CO_2 Emission Figures for Policy Analysis

Christine Pout
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For policy analysis and applications that relate to end users it is important to use CO_2 emission factors that accurately reflect the net change in CO_2 emissions that would result from specific policy action or other decision. For example, it is important that those used in SAP and SBEM encourage choices that result in lower annual carbon emissions for a particular building, and that their application in Part L of the Building Regulations provide an equitable basis between different fuels. This means using emission factors that relate to delivered energy, which include emissions from processing and distributing emissions, as well as from combustion, as a reduction in energy use at the point of delivery will also reduce these upstream emissions

The fossil fuel emission figures that are currently proposed for SAP 2005 are based on delivered energy CO_2 emission factors, which had previously been generated for DEFRA's Global Atmosphere Division for use in carbon abatement studies. To date, the way in which the SAP 2005 figures have been derived has not been set out which has led to the figures currently proposed for SAP 2005 figures being challenged.

This paper sets out to describe how delivered energy emission figures relate to other emission factors in the public domain, and to review the currently proposed SAP 2005 emission factors and describe their provenance. It considers more recent data on emissions arising from LPG that has been provided by the Liquid Petroleum Gas Association (LPGA) and makes recommendations as to how these emission factors should be adjusted, based on more recent information, but using the existing methodology. This work was funded by DEFRA's Global Atmosphere Division.

Background

The CO_2 emission factors that are presented in DEFRA's environmental reporting guidelines (and which are used to assess carbon emissions for both Negotiated Agreements and the UK Emissions Trading Scheme) differ from those proposed for SAP, which can lead to confusion. However, the key difference between the SAP figures and the environmental reporting guidelines lies in the scope of emissions considered. Whereas the environmental reporting factors are combustion factors, the SAP figures relate to delivered energy and thus include upstream emissions from fuel production and distribution as well as from combustion.

Whereas emission factors for fossil fuels are not likely to change significantly from year to year[1], for electricity, the emission factor will vary significantly depending on the mix of generation plant used in a particular year. For this reason, the emission factor for electricity needs to reflect the expected generation mix over the period which the emission factor is to be used. Hence the electricity emission factor is based on the expected fuel mix over the period in question, which for the purpose of SAP 2005 has been taken as 2005-2010. The emission factor for electricity is further complicated by the issue of marginal emissions, which relate to emissions avoided as a result of reduced or increased demand for electricity. In the past the marginal

[1] Whilst there may be year to year variations these are not generally large and significant changes are only likely to be relevant where this is a step change in either the composition of the fuel, or to the production or distribution of the fuel.

emission factor for UK generated electricity has been higher than the system average, although it is clear that the gap has been closing in recent years.

Delivered Emission Factors for Fossil Fuels

The fossil fuels emission factors for SAP 2005 put forward in the consultation document are listed below:

	$kgCO_2/kWh$
• mains gas	0.194
• bulk LPG	0.249
• bottled LPG	0.249
• heating oil	0.270
• house coal	0.291
• anthracite	0.317
• manufactured smokeless fuel	0.392

These emission factors are based on the combustion emission factor for that fuel, plus a production overhead emission factor. NETCEN values provide the combustion emission factors[2]. For solid and liquid fuels, these are provided in terms of emission per tonne and are converted to emissions per kWh based on the average annual calorific value as published in the Digest of UK Energy Statistics (DUKES)[3]. The total CO_2 emissions associated with the production of each fuel is calculated from the amount of fuel used in producing each fuel, which is provided by the aggregated energy balance provided by Table 1.1 of DUKES and the combustion emissions factor for that fuel.

The production overhead emission factor for each fuel is calculated by dividing the total CO_2 emission arising from production by the total UK energy production for that fuel. The production overhead for UK fuel production is then applied to the total UK fuel supply with losses between supply and consumption being accounted for by multiplying the production overhead for fuel supply by supply divided by consumption.

where,

Production = gross production
Supply = production + imports –exports -stock changes -statistical difference
Consumption = Supply - Losses[4]

An example calculation is set out below which shows how emissions from fuel production associated with exported fuels are “exported” along with the fuels and imported fuels are assumed to have the same production emissions as UK produced fuel. In contrast emissions associated with losses are included in the production overhead for final consumers.

