VIAVISION

VOLKSWAGEN GROUP • SHAPING THE FUTURE OF MOBILITY

NO 01
February 2013

More Energy, Less CO_2
Natural Gas

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Cleaner and Cleaner

Ways to Carbon Neutral Mobility

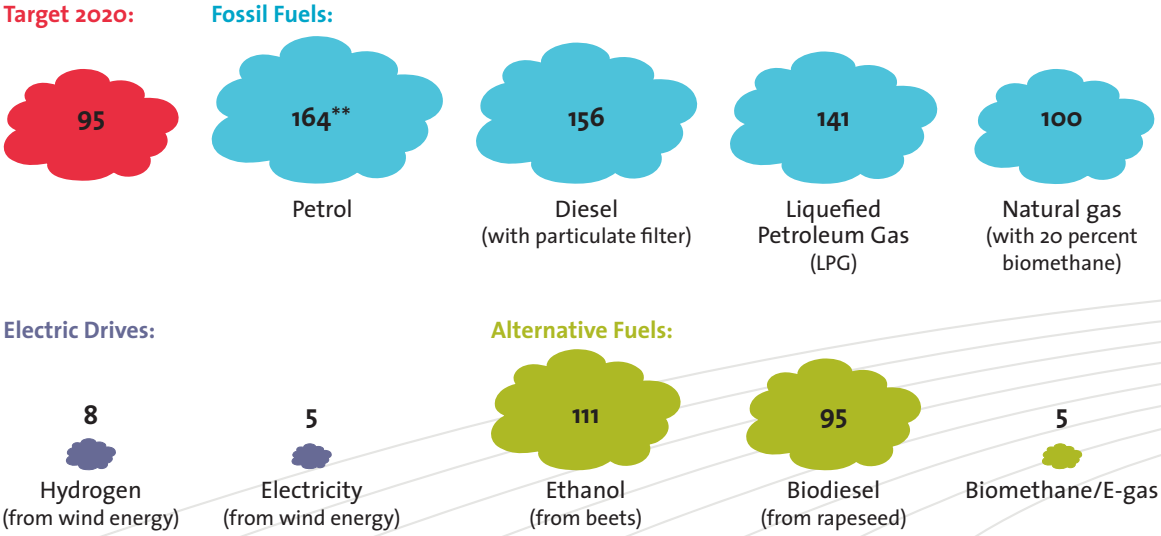
Carbon Neutrality

One speaks of carbon neutrality when emissions, caused by the combustion of fossil and non-fossil fuels, are bound by compensatory measures or off-set. This can be done during production, use and subsequent recycling, as well as by the reforestation of forests.

The goal is clear, global greenhouse gas emissions must be reduced. We are still a long way from the widespread adoption of electric or fuel cell vehicles. Therefore, in the meantime, work is being done on other solutions to immediately reduce CO_2 emissions: among them are optimized combustion engines and fuel efficient hybrid and electric drives as well as alternative fuels.

The EU emissions target for 2020: an average of 95 grams of CO_2 per kilometre across the whole new vehicle fleet.

Emissions Compared:
(in grams of CO_2* per kilometre)



* Greenhouse gas emissions incurred during production and consumption (well-to-wheel), in grams of CO_2 equivalent.

** For a naturally aspirated petrol engine with a fuel consumption of seven litres per 100 kilometres.

Compared to petrol and diesel, alternative fuels such as natural gas or biofuels, that means those of organic origin, release less CO_2. The clear leaders, in terms of CO_2 savings, are biomethane and E-gas, followed closely by electricity for electric cars and hydrogen fuel cell vehicles – but only if renewable energy is used for their production.

Clean and Cheap

The Case for Natural Gas

Dr. Ulrich Hackenberg, Member of the Board of Management of Volkswagen Brand with responsibility for Research and Development.

