Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory

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Units and conversions

Emissions of greenhouse gases presented in this report are given in Million tonnes (Mt) and kilotonnes (kt). To convert between the units of emissions, use the conversion factors given below.

Prefixes and multiplication factors

Multiplication factor	Abbreviation	Prefix	Symbol
1,000,000,000,000,000	10^{15}	peta	P
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^{9}	giga	G
1,000,000	10^{6}	mega	M
1,000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000,001	10^{-6}	micro	μ

1 kilotonne (kt) = 10^{3} tonnes = 1,000 tonnes
1 Million tonne (Mt) = 10^{6} tonnes = 1,000,000 tonnes

1 Gigagramme (Gg) = 1 kt
1 Teragramme (Tg) = 1 Mt

Conversion of carbon emitted to carbon dioxide emitted

To covert emissions expressed in weight of carbon, to emissions in weight of carbon dioxide, multiply by 44/12.

ES.1

This report set out the results of a work programme to review and update the carbon emission factors in the 2002 UK greenhouse gas inventory. This was part of a wider programme of inventory review and improvement to prepare the greenhouse gas inventory to deliver the UK's Assigned Amount under the Kyoto Protocol.

Table ES1 shows the overall change in carbon emissions using the updated carbon factors for solid, liquid and gaseous fuels.

Table ES1: Overall change in carbon emissions (MtC)

Year	2002 GHG inventory	Emissions using updated factors	Difference	% difference
1990	164.63	165.88	1.26	0.76
1991	165.66	167.43	1.77	1.07
1992	161.62	163.02	1.40	0.86
1993	157.45	158.62	1.17	0.75
1994	156.27	157.31	1.05	0.67
1995	153.83	154.17	0.34	0.22
1996	159.35	160.31	0.96	0.60
1997	152.65	153.84	1.19	0.78
1998	153.46	155.03	1.57	1.02
1999	151.13	152.07	0.93	0.62
2000	152.17	152.92	0.76	0.50
2001	155.75	157.09	1.33	0.86
2002	150.26	151.79	1.52	1.02
% change 1990-2002	-8.73%	-8.49%		

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Document revision history

Issue	Version	Revision history
Draft		• Issued to UK Defra for internal review and comment • Comments incorporated
1.0	**1.3**	• First issue
1.0	**1.3.1**	• Minor typographical errors corrected
1.0	**1.3.2**	• Minor typographical errors corrected in the headers and footers

Abbreviations, acronyms and definitions

Greenhouse gases

CH_4	Methane
CO_2	Carbon dioxide
N_2O	Nitrous oxide

General

AEP	Association of Electricity Providers www.aepuk.com
AS	Aviation Spirit
ATF	Aviation Turbine Fuel
BCA	British Cement Association
BFG	Blast Furnace Gas
C	Carbon
CEF	Carbon Emission Factor
COG	Coke Oven Gas
CORUS	The owner of the many of the integrated steel works in the UK
DTI	UK Department of Trade and Industry
DERV	Diesel Engined Road Vehicle fuel used in internal combustion engines that are compression ignition engines
DUKES	Digest of United Kingdom Energy Statistics www.dti.gov.uk/energy/statistics
EA	Environment Agency for England and Wales
EU	European Union
ESI	Electricity Supply Sector
ETS	Emissions Trading Scheme
GCV	Gross Calorific Value
GHG	Greenhouse gas
GHGI	Greenhouse gas inventory
IPCC	Intergovernmental Panel on Climate Change
JEP	Joint Environmental Programme funded by the Association of Electricity Producers (AEP)
kt	kilotonne
LPG	Liquid Petroleum Gas composed of a variable mixture of propane and butane
Mt	Mega tonne
NG	Natural gas

OPG	Other Petroleum Gas
SSF	Solid Smokeless Fuel
SEPA	Scottish Environmental Protection Agency
TRANSCO	Gas transportation company Ceased to exists in 2005, and now part of National Grid UK
UK	United Kingdom
UKPIA	UK Petroleum Industry Association Trade association which represents the oil refining and marketing industry in the United Kingdom www.ukpia.com
UN/ECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

1.1 BACKGROUND TO THIS PROJECT

The United Nations Framework Convention on Climate Change (UNFCCC) was ratified by the United Kingdom in December 1993 and came into force in March 1994. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs). The UK has been compiling and submitting GHG inventories to the FCCC since 1994.

