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Information paper – 5

Emission factors for black carbon

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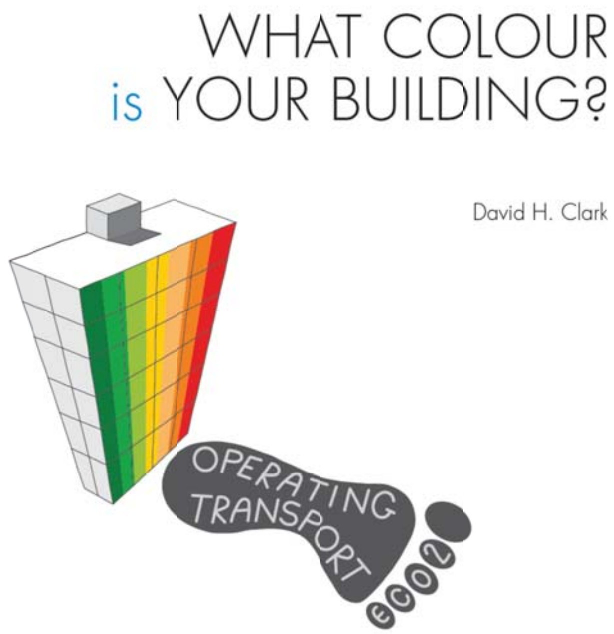
A paper referenced in the book:



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This information paper is one of a series of papers written during the preparation of the book **What Colour is Your Building?** (www.whatcolourisyourbuilding.com). The papers do not form part of the book and have not been peer reviewed. They provide further technical detail, analysis and information to support statements made in the book. All of the papers can be downloaded from www.wholecarbonfootprint.com.

Emission factors for black carbon

This information paper provides some further information and background on black carbon and how the potential CO_2e emission factor in Appendix B of the book was derived.

1. BLACK CARBON AND GLOBAL WARMING

Black carbon is basically soot from the incomplete combustion of fossil fuels, biofuel and biomass, and occurs naturally, such as forest fires, and from human activities. Roughly 20% of black carbon is emitted from burning biofuels, 38% from fossil fuels, and 42% from open biomass burning of forests and savannah.[1]

It contributes to global warming (radiative forcing) in two ways: it absorbs heat in the atmosphere (direct effect) while deposits on snow and ice reduce the ability to reflect sunlight. Black carbon stays in the atmosphere for only several days to weeks, whereas CO_2 has an atmospheric lifetime of more than 100 years.

In the IPCC's 4th assessment report in 2007 black carbon was estimated to have a radiative forcing effect of 0.3 W/m^2 ± 0.25 with two thirds due to direct atmospheric effect and one third to deposits on snow.[2] This makes it the third largest contributor to positive radiative forcing after greenhouse gases and tropospheric ozone.

More recent research suggests that the impact of back carbon could be three times higher at 0.9 W/m^2 (with a range of 0.4 to 1.2 W/m^2).[3] If this is correct then black carbon could account for about a quarter of the total positive radiative forcing effects. Fig 1 shows black carbon in comparison to other radiative forcing components.