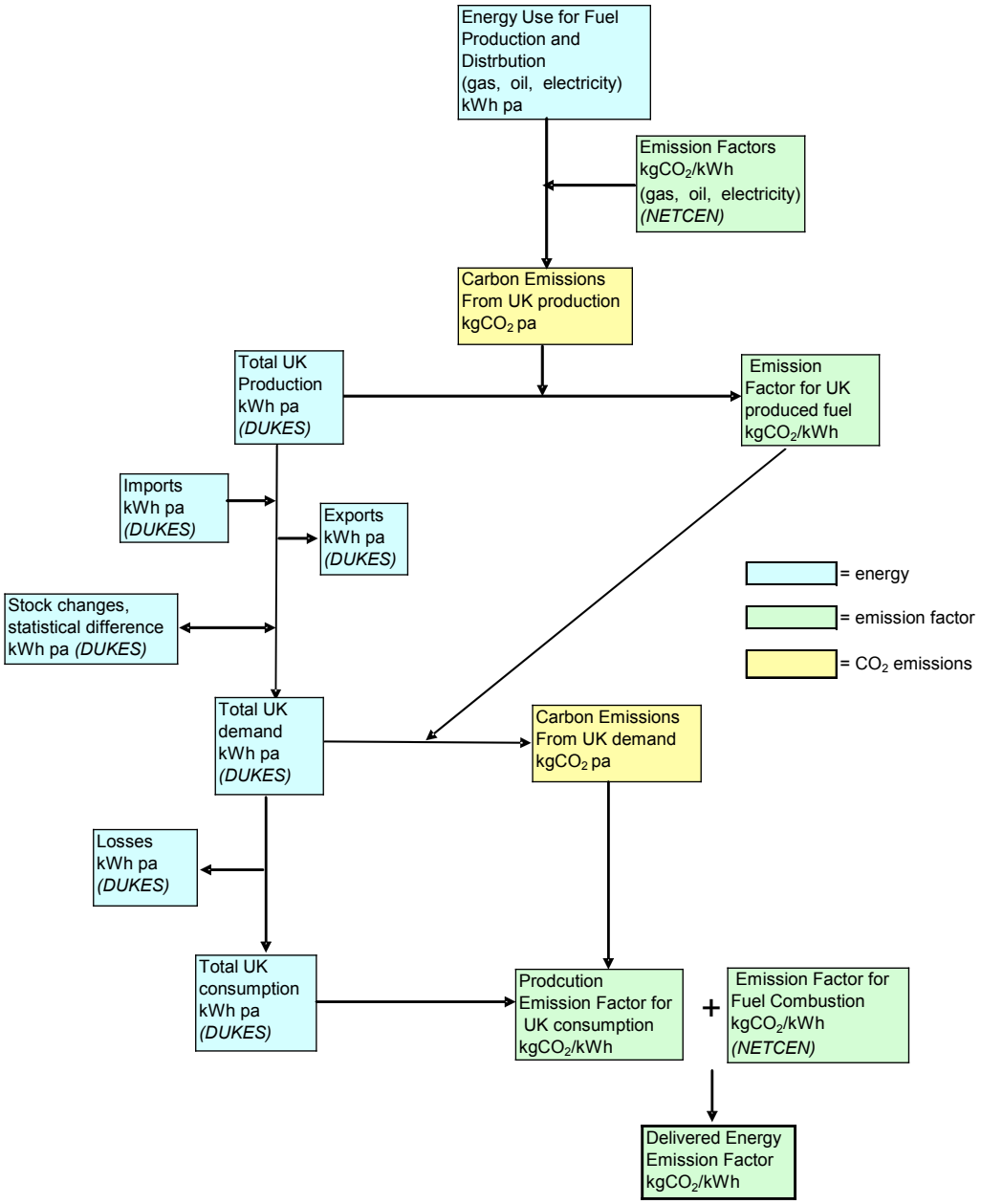
[2] UK Greenhouse Gas Inventory, 1990 to 1997, AG Salway November 1999, NETCEN, DETR

[3] Digest of United Kingdom Energy Statistics 2000, DTI, National Statistics, The Stationary Office, London

[4] Where losses include metering differences and theft as well as leakage assessment.

