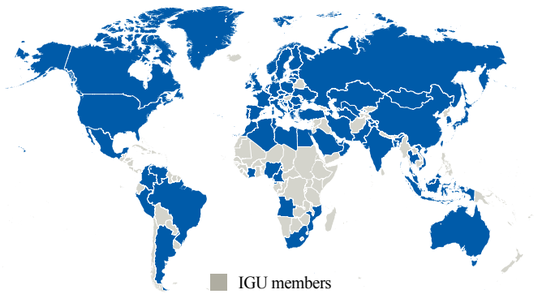
IGU

The International Gas Union (IGU), founded in 1931, is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate for gas as an integral part of a sustainable global energy system. IGU has more than 110 members worldwide and represents more than 95% of the world's gas market. The members are national associations and corporations of the gas industry. The working organization of IGU covers the complete value chain of the gas industry from upstream to downstream. For more information please visit www.igu.org.



International Gas Union

News, views and knowledge on gas – worldwide

Natural Gas as a Transportation Fuel

The alternative choice for cleaner energy

INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

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Summary

Natural gas as an alternative transportation fuel has made significant inroads in the light, medium and heavy duty vehicles market over the last decade, spurred by a combination of fuel cost savings, technology development, reduction of emissions and noise in big cities, and coupled with policy direction and mandates. The greenhouse gas and air quality benefits of natural gas vehicles are currently leveraged mostly in the commercial vehicle sector where fuel use, and thus potential fuel replacement, is at its greatest.

Natural gas can however be used for all classes of vehicles and further market penetration needs to materialise to make its presence more significant in the transportation sector.

Natural gas today, and for the coming decades, will remain the most abundant, safer, cleaner, and economically viable substitute for petroleum based transportation fuels. In this respect, natural gas is "the alternative choice for cleaner energy" and provides a transition path to renewable energy before the latter takes off as the fuel of choice as the millennium progresses.

Paper compiled in November 2009 by Dr. A.W. Karim for the Malaysian IGU Presidency (2009-2012).

Current Reality

The days of easy oil are over. Conventional oil will struggle to keep up with increasing global demand. The more "difficult" oil resources needs to come into play and then again, the question is for how long can this be sustained. The diversification away from oil resources is not a choice but a necessity for sustainable development. Natural gas not only plays a big role in this diversification, but also provides the benefit of reduced GHG (greenhouse gas) emissions and substantial improvement in air quality.

The transportation sector consumes approximately 25% of world primary energy demand, and apart from electrification of mass transportation, the large bulk of transportation relies on petroleum fuels, primarily gasoline and diesel. Imagine the pandemonium when fuel stations run dry for one reason or another even for a couple of days. Recall the hardship when oil prices surged to $150 per barrel in mid-2008. Only a global recession brought it down to the sub $40 per barrel in early 2009 before rapidly climbing again to breach $80 per barrel in October 2009. If alternatives are not developed at a faster pace, oil prices will move in a steep curve instead of a gradual increase as in consensus forecasts.

The two forces of environmental and economic costs make the development of alternative transportation energy sources imperative and urgent. While renewables would be the ultimate transportation fuel aiming towards zero emissions, the prospects of renewables being the dominant transportation fuel on a global scale for the next few decades are minimal. Natural gas can play a major role between dominant oil and fledgling renewables, as amongst the fossil fuels it is best placed, not only in terms of compatibility and hybridization fit with both oil and renewables, but also stemming from the fact that it is more abundant than oil resources on a global scale. In the U.S. for example, the advent of gas production from gas shale formation has led to analyses supporting the claim that the U.S. has now enough gas resources to meet its needs for the next 110 years (based on current consumption levels).

Natural gas as a transportation fuel seems a natural choice. It burns in a cleaner way than oil, produces less GHG emissions, and on an energy equivalent basis is generally sold worldwide at a discount to oil. However one of the main hurdles is simply getting the gas to the filling station, which requires the establishment of refuelling networks. Though the logistical and technical hurdles are not so great, policy and financial support are required to fully realise the emissions and economic benefits of natural gas as a transportation fuel.

