

CLEARING THE AIR: BLACK CARBON, CLIMATE POLICY AND LP GAS



WORLD LP GAS ASSOCIATION

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FOREWORD BY THE WORLD LP GAS ASSOCIATION (WLPGA)

Energy is essential for economic and social development. Yet for all the invaluable benefits that energy access brings, its consumption can have a negative effect on the environment, particularly with regard to climate change. However, not all kinds of energy have the same impact on our climate. It is therefore important that consumers are informed and able to choose clean energy sources. This is particularly true on the issue of Black Carbon (BC), or soot, which is formed from incomplete combustion, primarily from biomass and diesel and which some experts estimate is responsible for up to 16% of gross global warming. This study is a call for reexamination of energy and environmental policy regarding BC and climate change while noting that reducing BC emissions is in no way incompatible with pursuing ongoing CO2 mitigation strategies that are already in place. It also aims to educate worldwide energy stakeholders about the clean burning, low CO2 and low BC emissions profile of LP Gas so that they can make informed decisions about future climate change policy.

LP Gas is a clean-burning and efficient fuel. It is also a vital source of energy for hundreds of millions of people throughout the world today. It is a modern and safe energy providing heat and power to both urban and rural consumers. LP Gas can be used anywhere and is available now without large investments in technology and infrastructure. It is a multi-purpose energy with literally thousands of applications. It is portable; can be transported, stored and used virtually anywhere in the world and there are sufficient reserves to last for many decades. Importantly, and as this study shows, with its inherently low particle emissions LP Gas is an excellent tool for reducing BC emissions rapidly.

The World LP Gas Association (WLPGA) is the global voice of the LP Gas industry. Granted consultative Status with the United Nations Economic and Social Council in 1989, the WLPGA promotes the use of LP Gas worldwide to help foster a cleaner, healthier and more prosperous world.



LPG EXCEPTIONAL ENERGY

LPG is an exceptional energy source due to its origin, benefits, applications and its industry. With immediate and global availability, environmental benefits, its natural by-product origin, transportation flexibility and diverse application, LPG plays a pivotal role in the transition towards a more secure, sustainable and competitive energy model.

The World LP Gas Association (WLPGA) has created the global LPG Exceptional Energy brand to raise awareness of the exceptional features of LPG among policymakers, industry and consumers. An increased understanding of LPG's environmental benefits, versatile applications and its immediate global availability is of the essence to allow conscious and responsible decisions on the type of energy sources used.

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CONTENTS

Executive Summary	6
Climate Change Policy and Black Carbon	6
What is BC, and how does it create global warming?	6
Including BC can change relative carbon footprints of fuels	6
Policy should catch up with, and support, the science of BC warming	7
Introduction: Why this Report?	8
What is Black Carbon?	8
Particle size – coarse and fine	8
Sources and composition of particulate matter and Black Carbon emissions	9
How Black Carbon emissions are estimated?	10
Black Carbon and Global Warming	11
Black Carbon contributes significantly to global warming	11
Cutting Black Carbon could cut warming quickly	13
Adding Black Carbon to climate change demands policy change	13
Fuel footprints: What if we include Black Carbon?	14
Automotive comparison of LP Gas and diesel	14
Heating comparison of LP Gas and wood	15
Cooking comparison of LP Gas, wood and coal	16
Distributed generation comparison of LP Gas and diesel	17
Black Carbon and Human Health	17
PM is a health hazard	18
Respiratory ailments	18
Conclusion	19
Appendix: Inputs to the Comparisons	20
Fuel footprints, homogeneous GHGs	20
Fuel footprints, heterogeneous GHGs	23
Glossary	27
References	28

FIGURES

Figure 1: Relative footprints by fuel, with and without accounting for Black Carbon	7
Figure 2: Global sources of Black Carbon emissions (Bond 2007)	9
Figure 3: Contribution of Black Carbon to increases in global temperature	11
Figure 4: Global average radiative forcing since 1750, IPCC estimate	12

TABLES

Table 1: Automotive LP Gas vs diesel, footprint including Black Carbon	14
Table 2: Home heating LP Gas vs diesel, footprint including Black Carbon	15
Table 3: Cooking, wood vs coal vs LP GAS, GWP 20 footprint including Black Carbon	16
Table 4: Cooking, wood vs coal vs LP GAS, GWP 100 footprint including Black Carbon	16
Table 5: Static generation LP Gas vs diesel, footprint including Black Carbon	17
Table 6: Robustness of heterogen and homogen data	20
Table 7: Automotive homogen footprints, JRC	21
Table 8: Heating homogen footprints, EcoInvent	21
Table 9: Cooking homogen footprints, Edwards	22
Table 10: Cooking homogen footprints, McCarty	22
Table 11: Distributed power generation homogen footprint, 50 kW genset, Europe	23
Table 12: Data sources – emission factors for heterogeneous GHGs	24
Table 13: Emission factors for heterogeneous GHGs, except for cooking	25
Table 14: Cooking emission factors (combustion only), heterogeneous GHGs	26
Table 15: GWPs for heterogeneous GHGs, CO ₂ e	26

EXECUTIVE SUMMARY

CLIMATE CHANGE POLICY AND BLACK CARBON

In the global debate about how to respond to climate change, black carbon (BC) emissions are an elephant in the room. Research published in the past five or so years shows BC to be a significant contributor to global warming, indeed it is now ranked second only to that of carbon dioxide (CO₂), the world's primary warming emission. Yet this elephant is relatively unnoticed. Media and popular attention paid to BC is scant. BC emissions are not regulated under the Kyoto Protocol or other climate-change policy due to the lack of a valid metric for enabling clear comparisons to the long term gases such as CO₂ and methane.

Ignoring BC can seriously skew policy judgements by making some fuels or technologies appear misleadingly better or worse than they really are. This can lead to questionable assumptions: for instance, the notion that biomass fuels are always 'low CO₂', even though their warming footprints when taking into BC consideration can be similar to or even greater than those of conventional fuels. This inconsistency is particularly true when biomass fuels are compared to relatively clean burning fuels such as LP Gas, with its inherently low particle emissions. It is important to strongly underscore that reducing BC emissions is in no way incompatible with pursuing ongoing CO₂ mitigation strategies already in place. On the contrary, the links between and mutually reinforcing nature of CO₂ and BC reduction strategies can be easily demonstrated.

This document is a call for policy reconsideration. Part of its purpose is to inform worldwide energy stakeholders about BC emissions and their impact on the global climate and part of its purpose is to demonstrate the low BC emissions profile of LP Gas in a number of different applications. After a short review of the basics of BC-driven global warming, it shows how including BC can change the relative "carbon performance" of common fuels in common applications. This study will also examine the well known and documented negative health impacts of BC that make its reduction a double win which produces immediate health improvements for local populations. In this summary chapter and in the detailed chapters that follow, the overriding message is that climate policy should include BC and fuels such as LP Gas should be considered in the context of their ability to make BC reductions.

WHAT IS BLACK CARBON, AND HOW DOES IT CREATE GLOBAL WARMING?

Black carbon or BC is the charcoal-like residue left by burning fuels that are rich in carbon, seen in fires or fireplaces or sometimes in a diesel plume. In common speech it is often called soot or char; more technically it is also called elemental carbon. BC usually exists as one constituent of an air-pollutant known as particle matter (PM) or particles. Most BC emissions are man-made, with a smaller contribution from natural fires.

Current estimates are that BC accounts for about 16% of the earth's warming in the industrialised period from 1750 to the present. Airborne BC warms the atmosphere by absorbing sunlight and then radiating that energy as heat. It also affects cloud formation and rainfall patterns, which influence local or regional climates. When BC settles back to the earth's surface, it can increase the melting of ice and snow, making it particularly significant in cold regions.