Why does Volkswagen focus on natural gas?
As the largest car maker in Europe, we have a special responsibility to reduce global CO_2 emissions. With the use of **natural gas**, **biogas** and **E-gas** as fuel, CO_2 emissions will be reduced immediately and sustainably. Combined with the parallel use of electric vehicles and plug-in hybrids, there is substantial emissions saving potential, which we want to unlock. The goal is carbon neutral mobility. We have the necessary technology in our product portfolio.

What are the benefits of natural gas and biomethane?
Natural gas is available in our world in sufficient quantities. There is already well developed infrastructure in many countries. Comparing natural gas and petrol directly, approximately 25 percent less CO_2 is produced during combustion. When using biomethane or E-gas – regarding the entire event chain (well-to-wheel) – a potential reduction of more than 80 percent is possible. Natural gas can be stored excellently as an energy source and provides our customers with a distinct advantage in terms of running costs.

Which natural gas vehicles are in the Volkswagen product range?
We currently offer six natural gas models across the VW Group: Caddy and Caddy Maxi, Touran, Passat Saloon and Passat Estate and recently also the eco up!. This year the new Golf will be the first vehicle of the MQB family* available as an EcoFuel** version.

Natural gas discharges 25 percent less CO_2 at combustion than petrol.

* MQB is the German acronym for Modular Transverse Matrix – the uniform vehicle architecture which is the basis for many of the Volkswagen Group's models (see VIAVISION NO 02 2012).

** The EcoFuel label - with the exception of the eco up! - describes all models of the Volkswagen brand which are equipped with a natural gas engine.

Glossary

CNG/LNG (natural gas): Natural gas, which consists primarily of hydrocarbon methane, is compressed or liquefied for use in cars. Therefore it is designated as Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG).

LPG: Liquefied Petroleum Gas (LPG) has nothing to do with natural gas. It is not a naturally occurring gas but a byproduct created during the refining of crude oil.

Biomethane: First biogas is produced from renewable resources, then it is refined into biomethane and thus made usable in car engines. It has a better carbon footprint than natural gas, because the plant of which it consists previously absorbed CO_2 during photosynthesis.

E-gas: Synthetic methane (CH_4), is also called wind gas, if it is obtained using renewable energies. Hydrogen (H_2) is produced by electrolysis, using green electricity. Subsequently, employing the Sabatier process, H_2 reacts with CO_2 to form carbon monoxide and water. Synthetic methane is then produced from the reaction of carbon monoxide to H_2.

H-gas/L-gas: H-gas (high-calorific gas) refers to natural gas with a high methane content of at least 87 percent, L-gas (low-calorific gas), however, contains 80 to 87 percent methane. The higher the methane content, the more efficiently the fuel burns.

Good Prospects

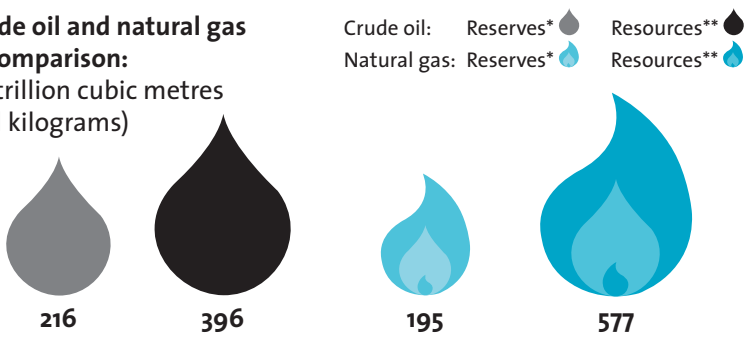
Natural and Biogas Secure Our Supply

Natural gas secures our energy supply and instantly helps reduce CO_2 emissions.

E-gas generated with renewable energies can be stored over the long term using existing infrastructure.

The notion that fossil fuels are available indefinitely is long since obsolete. Signs of incipient shortages are rising heating costs and oil prices as well as the public debate about alternatives to oil. In the coming decades natural gas resources can secure our energy supply, even giving increasing demand. In the medium term, biogas from renewable resources or E-gas can complement fossil-derived natural gas and eventually replace it in the long term.

