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Unconventional Gas
A Game Changer for Transport Too?

Maïté de Boncourt

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Ifri
27, rue de la Procession
75740 Paris Cedex 15 – FRANCE
Tel: +33 (0)1 40 61 60 00
Fax: +33 (0)1 40 61 60 60
Email: ifri@ifri.org

Ifri-Bruxelles
Rue Marie-Thérèse, 21
1000 – Brussels – BELGIUM
Tel: +32 (0)2 238 51 10
Fax: +32 (0)2 238 51 15
Email: info.bruxelles@ifri.org

Website: *Ifri.org*

Executive Summary

A new technology trend, the development of natural gas vehicles, is emerging in the transport sector. While not new this technology is now being simultaneously revived by the discovery of significant amounts of unconventional gas, by the rise of oil prices, and by the decreased confidence in the sustainability of nuclear technology (and subsequent rising electricity prices in Europe). Natural gas could provide a path to a lower carbon intensive transport sector in both developed and developing countries. Gas is cheaper and less polluting than oil. It emits significantly less local pollutants than diesel and less CO_2 than gasoline. Historically present in Italy, South America, Iran and Pakistan natural gas vehicles are emerging in other countries: in some European countries, in the United States, in the Chinese provinces of Shaanxi and Henan, and in India. Asia and developing countries are expected to be responsible for a large share of the car market growth in the next years and consequently for a significant share of transport CO_2 emissions. The adoption of a given technology there could impact global markets and global CO_2 emissions significantly. While the trend is still loose, this paper responds to the possibility that this technology will expand: what would it imply? would it compete with the development of the electric vehicle? is it desirable?

It appears that the advantages of natural gas vehicles are not as clear cut as they seem. Environmentally, they are beneficial only to countries with little -if no- CO_2 emissions standards. Several issues including the development of costly infrastructures are likely to raise costs. Natural gas vehicles development could also slow down the roll out of electric vehicles, hence delaying hopes of smoothing the integration of renewables into the power grid through the use of car batteries' storage capacity. But the main concern is the availability of cheap gas itself, on the basis of which this technology shift could take place. Markets for gas are tightening, price increases have already been announced in many places, and the development of unconventional resources is still surrounded by uncertainties in regards to its cost and timeframe. But even more, gas might be more efficiently used for power generation. The trend is however still nascent. The targeted markets are niche markets, and many bottlenecks including the determination of some governments to promote the electric vehicle instead, would have to be overcome before variants of natural gas transportation technologies can sustainably and significantly secure a large share of vehicle fleets.

Contents

Introduction

Unprecedented amounts of unconventional gas have been discovered in the US and elsewhere in the world, flooding world gas markets. The life span of gas reserves has been extended from 58 years of consumption at current rate to a potential of 250 years or more. Markets and politicians are therefore considering options for using the huge amount of this relatively cheap gas and at a time when oil prices are reaching unprecedented levels since the summer of 2008, driven in part by Mediterranean turmoil, and using these new gas resources in transport looks increasingly like an attractive option; even Gazprom CEO Alexei Miller thinks so[1].

Alternative technologies to diesel and gasoline engines have long been in the spotlight. Indeed, the fight against climate change and the need to reduce CO_2 emissions, as well as the fear of peak oil and the will to reduce dependence on foreign oil have driven the development of new technologies. Current oil prices are providing an even more compelling incentive. More than ever, governments are concerned with reducing their oil bill. While most energy and transport forecasts are based on assumptions of price at $120 per barrel by 2020, oil prices are currently fluctuating around $113 for Brent and $99 on the New York Mercantile Exchange.

Transport currently relies heavily on oil. Today, 53% of world oil production is used in transportation, and the IEA forecasts that almost all of the increase in oil demand between 2009 and 2035 will be driven by transport. Transport's share of oil consumption could indeed rise to 60% in 2035[2], most of it fueling passenger cars. Transport is expected to double by 2030 as China and other emerging economies increase their vehicle fleets at dramatic rates. At the same time, governments seeking to decrease GHG emissions and local pollution in ever-growing metropoles have many incentives to reduce oil consumption in transportation.

A variety of alternative technologies to conventional road transport have been developed, including bio-fuels and electric vehicles. Yet, some of the developed technologies are still in murky water and no short term solution has been found. The first generation of bio-fuels is competing with world food reserves while the roll out of the second and third generations, thought to be more sustainable though less profitable, is still expected. Meanwhile, the accident at

1 European Business Congress, 2nd June 2011, Prague, Czech Republic.
2 IEA, WEO New Policies Scenario 2010.

Fukushima is bringing into question the availability of low carbon electricity necessary to validate the electric vehicle option. The need to improve the safety of nuclear power plants may raise electricity prices, impacting negatively the life price of electric cars. Fukushima has also a short term impact on the development of the electric vehicle market, as it directly negatively impacted the manufacturing of cars in Japan, hence elsewhere in Asia[3]. In this new energy context, CNG technology appears as a new window of opportunity.

The question arises: Why should we develop expensive electric cars while huge amounts of gas, one of the cleanest fuels, could be fueled into transport and most of its current infrastructure at low cost? If the development of shale gas boosts gas vehicle sales, the transition to electric vehicles could well slip into the future. This note explores such a possibility.

3 Japan is a key supplier of cars electronic pieces. IHS estimated that production losses amounted to 700,000 vehicles at the beginning of April, this could increase to 1.5 million unit by July (Les Échos, 8th April 2011).

Natural gas for transport: A low-carbon technology for developed and developing countries

Thanks to the low carbon content of gas, green house gas emissions from compressed natural gas (CNG) cars can be 20%-25% lower those of gasoline engines[4]. Compared to diesel fuelled vehicles, they are not necessarily better on CO_2 emissions, but CNG vehicles emit on average 34% less CO, 24% less NOx and 79% less particulates. This would address the immediacy of unhealthy smog in urban areas and mega-cities.