Challenges of Gas as a Transportation Fuel

Cars, buses, trucks, railroad locomotives, boats and aircrafts that use natural gas as primary fuel are generally referred to as natural gas vehicles (NGVs). More frequently however, the term "NGV" is applied to road vehicles. There are basically two principal sources of natural gas for vehicles:

- Gas produced from underground reservoirs
- Gas produced from organic substances (crops or waste)

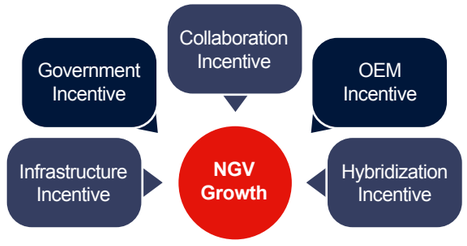
Natural gas is stored and transported in two forms, compressed and liquefied. Methane content in the gas transportation fuel exceeds 90%. The total global NGV population grew from around 0.8 million vehicles in 1998 to an estimated 10.1 million vehicles by the end of 2009, with significant changes in regional NGV market structure. In 2003, Latin America had the highest share of 56% of the world NGV market. But the rapid growth in the Asia Pacific region represents by far, the strongest market growth generator. By 2008 the market shares of Latin America and Asia Pacific region were almost equal, 40% and 37% of the global market respectively. The NGV market in Latin America doubled in the 2003-2008 period whilst that in Asia Pacific increased by a factor of five. The NGV worldwide share of total vehicle population in 2008 is approximately 1%. This represents 0.6% (2007) of the total worldwide natural gas consumption. Today's estimated annual volume of natural gas demand for vehicles is about 13 to 15 billion cubic metres (Bcm).

The underlying currents are there to propel the growth of NGVs, but there are hurdles and challenges that first need to be overcome, primarily the following:

- The main limitation of natural gas for vehicles is the shortage of refueling infrastructure, a problem exacerbated by the dominance of "status quo" gasoline and diesel refuelling stations. Therefore, investments need to be made to create the gas infrastructure for fuelling
- Car manufacturers have sunk huge investments in today's and tomorrow's gasoline and diesel cars. Major world original equipment manufacturers (OEMs) have however started to offer cars, trucks and buses designed with natural gas engines, currently offering more than 180 models worldwide
- Issues around maintenance costs, maintenance centers and availability of spare parts (this situation is however improving and most fleet operators report significant life cycle cost savings)
- Issues around vehicle range necessitating higher frequency of refuelling
- Public perception that NGVs are not on par on engine performance compared to their gasoline or diesel counterparts. These are primarily perceptual only, with natural gas engines proving themselves daily in the commercial arena and even in competitive world class motor sports. There is a "change syndrome" that needs to be overcome and the reasons must be compelling enough for that change to happen

Paving the Way to NGV growth

Whilst acknowledging the challenges above, there is general consensus that dedicated NGVs result in 20% to 25% less CO_2 emissions compared to petroleum fuels, due to its methane's chemical properties (four parts hydrogen to one part carbon). Natural gas is also competitively priced compared to petroleum fuels on an energy equivalent basis, often retailing at discounts in the range of 20% to 60%. There is also the realization that NGVs make a lot of sense for countries rich in gas resources, resulting in the lowering of oil imports or maximization of oil exports as the case may be. However, several things need to happen on several fronts before natural gas can truly take-off. These are summarized under the following five incentives:



1. Infrastructure Incentive

A number of cities around the world are already making and expanding gas infrastructure and fuelling systems available for fleet application. These include taxis, trucks and buses and off-road vehicles such as airport and agricultural vehicles. The focus has been largely on medium duty vehicles (MDVs) and heavy duty vehicles (HDVs), as these fleets offer great advantages for NGV development as they have their own filling stations, totally independent of public compressed natural gas (CNG) distribution network. Moreover, high polluting vehicles offer the advantage of reducing emissions in big cities where pollution is worst and more people are exposed. The public CNG infrastructure for light duty vehicles (LDVs) is however lagging behind and needs to be deepened and widened for NGV to truly take off as an alternative fuel.

Madrid –IVECO CNG Refuse Collection Fleet,
(Source: IVECO)

2. Government Incentive

Government incentives to promote NGV, for example personal tax rebates on purchase, fuel price advantages, infrastructure grants etc, and more stringent national and local emission standards where NGV has the edge over petroleum fuels will spur NGV growth. For example, in the U.S. since late 2005, the federal government has significantly expanded the economic incentives for purchase and use of NGVs. The Clean Cities Program was also launched by the U.S. Department of Energy (DOE) to encourage the use of alternatives to gasoline and diesel fuels, reduce its dependence on foreign petroleum, and improve local air quality.

