LPG and Local Air Quality

A Scientific Review

Atlantic **Consulting**

About the authors

Atlantic Consulting, an independent, privately-owned firm based in Zürich and London, specialises in the assessment of environmental impacts. Founded in 1994, the company has conducted hundreds of analyses for governments, NGOs and companies. Managing Director Eric Johnson is also editor of Environmental Impact Assessment Review, a Director of Green Cross, an advisor to the Global Pollution Remediation Fund and a nominated IPCC inventory assessor. Principal Derek Smith focuses on policy advice. Previously he was a senior environmental advisor to Ernst & Young and to BP.

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1 Foreword: The case for LPG

This document, on LPG and local air quality (LAQ), is one of a series of summaries for policy makers about LPG in Europe.

Other summaries set out the position of LPG in relation to other key policy challenges for the European Union, including; combating global warming, enhancing the security of its energy supply, and promoting the safe use of energy.

The summaries are intended to provide policy-makers, other stakeholders in energy and evironment policy and the LPG industry itself with an authoritative, quantified, and independent assessment of LPG's position and potential contribution.

This document presents conclusions from a comprehensive literature search and synthesis of relevant studies on LPG and air quality, drawing on the most credible and recent sources available.

LPG is a mixture of gaseous hydrocarbons, primarily propane and butane, derived during natural gas and oil extraction as well as during refining. At ambient conditions, propane is a gas, while butane can be either a gas or a liquid. LPG is easily liquiefied under modest pressure.

LPG has two physical properties that are particularly relevant to its local air quality (LAQ) footprint:

- While there is a degree of natural variation in its composition, LPG neverthless has a comparably high heating value, meaning it contains more energy per kilogramme than most competing fuels.

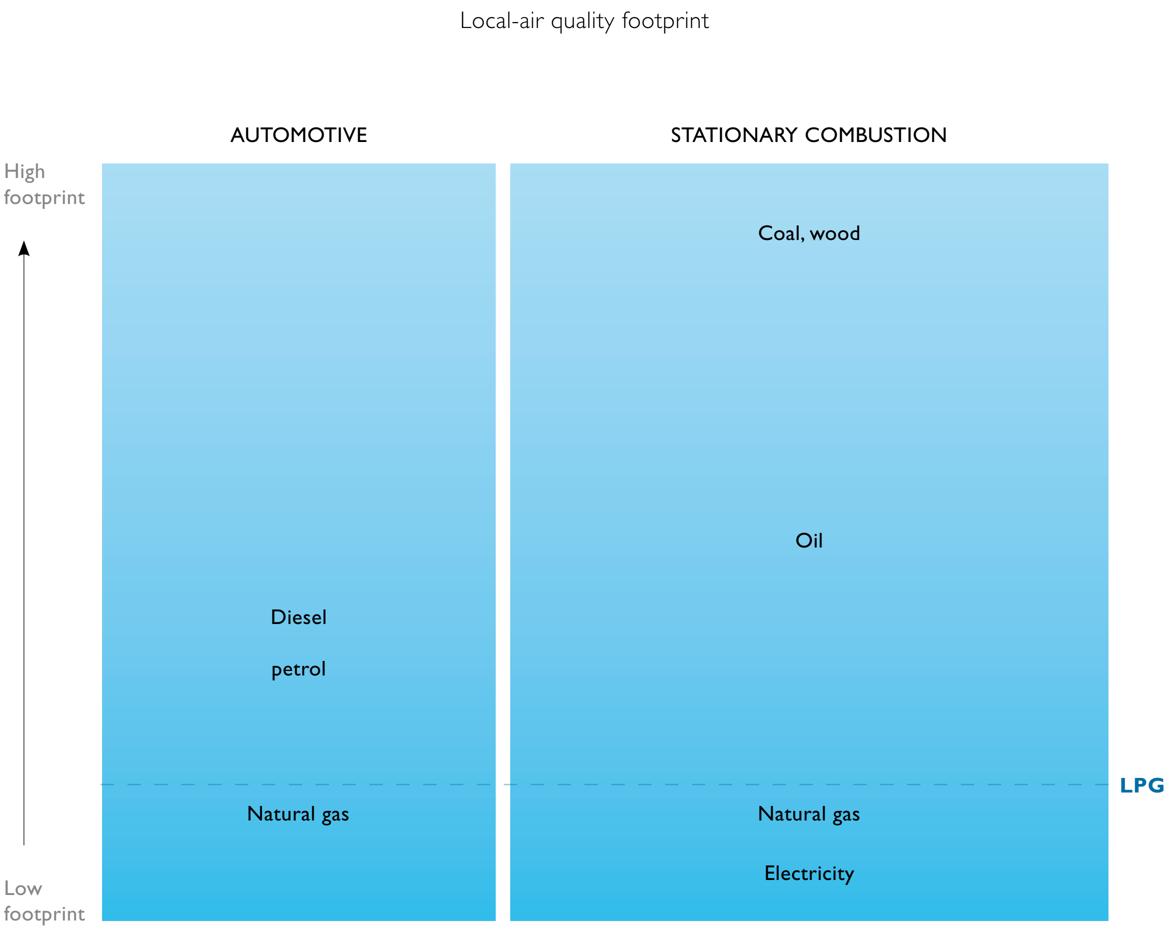
- LPG's simple molecular structure makes it easily combustible, giving it a lower pollutant emissions profile than most other fossil fuels.