In the future, CNG could further reduce CO_2 emissions by applying technologies initially invented for conventional internal combustion engine vehicles, such as downsizing (decreasing the size of the engine, without altering its power), direct injection or hybridization. These techniques can reduce the energy consumption of conventional diesel or gasoline vehicles by up to 25%[5], thereby reducing GHG emissions. Natural gas can also be a transition to biogas (i.e. methane obtained by upgrading biogas). Biogas can reduce GHG emissions by 80%[6], and up to 55% CO_2 compared to gasoline and diesel[7]. Finally, CNG can bridge to hydrogen; a technology intended to further reduce CO_2 emissions with no local pollutants.

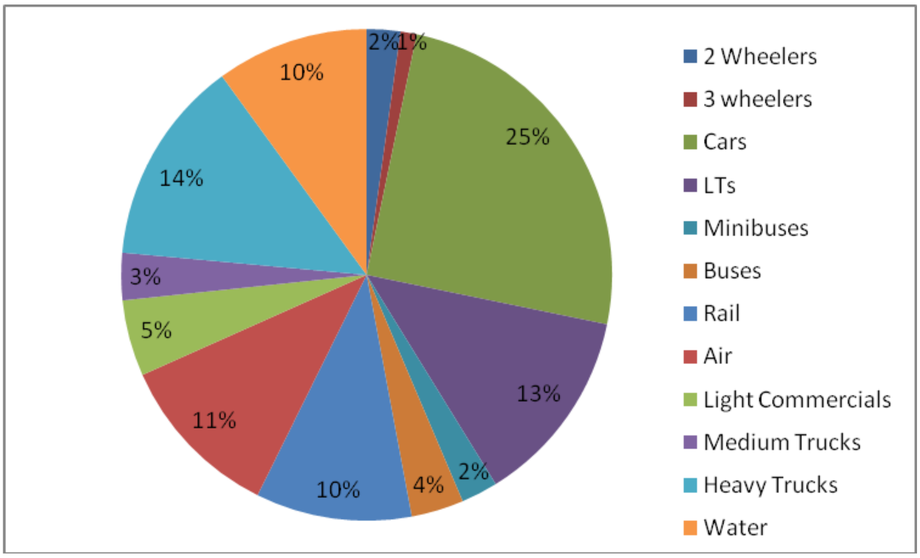
One of the main assets of the natural gas car is that it can be used for any type of vehicle: two or three wheelers, cars, utility, buses, agricultural vehicles, and medium or heavy trucks. It can even be applied for shipping or planes. Natural gas for transport could therefore provide an interesting option to decrease oil consumption and CO_2 emissions from freight, which contributes significantly to the share of GHG emissions. In addition, there are currently few “clean transport” technologies for heavy trucks. The electric vehicle technology, relying today on lithium batteries, is not applicable to the long haul because the distances far exceed the capacity of current lithium batteries. Even hybrid technologies such as start-stop are of little relevance because there is little braking in long-distance driving.

4 ADEME 2006, IEA 2010.
5 Syrota 2008.
6 ADEME 2006.
7 GDF Suez 2009.

Biofuels are a controversial option, especially when mixed with conventional gasoline or diesel, although second generation biofuels are expected to provide better benefits[8].

The familiar form of natural gas is compressed natural gas (CNG), but its energy density is too low for heavy trucks. Liquefied natural gas (LNG), a more energy efficient form of natural gas, is starting to be used for heavy trucks[9]. As heavy duty vehicles (HDV) consume more than light duty vehicles (LDV), they usually run on liquefied natural gas (LNG), as it offers a longer driving range (about 1 000 km compared to 300 km for CNG). LNG is nevertheless more expensive[10].

Figure 1: Transport Green House Gas Emissions by mode in 2010



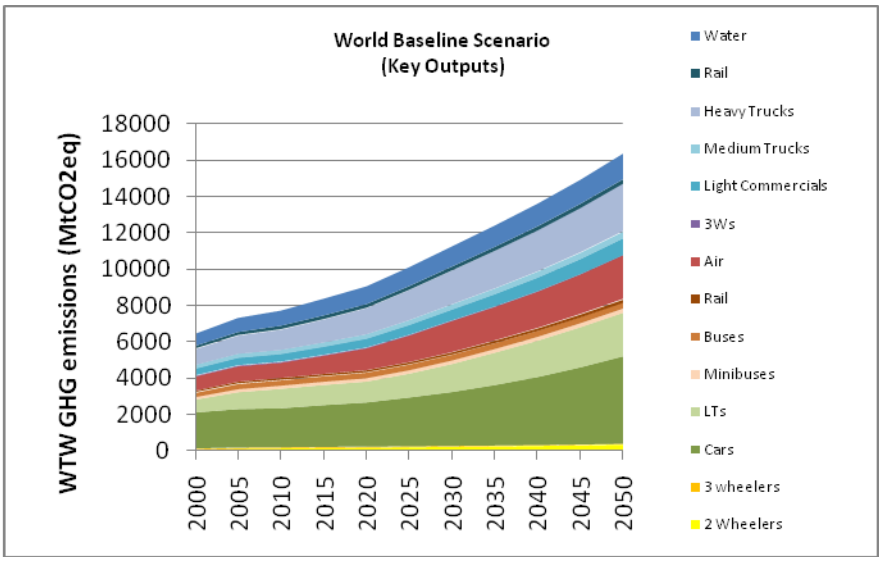
Source: IEA 2010.

8 According to the IEA, freight and medium traffic are responsible for 30% of oil consumption from transport worldwide, a share likely to increase to 35% by 2035 (IEA WEO 2010). For the US alone, heavy trucks were responsible for 12% of the total oil petroleum consumption for all sectors in 2008. Road freight is also responsible for a large share of CO_2 emissions (37% of total GHG Well-to-Wheel emissions world wide).

9 One liter of diesel amounts to 5 liters of Compressed Natural Gas (CNG) but only 1.8 liter of LNG according to the French association of Natural gas Vehicles (AGNV); in other words LNG is less voluminous than CNG.