AEA Energy & Environment, on behalf of UK Defra, has prepared the latest (at the time this report was written) greenhouse gas inventory (GHGI) and associated tables of emissions in CRF format according to UNFCCC guidelines contained in FCCC/CP/2002/8 (Baggott *et. al.*, 2004). The estimates within the inventory have been generated by following the methods and procedures set out in the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000).

The UK GHGI is subject to a range of external reviews. At the time this report was written, these reviews include reviews by experts from the FCCC during desk, centralised and in-country reviews, and, by invited independent examiners during a process of peer review. The Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (IPCC, 2000) defines expert peer review as follows:

> 'Expert peer review consists of a review of calculations or assumptions by experts in relevant technical fields. This procedure is generally accomplished by reviewing the documentation associated with the methods and results, but usually does not include rigorous certification of data or references such as might be undertaken in an audit. The objective of the expert peer review is to ensure that the inventory's results, assumptions, and methods are reasonable as judged by those knowledgeable in the specific field.'

The Good Practice Guidance requires that key sources should be subjected to external peer review. Key sources are those source categories with a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both.

The first peer review of the GHGI considered CO_2 emissions from fuel combustion (Simmons, 2002). This topic was chosen for peer review since IPCC sector 1A1[1] was identified as a key source because of the magnitude of emissions of carbon dioxide (CO_2) from the combustion of solid, liquid and

[1] Emissions from fuels combusted by the fuel extraction or energy producing industries.

gaseous fuels in that sector. In addition, fossil fuel combustion is the major source of UK emissions of carbon dioxide.

A key recommendation of this peer review was that the carbon emission factors (CEFs) currently used in the inventory should be reviewed:

> 'Many of the carbon emission factors used in the inventory date from 1989. Whilst they may still be accurate for the fuels used today there have been changes to the sources of fuels over the period of the inventory and changes in their qualities to reflect environmental requirements. It is recommended that the carbon content factors be reviewed, together with related factors accounting for incomplete oxidation of the fuels during combustion.'

This report presents the results of a review of the CEFs used in the 2004 UK National Inventory Report, containing the 2002 GHG inventory (1990 to 2002 inclusive). This work is important to the overall quality of the GHG estimates since accurate estimates of the carbon contents of fuels determine the accuracy of the estimated CO_2 emissions.

1.2 GENERAL APPROACH TO THE CEF REVIEW

A programme of work was developed to review CEFs of the fuels in the UK greenhouse gas inventory. The review concentrated on a selection of key fuels that contribute to the greatest proportions of CO_2 emissions. A range of stakeholders were consulted during the review process, including industry experts within the UK electricity supply industry, the petroleum industry, and the gas supply industry. To support this work, a selection of liquid fuels were analysed, on behalf of UKPIA, to determine their carbon contents. Analysis of gas composition data from TRANSCO was also considered. In addition, data presented in a range of reports (including data on UK CEFs, calorific values, fractions of fuels left unoxidised after combustion, and fuel compositions) were reviewed. A range of parties examined the initial recommendations for revised CEFs including industry experts and government representatives of the UK Energy Trading Scheme (UK ETS). Their recommendations were considered before the final set of CEFs was selected for the GHGI.

Following this review, CEFs were introduced into the 2002 greenhouse gas inventory, and the changes in the carbon emissions were quantified.

1.3 FUELS REVIEWED

An analysis of the quantities of fuel consumed according to IPCC sector was completed in order to identify which fuels contributed the most to emissions of CO_2 in the UK. This analysis clearly showed that the main effort of the work should be concentrated on revising the CEFs for natural gas, coal and the liquid fuels. The CEFs of other fuels were reviewed during the course of this work; the reason for selecting these additional fuels was to satisfy demands for revised CEFs for the UK ETS.

1.4 QUOTED ACCURACY OF THE EMISSIONS IN THIS STUDY

In this report, emissions are quoted to 0.01 ktonne (or better) purely for convenience, to avoid the risk of rounding errors, and for convenience when taking ratios. The number of decimal places used should not be taken as indicative of the accuracy of the estimates.