INCLUDING BLACK CARBON CAN CHANGE RELATIVE CARBON FOOTPRINTS OF FUELS

Conventional methods of measuring carbon footprints exclude BC. Usually they include only the global warmer gases defined under the Kyoto Protocol: mainly carbon dioxide (CO₂), methane and nitrous oxide. For some fuels and some applications, this omission can distort footprints considerably; for others, such as LP Gas, hardly at all. By including BC, diesel footprints can increase by almost half, wood and coal footprints can climb three- to five-fold, yet LP Gas footprints barely change (Figure 1).

In a given application, fuel selection and equipment type are the main variables affecting BC emissions. Per unit of heat delivered, some fuels emit more BC than others. Design matters, too. An open fire, for example, will emit far more BC than an enclosed stove, and variations in enclosed-stove design can further influence BC emissions. These same variables – fuel and equipment – are also the major ones in conventional footprints (using only Kyoto global warmers).

So it would be possible to include BC routinely in such analyses, without a fundamental change in analytical methods. Indeed, this study presents several examples, in: transport, heating, cooking and distributed generation. In every case, including BC makes a significant difference to the results, which in some cases suggests a re-think of policy and a strengthened position of fuels such as LP Gas in the discussion.

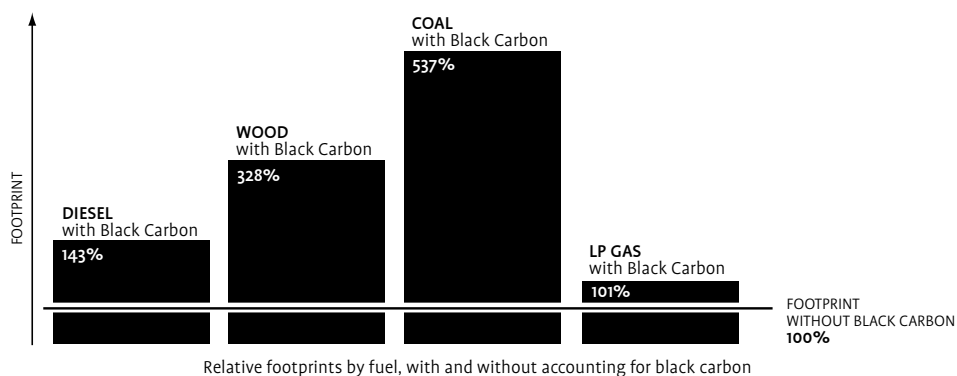


Figure 1: Relative footprints by fuel, with and without accounting for Black Carbon¹

POLICY SHOULD CATCH UP WITH, AND SUPPORT, THE SCIENCE OF BLACK CARBON WARMING

The knowledge of many of BC's effects is not new, but the recent findings make the benefits of focusing on BC mitigation clearer than ever. Because BC emissions could be reduced by fuel and equipment choices, policy – which already aims to influence such choices – should be broadened to include it. Because BC stays in the atmosphere only a short time, reducing BC would deliver cooling more quickly than reductions in CO₂ or methane and offer a fast-impact, global climate change mitigation strategy.

Not only would this mitigate global warming, it also would deliver a positive side-effect of improved human health. Particulate Matter (PM), of which BC is a main constituent, is responsible for hundreds of thousands of premature deaths every year, mainly in the developing world. It should also be noted that the local nature of the health benefits of BC reduction make them even more compelling. Unlike the case for CO₂ emissions, most of the health benefits of BC emissions stay in the country that makes the reductions in emissions.

Broadening policy to adopt BC could advance in three ways:

- Continue support of basic research – to investigate atmospheric and climatic phenomenon involving PM and BC.
- Promote application-specific research – to commission and support studies (such as the one presented in this document) that measure and compare BC emissions and effects, based on fuel and technology choices.
- Translate research into policy – to use this research in formulating policy (as similar research about Kyoto global warmers does). Two obvious areas for consideration are: questioning the promotion of biofuels in heating, which in some cases may be counterproductive; and boosting the promotion of cleaner fuels such as LP Gas in cooking, which can deliver immediate climate benefits in addition to well-recognised reductions of death and illness.
- Attempt to expand Kyoto Protocol to include black carbon as an offset - BC should ultimately be incorporated into a global climate change treaty to allow the large scale international effort, emissions markets and resulting financing to support BC mitigation.

¹ Relative GW20 footprints for each fuel, each for a specific application (automotive, heating, cooking and heating, respectively), are compared with and without BC. All the 'without BC' footprints are set at 100%, while the 'with BC' footprints are expressed as a proportion of that. Absolute footprint comparisons between different fuels are not possible from these data.

INTRODUCTION: WHY THIS REPORT?

Black carbon (BC) emissions are a significant contributor to climate change. Nonetheless, they are not regulated under the Kyoto Protocol or other climate regulations, and they are not counted in conventional carbon footprints. The reason that BC is not regulated under the Kyoto Protocol is because like other short-lived agents, it currently has no agreed upon Global Warming Potential (GWP) for a short or long term timeframe, which would enable clear comparisons to the long lived gases such as CO₂. Like other short-lived greenhouse gases, BC should be integrated into a global climate change treaties to facilitate coherent international reduction efforts.

This report is meant to raise recognition of this issue among policy-makers. After an overview of what BC is, it reviews the currently understood role of BC in global warming, and it presents BC-inclusive footprints for several common fuels in four common applications:

- automobile transport,
- residential heating in the developed world,
- cooking in the developing world, and
- distributed power generation.

The findings suggest that current policies are, to some extent, internally conflicted. The report concludes with a review of how BC and other particle emissions harm human health.

WHAT IS BLACK CARBON?

Picture a fireplace, a burnt field or forest, or the dark residue in a boiler's firing chamber – this is how many laypeople encounter BC. Commonly referred to as soot or sometimes char, this residue is actually a mixture of BC², and another type of carbon called organic carbon (OC), plus typically some inorganic ash and salts.

BC is emitted mostly from combustion (burning), more specifically from incomplete combustion primarily from biomass and diesel use. Due to a lack of oxygen or a low temperature, some of the carbon in the fuel converts to BC rather than to CO₂. BC is almost always emitted together with other substances, in particles (PM³) of varying sizes. There are many types of particles in the air, containing varying amounts of BC, emitted by a variety of sources. BC emissions are usually not monitored directly, but are instead estimated from samples of PM and BC factors.

PARTICLE SIZE – COARSE AND FINE

Particles are broadly classified as coarse and fine, which is important, because as a particle's size increases, its time in the air decreases. Fine particles can remain air-borne for months, during which they can travel hundreds of kilometres. Coarse particles do not remain airborne as long; they tend to deposit on the ground downwind of emissions sources. Coarse particles are not readily transported across urban areas or beyond, because they are generally too large to follow air streams and they tend to be removed easily on contact with surfaces (US EPA 2008).

Two size ranges of particles, known as PM₁₀ and PM_{2.5}, are widely monitored, both at major emissions sources and in ambient air. The 2.5 fraction is considered to consist of fine particles, the 2.5-10 fraction of coarse particles⁴. The 2.5 and 10 refer to particle diameter measured in microns (one-millionths of a metre). Individually, even the largest of the particles are about one-tenth the diameter or a small grain of sand, so they are invisible to the human eye. As a swarm particles sometimes can be seen, for instance, in the plume of a diesel engine.

² Often called elemental carbon (EC).

³ PM stands for particulate matter, or particles.

⁴ So the PM₁₀ fraction is coarse and fine particles combined, while the PM_{2.5} is just the fine ones.

SOURCES AND COMPOSITION OF PARTICULATE MATTER AND BLACK CARBON EMISSIONS

Composition of individual particles varies widely. For instance sea salt from ocean spray, a major source of PM in coastal areas, contains no carbon. The PM emitted by kerosene combustion in a jet engine, consists of about 95% carbon by weight, in about a two-third:one-third ratio of BC and OC (US EPA 2005).