	GWh	tonnes CO_2*1,000	kgCO2/kWh
UK fuel production	17,000		
Carbon emissions from energy use during fuel production		170	
Production overhead UK produced fuel			0.010
Imports and other additions	+5000	50	0.010
Exports and other removals	-2000	-20	0.010
UK fuel supply	20,000	200	0.010
Losses	-2000	-	
UK fuel consumption	18,000	200	0.011

The methodology for deriving delivered energy emission factors is summarised in the following schematic:



This methodology:

- Assumes carbon emissions arising from the production of imported fuel are the same as those for UK produced fuel.

- Restricts consideration of greenhouse gas emissions to CO_2. This is appropriate for SAP and SBEM as the Energy Performance of Buildings Directive states, "The energy performance of a building shall be expressed in a transparent measure and may include a CO_2 indicator" and makes no mention of other greenhouse gases

- Treats all distribution losses (as they appear on Table 1.1 of DUKES) as material loss to the energy supply chain. Thus, methane leakage from natural gas distribution increases the emission figures in proportion to the relative loss, but takes no account is taken of the relative greenhouse impact of methane[5].

- Where energy industry use is associated with production of one or more fuels the emissions are apportioned between the fuels according to their energy content.

- Does not include emissions from transportation by road or rail, for oil and gas these make up less than 10% of the total production overhead[6] for most fuels.

Smokeless fuel is slightly different in that it is produced by transforming coal. Here, in addition to emissions associated with energy used in the manufacture of smokeless fuel, a mass balance approach is used to determine the additional emissions from the fuel transformation process itself. This relates to the difference between the emission that would result from combustion of the input fuel (coal) and the output fuel (smokeless solid fuel).

These emission factors have been checked against delivered energy emission factors calculated using 2001 energy consumption data and 2001 NETCEN combustions emission factors. There are some small variations which arise from either, revisions to DUKES consumption data, yearly variations in the average annual calorific value and changes to the NETCEN emission factors, and/or to converting figures quoted to two significant figures between units. Nevertheless these changes are not significant, However, for oil, it appears that the mix of heating oil, fuel oil and gas oil used across all building types was assumed for the domestic sector, when in fact nearly 90% of domestic oil consumption is burning oil. For this reason it is recommended that the proposed emission factor for SAP should be changed to that of burning oil, 0.265kgCO_2/kWh. (Coincidently, the emission factor would be the same for the average mix of heating oil used in the domestic sector.). As burning oil is the main heating oil for all buildings it may also be applied to the non-domestic oil

[5] This approach is consistent with the requirement of Part L and the Energy Performance of Buildings Directive which only require consideration of CO_2 emissions.

[6] Fuel and energy production emission factors Dr C A Lewis MEET project: Methodologies for Estimating Air Pollutant Emissions from Transport, Task No. 3.4, Deliverable No. 20, Contract No. ST-96-SC.204, 1997.

use as well[7]. emission factor is also 0.265 to reflect the mix of oil products used in the domestic sector.

The proposed figures only quote an emission factor for house coal, so an additional emission factor is suggested for the non-domestic coal of 0.300kgCO_2/kWh. (c.f. 0.291kgCO_2/kWh for domestic).