2 Overview of the changes in estimated GHG emissions due to the revisions in the selected CEFs

This chapter of the report presents a summary of the changes in estimated GHG emissions due to the revisions in the selected CEFs. **Table 2.1** shows the values of the original CEFs used in the 2002 GHGI for 1990 and 2002, and the revisions to those CEFs. The changes in emissions are summarised according to fuel, and IPCC reporting sector. **Table 2.1** shows the overall effect on the revised CEFs on the national GHG totals.

2.1 ORIGINAL AND REVISED CARBON EMISSION FACTORS

Table 2.1: Original and revised CEFs values used in the 2002 GHGI for 1990 and 2002 (KtC/Mt fuel for solid and liquid fuels, and Kt/Mtherm for gaseous fuels)

Fuel Type	Consumer	IPCC Fuel	Original CEF 1990	Revised CEF 1990	Original CEF 2002	Revised CEF 2002
Solid		Petcoke	800	930	800	930
		Petcoke (cement)	800	829.6	800	829.6
	Agriculture	Other bituminous coal	659.6	656.6	659.6	650.4
	Autogenerators	Other bituminous coal	659.6	659.6	659.6	628.7
	Cement (combustion)	Other bituminous coal	659.6	757.7	659.6	725.5
	Collieries	Other bituminous coal	659.6	659.6	659.6	684.9
	Domestic	Other bituminous coal	676.8	676.8	676.8	696.9
	Domestic	Anthracite	813.4	813.4	813.4	820.6
	ESI	Other bituminous coal	588.2	605	588.2	627.2
	Iron & Steel blast furnaces	Coking coal	-	-	710	694
	Iron & Steel (combustion)	Other bituminous coal	659.6	659.6	659.6	693.8
	Lime production (combustion)	Other bituminous coal	659.6	659.6	659.6	628.7
	Miscellaneous	Other bituminous coal	659.6	659.6	659.6	721.9
	Other industry	Other bituminous coal	659.6	659.6	659.6	633.5
	Public services	Other bituminous coal	659.6	659.6	659.6	721.9
	Railways (stationary sources)	Other bituminous coal	659.6	659.6	659.6	721.9
Liquid		Aviation spirit	850	853	865	853
		Diesel Oil	857	864	857	863
		Fuel Oil	850	867	850	879
		Gas Oil	857	869	857	870
		Naphtha	940	854	940	854
		Residual Fuel Oil	850	867	850	879
Gaseous		Natural Gas	1.50	1.45	1.50	1.48
		Blast Furnace Gs	6.27	7.46	6.27	7.46
		Other Petroleum Gas	1.68	1.64	1.63	1.64

- The original CEFs are taken from the 2002 GHGI
- ESI – Electricity Supply Industry
- Emissions of the gaseous fuels are gross
- The CEFs for solid fuels in this table account for the incomplete oxidation of the fuels following combustion. Oxidation factors are considered in **Chapters 3, 4 and 5**.

2.2 CONTRIBUTIONS OF FUELS TO CARBON EMISSIONS IN INVENTORY

Different fuels contribute different amounts to overall carbon emissions in the UK. It is those fuels that contribute the most to emissions that will have the most significant effect on emissions if their factors are altered. **Table 2.2** list the major contributors to carbon emissions both in 1990 and 2002.

Table 2.2: Percentage contributions of fuels to overall carbon emissions in the UK in 1990 and 2002

Fuel	1990	2002
Coal	***35***	***21***
Natural Gas	***19***	***38***
Petrol	***13***	***11***
Fuel oil	7	2
DERV	6	10
Gas Oil	4	4
Blast Furnace Gas	3	2
OPG	1	1
Coke	1	1
Clinker Production	1	1
Burning Oil	1	2
Aviation Turbine Fuel	1	1
Anthracite	1	-
SSF	1	-
Coke Oven Gas	1	-
LPG	1	1
Limestone	1	-
Petroleum Coke	-	1

The fuels listed in the above table contribute 97% to overall carbon emissions in 1990 and 2002. In each year, the remaining 3% is made up of a number of other fuels, each contributing 1% or less to the overall total.