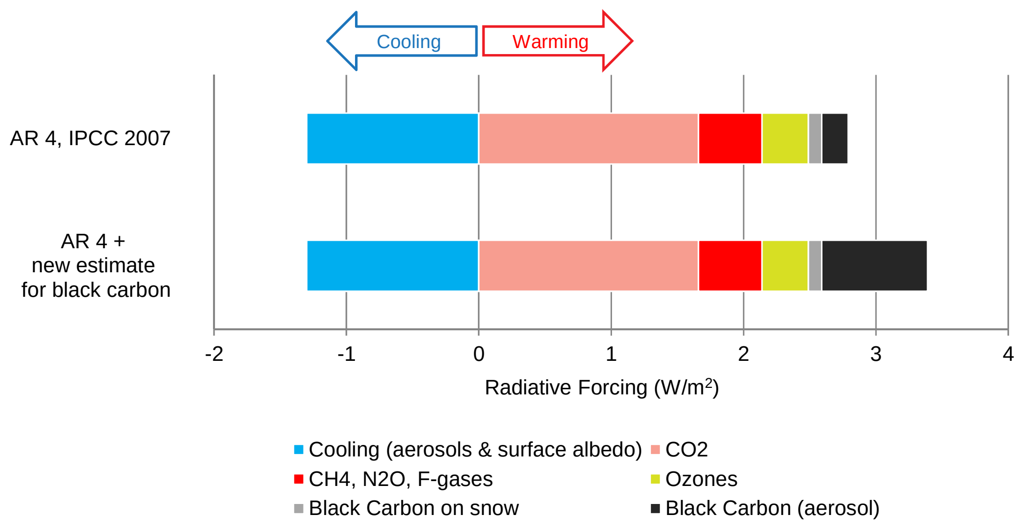

Fig 1 Main components of radiative forcing from IPCC data with new estimate for black carbon added

Since the middle of the last century, many countries have significantly reduced black carbon emissions, primarily to improve public health by improving air quality. Due to its short lifespan (compared to hundreds of years for greenhouse gases) reducing black carbon would reduce radiative forcing (warming) almost immediately and is possibly the fastest means of slowing climate change in the near future. Further work continues on determining the impact of black carbon on global warming and how to implement the known technologies to mitigate this. This must not distract efforts to reduce greenhouse gas emissions.[4]

2. EMISSIONS FACTOR FOR BLACK CARBON

There is currently no agreed emissions factor for Black Carbon because:

- It behaves very differently to the six Kyoto greenhouse gases (CO_2, CH_4, N_2O and F-gases) as it is so short lived (days to weeks rather than years).
- There is little consensus on the level of past, current and future emissions of black carbon.
- Concentrations in the atmosphere vary regionally.
- The albedo effect (soot on snow) varies regionally.

Table 1 shows various suggestions for the 100 year global warming potential (GWP) of black carbon so that it can be compared to CO_2 (which has a GWP = 1).[5]

Region that black carbon is emitted	100 year GWP	Upper GWP estimates
Global average	680	
Europe	374	1600
Africa	677	

Table 1 Estimates for the global warming potential of black carbon (source: MET office)

Global emissions of black carbon have doubled over the last century to 4.6 million tonnes, with Asia accounting for 60% of this. Applying a GWP of 680 gives emissions equivalent to 3.1 billion tonnes of CO_2. In 2008 the total emissions of CO_2 were 30.8 billion tonnes suggesting black carbon contributes about 10% of global warming.[6] This is consistent with the IPCC's estimates for black carbon (refer Figure 1 above and Figure A.5 in Appendix A of the book). New research indicates that black carbon may be contributing up to 25% towards global warming, suggesting a GWP of around 1600 may be more appropriate.

Recent studies of air quality indicates that particulate emissions from biomass boilers vary between 10g/GJ and 105g/GJ compared to a typical gas boiler of 1g/GJ, where GJ is the Gigajoules of energy input to the boiler.[7]

To put this into context consider Building X (refer Appendix M of the book) which has a floor area of 10,000m^2 and is heated by a natural gas boiler consuming 75 kWh/m^2 each year (15 kgCO_2e/m^2). This is equivalent to 0.27 GJ/m^2. If the global average GWP for black carbon of 680 is assumed then:

- Total particulates (black carbon) = 0.27 GJ/m^2 x 1 g/GJ = 0.27 g/m^2
- Equivalent greenhouse emissions = 0.27 g/m^2 x 680 / 1000 = 0.18 kgCO_2e/m^2

This adds about 1% on to the CO_2e emissions using the standard factors for natural gas and represents less than 0.2% of Building X's total emissions (105 kgCO_2e/m^2) due to operating energy. Modern buildings with gas boilers are not a major contributor of black carbon. The impact of black carbon from power stations may be factored into national electricity emissions factors in the future but is currently not taken into consideration.

