different NGV programs have shown that this type of motor fuel is commercially viable in countries that possess adequate gas resources, an adequate distribution network and long experience in the use of natural gas by households and in the industrial sector.

In Europe, NGV has been mainly used by captive fleets, but the development of NGV private cars is a major objective for the years to come. This will require the development of

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distribution infrastructure, both installations at filling stations and at home.

How fast NGV develops largely depends on the implementation of distribution infrastructure. This would encourage carmakers to extend their range and help this technology win over the public at large. To replace 10% of gasoline and diesel with NGV, it would be necessary to equip about 25% of all filling stations to distribute it.

According to work by the European Commission, NGV will become a major contributor in the mix of alternative motor fuels by 2020. The latter are called upon to replace 23% of diesel and gasoline by 2020, with NGV making the largest contribution (10%), ahead of biofuels. This target represents about 5% of EU demand for natural gas. At this stage, the potential market share of NGV should not be limited by problems of supply.

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