Where does PM come from? Sources of PM_{2.5} emissions – the most relevant fraction for global warming and other air quality issues – are not well documented globally or for Europe, but they are in the US. Roughly measured, about one-half of fine PM comes from combustion, one-quarter from industry and agriculture and the remaining one-quarter from construction and road traffic, particularly on unpaved roads (US EPA 2006). Roughly one-third of this is considered biogenic – mainly that from forest fires (US EPA 2008).

In Europe the sources of PM are not as well documented. One researcher (Friedrich 2009) estimates European emissions of PM₁₀ to be about equally split between anthropogenic and biogenic, but he does not estimate PM_{2.5}, and his uncertainty is very high. Although he reckons a ‘base case’ 1:1 ratio of natural, man-made PM₁₀, he adds that it also might be as high as 4-5:1 or as low as 0.5:1.

Combustion Sources of black carbon

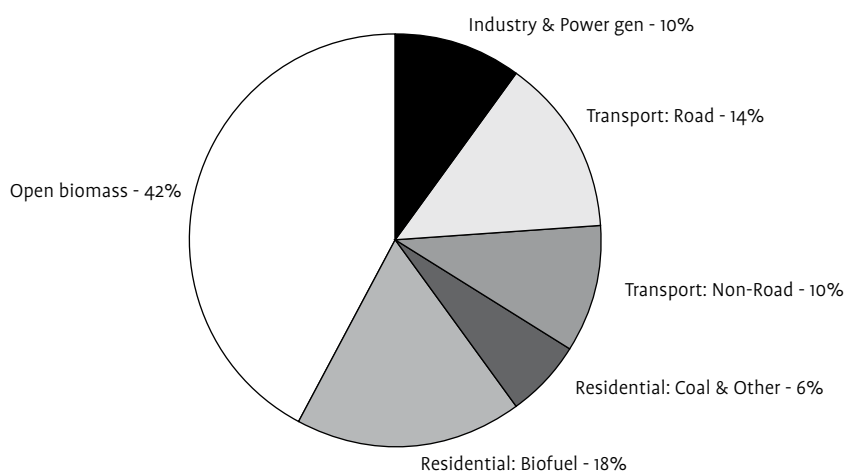


Figure 2: Global sources of black carbon emissions (Bond 2007)

Much clearer is the sourcing of BC in PM. Nearly all of global BC emissions come from combustion, the bulk of which is man-made (Figure 2). Some 20-30% arises from forest fires, the major biogenic source.

HOW BLACK CARBON EMISSIONS ARE ESTIMATED?

Emissions of BC by itself are not usually directly monitored but are indirectly monitored as a proportion of small PM emissions, a category of PM damaging to human health that includes BC. The reason BC emissions are not directly monitored has to do with the lack of an adequate metric. Under the Kyoto Protocol, actions to reduce GHGs are evaluated using the 100yr GWP, a figure given in relation to the effect of CO₂ over 100 years, which is given a GWP of 1. But BC currently has no agreed upon GWP for any timeframe to enable accurate comparisons to CO₂. A key first step to gain a better understanding of the impact of BC is to develop metrics so that it can be included in the climate change policies that are emerging.

Today BC emissions are usually estimated as a product of two factors:

- PM₁₀ or PM_{2.5} emissions from a given fuel and/or a given application
- BC content of that PM emission

PM emission factors are published for a wide range of fuels and applications. PM_{2.5} factors are published less frequently than PM₁₀s, because measurement of the former began later. Studies conducted in the past five years tend to include PM_{2.5}; studies before that less so.

BLACK CARBON AND GLOBAL WARMING

Through a variety of physical mechanisms, BC contributes to global warming. Over the past 10-15 years this contribution has been recognised as significant; indeed it is now ranked second only to that of CO₂, the world's primary warming emission.

Putting BC on a like-for-like footing with CO₂ and other conventional global warmers is complicated, because BC acts more locally than CO₂; has an atmospheric residence time of weeks, not years; influences clouds and rainfall; and can be co-emitted with compounds that also cause cooling. Nonetheless, climate scientists agree that cutting BC emissions could substantially slow warming, and more rapidly than by cuts in other emissions.

Cutting BC emissions would also require a re-think of climate policy. When reduction of BC, not just conventional global warmers, becomes a goal it adds new trade-offs and dimensions to policy. For instance, biomass combustion – encouraged under existing policy – appears much less attractive. Decarbonisation takes on a double meaning, referring not to just CO₂ but also to BC. And poor performance gains in importance.

BLACK CARBON CONTRIBUTES SIGNIFICANTLY TO GLOBAL WARMING

According to Jacobson (2007), BC accounts for about 40% of net global warming or 16% of gross global warming (Figure 3). This makes it a clear number two to number one global warmer CO₂, which accounts for about 70% of gross warming.

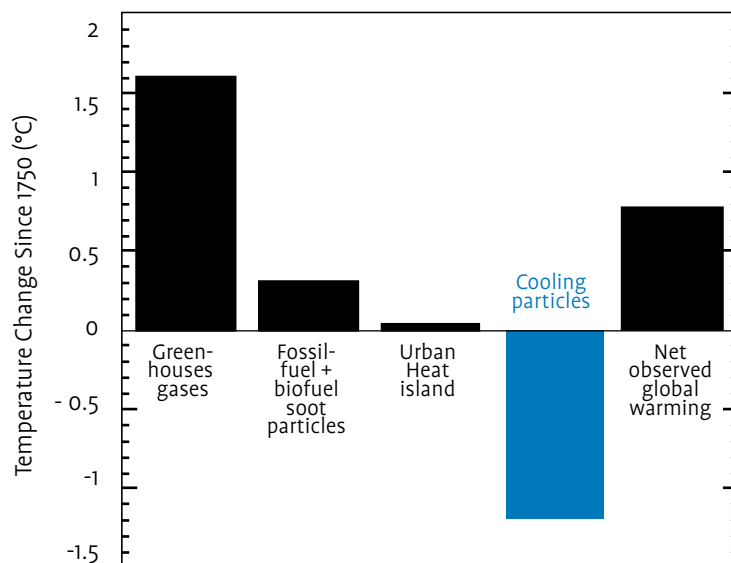


Figure 3: Contribution of Black Carbon⁵ to increases in global temperature

Estimates by the UN's Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (2007) corroborate BC's number two position (Figure 4). From the IPCC data, it is difficult to corroborate Jacobson's 40% and 16% estimates precisely, but from inspection they appear to be in reasonable agreement.

⁵ Shown in the graph as 'fossil fuel + biofuel soot particles'.