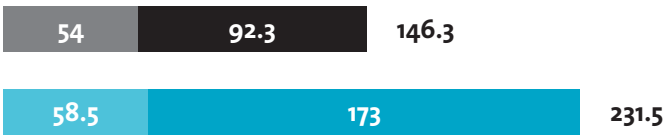
Crude oil and natural gas in comparison: (in trillion cubic metres and kilograms)



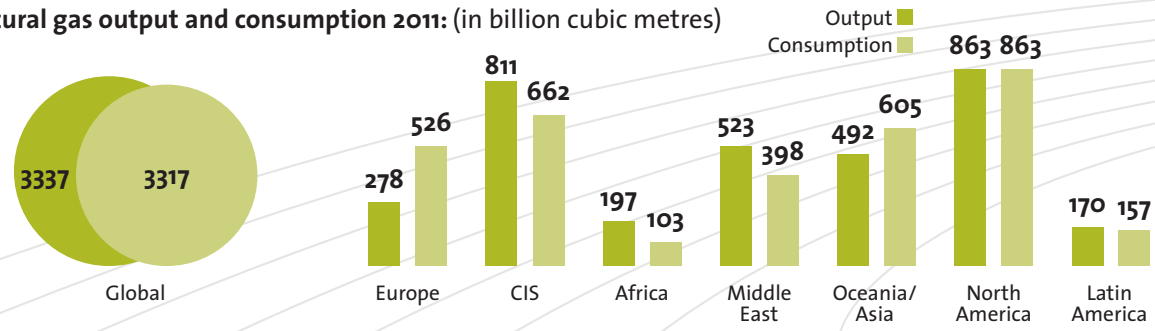
* Detected and economically exploitable quantity of raw materials, using today's technology.
** Detected, as well as suspected, quantity of raw materials, not currently exploitable.

The static lifetime is a theoretical construct that is derived from the ratio of the world's reserves of fossil-derived raw materials to the current annual mining output. It indicates, from today's standpoint, how many years of consumption can be sustained given constant output and constant reserves.

Static lifetime: (in years)

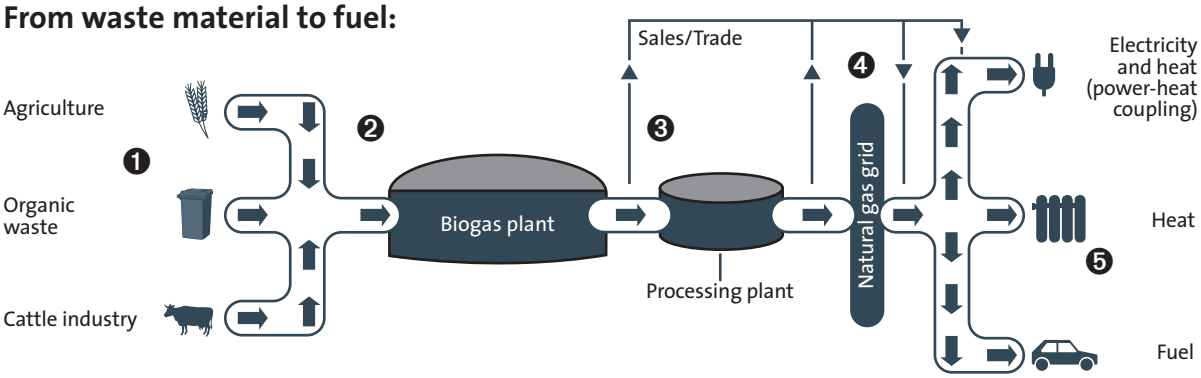


Natural gas output and consumption 2011: (in billion cubic metres)



Viewed globally, output and consumption of natural gas are almost equal. The largest consumers are the North Americans, who produce their natural gas themselves. About half of the world's natural gas reserves are located in Iran, Russia and Qatar. The main natural gas suppliers for Germany are Russia, Great Britain, Denmark, Norway and the Netherlands.