CNG Bus in Gyeongju South Korea (2008)
Source: www.energypicturesonline.com

However, by and large, governments' support for clean fuels have been mainly directed for liquid biofuels, electric vehicles, hybrid vehicles and hydrogen fuel cells, as they consider NGVs to be a matured industry segment. In the majority of countries with emerging NGV markets, the weakest link in the chain is the CNG business, which is the production and retailing of CNG. In essence, even though NGVs are a ''here and now'' solution to climate change, air quality and energy security issues, they are disadvantaged due to the dominance of the ''status quo'' fuels (gasoline and diesel). The question ''how to make a CNG filling station profitable'' has to be answered. Government incentives which reflect the social, environmental and macroeconomic benefits of NGVs would address this problem. Governments need to be convinced that more financial resources for NGV market development and R&D could dramatically improve the future potential contribution of NGV's environmental benefits, and contribution to overall energy security and its role towards mitigating climate change through lower emissions.

3. Original Equipment Manufacturer (OEM) Incentive

Much of OEM incentives have focused on HDVs, especially urban buses where range is not a limiting factor. What is further required is technology development to increase OEM NGV availability in the other vehicle classes, particularly passenger cars equipped with advanced technologies for enhanced performance and fuel efficiency for greater vehicle range. There is already development around direct injection engine technology that results in both increased vehicle range and further lowering emissions.

In many cases, OEMs already have market ready technology available, but do not have sufficient demand to offset the risk and cost of launching products in the marketplace. Incentives to offset this would likely result in more products being made available.

Efforts to continue harmonisation of worldwide standards and regulations are needed to make NGVs more competitive in the market, as most consumers will continue to make pragmatic choices about which car to buy based on cost, performance and convenience.

OEM NGV availability in such countries as India, China and South Korea coupled with innovative technologies will push long term NGV demand in these countries and place the Asia Pacific region at the forefront of NGV growth. The growth of the OEM development in Europe should provide the long term sustainability for NGV markets as long as the growth of fuelling stations continues steadily and unabated. These markets will be fuelled by concerns of CO_2 and emissions reductions as well as energy security, particularly as Europe looks to diversify its energy sources.

Dedicated OEM CNG Vehicle – Opel Zafira
(Source: Erdgas Mobil)

A breakthrough in NGV technology was achieved in Russia in 2009 for the GT-1 locomotive, where a gas turbine running on vaporised LNG was used to drive the locomotive's power, offering some 25% fuel cost savings and very significant environmental benefits (far below the emission standards to be applied to locomotives in 2012).

LNG Gas Turbine GT-1 Locomotive
(Source: Russian Railways, Moscow, Russia)

4. Hybridisation Incentive

Natural gas lends itself easily to hybridisation with gasoline engines, and with advanced computerised diesel technology, considerable advancement has been made in dual fuel natural gas/diesel technology to provide the correct fuel mix in each combustion cycle, ensuring optimum efficiency and power and fuel economy. Future developments include the possibilities of hybridisation, hydrogen mixtures or with renewable bio-methane.

In the realm of gas hybridisation with electro mobility, natural gas can also be the source of electricity from gas fired power stations where CO_2 emissions are about half of coal burning power plants to produce the same amount of electricity.

Including bio-methane (purified biogas) in the fuel mix would "green the gas". A fine example of this is in Sweden, where some 58% of gas used in the transportation sector is derived from biomass. Where such opportunities arise where the biomethane source is close to market, and where government support covers extra costs, this should be taken advantage of. This would be consistent with many governments' policies oriented to take advantage of CO_2 reduction potential, fuel diversity in the transportation sector, energy efficiency and security of supply.

Natural gas in the form of GTL (gas to liquids) also lends itself to hybridization possibilities. As GTL is more easily transportable, its niche lies in pin pointing application with regards to air quality improvement in mega cities as a very clean and pure fuel or blended with petroleum diesel or in electric hybrid vehicles. BTL (biomass to liquids) has the same fuel properties as GTL and can be blended together, but being biomass based has the advantage of a low carbon footprint. A pure BTL product has the potential to reduce carbon footprint by up to 90% compared to refinery processed petroleum fuels.

In the field of aviation, natural gas has the potential of making major breakthroughs as an aircraft fuel in the form of GTL or liquefied natural gas (LNG). In October 2009, the world's first commercial passenger flight operated by Qatar Airways made a historic journey from London to Doha powered by a 50:50 blend of GTL kerosene and conventional

oil-based kerosene fuel. The use of LNG was technically proven to be possible by a specially designed Russian airplane, the Tupolev TU-155 "flying laboratory", which made more than 40 test flights during the period 1988 to 1990 using first LH2 (liquefied hydrogen) and later LNG instead of conventional jet fuel. Modern technologies make it possible to fly on LNG to most of the major airports in the world, and this opens up a new future horizon in its utilization as a transportation fuel.