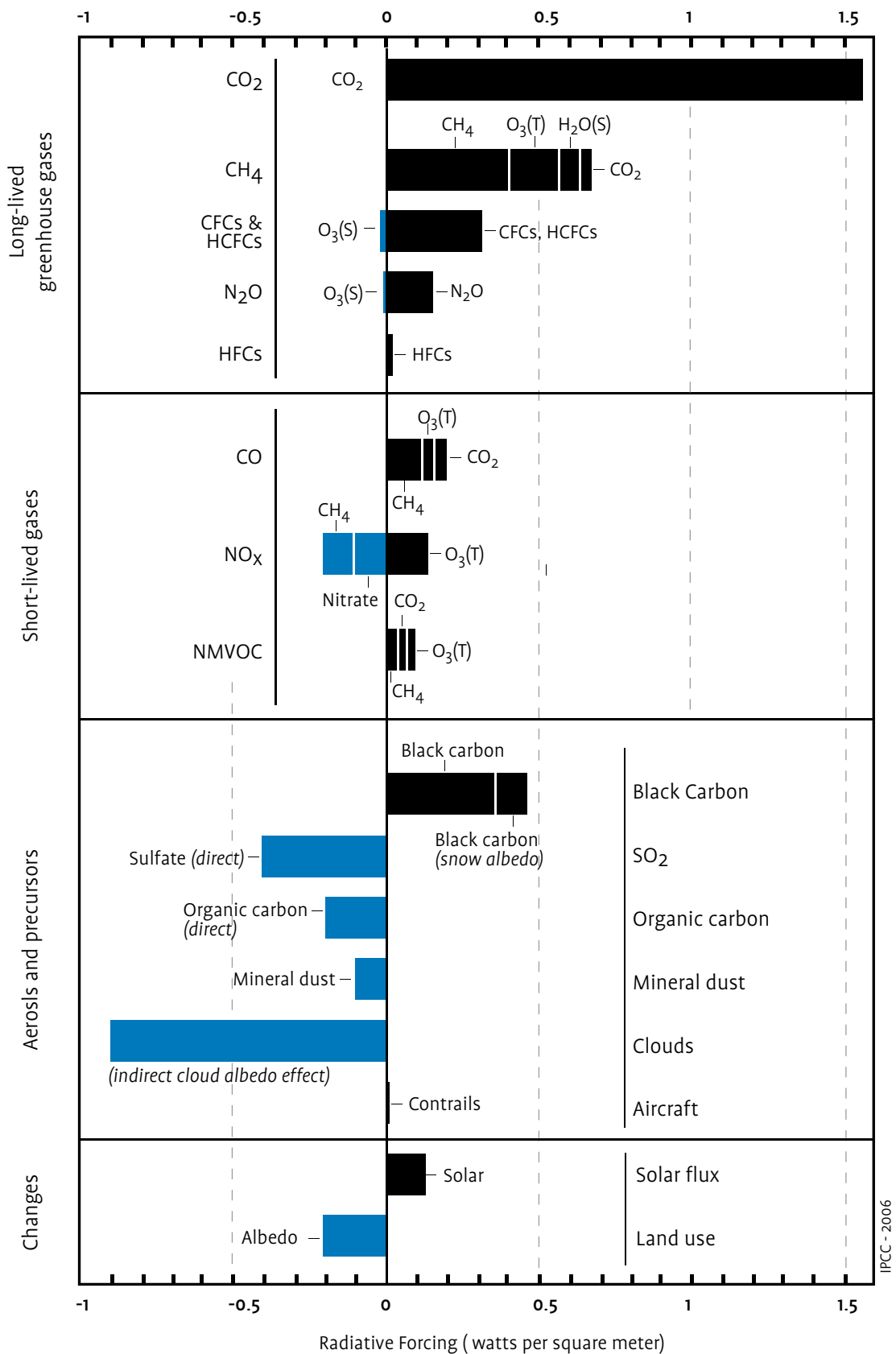


Figure 4: Global average radiative forcing since 1750, IPCC estimate⁶

6 From a draft of the IPCC report, presented in EMF-22 (2006). Black Carbon Update. EMF-22 Meeting. Tsukuba, Japan.

BC's temperature effects occur through several mechanisms, which can vary according to region. Primarily, BC absorbs sunlight and radiates it back to the atmosphere as heat. It also affects cloud formation and rainfall patterns.

When BC settles back to the earth's surface, it can increase the melting rate of ice and snow, which makes it particularly significant in colder regions. For instance, experiments by Ramanathan (2009) and colleagues suggest that BC and CO₂ play nearly equal roles in inducing springtime snow-cover loss in Eurasia. Similar work by NASA's Drew Shindell finds that half or more of the warming measured in the Arctic from 1976-2007 is due to BC plus OC (Kintisch 2009). It is in the Arctic that BC is of particular concern because it settles on ice and snow, reducing its reflectivity and increasing the rate of melting. The Arctic climate is very sensitive to the surface warming that BC causes, and BC appears to warm the Arctic more than any other agent except CO₂. Most arctic BC comes from fuel-combustion, not from open fires.

CUTTING BLACK CARBON COULD CUT WARMING QUICKLY

As shown above, cutting BC in the atmosphere would reduce warming. Moreover, because it has a relatively short atmospheric lifetime, cutting BC would reduce warming more quickly than cuts in other greenhouse gases or particles.

Jacobson (2007) shows that eliminating emissions of BC would bring about temperature reductions more rapidly than elimination of CO₂ or methane emissions. Accord to his calculations, eliminating BC emissions would cool global temperatures by about 0.4 C over the subsequent decade, whereas eliminating CO₂ or methane would deliver cooling of only about 0.1 C over the same period. Conventional analyses (using 100-year horizons) understate this short-term impact, which may be why it appears to have been overlooked by most policy-makers.

As an airborne solid, BC behaves differently in the atmosphere than global warming gases do. This is a worthwhile area of further research. So too are the phenomenon of BC's influence on clouds and rainfall, and the effects of pollutants often emitted together with BC, primarily organic carbon (OC) as well as sulphates and nitrates. Moreover, net cooling or warming effects of a given fuel or application should be considered in policy. Ramanathan (2009) calls for this, and more recent research (Unger 2010) picks up that lead, showing that a focus on BC reduction in four economic sectors will bring about most rapid cooling: household biofuels; on-road and off-road transport; and waste disposal.

ADDING BLACK CARBON TO CLIMATE CHANGE DEMANDS POLICY CHANGE

Reducing BC emissions will not necessarily happen under current climate policies; indeed they could promote increased BC emissions. To optimise climate policy, decision-makers should:

- Reconsider the promotion of biofuels. As Reddy and Boucher (2007) show, biofuels account for one-third of all energy-related BC emissions and the vast majority of non-energy-related BC emissions. As (Unger 2010) shows, BC emissions from household biofuel use generates net positive global warming.
- Raise the importance of combustion-performance standards. A minority of combustors – sometimes known as 'super emitters' – can emit the majority of BCs. As Bond (2007) points out, 10-20% of a given vehicle fleet can produce half the total emissions. Unfortunately, reducing BC emissions often is not in the economic interest of the emitter; he spends, not saves money in cutting them. By contrast, there is often an economic incentive to cut CO₂.
- Include BC and other non-Kyoto global warmers when assessing policy options. A detailed example of this is shown in the next chapter.

FUEL FOOTPRINTS: WHAT IF WE INCLUDE BLACK CARBON?

Conventional carbon footprints account for only homogeneous greenhouse gases (GHGs) specified by the IPCC as global warmers: CO₂, CH₄, N₂O, and halocarbons. Footprints generally do not include gases or particles not specified by the IPCC such as BC or other heterogeneous species such as carbon monoxide (CO), hydrogen (H₂), organic carbon (OC), ozone, (O₃), nitrogen oxides (NO_x) or sulphates (SO_x).

What difference would it make to footprints if BC and the other heterogeneous species were included? This chapter examines that with comparisons of four applications: automotive transport, residential heating in the developed world, cooking in the developing world and static generation⁷. The comparisons show that if heterogens – primarily BC – are included in the footprint, relative advantages can shift significantly, mainly because some fuels emit more black carbon than others.

AUTOMOTIVE COMPARISON OF LP GAS AND DIESEL

The first comparison is of typical automobiles in Europe, as defined by research agency of the European Commission (Joint Research Centre of the EU Commission, EUCAR et al. 2006). On a conventional, homogen basis, LP Gas' footprint is about 10% lower than that of diesel's. When heterogen emissions are added to that, LP Gas' advantage to diesel is increased: on a GWP 20 basis, which examines global warming potential over a 20 year period, the difference rises to about one-third; on a GWP 100 basis, looking at the global warming potential over 100 years, which is the usual period of comparison used in global warming comparisons, it is just over 15% (Table 1). BC is by far the main actor, accounting for 95+% of the increase.