From waste material to fuel:



❶ Manure, organic waste, industrial and agricultural waste as well as energy crops – meaning plants such as rapeseed or corn, which are grown solely for that purpose – are used as raw materials for the production of biogas.

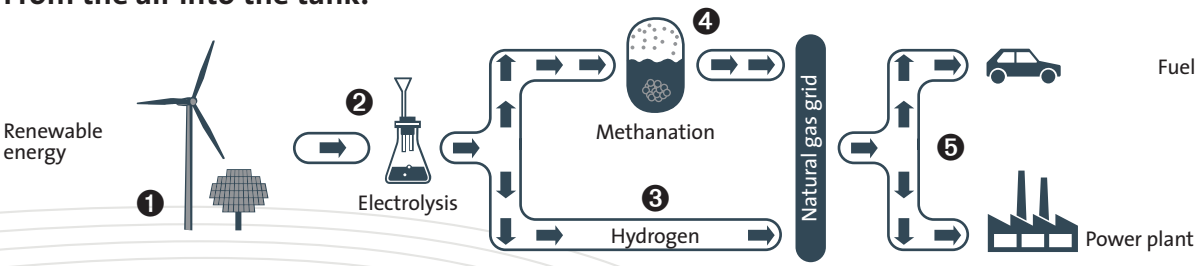
❷ In a biogas plant, raw biogas is produced by fermentation which then is crudely processed (by desulphurisation and drying) and mainly used in cogeneration units.

❸ In another preparation process raw gas can be refined to biomethane. The methane content increases to up to 98 percent.

❹ The resulting biomethane can then be fed into the natural gas grid.

❺ After feeding, biomethane serves as source of heat and electricity, or – compressed to 200 bar – as fuel at natural gas filling stations.

From the air into the tank:



❶ Electricity is generated from renewable energy sources such as solar, wind or biomass.

❷ Excess electric capacity is used to split water into hydrogen and oxygen via electrolysis.

❸ The hydrogen produced can be fed into the natural gas network to increase the available volume in the grid. An admixture of up to five percent is allowed.

❹ In addition, hydrogen mixed with carbon dioxide turns into synthetic natural gas (E-gas) via methanation.

❺ Via the gas grid, the fuel either reaches natural gas filling stations or can be used for industrial purposes, such as generating electricity and heat.

Both charts show the production of non-fossil gases. The gas produced in biogas plants (top chart) is fed in to the gas grid as a supplement to fossil derived natural gas. The storage of energy, by converting electricity into hydrogen and methane (see chart below), is planned to relieve the network in the future. It is currently being tested in six pilot plants across Germany.

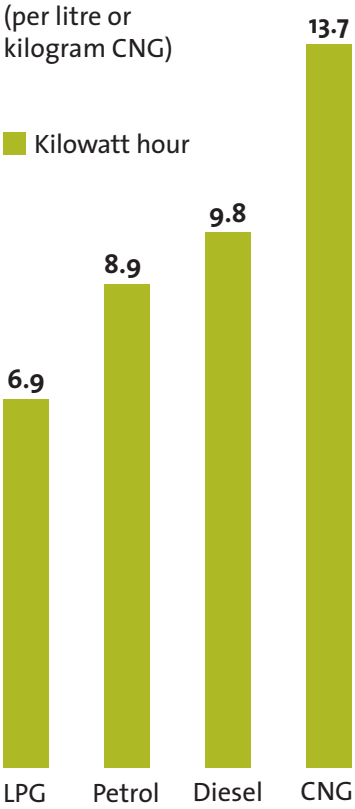
Gas in the Tank

Safe as Well as Efficient

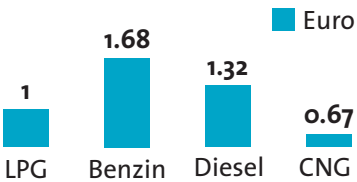
Natural gas is a step on the way to carbon neutral mobility. Although natural gas vehicles are usually more expensive to acquire than their Otto engine counterparts to begin with, nevertheless the purchase pays off in the long run thanks to tax concessions. Safety is also not a problem in gas powered cars, as the German Automobile Club has proven in crash tests under the most rigorous conditions.