In both 1990 and 2002 the top three contributors remain the same – natural gas, coal and petrol, although the relative contribution from coal decreases and the importance of natural gas increases in 2002, relative to 1990.

2.3 UNITS OF CEFs USED IN THE UK GHG INVENTORY

The emission factors used in the 2002 UK GHG inventory are expressed in terms of kg pollutant/tonne for solid and liquid fuels, and g/TJ *gross* for gases. This differs from the IPCC approach which expresses emission factors as tonnes pollutant/TJ based on the *net calorific value* of the fuel. For gases the factors used in the UK GHG inventory are based on the *gross calorific value* of the fuel. This approach is used because the gas consumption data in commodity balance tables produced by the UK DTI are reported in terms of energy content on a gross basis.

Emissions factors for solid and liquid fuels are in terms of mass. These mass based factors can then be applied to consumptions of UK fuels expressed on a

mass basis published by the DTI. Emissions factors for natural gas are in terms of the energy content of the gas consumed (g carbon/GJ gross). These energy based factors can then be applied to consumptions of UK fuels expressed on a energy basis published by the DTI.

3 Solid fuels

3.1 INTRODUCTION

Within the UK, the main solid fuels that are used are coal, anthracite, coke and petroleum coke. In 1990 coal was the major contributor to carbon greenhouse gas emissions, with 34% of emissions arising from this fuel. This declined to 21% in 2002. The main user of coal is the power station sector, which accounted for 88.5% of emissions in 2002. **Table 3.1** displays the main sectors that use coal in the UK and their percentage contribution to overall carbon emissions

Table 3.1 Significant sources of coal in the UK

Source	% contribution to overall coal emission
Power Stations	88.5
Coke Production	1.2
Public Services	0.3
Domestic	2.2
Autogenerators	3.4
Other Industry combustion	3.2
Cement fuel combustion	0.8
Lime production - combustion	0.2

Minor emissions also occur from the Iron and steel industry, agriculture, railways, collieries and miscellaneous sources.

Coke use in the UK accounted for 1% of overall carbon emissions in the UK in 2002. Coke is mainly used by the iron and steel industry and in 2002, emissions from this sector accounted for 69% of emissions. Other significant emissions arise from combustion in other industry and domestic use.

Petroleum coke emissions accounted for 1% of overall carbon emissions in the UK in 2002. Petroleum coke is used mainly by the refineries sector (48% of emissions in 2002) and the cement industry (40% of emissions in 2002).

3.2 CEFs OF SOLID FUELS USED IN THE 2002 GHG INVENTORY

3.2.1 Coal

The current carbon emission factors for coal were supplied to AEA Technology by British Coal in 1989. Since then, the emission factors used have not been altered. The production of coal within the UK declined steadily during the 1990s and gradually more coal has been imported from elsewhere. Due to this change in the mix of home/imported coal now used in the UK, the factors were reviewed.

All the coal CEFs in the inventory take into account the proportion of un-oxidised carbon that remains in the ash after combustion. **Table 3.2** shows the assumed

oxidation factors for each type of coal and the corresponding un-oxidised carbon emission factor.

Table 3.2: Carbon retention in ash figures for coal use in UK in the 2004 GHG inventory

Coal use	Un-oxidised factor (kt/Mt)	C retention in ash (%)	Oxidation factor	Oxidised factor (kt/Mt)
Power Stations	590	0.3	0.997	588.2
Other	680	3	0.97	659.6
Domestic	720	6	0.940	676.8

Table 3.3 displays the sources of coal emissions in the inventory and their corresponding emission factors.

Table 3.3: Current coal emission factors (kt/Mt)

Source	Current coal emission factor (kt/Mt)
Power Stations	588.2
Public Services	659.6
Domestic	676.9
Autogenerators	659.6
Other Industry combustion	659.6
Cement fuel combustion	659.6
Lime production - combustion	659.6

Minor emissions also occur from the iron and steel industry, agriculture, railways, collieries and other miscellaneous sources. The emission factor used for iron and steel blast furnaces is currently 710 kt/Mt and for other sources mentioned, the emission factor used is 659.6 kt/Mt.