Table 1: Automotive LP Gas vs diesel, footprint including Black Carbon⁸

	Footprint, g CO ₂ /km			Comment
	Homogen	Heterogen	Sum	
Scenario: GWP 20				
LP Gas	141	9	151	
Diesel	158	69	226	without DPF
Scenario: GWP 100				
LP Gas	141	5	146	
Diesel	152	22	174	without DPF

HEATING COMPARISON OF LP GAS AND WOOD

The second comparison is of space heating in Europe, as defined by the most authoritative research database in the field (Ecolnvent 2007).

Conventional, homogen footprints of wood-fired heating can vary dramatically (Table 2), depending on whether or not the wood is considered to be carbon neutral. As yet, opinions on this differ (Johnson 2009), so to sidestep that dispute this analysis, we present both 'carbon neutral' and 'not carbon neutral' footprints for wood (Table 2).

⁷ Interested readers can follow the detailed inputs in an appendix.

⁸ In the GWP 20 calculation, contributions of hydrogen and ozone were omitted, because for them there were no available GWP factors. For NO_x, a GWP 100 factor was applied, because a GWP 20 factor was not available. It is believed that these adaptations would not significantly change the results. Nonetheless, this gap would be a good topic, among others, for further research.

In either case, inclusion of BC (and other heterogens) increases wood footprints substantially: in the carbon neutral cases, it increases 2-3-fold; in the not carbon neutral cases, it climbs by 10-20%. Again, BC is by far the main actor, accounting for 95+% of the change. LP Gas' footprint, by contrast, is almost identical throughout, whether GWP 20 or GWP 100, with or without heterogens.

Table 2: Home heating LP Gas vs diesel, footprint including Black Carbon⁹

	Footprint, g CO ₂ /km			Comment
	Homogen	Heterogen	Sum	
Scenario: GWP 20				
Wood pellets	18.4	41.9	60.3	Carbon neutral
LP Gas	70.3	0.4	70.7	
Wood pellets	198.0	41.9	239.9	Not carbon neutral
Scenario: GWP 100				
Wood pellets	15.7	13.1	28.8	Carbon neutral
LP Gas	70.0	0.2	70.2	
Wood pellets	169.2	13.1	182.3	Not carbon neutral

Inclusion of BC (and other heterogens) in the carbon neutral case changes the relative footprint position of wood to LP Gas. In this case, wood's footprint without BC is well below that of LP Gas'; when BC is included, the footprints become comparable.

COOKING COMPARISON OF LP GAS, WOOD AND COAL

The third comparison is of cooking in the developing world as well as in many rural areas of the developed world, where wood and coal fires still are commonly used. According to MacCarty (2008 p 56):

- *“An August 2007 headline in the online BBC News stated ‘Clouds of pollution over the Indian Ocean appear to cause as much warming as greenhouse gases released by human activity’. These clouds are composed primarily of soot, or black carbon particles. A similar article in Scientific American stated ‘The dominant source for all this black carbon is cooking fires.’ A later article in Nature Geoscience, summarized in the New York Times, showed the contribution of cooking fires to overall Asian black carbon concentrations...”*

The bases of the comparison are two studies, (Edwards 2004) and (MacCarty 2008), that compare cooking footprints on, respectively, a GWP 20 and a GWP 100 scale¹⁰.

In the GWP 20 comparison (Edwards 2004), again we have sidestepped the ‘carbon neutral’ debate by presenting wood with and without carbon neutrality (Table 3). The GWP 100 comparison by contrast, assumes that wood is not carbon neutral (Table 4).

⁹ The same conditions as stated in the previous footprint apply.

¹⁰ The global warming potential over 20 years and 100 years, respectively. These vary according to the persistence and degradation of global warmer emissions in the atmosphere.

Table 3: Cooking, wood vs coal vs LP GAS, GWP 20 footprint including Black Carbon^{11 12}

Fuel	Stove type	Footprint, g CO ₂ e/MJ delivered			Comment
		Homogen	Heterogen	Sum	
LP Gas	Traditional	140	1	141	
Processed coal	HBC-ImproC	291	62	353	
Fuel wood	Improved	43	725	768	Wood treated as carbon neutral
Fuel wood	Improved	431	725	1,156	Wood treated as NOT carbon neutral
Unprocessed coal	UNCW-Metal	1,154	5,040	6,194	

Note: HBC-ImproC¹³

LP Gas' GWP 20 footprint once again, is little changed, whether GWP 20 or GWP 100, with or without heterogens. By contrast, footprints of both coal and wood are changed substantially when BC is included, particularly in the GWP 20 case (Table 3): with the exception of processed coal, their heterogen footprints are larger than their homogen ones. In the GWP 100 case (Table 4), wood's footprint again is changed significantly by the inclusion of heterogens; so too is charcoal's.

Both in the GWP 20 and GWP 100 cases, when heterogens are included, LP Gas' footprint comes out well below those of coal, charcoal and wood. BC is once again a significant factor in the heterogen footprints of coal and wood, but not as dominantly as in the previous comparisons. For charcoal (Table 4), BC contributes relatively little to the overall footprint in comparison to the other heterogens.

Table 4: Cooking, wood vs coal vs LP GAS, GWP 100 footprint including Black Carbon^{14 15}

Fuel	Stove type	Footprint, g CO ₂ e/litre of water				Comment
		Homogen	Non CO ₂ gases: Methane, CO and NMHC	PM net, EC + OC	Sum	
LP Gas	Traditional	138	0.22	0.22	138	Estimate, based on relative efficiencies
Fuel wood	Rocket	206	14	61	281	Wood treated as NOT carbon neutral
Charcoal	Not specified	300	240	3	543	Wood treated as NOT carbon neutral
Fuel wood	3-stone fire	536	100	54	690	Wood treated as NOT carbon neutral

Note: Methane¹⁶, NMHC¹⁷

These results contrast not just the inherent characteristics of the different fuels, but also stove performance. Processed coal versus unprocessed coal (Table 3) and fuel wood in a rocket stove versus a 3-stone fire show stove-type influence to be large. In the other applications compared in this study, equipment type plays a role in determining footprints, but less obviously than it does in the case of cooking.

¹¹ N₂O not included, combustion-only footprints.

¹² Processed and unprocessed coal are presented, because these represent the high and the low coal footprints determined in this study.

¹³ A stove design for processed coal – a detailed name was not given by the authors.

¹⁴ N₂O not included, combustion-only footprints (i.e. production of the fuels is not included).

¹⁵ The rocket and the 3-stone fire are presented, because these represent the high and the low wood footprints determined in this study.

¹⁶ Methane is a homogen global warmer. We have reported it as part of the heterogens here, because it is reported that way in the original study, which does not report the individual emission in a disaggregated form. From inspection, it would appear that shifting the methane emission to the homogen column would not affect the findings.

¹⁷ Non-methane hydrocarbons.

DISTRIBUTED GENERATION COMPARISON OF LP GAS AND DIESEL

The final comparison is of static, non-grid distributed generation (often referred to as ‘gensets’) in Europe, as defined in a survey of manufacturers (Energetics Inc 2008).

For conventional, homogen footprints, diesel generators report a higher efficiency than those powered by LP Gas. This might be due to the generally-higher efficiency of compression to spark-ignition engines, but it also could be due to more subtle design factors. In any case, the efficiency lead is more than cancelled out by LP Gas’ higher energy content, so that LP Gas’ homogen footprint is lower than diesel’s (Table 5).