10 The liquefaction of gas consists of an energy intensive cooling process and the liquefied gas then has to be stored in a special cryogenic tank (so has to be kept below its boiling point of -163°C).

Figure 2: The evolution of transport GHG emissions by mode, if nothing is done to fight climate change



Source: IEA data 2010.

CNG technology would help to reduce emissions from the two major future sources: old cars in Europe and cars in developing countries.

CNG technology can be installed on existing vehicles by converting conventional combustion engines. This retrofitting process can be made on both gasoline and diesel engines.

> Gasoline engines are more easily adapted to gas as they rely on spark ignition. But natural gas can also be used in diesel engines although they rely on compression ignition. To this end, either the diesel engine is modified (by replacing diesel injectors by spark plugs) or dual fuel technology is applied (the gas is the main fuel, and diesel is used to start the engine). Considering the evolution of car fleets worldwide, the possibility to retrofit vehicles, and in particular passenger cars is interesting.

In developed countries, car ownership is quite high at 700 and 500 vehicles per 1,000 people in the US and Europe respectively[11]. New vehicle sales, however, are not expected to growth and may

11 IEA 2010.

even slow. In Europe the fleet renewal rate was 6.7% in 2007[12], and if Eastern Europe is indicative of the European automotive industry, the market will shrink in the rest of the EU also. The car market is also ageing, with people keeping their cars longer. This means that the penetration of new cars with higher emissions standards will have little immediate environmental benefits, with benefits delayed by 8 to 10 years (depending on the car renewal rate). Retrofitting vehicles could accelerate the technology penetration and ease GHG emissions from the existing car fleet. While European regulations limit emissions from new cars to 130gCO_2/km by 2015 and from vans to 175gCO_2/km by 2017, the average European fleet emissions are actually 160gCO_2/km and 203gCO_2/km respectively. This is even more pronounced in the United States.

Because CNG and LNG for transport do not require substantial research and development investments (the automotive sector is considered to be an R&D intensive industry), vehicles could be rapidly and massively produced and manufacturers could make immediate profits.

Retrofitting is also interesting in developing countries. In fact, most of the world car fleet growth, and hence the bulk of GHG by LDV, is expected to come from developing countries. China alone overtook the US for passenger car sales in 2009 and ownership rates are still much lower than in the US (30 versus 700 cars for 1000 people)[13], reflecting the huge market potential. In the medium and longer terms, developing countries, and in particular Asia, will be responsible for a large share of GHG emissions and of oil consumption. They are already facing problems of local pollution in their crowded cities. Yet these countries do not always have the budget or the capacity to develop expensive new technologies such as electric vehicles. But retrofitting an existing car is relatively cheap. The cost of retrofit varies among countries from around \$800 in India, \$2,500 in Europe up to \$10,000 in the US, depending on the size of the vehicle[14]. According to Ford, a basic transit connect model (a van) can be converted to CNG for a cost of \$315[15]. Although this adds to the price, this is much less than an electric car, which costs up to twice the price of its conventional counterpart[16]. The IEA estimates that there is an average price difference of €1956 for an NGV-dedicated car versus its petrol equivalent[17]. Acquiring a CNG car or retrofitting an old conventional car is therefore much cheaper than

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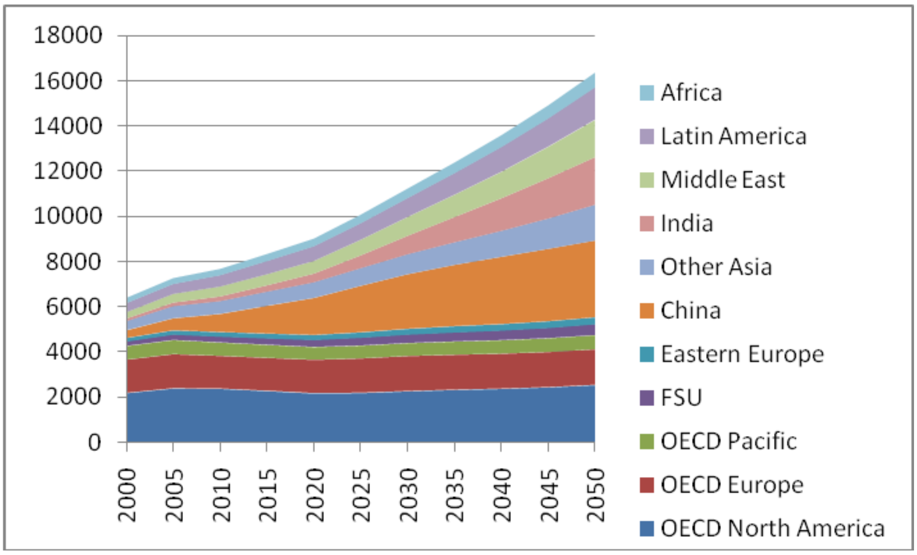
12 Eurostat 2007.
13 IEA WEO 2010.
14 Greencar Website, <http://www.greencar.com/articles/can-convert-natural-gas.php>.
15 Natural Gas Intelligence, 4th April 2011.
16 In other words the price difference between CNG and internal combustion engines (ICE) cars is substantially smaller than between conventional ICE and electric vehicles (the Honda civic GX is priced at more or less \$5,500 than the equivalent conventional Civic Sedan; Volkswagen and Fiat bi-fuel cost an additional \$3,700) (MIT study 2010).
17 IEA CNG 2010.

buying an electric or a plug-in hybrid. Despite signals that hybrid prices are decreasing (the luxurious Ford MKZ conventional and hybrids share the same price, but not the same power), hybrid vehicles are still much more expensive than their conventional counterparts (from $2000 up to $10,000)[18] and their CO_2 efficiency is lower than for natural gas vehicles. CNG vehicles therefore have a good price advantage. The conversion of conventional cars to natural gas is in fact already practiced in several Asian and South American countries such as Pakistan, India, Argentina and Brazil. Gas can not only be used for cars but also for buses, a popular transport mode in these countries. CNG could be a cost efficient way to reduce CO_2 emissions from transport in developing countries, and to combat the unhealthy smog of ever-growing giant cities.