If 85% of Building X's heating was provided by an efficient biomass (wood pellet) boiler (60 kWh/m^2) and the rest by natural gas (18 kWh/m^2) then the total CO_2 emissions due to heating (biomass and natural gas) are 6 kgCO_2e/m^2 (refer Table I.11 in Appendix I of the book). Assuming the biomass boiler has flue filtration with particulate emissions of 20 g/GJ then the equivalent greenhouse emissions would increase by 3 kgCO_2e/m^2 [0.22 GJ/m^2 x 20 g/GJ x 680 / 1000], adding 50% on to the standard emissions. This is probably an underestimate of the impact of many biomass boilers currently in operation which are not fitted with ceramic filtration systems.

Table 2 shows the black carbon emission factors converted into kgCO_2e/kWh.

	Particulate emissions g/GJ	Global average kgCO_2e/kWh	Upper Europe estimate kgCO_2e/kWh
Natural gas	1	0.002	0.005
Biomass (efficient)	20	0.05	0.11
Biomass (average)	60	0.15	0.35

Table 2 **Potential black carbon CO_2e emission factors**

The values in Table 2 are not official factors. Clearly further research on black carbon emissions from combustion of biomass in buildings, and its impact on global warming is required, so that this can be considered in the assessment of biomass systems in building. It is hoped that this information paper may stimulate some debate in this field.

Notes

All websites were accessed on 15 June 2013 unless noted otherwise.

1. *A technology-based global inventory of black and organic carbon emissions from combustion*. Bond, T. C. et al. Journal of Geophysical Reseach. Res. 109, doi:10.1029/2003JD003697 (2004). http://earthjustice.org/sites/default/files/black-carbon/bond-et-al-2004.pdf

2. The IPCC AR 4 report, *Climate Change 2007: Working Group I: The Physical Science Basis* provides the following estimates for radiative forcing of black carbon:
   Aerosol from Fossil Fuels (ch 2.4.4.3): 0.2 $W/m^2 \pm 0.15$
   On snow and ice (ch 2.5.4): 0.1 $W/m^2 \pm 0.1$

3. Data from *Global and regional climate changes due to black carbon* by V. Ramanathan and G. Carmichael, Nature Geoscience 221-22 (23 March 2008). www.climate.org/PDF/Ram_Carmichael.pdf

4. http://wwf.panda.org/what_we_do/how_we_work/conservation/one_planet_living/?203558/Black-carbon-initiative-should-not-block-real-carbon-action

5. The various estimates of GWP for black carbon are summarised in section 3.1 of *Assessment of climate metrics for comparing the climate impacts of short-lived and long-lived chemical species*, Boucher et al, Hadley Centre Technical Note 75, published by MET Office in October 2008. www.metoffice.gov.uk/media/pdf/8/a/HCTN_75.pdf
   Further discussion on the difficulties of using GWP for black carbon, and estimates of total emissions, are found in *An Analysis of Black Carbon Mitigation as a Response to Climate Change* by Baron et al, Copenhagen Consensus Center, August 2009. http://fixtheclimate.com

6. Global Carbon Project's Carbon Budget 2009 - http://www.globalcarbonproject.org

7. *Measurement and Modelling of Fine Particulate Emissions (PM10 and PM2.5) from Wood-Burning Biomass Boilers*, a report to The Scottish Government prepared by AEA Energy & Environment (September 2008) gives a range of 20 to 105 g/GJ. The Biomass Energy Centre's website suggests a range of 10 to 70 g/GJ and that over half the boilers tested in a study achieved 20 g/GJ or less. Fitting ceramic filters can reduce this further.
   www.biomassenergycentre.org.uk/portal/page?_pageid=77,109191&_dad=portal&_schema=PORTAL