Table 5: Static generation LP Gas vs diesel, footprint including Black Carbon

Fuel	Footprint, g CO ₂ e/MJ		
	Homogen	Heterogen	Sum
GWP 20			
LP Gas	72.1	4.6	76.6
Diesel	89.6	39.4	129.0
GWP 100			
LP GAS	71.8	2.4	74.2
Diesel	86.3	13.0	99.3

To this homogen comparison we have estimated the inclusion of heterogens, using automotive emission factors (Table 13, see section 0) as a basis. We did not use actual genset emission factors, because none were found in the literature. The automotive heterogen emissions are under the current EU emission limits, as defined by Euro Stage III A standards for non-road engines .

Thanks to this similar estimation method for the heterogen emissions, the resulting footprints (Table 5) are similar in pattern to those for automotive transport (Table 1). In the GWP 20 case, the diesel’s footprint is almost 70% greater than LP Gas’; in the GWP 100 case it is about one-third larger than LP Gas’.

BLACK CARBON AND HUMAN HEALTH

BC's global warming impacts are a relatively new discovery, with official recognition starting in the early 1990s. By contrast, the hazard to human health of BC and other PM constituents has been known since the mid-20th century.

So-called 'killer smog' events in numerous cities – most notably London in 1952 – caused death and disease among thousands of people, thus alerting the public and regulators to the danger of high PM concentrations in ambient air. Thanks to emissions regulations, killer smogs have disappeared from the developed world. Nonetheless, PM at lower, less visible concentrations still constitute a danger to human health and killer smogs now plague developing-world cities such as Beijing, Cairo, Mumbai and Teheran.

It should also be pointed out that PM including BC damages property, in that it soils buildings. This is obvious on some brick or stone structures. The relatively hidden 'amenity' cost this imposes on cities globally surely amounts to significant cost outlays. This point should strengthen the case for action.

PM IS A HEALTH HAZARD

Particles in the air, not just BC but also OC, worsen respiratory ailments such as asthma, adding to the toll of infirmity and death. This damage is well understood, and reducing it is a key aim of existing PM-emission regulations. Over the past decade or so, a general consensus has emerged that the PM_{2.5} fraction of particles is much more harmful to health than the larger part of the PM₁₀ fraction.

PM's health effects in the developing world are even more dramatic. According to research led by Henning Rodhe, Professor of Chemical Meteorology at the University of Stockholm¹⁸, "The brown cloud that covers South Asia for most of each winter is responsible for the deaths of approximately 340,000 people in India and China every year from related cardiovascular and respiratory problems. Some studies have put the figures much higher, possibly even into the millions."

RESPIRATORY ALIMENTS

Exposure to particles causes higher rates of asthma, chronic bronchitis in adults and episodes of bronchitis in children. It also aggravates cardiovascular problems and it forces some adults to restrict their activity due to breathing difficulties (Künzli, Kaiser et al. 2000). Some indicative estimates of its impacts are:

- Cutting UK particle emissions from 231 kilotonnes in 1995 to 112 kilotonnes in 2005 eliminated about 500 early deaths and about 400 emergency hospital admissions per year, estimates a study (Stedman, King et al. 2002) commissioned by the government.
- PM emissions from diesel automobiles annually cause 10,000-19,000 premature deaths through respiratory and cardiovascular disease in Germany, according to a study conducted for the Federal Environmental Agency (Wichmann 2004).

Reductions in BC will clearly produce immediate health improvements that make such interventions a double win. Given this and given the local nature of the health benefits of BC reduction makes them even more compelling. For unlike the case for CO₂ emissions, most of the health benefits of BC emissions stay in the country that makes the reductions in emissions. This avoids the blame game, and incentive to get others to shoulder the burden of emissions reductions. Moreover, the estimated health benefits in developing countries are larger than in the developed world, although they too are substantial.

¹⁸ As reported in http://cordis.europa.eu/search/index.cfm?fuseaction=news.document&N_RCN=30466

CONCLUSION

In the global debate about how to respond to climate change, BC emissions are just beginning to come to the attention of both energy stakeholders and policy makers and this study's analysis points to an emerging understanding of BC as one of the key causes of global warming. Indeed, as is noted above, many scientists now rank BC second only to CO₂, as the world's primary warming emission. Yet media and popular attention being paid to BC is scant and BC emissions are not regulated under the Kyoto Protocol or other climate-change policy due to the lack of a valid metric for enabling clear comparisons to long term greenhouse gases such as CO₂ and methane.

This document attempts to shed new light on the role of BC in climate change. Part of its purpose is to inform worldwide energy stakeholders about BC emissions and their impact on the global climate and part of its purpose is to demonstrate the low BC emissions profile of LP Gas in a number of different applications. Better understanding of the effects of BC and its immediate impact on the climate can be a short term advantage. Unlike CO₂, with its long lifeline and resultant cumulative buildup, BC's effects are immediate, last only a matter of weeks, and are regional in their effect. Reducing BC emissions can create rapid relative cooling, buying time to keep temperature increases below a critical value while long term strategies for reducing CO₂ emissions are implemented. It is important to strongly underscore that reducing BC emissions is in no way incompatible with pursuing ongoing CO₂ mitigation strategies already in place. On the contrary, because of the links between and mutually reinforcing nature of CO₂ and BC reduction, approaches can be easily demonstrated.

This study also examines the well known and documented negative health impacts of BC that make its reduction a double win, which produces immediate health improvements for local populations particularly in the developing world. What's more, nearly all the health benefits of reducing BC emissions stay in the country that actually makes the reductions thus rendering the case for action that much more compelling. In addition, this study notes that BC also damages property by soiling buildings and infrastructure which has a long term cost that bears consideration.

The inherent low particle emission qualities of LP Gas make it an excellent tool for reducing BC emissions quickly. This is especially true in two of the principal areas of BC emissions worldwide; in substituting wood, coal and other forms of biomass for cooking fires in the developing world and in displacing petrol and diesel in road transport in the developed world. It is notable that dominant BC emitters change from residential solid fuels to transport as development occurs.

Reducing BC emissions will not necessarily happen under current climate policies and ignoring BC can seriously skew policy judgments by making some fuels or technologies appear misleadingly better or worse than they really are. To optimize climate policy, decision-makers should consider the following actions:

- Continue support of basic research to investigate atmospheric and climatic phenomenon involving PM and BC.
- Promote application-specific research – commission and support studies that measure and compare BC emissions and effects, based on fuel and technology choices.
- Translate research into policy – use this research in formulating policy. Two obvious areas for consideration are: questioning the promotion of biofuels for some domestic applications and boosting the promotion of cleaner fuels such as LP Gas when appropriate.
- Promote having BC ultimately incorporated into a global climate change treaty to allow the large scale international effort, emissions markets and resulting financing to support BC mitigation.

APPENDIX: INPUTS TO THE COMPARISONS

Inputs to the footprint comparisons are of two basic types: data about homogeneous GHGs, which were covered in a Carbon Footprint study for AEGPL (Atlantic Consulting 2009a); and data about heterogeneous GHGs. Some of the heterogen data was provided in a previous local-air-quality (LAQ) study for AEGPL (Atlantic Consulting 2009b); these have been expanded and supplemented from other sources.

There are two main inputs used to estimate footprints of fuels: 1) emission factors, i.e. how much of a given GHG is emitted in production and use of the fuel; and 2) global warming potential (GWP) of the GHG, i.e. how much warming does it generate in the atmosphere. The robustness of these inputs varies (Table 6): for homogens they are moderately robust; for heterogens they are still highly variable.

Table 6: Robustness of heterogen and homogen data

Type of GHG	Inputs used to estimate footprints	
	Emission factors	GWPs
Homogens	Moderate uncertainty and dispute about factors. In some applications, e.g. heating, published figures vary widely. LP Gas is not covered in many databases and comparisons.	In footprinting, these are generally agreed and rarely disputed.
Heterogens	Moderate uncertainty and dispute about factors. In some applications, e.g. heating, published figures vary widely. LP Gas is not covered in many databases and comparisons.	This is an area of active research, with significant dispute and uncertainty. E.g. reported GWPs for NOx range from slightly negative to 400. Even the concept of GWP is disputed, as is the footprint convention of using 100-year GWPs.