Figure 3: Share of transport GHG emissions by region (in $MtCO_2eq$)



Source: IEA data, Reference Scenario, World Energy Outlook.

But first and foremost, fuel prices for CNG and LNG vehicles are now low. This increases the cost efficiency of CNG as a CO_2 abatement tool, and boosts its competitiveness.

18 Site Internet *About.com*, <http://alternativefuels.about.com/od/hybridvehicles/a/hybridhype.htm>.

Unconventional gas sparks interest in natural gas vehicles

The use of natural gas in road transport is not new. Compressed natural gas vehicles make up 3% of the world LDV fleet, and 4% of sales each year. The introduction of natural gas vehicles was driven in different countries either by the low price of gas or by concerns over the security of supply, and often by a combination of both. Iran promoted the roll out of CNG vehicles following UN sanctions. In South America, governments wanted to reduce account deficits by replacing oil imports by indigenous gas. This happened in countries with indigenous gas reserves such as Argentina, Bolivia or Brazil after the second oil shock; Columbia also wanted to use gas for cars so as to export its oil. In the 1990s these countries sustained the market through tax incentives and infrastructure development. In Europe too (in particular Ukraine, Italy, Moldova) CNG cars were once introduced. In Italy, gas vehicles were first introduced in the 1940s as Mussolini wanted to cut dependency on foreign oil, and then the market was revived in the 90s after ENI started the exploration of gas in the Adriatic Sea[19]. In other places like India the development of CNG cars was an environmental necessity; CNG was introduced in order to reduce local pollution, and in particular diesel exhaust. In the 1990s, governmental programs were finally dropped out of fear that there would be insufficient gas.

19 The sales of CNG cars now represent 9% of the Italian manufacturer FIAT, which owns also the larger share of sales in Brazil.

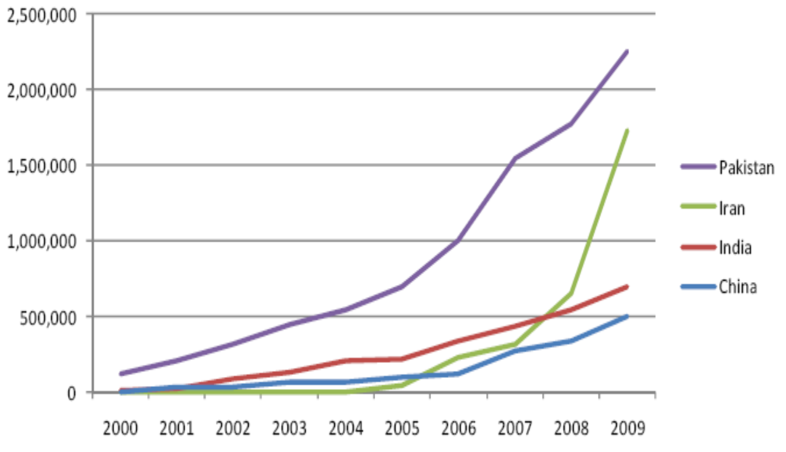
Table 1: NGV Market Share by Country (Source: NGVA 2010)

Country	NGV market share (%)	Country	NGV market share (%)
Bangladesh	61	Tajikistan	5
Armenia	30	India	5
Pakistan	26	Egypt	5
Bolivia	26	Kyrgyzstan	3
Argentina	24	Ukraine	3
Colombia	24	Bulgaria	2
Iran	14	Italy	2
Malaysia	11	Moldova	1
Myanmar	8	Trinidad & Tobago	1
Peru	7	China	1
Brazil	5		

Source: NGVA Europe, NGV Communications Group.

Source: NGV Europe.

Figure 4: Growth of CNG fleet in given countries



Source: NGV Global, NGV Communications Group.

Source: NGV Global.

The discovery of vast unconventional gas reserves world-wide has shifted the picture.

The current glut of gas in the US due to the surge in unconventional gas production, increased global production of LNG, and decreased demand resulting from the economic crisis has decreased prices in the US itself, and other gas markets through LNG arbitrage to Europe. Today's high price of oil makes natural gas look cheap in comparison.

The table below reveals that CNG final price for consumers (including subsidies) is roughly half the cost of gasoline and around 20%-30% less than diesel. In January 2011, the US Department of Energy Clean City Initiative fuel price report estimated that the pump price of CNG per gallon equivalent was 1,93$, compared to 3$ per gallon for regular gasoline. In 2010, the Energy Information Agency stated that "natural gas for transport vehicles currently costs 42% less than diesel fuel, [and] the gap is projected to widen to 50% in 2035 in the reference case"[20].

Table 2: Comparative Fuel prices (in USD/lge)

Country/Region	Diesel (USD/lge)	Gasoline (USD/lge)	CNG (USD/lge)
OECD Europe	1.32	1.39	0.74
OECD North-America	0.57	0.59	0.30
OECD Asia	1.39	1.79	0.62
Argentina	0.56	0.63	0.26
Bangladesh	0.42	0.67	0.22
Brazil	0.89	1.25	0.71
China	0.62	0.77	0.42
Egypt	0.19	0.16	0.07
India	0.65	1.04	0.33
Iran	0.01	0.10	0.04
Malaysia	0.57	0.63	0.22
Pakistan	0.70	0.93	0.49

Notes: Data are taken at various points in time and can therefore vary from data elsewhere in this document; gasoline refers to regular gasoline, except for Pakistan (only premium available).

Source: NGV Europe, 2010.