3.2.2 Coke

Coke emissions in the inventory arise from a variety of sources and overall contribute 1% to carbon emissions in the UK. Currently, as with coal, the factors were supplied by British Coal in 1989.

As with coal, assumptions were made about the proportion of un-oxidised carbon left after combustion. **Table 3.4** shows the assumed oxidation factors for coke and the corresponding un-oxidised carbon emission factor along with the oxidised factor that is currently used in the UK GHGI.

Table 3.4: Carbon retention in ash figures for coke use in UK

Coke use	Un-oxidised factor (kt/Mt)	C retention in ash (%)	Oxidation factor	Oxidised factor (kt/Mt)
Domestic	820	2	0.98	803.6
Power stations	820	3	0.97	795.4
Other	820	3	0.97	795.4

Table 3.5 displays the sources of coke emissions in the inventory and their corresponding emission factors.

Table 3.5: Sources of coke emissions and corresponding emission factors

Source	Current coke emission factor (kt/Mt)
Domestic	803.6
SSF production Coke production	820
Iron and Steel (sinter) Other industry (combustion) Iron and steel (combustion) Lime production (combustion) Power stations Railway (stationary sources) Public services Agriculture Miscellaneous	795.4

Emissions from iron and steel blast furnaces are calculated from a mass balance approach (see Section 3.4.2).

3.2.3 Anthracite

Carbon emissions from anthracite occur from the domestic sector only. The current carbon content of anthracite was supplied by British Coal in 1989 and has a value of 859 kt/Mt. This has a correction applied to it for the un-burnt fraction of carbon of 5.3%, giving the carbon emission factor of 813.4 kt/Mt.

3.2.4 Petroleum coke

The current factor for petroleum coke was supplied by the UK Petroleum Institute Association (UKPIA) in 1989. The value is 800 ktC/Mt and applies to all sectors burning petroleum coke.

3.3 REVISED CEFs

3.3.1 Fraction of fuel unoxidised after combustion

The CEFs in this section account for the carbon left unoxidised after combustion.

3.3.2 Coal – ESI sector

Power stations are the major contributor to carbon emissions from coal combustion, and so obtaining updated emission factors for this sector was considered a priority.

A time series (1990-2003) of updated carbon emission factors (**Table 4.6**) was obtained from Powertech (Quick, 2004). It was advised that data in this time series was based on Powergen operated sites only but would be fairly representative of the UK as a whole. These updated emission factors took into account the increase in the UK's use of imported coals as well as a carbon in ash content (i.e. un-burnt carbon).

Table 3.6: Carbon emission factors provided by Quick (2004)

Year	% C in coal	% C in Coal corrected for 5% C in ash, 13% ash coal	Kte C/Mte coal burnt
1990	60.37	59.69	596.86
1991	61.05	60.37	603.66
1992	60.78	60.10	600.96
1993	60.78	60.10	600.96
1994	60.63	59.95	599.46
1995	59.73	59.05	590.46
1996	60.92	60.24	602.36
1997	61.74	61.06	610.56
1998	62.35	61.67	616.66
1999	61.94	61.26	612.56
2000	61.76	61.08	610.76
2001	62.54	61.86	618.56
2002	62.99	62.31	623.06
2003	62.58	61.90	618.96

A working paper from the Association of Electricity Producers (AEP) (Joslin et al, 2004) detailing their recommended carbon content of fuel and oxidation factor for 2003 was also obtained. This paper recommended a carbon content of 0.64 and an oxidation factor of 0.98. After discussion with both the AEP and Powergen it was established that the slightly higher carbon content quoted by the AEP was due to the influence of Aberthaw power station which burns coal with a higher carbon content. There was also a difference in the oxidation factor between the Powertech and AEP studies, and this occurs for two primary reasons. Firstly, the influence of Aberthaw, which due to its unique nature has high carbon content in ash. Secondly, Powergen stations have tended to be run as 'base-load' stations more than others, which invariably results in better combustion performance and lower carbon in ash (Quick, 2004b). It was therefore agreed by all parties that the time series of emission factors provided by Quick (2004) should be scaled to the AEP carbon content for 2003. It was also agreed that the oxidation factor of 0.98 should be used. Both these assumptions were considered to provide representative parameters from coal use within the UK.