As the combustion emission factor for propane has been revised downwards since 1997, a revised emission factor for LPG has been proposed by the LPGA. This is based on 2003 emission factors for propane and production overheads provided in a 1997 report for an EC funded project on transport emission produced by AEA Technology[8], resulting in a figure of 0.237 kgCO_2/kWh. However, this report is specifically concerned with transport fuels and the the production emissions considered are wider in the scope than that for other fuels in that they include transportation as well as other processing and distribution overheads. Hence value of 0.234 kgCO_2/kWh is proposed.

Delivered Energy Emission factors for renewable fuels

The renewable fuels emission factors for SAP 2005 put forward in the consultation document are listed below:

	kgCO_2/kWh
• wood logs	0.025
• wood pellets in bags	0.025
• bulk wood pellets	0.025
• wood chips	0.025
• heat from boilers – biomass or biogas	0.025
• heat from boilers – waste combustion	0.043
• waste heat from power stations	0.018

The emission factors for the first five fuels listed above include estimates of CO_2 emissions from planting, harvesting, sawing up and other processing, and delivery to the point of use[9]. The inclusion of transportation for renewable fuels is justified as they tend to be bulkier than fossil fuels, and because they are less widely used so the distances travelled are likely to be larger.

As around 90% by weight of the combustible materials in municipal solid waste is from renewable sources, the remaining 10% being mainly plastic. On this basis a more reasonable figure here would be 0.057kgCO_2/kWh, which is based on 30% of MSW heat[10] arising from non-renewable sources and assumes similar processing overheads to other renewable sources.

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[7] Alternative options would be to use the emissions factor for fuel oil (which is the main heating oil used in the public and commercial sectors) of 0.278kgCO_2/kWh, or an emission factor based on the average mix of heating oils used , which would be 276kgCO_2/kWh.

[8] Fuel and energy production emission factors Dr C A Lewis MEET project: Methodologies for Estimating Air Pollutant Emissions from Transport, Task No. 3.4, Deliverable No. 20, Contract No. ST-96-SC.204, 1997.

[9] These estimates are notional and are not based on detailed assessments.

[10] 10% by weight translates to 30% by heat content as the calorific value of plastic is three times that of wood/paper.

Delivered Energy Emissions factor for dual fuel appliances

Dual fuel appliances are ones that can burn either mineral solid fuel or wood. The actual choice of fuel is a matter of user preference, and for the purposes of ratings and building regulations a figure was derived on the basis of a market mix of mineral and wood fuels.

A report commissioned from HETAS[11] made estimates of the total annual burn of wood and mineral fuels for domestic heating purposes. The primary estimate of wood burn was obtained from consideration of wood purchased from merchants, wood purchased from arboricultural arisings (woodland management) and wood usage from own land (principally farmers) giving a total estimated burn (England, Scotland and Wales) of 1,041,000 tonnes. Broadly similar figures were obtained from the 1997 GfK Marketing Services Report for the Solid Fuel Industry, and the 2001 English House Condition Survey. A figure of 1m tonnes was taken as a reasonable estimate of current wood burning for domestic heating.

The total burn of mineral fuel (bituminous coal, anthracite and manufactured smokeless fuel) was estimated at 1.6m tonnes in 2001. It has reduced appreciably since then, particularly for anthracite due to a decline in the number of gravity-feed boilers in use. The total usage of mineral fuel in 2004 was estimated as 1.05m tonnes, of which about two-thirds being used outside smoke control (0.45m tonnes of bituminous coal, 0.135m tonnes of anthracite and 0.11m tonnes of smokeless fuel). This has been estimated on the basis that ~50% of UK properties are covered by smoke control legislation (ref NETCEN) the overwhelming majority of which have gas available: solid fuel usage is increasingly concentrated in rural areas off the gas network. Taking account of the relative calorific values, the weighted average emission factor is 0.187 $kgCO_2$/kWh.

Within smoke control areas, all appliances (other than exempted appliances) are taken as burning anthracite or manufactured smokeless fuel.