FUEL FOOTPRINTS, HOMOGENEOUS GHGS

For both the automotive and heating comparisons, we used homogen footprints presented in a previous study (Atlantic Consulting 2009a). For cooking we used figures from two studies (Edwards 2004) (MacCarty 2008); for static generation we used figures from an industry survey (Energetics Inc 2008).

With only one exception (Edwards 2004), these were reported on a GWP 100 basis, so we adjusted them for the GWP 20 calculations. For diesel and LP Gas the adjustment is minor, 3.9% and 0.3% respectively. For wood, the adjustment is greater: its GWP 20 footprint is 17% greater than its GWP 100 one.

Automotive

For the automotive comparison, the homogen data (Table 7) were copied from the Carbon Footprint Study of Studies (Atlantic Consulting 2009a); the original source is EU's JRC (Joint Research Centre of the EU Commission, EUCAR et al. 2006), which is among the most authoritative for this application.

Table 7: Automotive homogen footprints, JRC

	Footprint g CO ₂ e/km travelled			Scenario
	Prod/ Dist	Combust	Total	
Biodiesel (ME)	-51.0	136.0	85.0	RME DICI with DPF (scenario ROFA1), 100% biodiesel basis
Biodiesel (ME)	-90.0	136.0	46.0	SME DICI with DPF (scenario SOFA1), 100% biodiesel basis
Bioethanol	-26.0	137.0	111.0	Sugar beets, PISI 2010, pure EtOH basis
Bioethanol	-23.0	137.0	114.0	Wheat, PISI 2010 (scenario WTET1a), pure EtOH basis
Diesel	24.0	128.0	152.0	DICI 2010 no DPF
Diesel	25.0	131.0	156.0	DICI 2010 with DPF
Gasoline	24.0	140.0	164.0	PISI 2010
Gasoline	24.0	139.0	163.0	DISI 2010
LP Gas	15.0	126.0	141.0	PISI 2010
Natural gas	16.0	108.0	124.0	EU Mix, PISI monofuel 2010
Natural gas	41.0	108.0	149.0	Pipeline 7,000 km, PISI monofuel 2010

HEATING

Also for the heating comparison, the homogen data (Table 8) were copied from the Carbon Footprint Study of Studies (Atlantic Consulting 2009a); the original source is the Ecoinvent database (Ecoinvent), among the most authoritative in this application.

Table 8: Heating homogen footprints, Ecoinvent

Fuel	Boiler/system	Carbon footprint g CO ₂ e /MJ	As a multiple of the gas footprint	Comment
Wood chip	50 kW	4.3	6%	Wood is carbon neutral
Wood logs	6 kW	4.9	7%	Wood is carbon neutral
Wood pellets	15 kW	15.7	22%	Wood is carbon neutral
Gas	<100 kW	70.0	100%	
Oil	10 kW	86.7	124%	
Coal	NA	158.5	226%	
Wood logs	6 kW	169.2	242%	Wood is NOT carbon neutral

In the heating case, natural gas is used as a proxy for LP Gas, because Ecoinvent does not cover LP Gas. This same proxy is assumed by the EU in its fuel comparisons made for the Energy Using Products Directive.

COOKING

For cooking, the aim was to compare traditional methods in the developing world – wood and coal fires – versus LP Gas. Numerous studies are found in the literature that measure emissions from wood-fired cooking, but only a few of them allow a normalised comparison to LP Gas or to coal. Out of about 15 studies identified in a literature search, we found two suitable for use in comparisons:

- One study (Edwards 2004) that compared wood, coal and LP Gas on a GWP 20 basis (Table 9). This was meant to represent cooking in China.
- Another study (McCarty 2008) that compared wood, charcoal and LP Gas on a GWP 100 basis (Table 10). The testing, done in a laboratory setting, was meant to replicate typical conditions in the developing world. Footprints are expressed per litre of water (which is brought to a boil and simmered for 30 minutes).

In both cases, the homogen footprints presented (Table 3, Table 4) are those reported by the studies; i.e. we have not calculated them ourselves. Indeed neither is presented with enough transparency for us to do so.

Table 9: Cooking homogen footprints, Edwards¹⁹

Fuel	Stove type	Homogen footprint g CO ₂ e /MJ delivered, GWP 20	Comment
Fuel wood	Improved	43	Wood treated as carbon neutral
Fuel wood	Improved	431	Wood treated as NOT carbon neutral
Processed coal	HBC-ImproC	291	
Unprocessed coal	UNCW-Metal	1,154	
LP Gas	Traditional	140	

Table 10: Cooking homogen footprints, McCarty²⁰

Fuel	Stove type	Energy consumed MJ/litre water	Homogen footprint g CO ₂ e /litre	Comment
GWP 100				
Fuel wood	3-stone fire	6.553	536	Wood treated as NOT carbon neutral
Fuel wood	Rocket	2.470	206	Wood treated as NOT carbon neutral
Charcoal	Not specified	4.216	300	
LP Gas	Traditional	2.175	138	

¹⁹ Combustion only, N₂O emissions apparently not included (but these would be negligible anyway)

²⁰ Combustion only, N₂O emissions apparently not included (but these would be negligible anyway)

DISTRIBUTED POWER GENERATION

Only one study was identified (Energetics Inc 2008) that reports footprints for static generators (Table 11).

Table 11: Distributed power generation homogen footprint, 50 kW genset, Europe

Fuel	Energy content MJ/kg	Genset performance		Footprint, g CO ₂ e /MJ			
		MJ/h	Efficiency	Combustion	Pre-Combust	Sum	
						GWP 100	GWP 20
LP Gas	46	672	27%	60.2	11.6	71.8	72.1
Diesel	43.1	585	31%	71.0	15.3	86.3	89.6

Note: GWP 20²¹

Diesel generators report a higher efficiency than those powered by LP Gas. This might be due to the generally-higher efficiency of compression to spark-ignition engines, but it also could be due to more subtle design factors. In any case, the efficiency lead is more than cancelled out by LP Gas' higher energy content, so that LP Gas' homogen footprint is lower than diesel's.

FUEL FOOTPRINTS, HETEROGENEOUS GHGs

For heterogen footprints, we collected both inputs need to calculate a footprint: emission factors and GWPs.

HETEROGEN EMISSION FACTORS

Heterogeneous GHGs are defined (2003) as: black carbon (BC), carbon monoxide (CO), hydrogen (H₂), organic carbon (OC), ozone, (O₃), nitrogen oxides (NO_x), non-methane organic carbon (NMOC) or sulphates (SO_x). Having three types of carbon can be confusing. The simple explanation is that BC and OC are particles, while NMOC is gaseous.

For most of the significant heterogens in the two applications and three fuels being compared, we found reported emissions factors (Table 12, Table 13). For CO, NMOC and NO_x, factors were copied from the LAQ SoS (Atlantic Consulting 2009). This same study provided particle matter (PM) emissions for diesel and LP GAS: the breakdown of PM among its two main constituents, BC and OC, was estimated using data and methods created by Bruce Hill of the Clean Air Task Force (Hill 2009). BC and OC factors for wood were taken from a study that measured various types of actual wood burners (Gaegauf, Schmid et al. 2005).

For H₂, O₃ and SO_x, however, we found no published emission factors for these fuels in these applications. This is not believed to be significant in the comparisons studied, with perhaps one exception: SO_x might be significant in some wood heating, yet probably not as a general rule.

²¹ This has been estimated from the sum footprint for GWP 100. For LP Gas and diesel combustion, the homogen footprints for GWP 20 are slightly higher than those for GWP 100, respectively 3.9% and 0.3% greater.