The gas club is also expanding. Unconventional gas in shale, tight formations and coal bed methane is present in many countries. According to IEA forecasts[21], Chinese gas production could increase from 80bcm in 2008 to 180 bcm by 2035. Indian production, which surged in 2009 to 46 bcm, will probably increase steadily to 60 bcm in 2015 and 100 bcm, thanks in particular to the exploitation of coal bed methane. Unconventional gas also became a game changer in the US, probably holding the biggest reserves of unconventional gas. In Europe, some countries also benefit from unconventional gas resources, and while exploration has been halted in the south of France due to environmental concerns, it is pursued in both Poland and the UK. The growth in natural gas reserves, coupled with high oil prices, could stir interest for natural gas vehicles in these countries.

The use of gas as transport fuel appears a compelling argument for energy security in countries holding indigenous gas resources. For instance, 85% of CNG used in the US is produced domestically[22]. The use of gas as a transport-fuel can ease national budgets, whose deficits are worsened by high oil prices. This aspect was the main driver behind the introduction of the Natural Gas Act by the US president in May 2011.

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20 IEA 2010.
21 World Energy Outlook 2010.
22 Marketing Weekly News 16th April 2011.

The interest for natural gas vehicles has apparently surged in recent months. The most obvious political manifestation of this was the recent endorsement of the New Alternative Transportation to Give Americans Solutions, the so called NAT GAS, by President Obama. The plan, long advocated by the billionaire T. Boone Pickens (the largest share holder in Clean Fuel Energy, a California company owning and operating about 200 natural gas refueling stations in the US), had been put on ice for years. The act, although downplayed from the initial version, aims at refitting the fleet, at least the heavy trucks, through tax credits. In this respect, tax rebates will be granted for the purchase of natural gas, bi- and dual-fuel vehicles (up to 80% of the incremental price under a maximum valued threshold), natural gas fuel (50 cents per gallon equivalent of natural gas), building fuelling stations (up to 50% under a maximum price of 100,000$, equivalent to a Infrastructure tax credit 50% of a maximum price of (100,000$ = medium sized station) and production of natural gas vehicles. The annual cost of this 5-year measure is around $47.5 million.

The use of natural gas vehicles responds to the continuing US concern over dependency on oil imports. As President Obama reaffirmed in a speech in March 2011, the point is to reduce oil imports by one third by 2025. The promotion of natural gas vehicles is one of the few climate and energy efficiency related issues enjoying bipartisan support. Some states are more interested than others, in particular Pennsylvania which holds part of the one of the largest shale gas fields (the Marcellus shale). The “Marcellus Work” is a legislative package targeting the conversion of administration buses, and spending about $208 million over five years for the development of the labeled “clean transportation corridor” composed of 17 new refueling stations, and 85 heavy duty natural gas vehicles. The US Environmental Protection Agency (EPA) also relaxed the regulatory barriers to convert vehicles to alternative fuels. The market has also given some signals. For instance, General Motors has announced the roll out of a CNG van, matching Ford roll out of electric counter-parts[23], and companies have already placed orders for the purchase of such vehicles. In particular, since gas prices are very low at the moment, companies seemed to be interested in LNG for long-haul trucks. Several companies in California ordered new trucks, including Heckmann Water Resources (conversion of water-hauling truck fleet from diesel); AT&T, a telecom company who just ordered an additional 8,000 CNG trucks; Cheasapeake (Oklahoma, US) or U.P.S which opted for 48 LNG trucks with diesel ignition. This is interesting for the use of spare LNG capacity resulting from the discovery of unconventional gas.

India also represents a major opportunity as it has seen significant growth in recent years. Delhi, India’s second most populated city after Mumbai (14 million inhabitants), has been

[23] *Newyorktimes.com*, June 2, 2010.

promoting the adoption of CNG for environmental purposes. Growing urbanization and the expanding share of diesel vehicles in the fleet drive the need for alternative transport options. Furthermore, buses can also be converted to CNG, and cities increasingly develop programs of bus expansion, one of the easiest public transport options as it does not require costly infrastructure. While the majority of bus manufacturers are Indian, Volvo announced last year the roll out of CNG buses. Meanwhile, the Swedish government is also sharing its experience with Delhi on biogas from sewage for transport.

The Chinese case is also interesting. Indeed the government is concerned both with oil dependency and local pollution in cities. According to McKinsey, China could need up to 3 million new buses and will probably have 250 million cars on its roads (as compared to 69 cars in 2010)[24]. Transport will probably burn half of total oil consumption, including 10% for cars alone, and this oil will have to be imported (currently china imports most of its oil from Middle East, some forecasts estimate that up to 70% of oil imports will come from the Middle East). In this respect, since 2005 china is implementing fuel economy standards for urban vehicles. Despite the strong governmental support to electric vehicles (about $15 billion were allocated to research and market development), the CNG fleet (mainly through retrofit) is expanding quickly. In particular the government is planning to replace its own fleet, including public buses. Cities such as Chengdu are massively converting their buses to CNG[25]. Provinces benefiting from unconventional gas have displayed interest in natural gas for transport. The gas network is developing fast in China where 65% of cities are expected to be connected to natural gas by 2050 (source). The Shaan Xi province (a historical coal province) has the highest share of Natural Gas fuelling stations, but the business is expanding also in the Henan province (which also holds unconventional gas).

Natural gas for transport is also expected to develop further in countries where markets have been sustained by direct or indirect government subsidies (Iran, Pakistan, Argentina etc.). In Europe too, despite a very limited market share (less than 1% of the car park with the exception of Italy) some “gas” countries have developed research. The market for LPG (liquefied petroleum gas), in most cases exempted from energy taxes and for which the distribution network is quite developed, will compete with the further development of CNG. This is also explained by the fact that Europe has insufficient indigenous gas reserves, and thus the energy security incentive is less of an argument. This could shift with the discovery of unconventional gas in Poland, which nevertheless renewed its contracts with Russia leading to a potential oversupply of gas by 2014. The development of biogas could also become a driver. Germany and Sweden for instance are developing biogas. Germany has the largest biogas capacity in

[24] China FAQs, Transportation Revolution, World Resource Institute.
[25] McKinsey.