Delivered Energy Emission factors for Electricity

The expected average annual emission factor for grid electricity of 0.422 $kgCO_2$/kWh is based on the expected mix of electricity supply for the average of the Central Growth/Low Price and Central Growth/High Price scenarios between 2005 and 2010 from the DTI energy projections presented in Energy Paper 68[12] which have been adjusted to take account of expected transmission and distribution losses[13]. Although there will be variations in the actual emission factors at different times of the day, it is appropriate to use an average value for SAP calculations.

The emission factor of 0.568 $kgCO_2$/kWh which is used for avoided electricity consumption is based on a mixture of the average carbon intensity of the marginal plant and the carbon intensity of new plant built or avoided. Here the average carbon intensity of marginal plant has been modelled based on actual electricity generation

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[11] An assessment of annual wood and mineral fuel usage in the domestic solid fuel heating industry, Report 3404 B, HETAS Ltd, April 2005.

[12] Energy Projections for the UK, Department of Trade and Industry Paper 68, HMSO, 2000.

[13] The carbon intensity of electricity: How many kgC per kWhe?, ER Hitchin, CH Pout, 2002.

data for 1998/1999 for England and Wales, and new plant build/avoided is assumed to be combined cycle gas turbines[9]. As for the system average emission factor the avoided electricity consumption factors takes account of expected transmission and distribution losses.

The data and data sources used to calculated the delivered fuel emission factors are summarised in Table 1.

Emission figures for SAP 2005 and Part L

With the amendments mentioned above, the emission factors given in SAP 2005 and SBEM, and used to derive the fuel factors given in the Approved Documents for Part L, are summarised in the final column of Table 1.

2001 Data unless otherwise stated	DUKES Calorific value	NETCEN emission factor		Combustion only	Production overhead	Delivered energy	Proposed SAP 2005	Revised SAP 2005
Fuel	**GJ/Tonne**	**kgC/kWh**	**gC/GJ**	**kgCO2/kWh**	**kgCO2/kWh**	**kgCO2/kWh**	**kgCO2/kWh**	**kgCO2/kWh**
mains gas	-	-	14,230	0.188	0.006	0.194	0.194	**0.194**
bulk LPG	-	-	16,230	0.214	0.020	0.234	0.249	**0.234**
bottled LPG	-	-	16,230	0.214	0.020	0.234	0.249	**0.234**
fuel oil	43.5	850.0	-	0.258	0.020	0.278		
burning oil	46.2	859.0	-	0.245	0.020	0.265		
gas oil	45.6	857.0	-	0.248	0.020	0.268		
domestic oil						0.265		**0.265**
non-domestic oil						0.276		**0.265**
heating oil							0.270	
house coal	30.9	676.8	-	0.289	0.001	0.291	0.291	**0.291**
non-domestic coal	29.2	659.6	-	0.298	0.001	0.300		**0.300**
anthracite	33.9	813.4	-	0.317	0.001	0.317	0.317	**0.317**
manufactured smokeless fuel	30.6	774.2	-	0.334	0.058	0.392	0.392	**0.392**
wood logs	Production overheads for planting, harvesting, sawing up and other processing, and delivery to the point of use.				0.025	0.025	0.025	**0.025**
wood pellets in bags					0.025	0.025	0.025	**0.025**
bulk wood pellets					0.025	0.025	0.025	**0.025**
wood chips					0.025	0.025	0.025	**0.025**
dual fuel appliance (mineral and wood)	Separate calculation - see text						0.187	**0.187**
heat from boilers – biomass or biogas	As for other biofuels						0.025	**0.025**
heat from boilers – waste combustion	See text						0.043	**0.057**
waste heat from power stations							0.018	**0.018**
electricity from grid	Average emission for grid electricity between 2005-2010 based on DTI EP65 CL/CH						0.422	**0.422**
electricity displaced from grid	Average of marginal carbon intensity and generation plant built or avoided 2005-2010						0.568	**0.568**

NB – Production overhead + combustion only emission factor may not equal delivered energy emission factor due to rounding.