2 Summary: LPG has a lower local-air-quality footprint

Air pollution at a local level, particularly in urban areas, is an immediate and long-term health hazard. Polluted air not only compromises human health – causing increased hospital admissions due to respiratory and cardiovascular problems – it also afflicts plants, animals and even buildings. Local air pollutants are primarily generated by fuel combustion in the transport, heating and power generation sectors.

Based on the most authoritative, consistent data available, LPG in Europe generates a lower local-air-quality-footprint. Compared to the main other fuels in its four primary applications, LPG's LAQ footprint is consistently at the lower end of the range (Figure 1).

Figure 1: Competing fuels' footprints vs LPG's footprint, Europe



3 Footprints by application

For the purposes of this summary, LAQ studies in Europe and in the US on the four major applications of LPG were reviewed in detail.

In volume terms, LPG has four major applications in Europe: automotive, heating, cooking and distributed power generation. However, studies of local-air-quality footprints have not been conducted to this level of detail. Instead, they fall into two types: automotive and stationary combustion, which covers heating, cooking and distributed power generation.

3.1 AUTOMOTIVE

LPG is currently Europe's most widely used alternative fuel, accounting for roughly 2% of the European road transport fuel mix. Studies consistently demonstrate that LPG generates LAQ footprints lower than diesel's and broadly equivalent to petrol's (gasoline's).

Two European studies of LAQ automotive emissions covering LPG are publicly available:

- The EETP (European Emissions Test Programme) study, sponsored by governments and energy companies and conducted by four testing laboratories, is a direct comparison of LPG, petrol and diesel.

- The UK Department of Transport's Cleaner Vehicles Task Force compared LPG to petrols and diesel, and although some general findings were published, specific emissions data for LPG were not published.

Three other European studies are related to the EETP work, but not conclusive with respect to comparing LAQ footprints of LPG to other fuels. *CONCAWE* published a comprehensive review of emission standards and fuel specifications, but not of actual emissions. It is nonetheless a useful reference and is particularly helpful in explaining various drive cycles used to test emissions. *Corinair* is a very detailed review of automotive emissions in Europe, but is designed to estimate national and regional emissions, rather than to compare fuels. Corinair provides no consumption factors by which emissions could be normalised for comparison. EcoInvent is probably the most authoritative database for LCA and carbon footprinting in general, but it does not cover LPG.

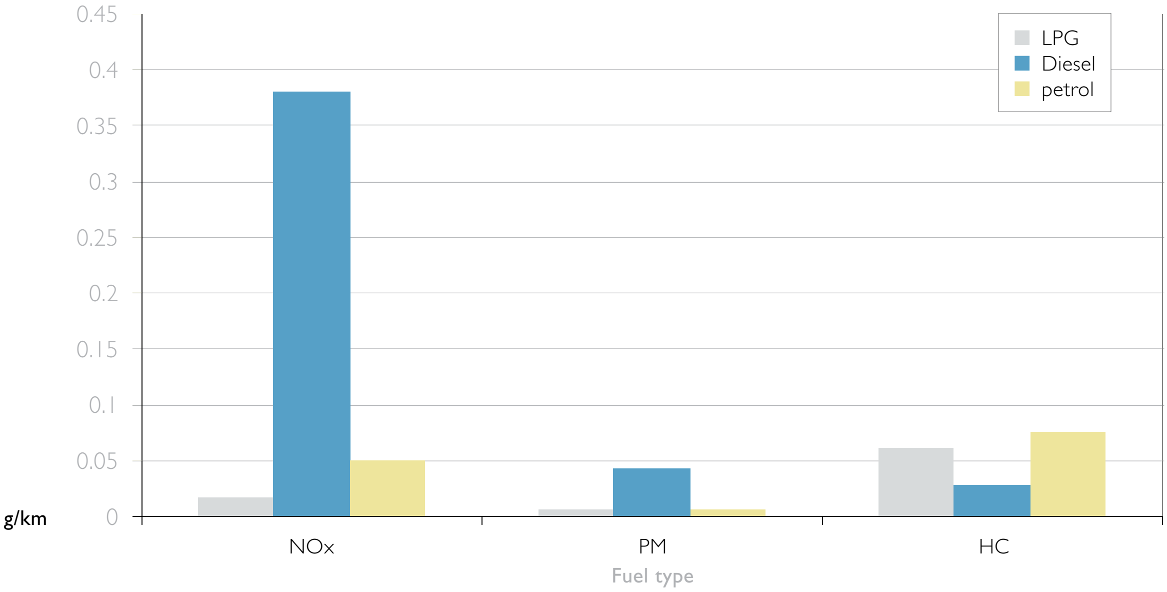
Two US studies have compared local air pollutant emissions of LPG and its main competitors, but only one of those studies (Argonne Labs GREET) does so in a way that is reasonably relevant to this assessment. Even GREET is of limited use for comparative purpose as its assumptions are not transparent. The other study, by the California Energy Commission is useful for comparisons within California, but not for out-of-state comparisons. (For study details, see References, page 8.)