Table 12: Data sources – emission factors for heterogeneous GHGs

Species	Fuel and application				
	LP Gas – automotive	LP Gas - heating	Diesel - automotive	Wood – heating	Wood and coal – cooking
CO	Tab 6 (Atlantic Consulting 2009)	Tab 10 (Atlantic Consulting 2009)	Tab 6 (Atlantic Consulting 2009)	Tab 10 (Atlantic Consulting 2009)	(Edwards 2004)
H2	NA	NA	NA	NA	NA
O3	NA	NA	NA	NA	NA
Particles, of which	PM from Tab 6, (Atlantic Consulting 2009)	PM 2.5 Tab 12 (Atlantic Consulting 2009)	PM from Tab 6, (Atlantic Consulting 2009)	BC and OC estimated directly, see cells directly below.	(Edwards 2004)
BC	Est based on (US EPA 2005) and (Hill 2009)	Est based on (US EPA 2005) and (Hill 2009)	(Hill 2009)	(Gaegauf, Schmid et al. 2005)	(Gaegauf, Schmid et al. 2005)
OC	Est based on (US EPA 2005) and (Hill 2009)	Est based on (US EPA 2005) and (Hill 2009)	(Hill 2009)	(Gaegauf, Schmid et al. 2005)	(Gaegauf, Schmid et al. 2005)
NMOC	VOC from Tab 6, (Atlantic Consulting 2009)	Tab 10, (Atlantic Consulting 2009)	VOC from Tab 6, (Atlantic Consulting 2009)	VOC, Tab 10 (Atlantic Consulting 2009)	NA
NOx	Tab 6 (Atlantic Consulting 2009)	Tab 10 (Atlantic Consulting 2009)	Tab 6 (Atlantic Consulting 2009)	Tab 10 (Atlantic Consulting 2009)	NA
SOx	NA	NA	NA	NA	NA

Note: LP GAS - heating²² / Diesel - automotive²³

Although carbon particles are of two types, BC and OC, most emission factors are reported simply as the sum of the two, usually called PM. Wood is an exception; we found separately reported BC and OC in (Gaegauf, Schmid et al. 2005). For diesel, Hill has estimated the split to be 75% BC and 25% OC (Hill 2009), so we used this.

For LP Gas there is no reported split for BC and OC. For his diesel estimate, Hill used source data (US EPA 2005) that does not report a split for LP Gas, but does report a split for natural gas of 0% BC and 100% OC. Based on this, we have made our own, conservative estimate for LP Gas of 50% BC and 50% OC.

²² The same sources were also used to estimate LP GAS emissions in cooking for the MacCarty case

²³ The same sources were also used for estimating emissions from static generation

Table 13: Emission factors for heterogeneous GHGs, except for cooking

Species	Fuel and application			
	LP GAS – automotive g/km	LP GAS - heating g/Gigajoule	Diesel – automotive g/km	Wood pellet – heating g/Gigajoule
CO	0.915	9.03	0.200	15.8
H2	NA	NA	NA	NA
O3	NA	NA	NA	NA
PM, of which	0.005	0.33	0.042	
BC	50%, i.e. 0.0025	50%, i.e. 0.165	75%, i.e. 0.035	20.05
OC	50%, i.e. 0.0025	50%, i.e. 0.165	25%, i.e. 0.007	9.60
NMOC	0.061	8.8	0.028	7.1
NOx	0.016	2.42	0.381	22.9
SOx	NA	NA	NA	NA

For one of the cooking studies (Edwards 2004), we used its reported emission factors (Table 14) to calculate heterogeneous footprints. In the other cooking study (MacCarty 2008), however, we simply presented the heterogeneous footprints reported by the study itself, because the paper is not presented with enough detail for us to repeat or check the calculation.

Table 14: Cooking emission factors (combustion only), heterogeneous GHGs

Fuel	Stove type	Total suspended particles	CO
		g/MJ	g/MJ
Fuel wood	Improved	1	30
Fuel wood	Improved	1	30
Processed coal	HBC-ImproC	0.05	8
Unprocessed coal	UNCW-Metal	8	50
LP Gas	Traditional	0.0005	0.1

HETEROGEN GWPs

This is an area of active research, with significant dispute and uncertainty of not just the figures themselves, but over what figures should even be used and how. Some researchers argue that other measures of global warming than GWP should be applied, such as Carbon dioxide Equivalency Factors (CEFs) or Global Temperature Potentials (GTPs). Some also point out that the 100-year effect period – the convention used in most carbon footprints – should in some analyses be shortened. These same disputes and uncertainties apply to homogeneous GWPs, but to a far lesser degree.

We found published 100-year GWPs for five of the heterogens: BC, CO, OC, NMOC and NO_x; and we found 20-year GWPs for BC, CO and OC (Table 15). Because the GWPs of BC and OC are greatest among the heterogens, and because they change significantly from the 20-year to the 100-year period, we devoted more effort to finding their 20-year values than we did for those of the other heterogens.

Table 15: GWPs for heterogeneous GHGs²⁴, CO_{2e}

Species	GWP 20	GWP 100	Comment
BC	2200	680	(Hill 2009) Table 4
CO	4	3	(Bailis 2004) Table III - (Brakkee, Huijbregts et al. 2008) Table 4
OC	-250	-75	(Hill 2009) Table 4
NMOC	NA	8	(Brakkee, Huijbregts et al. 2008) Table 3
NO _x	NA	1.4	(Delucchi 2003), Table D-1, p 110 – average of the reported figures.

For BC and NO_x, GWPs are very much disputed. For instance, Hill (Hill 2009) lists GWP₁₀₀ estimates for BC that range from 460 to 1,500; we have used what he calls the ‘best estimate’ of 680. For NO_x we have used an estimate (Delucchi 2003) that was verified in a separate, detailed study (Riffel 2007); this appears to be most authoritative for the applications being compared²⁵.

²⁴ For H₂, O₃ and SO_x, we have not reported their GWPs, because we did not find emission factors for them. To derive a footprint, both an emission factor and a GWP are needed.

²⁵ That is to say it is not an estimate for NO_x emitted by aircraft, which is considerable and also highly disputed.

GLOSSARY

Term	Definition
BC	Black Carbon
CO ₂	carbon dioxide, the greenhouse gas most responsible for global warming Global warmers – gases or particles that, when in the atmosphere, cause global warming
GHG	greenhouse gas, a gaseous global warmer
GWP	global warming potential
GWP 20	global warming potential over 20 years
GWP 100	global warming potential over 100 years, which is the usual period of comparison used in global warming comparisons
Heterogens	heterogeneous molecules such as carbon monoxide (CO), hydrogen (H ₂), organic carbon (OC), ozone, (O ₃), nitrogen oxides (NO _x) or sulphates (SO _x)
Homogens	homogeneous greenhouse gases (GHGs) specified by the IPCC as global warmers: CO ₂ , CH ₄ , N ₂ O, and halocarbons.
IPCC	Intergovernmental Panel on Climate Change, a United Nations' organisation tasked with studying global warming and climate change
LP Gas	liquefied petroleum gas, usually a mixture of propane and butane
NMOC	non-methane organic carbon
OC	organic carbon
PM	particle matter, sometimes called particles
PM 2.5	the fraction of particle matter (usually denominated by weight) with particle diameters of 2.5 microns or less
PM 10	the fraction of particle matter (usually denominated by weight) with particle diameters of 10 microns or less

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As the global voice for LP Gas, the WLPGA promotes the use of the fuel to foster a cleaner, healthier and more prosperous world.

The Association was officially granted Consultative Status with the United Nations Economic and Social Council in 1989 and actively represents the interests of the LP Gas industry in numerous UN processes including the UN Framework Convention on Climate Change (UNFCCC) negotiations.



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