Europe (3,695 t-toe), followed by UK (1,637 t-toe), and far behind France, Italy, the Netherlands etc[26]. Germany has concentrated on the development of infrastructure, and might be tempted to return to this technology now that electricity production is expected to fall dramatically after the announced closure of nuclear power plants. In Sweden, biogas from farms is directly delivered to CNG fuelling station, and the country is trying to export its technology, even more so as its national automotive champion, Volvo, is the second world trucks producer. In Europe, bio-methane is recognized as a renewable fuel by the European Commission, and as such benefits from regulatory advantages (both for use in electricity generation or as a fuel for transport). In Europe, some car manufacturers offer CNG models (Fiat, Mercedes, VW and Opel) and Audi recently announced a new model A3 e-gas which will be produced in series from 2013 on.

[26] Eurostat 2008.

Fueling gas into transport: a sustainable option?

If CNG and LNG vehicles were to meet with success, this could compete with other technologies and in particular delay electric vehicles. Yet, there is no rose without a thorn.

The technology should be quite cheap, but the payback period varies across countries. A recent study conducted by MIT (Massachusetts Institute of Technology) found out that only two types of vehicle actually really offer an interesting payback period: high mileage LDV vehicles and high mileage long haul heavy vehicles; even with a high CO_2 price of $100/ton, the payback period for a LDV would be only reduced by 3 years (over 15)[27]. The cost of infrastructure is also important, electric vehicles likewise.

The uncertainty surrounding the environmental benefits of natural gas raises some questions too. Retrofitted CNG vehicles represent the larger share in important countries like India. Yet they emit more CO_2 than OEM vehicles (vehicles designed from scratch for the specific use of natural gas) and are two times less energy efficient[28]. Secondly, the level of GHG emissions uncertainty is higher for Compressed Natural Gas Vehicles which emit more CO_2 than diesel and hybrid diesel vehicles[29]. LNG is also more carbon intensive than CNG (72-83 gCO_2-eq/MJ compared to 68gCO_2-eq/MJ)[30]. Additionally, the well-to-wheel carbon emissions of a vehicle fuelled with unconventional gas could be slightly altered (depending on the quality of the natural gas, the WTW outcome differs)[31]. In this respect, there is less rational in developing this technology in countries with already heavily regulated CO_2 and local pollutants emissions, such as the European Union. But more worrying than CO_2 emissions, methane leaks can occur during the compression and transport of natural gas; this gas has a global warming 20 times higher than CO_2[32].

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[27] MIT 2010.
[28] This is due to the cost difference. An OEM CNG vehicle costs up to 4 times the amount of a retrofitted vehicle (IEA 2010 report).
[29] French Association for Natural Gas Vehicles, report, 2011.
[30] IEA paper, 2010.
[31] Unconventional gas exploration and production can be more harmful to the environment than conventional gas if not properly practiced; in particular Hydraulic fracking could impact on water quality.
[32] ADEME 2006.

Last but not least, if this technology happens to compete and further delay the adoption of electric vehicles, this would mean getting less out of a low carbon transport option.

Will natural gas vehicles challenge electric cars?

Natural gas vehicles have many competitive assets. Technically they offer a driving range of about 300 km for CNG (which can be extended with a bigger tank or with dual fuel technologies) - twice the driving range of electric cars (about 150 km on average) – and about 1 000 km for trucks (not possible at all with batteries). The very short driving range of an electric vehicle makes its adoption very hard in a country such as the US, where the daily mileage of cars is much higher than in Europe. They are apparently safer than gasoline cars; do not suffer from weather conditions and do not suffer from the use of air conditioning or heating which can be of significant concern to electric vehicle autonomy[33]. Having less friction than conventional engines, CNG vehicles are also less noisy. To some extent the disadvantage as compared to gasoline vehicles (lower power and higher consumption) can be overcome. Finally, disposal and maintenance of natural gas vehicles is low cost and easy. On the contrary the repair of an electric car, calls for services of battery specialists as local repair shops do not have this ability.

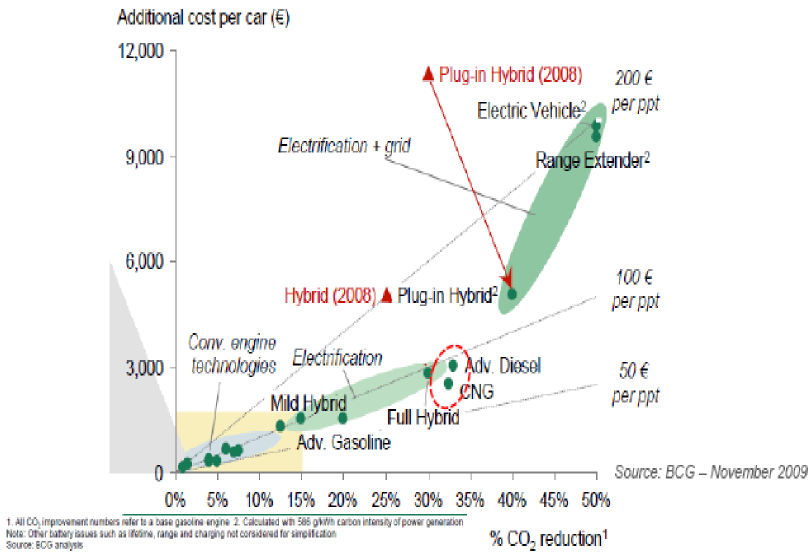
On the other hand, electric vehicle technology is still fairly immature. Its development is encountering plenty of speed bumps that high governmental subsidies struggle to overcome. They include short driving range, long charging times, shorter time life and the cost of infrastructure development. The need to develop similarly expensive infrastructure for natural gas vehicles could be reduced by dual fuel or bi fuel technologies, which expand the driving range and reduce the need for refilling (refueling takes up to 30 minutes for a CNG car while it takes between 30 minutes at fast charging to 8 hours at slow charging for an electric counterpart). Electric vehicles are, for these reasons, expected to remain a niche market.