Through well-to-wheel analysis, the EETP study shows LPG to be: clearly lower than petrol and diesel on NOx; essentially equivalent to petrol and well-below diesel on PM; and just below petrol yet well above diesel on HC (Figure 2). For carbon monoxide, LPG comes out higher than petrol and both are significantly higher than diesel. On emissions of so-called 'toxics' (such as aldehydes, benzene, toluene, xylenes (BTX), polyaromatic hydrocarbons (PAHs) and so on), LPG nearly always generates a footprint lower than diesel's and often lower than petrol's.

Volumes of these pollutants are orders-of-magnitude lower than that of carbon dioxide, the main product of combustion[A]. The mass of carbon monoxide emitted in LPG combustion, for example, is over 1000 times less than that of carbon dioxide emitted (European Environment Agency 2007). Some local pollution is also caused not only by combustion, but also by the evaporation of hydrocarbons (intentional in the case of solvents, unintentional in the case of stored fuels).

[A] Carbon dioxide is a global problem, in that it causes global warming, but it is not a local air quality problem.

Figure 2: Automotive priority pollutant emissions by fuel type



The UK Department of Transport verifies the EETP findings on NOx and PM: *"For light duty vehicles, the use of LPG and NG can provide a moderately cost-effective way of reducing emissions of NOx and PM10 (compared to diesel) and* CO_2 *(compared to petrol), though this is set to reduce over time… Gaseous fuels also provide reduced engine noise emissions. Most currently available light duty vehicles are bi-fuel, using petrol and either LPG or NG. However, greater emissions benefits can be gained from the use of dedicated gas engines, so introduction of dedicated engines for light duty LPG and NG vehicles should be encouraged."*

Euro 5 emission standards to come into effect in late 2009 will require new diesel automobiles to have particle filters. The proliferation of this technology is expected to diminish diesel-fuelled vehicles' PM emissions relative to those of vehicles running on LPG and petrol. The alignment of the European diesel fleet with Euro 5 standards will be a lengthy process that will not be complete until after 2020.