The additional price of an eco up! amortises, thanks to low fuel consumption and gas tax breaks, just below 60,000 kilometres – significantly earlier with support from local gas providers.

Energy content: (per litre or kilogram CNG)

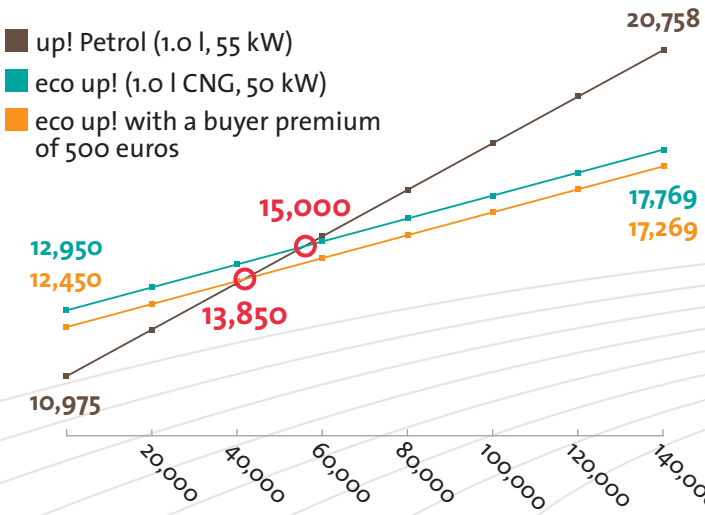


Costs: (per litre petrol or petrol equivalent)



Natural gas has a higher energy content than other fuels, one kilogram is equivalent to approximately 1.5 litres of petrol or 1.3 litres of diesel. Converting the tax-relieved natural gas price for a litre, results in a significantly lower price than petrol or diesel. The tax break for natural gas in Germany is available until 2018. An extension is currently being discussed.

Comparison of acquisition and running costs, using the example of the up!:
(Mileage in kilometres, costs in euros)



The initial, higher costs of a natural gas vehicle, in this case the eco up!, have amortised after a mileage of just under 60,000 kilometres, through tax and fuel savings. A buyer premium of 500 euros would lead to this point being reached after some 40,000 kilometres. Many regional gas suppliers pay premiums from 250 to 1,000 euros, others give new buyers or re-fitters a tank voucher.

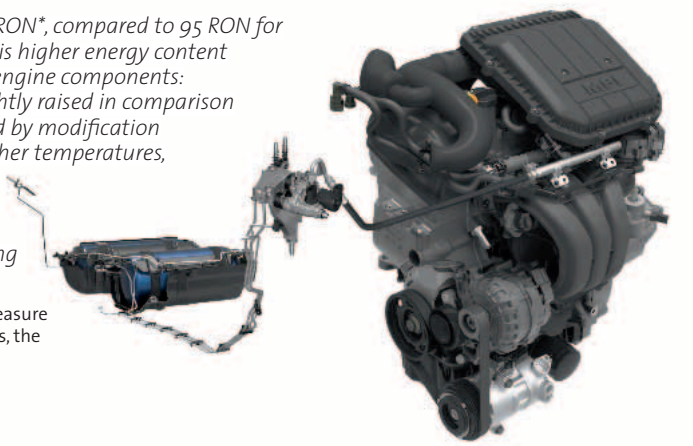
Small Car, Big Saving

The eco up!

Engine

Natural gas has an octane rating of 130 RON, compared to 95 RON for premium gasoline. The optimal use of this higher energy content requires the adaptation of a number of engine components: the compression of the gas engine is slightly raised in comparison to the petrol variant, this can be achieved by modification of the piston head. As CNG ignites at higher temperatures, different spark plugs are used too. Above all, the valves and valve guides are adjusted to the new conditions because a gaseous fuel has less lubricating properties than gasoline or diesel.*

* RON defines the octane rating, which is the measure of the knock resistance of a fuel. The higher it is, the more uniform the combustion process.