Announcements of electricity price increases have recently spread across Europe, tipping the balance in favor of CNG. CNG more specifically appears at first sight more cost efficient than other technology options in particular for local pollutants reductions but also

[33] While conventional cars can make use of their engine heat, electric vehicles have to use the power stored in the battery to produce heat, and this is quite energy consuming. Some tests conducted in Japan on the electric Nissan leaf, revealed that the autonomy of electric vehicles can be reduced by half in given weather conditions (cold or hot weather) due to the use of applications.

for CO_2 abatement. The graph below gives an outlook of different low-carbon transport technology costs[34].

Figure 5: CO_2 cost efficiency of car technologies



Source: BCG, November 2009.

In fact, CNG cars have a lesser potential than Electric Vehicles (EV) in terms of carbon emissions reductions (20% as compared to 80% in some cases) depending on the source of the electricity. Electric vehicles offer a higher energy efficiency (85% versus 20-30% for internal combustion engines), and work well in Europe where the carbon in electricity is around $400gCO_2/kWh$[35]. As the carbon emissions of electric vehicles still depend heavily on the source of electricity, where the power sector is not decarbonized EVs do not outperform conventional engines. Otherwise both CO_2 and "local" pollutants such as particulate matters, sulphur or nitrogen are simply transferred to the power sector. Therefore unless power is produced mainly with nuclear or renewable, EVs do not have a decisive environmental advantage. In turn, this would require a better management of power demand and supply, smart grids and possibly

[34] The position of technologies on the graph would vary across countries. For instance, the carbon electricity factor is about 585gCO2/kWh which is superior to the EU average of 400gCO2/kWh. In this respect, considering the EU, the EV point will move further to the right hand of the graph. Additionally, if the gas price were to increase, the CNG technology would move up as it would become more costly. Yet, the GCC took the average gas and oil prices for the last years; in this respect the graph is not distorted by current low gas prices i.e. the CNG technology is not favored. The graph also reveals that diesel is more efficient than gasoline as CO2 abatement tool, but it emits more particles.

[35] For a more detailed study on electric vehicles sustainability please refer to http://www.ifri.org/?page=detail-contribution&id=6543.

storage system. But the environmental advantage of CNG vehicles as compared to electric vehicles is not universally clear cut.

Natural gas vehicles could actually end up being a challenge for electric vehicles, all the more so as natural gas vehicle manufacturers target the same niche market of captive fleet as electricity (van, taxis, light duty vehicles). The aggregated purchase of large amount of vehicles helps to decrease production costs, and captive fleets often do not require the roll out of public infrastructure (they are most of the time refueled at a central privately owned station), thus overcoming the main bottleneck and helping private customers adjust to this new technology. They are perceived as a good launching pad for electric vehicles.

Natural gas can also enter the market through the heavy truck segment, contrary to electric vehicles. Even more so as usually a large segment of the heavy truck market has a limited operating range. The IEA found that in 2002, 50% of the 145 billion trucks (excluding light trucks for personal transportation) operated in a range of 200 miles or less, and one third of them were fueled at private stations. The usual prerequisite of car market development, i.e. the development of an expensive refueling stations network, is therefore less limiting. Moreover if fueling infrastructure ends up being developed for freight, it could also service natural gas passenger cars. This competition could slow the pace of electric vehicle deployment.

Electric vehicles may over time and thanks to their lithium batteries become a tool to balance the electric grid. Electricity can be generated by a large variety of lower carbon emitting sources including all sorts of renewable, nuclear, or gas itself. Therefore electric vehicles diversify the range of primary energy sources for transport fuels, making its own contribution to one security of supply. CNG and Electric Vehicles technology do not offer the same perspective, while the first is the displacement of fuel in transport, the second offers the possibility of a new energy system.

Nonetheless, natural gas is not an imminent threat to electric vehicles. Its ability to challenge or delay the full electrification of the park mainly depends on how decisive captive fleets are for the launch of the market, and the rate at which vehicles can be rolled out in the next five years. Indeed there are a limited number of models (mainly vans) on the market. Manufacturers are mainly also truck manufacturers (Volvo, Chrysler) or historical producers (Fiat), a few other offer some dual fuel model (VW, Peugeot). In the US, the infrastructure is still underdeveloped, and the development of gas passenger cars would require a significant expansion[36].

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[36] Additionally the issue of safety may act as a speed bump for the development of natural gas vehicles. For instance underground parking may only be accessible to gas vehicles under given conditions, such as additional technology requirements to limit the risk of explosion. Accidents, like those which occurred with LPG vehicles in France, have a negative impact on public acceptance. Hence safety norms and vehicles testing will have to be first developed and harmonized.

A market trend pushing for the development of natural gas vehicles will in any case face political opposition. In Europe, North America or Asia political leaders are committed to the development of electric vehicles. China, who seems to dictate the trend, is investing 15 billion dollars in the electric vehicle; Europe and in particular some countries like France have also launched significant programs and Germany just announced €1 billion funding for research and development. In the US too, President Obama is now officially committed to the development of plug-in hybrids and electric vehicles. Even if natural gas passenger vehicles became an obvious economical choice, it would probably come across the reluctance of governments and of some manufacturers.

These governments have the power to directly or indirectly impede or support a technology. The market development of natural gas vehicles, and in particular retrofitting is currently slowed down by numerous regulatory bottlenecks. In the US for instance conversion systems had to be covered by a certificate of conformity to gain exemption from potential tampering charges. The key reason was not to affect the warranty of vehicles issued by manufacturers. Some countries are also quite reluctant for security reasons, as they had negative experiences with GPL for instance.

In Europe in particular, unconventional gas exploration could face public opinion opposition like in France, and high environmental standards could slow production and rise prices.

Biogas, which could serve as a second generation fuel for CNG cars, is developing slowly. Indeed several countries, are still reluctant to grant bio-methane non discriminatory access to the gas distribution grid (bio-methane first has to be upgraded as it is of lower quality than natural gas)[37].