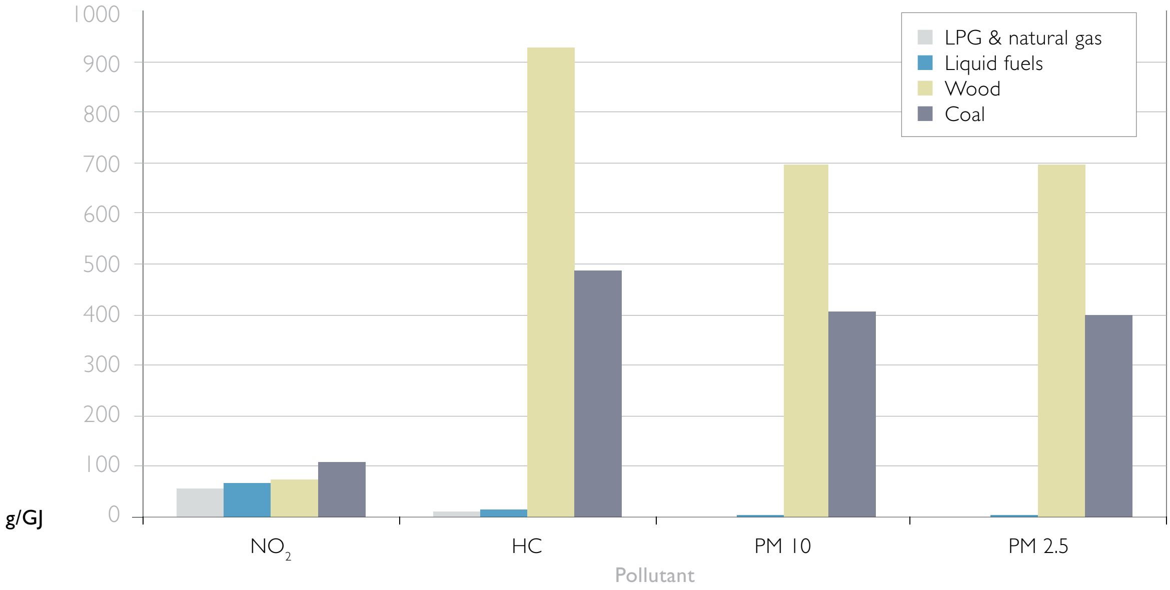
3.2 STATIONARY COMBUSTION

There have been three major studies that compare LAQ footprints of heating fuels in Europe. The two by the European Environmental Agency (EEA) and VHK (a consultant to the EU) cover LPG under the general heading of 'gaseous fuel'. EEA's Corinair covers gaseous fuels, which include natural gas and LPG, while VHK explicitly considers gas to be a proxy for LPG, i.e. their footprints (carbon and local air quality) are presumed to be equal. The third study, by EcoInvent, does not specifically address LPG in stationary combustion, referring instead to gas in general.

Based on the most authoritative, consistent data available, gaseous fuels (LPG and natural gas) are in general superior to competing fuels on local air emissions (Figure 3), except for electricity and some types of heatpumps, which generally generate lower levels of urban emissions. On all three priority pollutants, hydrocarbons (HC), nitrous oxides (NOx) and particle matter (PM), as well as on carbon monoxide (CO), toxics and heavy metals, gaseous fuels' footprints are in general lower than those of liquid fuels (heating oil and residual oil) and dramatically lower than those of solid fuels (coal and wood). When more sophisticated combustion and control equipment are used, gaseous fuels' advantage diminishes somewhat but generally remains significant.

[8] Often referred to as VOCs, or volatile organic compounds.

Figure 3: Stationary-combustion priority pollutant emissions by fuel type



4 Appendix: Overview of local air quality

Pollution of air at a local level can seriously influence health. Polluted air not only affects humans through respiratory ailments and cancers, but it also afflicts plants, animals and even buildings (via acidic decay and deposition of soot, for example).

The bulk of local air pollution is caused by fuel combustion for transport, heating and power generation. Combustion generates a variety of pollutants: hydrocarbons, carbon monoxide (CO), nitrogen oxides (NOx), sulphur dioxide, particles (PM), heavy metals and even ammonia.

When listed by species, local air pollutants can total 30-40 different types. Among them, regulators have determined priorities, based on toxicity and exposure. The current priority pollutants in Europe, as determined by the World Health Organization in a study for the European Commission (WHO 2003), are PM, nitrogen dioxide (NO_2) and ozone (O_3). Perhaps confusingly, NO_2 and ozone (O_3) are not reported as combustion-caused pollutants. This is because nitrogen dioxide (to some extent) and ozone are created indirectly as a result of chemical reactions in the atmosphere. Simply put, nitrogen oxide tends to converted to nitrogen dioxide (by reacting with oxygen), while NOx and hydrocarbons [C] react in sunlight to create ozone.

Regulators' response had been to focus primary attention on three pollutants:

NOx - Oxides of nitrogen react in the atmosphere to form nitrogen dioxide (NO_2) that can have adverse effects on health, particularly among people with respiratory illness. High levels of exposure have been linked with increased hospital admissions due to respiratory problems, while long-term exposure may affect lung function and increase the response to allergens in sensitive people. NOx also contributes to smog formation, acid rain, can damage vegetation, contributes to ground level ozone formation and can react in the atmosphere to form fine particles ('secondary particles').

Particles - Fine particles can have an adverse effect on human health, particularly among those people with existing respiratory disorders. Particles have been associated with increased hospital admissions due to respiratory and cardiovascular problems, bringing forward the deaths of those suffering from respiratory illnesses and reducing life expectancy.

Hydrocarbons - Hydrocarbons contribute to ground level ozone formation leading to risk of damage to the human respiratory system. In addition, some kinds of HCs are carcinogenic and are also indirect greenhouse gases.

[C] Including carbon monoxide, which, strictly speaking, is not a hydrocarbon.

5 References

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