Natural gas storage system

In the eco up! two steel gas storage systems are installed, both located in the rear underbody. The tanks have a combined volume of 72 litres, corresponding to 11 kilogram CNG, which is stored under 200 bar pressure. The tanks have multiple safeguards: a thermal fuse prevents heat-induced overpressure in the tank, by melting at 110 degrees and letting the pressure escape. An electrical shut-off valve prevents an excessively fast discharge of the tanks, by means of a mechanical shut-off valve, which can be closed, for example, during maintenance. In addition, the eco up! has a small petrol tank with ten litres capacity – if the gas tank is almost empty, it switches to petrol mode. This results in a range of about 600 kilometres.

Engine control unit

In a CNG vehicle the engine control unit also takes over control of the gas-injection and the gas pressure regulator. Moreover, it recognises whether H-gas or L-gas was used for refuelling and adjusts the injection timing accordingly. This ensures maximum efficiency.

Gas pressure regulator

The innovative electronic gas pressure regulator reduces the pressure of the gas from 200 bar to 4 to 9 bar, depending on the load demand. This ensures natural gas can be used as long as possible, and that the tanks are largely emptied.

Room for Improvement

Subsidy Programs for Natural Gas Vehicles

Top ten countries for natural gas vehicles:
(in thousands)

1.	Iran*	2,859
2.	Pakistan	2,851
3.	Argentina	2,044
4.	Brazil	1,703
5.	India	1,100
6.	Italy	779
7.	China	600
8.	Columbia	349
9.	Thailand	268
10.	Armenia	244
⋮		
17.	Germany	90

Among the ten countries with the largest natural gas vehicle fleet in the world there is only one European: Italy. The natural gas vehicle population particularly grows where purchase incentives are created through government subsidies.

* In Iran the law requires that the domestic fleet is primarily powered by natural gas, so the oil produced in the country can be sold internationally.

It lowers CO_2 emissions, reduces dependence on oil and facilitates the use of renewable energy – three good reasons in favour of natural gas. Nevertheless, we rarely see natural gas vehicles on the streets. Countries such as Italy and Argentina, however, show that it can be possible to increase the population of natural gas vehicles, by employing the appropriate framework.

Incentives for the purchase of natural gas vehicles:

- Lower motor vehicle tax
- Buyer's premium
- Low gas tax

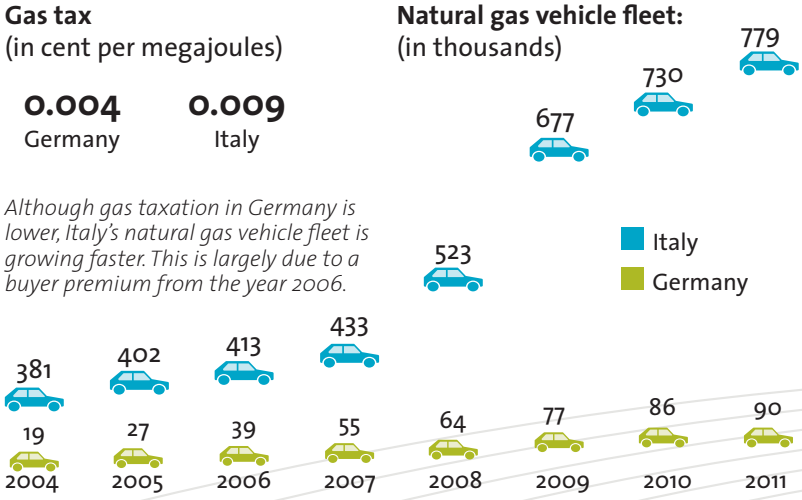
Gas tax
(in cent per megajoules)

0.004 Germany

0.009 Italy

Although gas taxation in Germany is lower, Italy's natural gas vehicle fleet is growing faster. This is largely due to a buyer premium from the year 2006.

Natural gas vehicle fleet:
(in thousands)



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