37 While, the European Union directive setting common rules for natural gas market development explicitly states that biogas should be given a non discriminatory access (unless it is not brought up to the pipeline quality), several countries such as France still prohibit the injection of biogas from landfill or sewage.

Favorable gas markets dynamics?

The competition of electric and gas vehicles is just one issue among others. The key issue is more whether the opening of a new gas market for transport would be desirable? This is not certain.

Current low prices are the direct consequence of a US gas glut. Coincidently at the same time LNG capacity is coming on stream in a number of countries, unconventional gas was discovered and produced, and the economy fell into recession. There was consequently too much gas, and prices dropped.

Is this temporary? Arguably, as the availability of natural gas and current low prices are the main driver of CNG, they have to be considered closely. Gas discoveries may happen not to be much bigger than the forecasted increase in demand. The United States currently produce about 120 bcm per year, while China consumption will rise by 50/60 bcm. As the IEA puts it, there is also a high uncertainty on the extent to which unconventional gas is recoverable[38]. Therefore prices could vary up to one third in different "shale scenario". Additionally, outside the US the pace of unconventional gas production remains uncertain. As compressed natural gas is less energy efficient than diesel or gasoline, the switch to gas for transport would require substantial extra amounts.

How long will low gas prices last? A report recently published in Energy Policy, concluded that while low gas prices had been the main factor driving the adoption of compressed natural gas vehicles in Argentina back in the 80s/90s, this would not have been possible without government support. Indeed the market was sustained by differentiated pricing for fuel[39]. This shows that CNG is from a competitive option as long as gas prices remain (artificially or naturally) low. Yet if current prices are low, demand will certainly resume with the end of the crisis, OPEC could also react, and prices consequently go up again. Furthermore future tight, shale or coal-bed methane gases will be expensive to produce.

Several increases in CNG and gas have already been observed, mainly as a result of subsidies cut. Consumers might be more open to buy CNG cars than electrics, but they could still decide to stay with oil. Dynamics are not always virtuous. In the US, Gas companies are one of the main market drivers, yet these companies also have an interest in firming up gas prices. If governments have to maintain artificial low gas prices to support CNG fleet, up to what point is this a viable economic option? What is the threshold for both consumers and governments? Most American companies, who

38 Based on the assumption of current production rates, recoverability varies to a factor of three (considering furthermore that production taking place in sweet spots has been developed first).

39 Energy Policy, 2011 (39), Gustavo Collantes, Marc W. Melaina, pp.664-675.

recently purchased compressed natural gas vehicles, actually benefitted from governmental grants. For instance, AT&T received a $565 million grant and U.P.S who already adopted CNG vehicles in the 80s received a $5 million grant from the state of California. The latter will use $4 million to buy vehicles, and $1 million to build fuelling infrastructure in partnership with Clean Fuel Technology.

Is transport the best way to make use of gas? Power production could use it in a more efficient way. A CNG engine indeed has a lower energy efficiency ratio than new generation gas fired power plants. CNG cars consume more than diesel vehicles (and so do heavy CNG trucks), said to have an energy efficiency of around 25% to 30% (for heavy trucks)[40]. Ecofys, a consultancy, reports that the best available technique for gas power plants available today (Natural Gas Combined Cycle), reaches energy efficiency levels up to 59-60%[41] [42]. CNG vehicles are about two times less efficient than new gas fired power plants. Moreover, gas is necessary to decrease the carbon content of electricity in many coal fired countries and as a backup to intermittent renewable. Therefore it is debatable whether fueling gas in transport is a good option.

40 For diesel vehicles there is a trade -off between energy consumption and emissions – hence energy efficiency can vary from one car to another.
41http://www.ecofys.com/com/publications/documents/RPTEnergy-efficiencyandcarboncaptureinnewpowerplantsENFinal.pdf.
42 Single gas turbines have an energy efficiency of 35-40%.

Conclusion

While governments are supporting the exploration of technology alternatives to conventional road transport, the development of unconventional gas sources and the resulting gas glut has brought natural gas vehicles back to the fore.

The introduction of natural gas vehicles could impact and delay the electrification of road transport, and in particular the roll out of full electric vehicles, on which several governments have placed their bets. Yet the intensity of the rivalry between these two technologies will depend on the importance of captive fleets and will surely vary across countries. Policies have an impact on market developments.

Many are criticizing the support and the money spent on electric vehicles, but while Europe and France may be trapped in an electric paradigm, Obama is currently cornered by bipartisan issues and gas looks like the only common ground. The current competitiveness of natural gas vehicles and their cost efficiency as a carbon abatement tool relies on current low gas prices. Yet, gas markets are evolving. If a new gas market for transport was opened, this could have the exact reverse effect of firming prices. On the other hand, gas could be more efficiently used in power generation. The introduction of natural gas vehicles is neither easy nor desirable everywhere and it will not come without drawbacks.

Sources

GNV (French Association of Natural Gas for Vehicles), Le CNG: quel potential? Summary of findings, financed by the French ministry of economy, finances and industry, ADEME, IFP and AFGNV, October 2006

Engerer H. & Horn M., Natural Gas Vehicles: An option for Europe, Energy Policy 38 (2010) 1017-1029

International Energy Agency, World Energy Outlook, 2010

ADEME, Le Gaz Natural pour Vehicles, Panorama, 2006

Energy Information Agency, Annual Energy Outlook 2010 with projections to 2035

GDF Suez, presentation, IFP sessions, December 9, 2009

Collantes G. & Marc W. Melaina, the co-evolution of alternative fuel infrastructure and vehicles: a study of the experience of Argentina with compressed natural gas, Energy Policy 339 (2011) 664-675

World Resources Institute, ChinaFAQs, the Network for Climate and Energy Information, November 12, 2009

GNV, Le gaz naturel dans les transports, 2010

International Energy Agency, The contribution of Natural Gas Vehicles to Sustainable Transport, Michiel Nijboer, 2010

Massachusetts Institute of Technology MIT, the future of natural gas, an interdisciplinary study, interim report, 2010

Mexico Auto Reports Q1, 2011