5. Collaboration Incentive

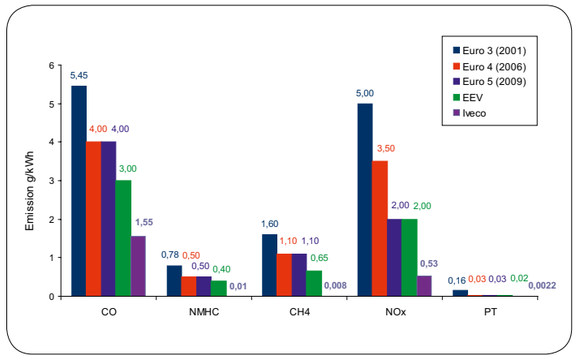
Collaboration among NGV stakeholders, primarily OEMS, gas supply companies, petroleum retail companies (integrating CNG in retail mix), transportation companies and governments (local, regional, national) is of paramount importance as it is the gear that moves everything else. The well-organised, highly focused German stakeholders market is a valuable model of NGV development. The success of the developing German NGV market has been built upon a strategy involving the various stakeholders, namely, the gas industry, government and the vehicle manufacturers, who have focused targets for vehicle and fuelling station growth.

Treat or Pay

There is a strong push from the European Commission to reduce CO_2 emissions from all vehicles. The status of the policy directive as at December 2008 are as follows;

- As from 2012 reduction of the specific CO_2 emissions for all new vehicles within the EU below 130g CO_2/km and 120g CO_2/km considering biofuel share
- By 2020, target of 95 g/CO_2/km for all new vehicles (subject to review in 2013)
- Penalty proposal for OEMs that fail to comply, severity of which increases year by year from 2012

There is therefore a strong financial incentive for OEMs to come up with short term solutions to meet 2012 targets. There is available OEM natural gas technology that already offers superior emissions often below the Environmentally Enhance Vehicle (EEV) limits. For example, emission comparison based on IVECO Cursor 8 CNG engines show performance that are far below the EEV limit. Longer term solutions to meet the 2020 targets and beyond are likely to involve hybrids which could be a combined approach involving CNG/biomethane and electro mobility.



Emissions of IVECO CURSOR 8 CNG Engine versus Present and Future Euro Limits (Source: IVECO and NGVA Europe)

Future Growth Projections

Scenarios developed by IGU, based on a US$ 150 per barrel crude oil price in 2030 (within the range of the International Energy Agency 2008 outlook - reference and high scenarios) postulated the following growth in NGVs;

- **Business as Usual (BAU) Scenario:** 100 million NGV equivalent [1] vehicles in 2030 representing some 7% of worldwide vehicle population linked to expected crude oil price increase as the main growth generator
- **Policy Governed Scenario:** 145 to 200 million NGV equivalent in 2030 based on 2% and 3% worldwide vehicle growth respectively, representing some 10% NGVs in the total vehicle population. In this scenario, on top of crude oil price increase, NGV development is spurred by supportive measures, mandates and other policy instruments typically triggered by environmental protection and security of supply issues. The difference between the low and high growth in vehicle population is essentially attributed to the Asia Pacific and the strength of the policy direction in this region.

[1] Equivalent NGVs in general means number of NGVs if all NGVs are considered to be LDVs (or better to say personal cars). In other words, one NGV truck or bus is equivalent to 10-15 cars, one van is equivalent of two personalcars etc.

All references, photos and charts used in this publication are for the sole interest of promoting the use of natural gas as a transportation fuel and is not intended to promote the interests of any specific country, company or OEM

Main references:
1) International Gas Union (IGU) Final Report (June 2009) on Study Group 5.3 – Natural Gas for Vehicles (NGV)
2) Natural Gas Vehicles – the German Business Development Case (Dr. Ing. Stephan Ramesohl; presented at the 24th World Gas Conference, Argentina, 5-9 October 2009)

Sources:
1) International Association for Natural Gas Vehicles (IANGV) – www.iangv.org
2) Various additional contributions from IGU Study Group 5.3 (NGV) members

Natural Gas – Contributing to a Sustainable Energy Future