Taking these changes into account, proposed new carbon emission factors for the Greenhouse Gas Inventory are shown in **Table 3.7**. Emission factors are scaled as follows:

A * (0.64/0.6258) = Carbon Emission Factor

Where A = Carbon emission factor provided by Quick

So in 2003, Carbon emission factor = 0.6258 * (0.64/0.6258) = 0.64

Applying the oxidation factor of 0.98 provides a carbon emission factor of 0.6272.

Table 3.7: AEP scaled Carbon emission factors

Year	% C in coal	% C in coal corrected for 2% C in ash	kte/Mte coal burnt
1990	61.74	60.51	605.05
1991	62.44	61.19	611.87
1992	62.16	60.92	609.16
1993	62.16	60.92	609.16
1994	62.01	60.77	607.66
1995	61.09	59.86	598.64
1996	62.30	61.06	610.56
1997	63.14	61.88	618.78
1998	63.76	62.49	624.89
1999	63.35	62.08	620.79
2000	63.16	61.90	618.80
2001	63.96	62.68	626.80
2002	64.42	63.13	631.31
2003	64.00	62.72	627.20

3.3.3 Coal – Other sectors

3.3.3.1 Other sectors – excluding cement production

Table 3.1 shows that the ESI sector is an important contributor to carbon emissions from coal combustion in the UK. Other sectors that use coal contribute just over 10% to overall emissions, with most of these sectors individually contributing less than 1% to totals. A full review and consultation with all the industry representatives in these sectors was not considered to be a wise use of resources in this project, and so an approach was developed to scale existing CEFs to GCVs reported in DTI (2003) relative to 1990. Carbon emission factors and GCVs are closely related and so an increase or decrease in a GCV is likely to reflect similarly in the carbon content of the fuel. **Tables 3.8** to **3.11** display the results of the simple method used to calculate revised emission factors for the sectors consuming smaller quantities of coal. The cement sector is considered later.

Table 3.8: Carbon emission factors used in the 2002 GHG inventory

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Agriculture	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Coke Production	41.87	38.29	31.42	34.08	34.31	40.61	36.74	45.21	44.84	58.09	42.85	58.57	58.54
Collieries	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Domestic	676.8	676.8	676.8	676.8	676.8	676.8	676.8	676.8	676.8	676.8	676.8	676.8	676.8
I&S (blast furnace)					710	710	710	710	710	710	710	710	710
I&S (combustion)	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Lime Production (combustion)	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Miscellaneous	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Other Industry (combustion)	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Public services	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Railways (stationary sources)	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
SSF production	127.22	79.47	77.52	49.59	23.56	33.43	93.15	135.47	46.64	36.45	27.39	37.33	33.87
Autogenerators	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6
Cement (Fuel combustion)	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6	659.6

Table 3.9: GCVs reported in the DTI DUKES publication

Source	DUKES class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Agriculture	Agriculture	28.9	28.9	28.9	28.7	28.8	29	28.9	29.1	28.5	28.9	29.2	29.8	28.5
Collieries	Collieries	28.6	28	26.8	26.8	28.2	28.2	26.2	27.8	29.6	29.3	29.6	29.8	29.7
Domestic	House Coal	30.2	30.2	30.2	30.2	29.8	30.4	30.6	30.6	30.9	30.9	30.9	30.9	31.1
I&S (blast furnace)	Coke Ovens: Home & Imports	31.2	31.4	31.45	31.46	31.43	31.4	32	32	32	30.5	30.4	30.5	30.5
I&S (combustion)	Iron and steel industry	28.9	28.9	28.9	28.7	29.4	31.5	31.3	31.3	31.3	30.7	30.7	29.4	30.4
Lime Production (combustion)	Other industries	27.8	27.8	27.8	28.1	28.8	27.7	27.3	27	26.9	26.6	26.8	26.7	26.5
Miscellaneous	Other Consumers	27.5	27.5	27.5	28.7	28.8	28.9	30.4	29.3	29.2	29.1	29.2	29.2	30.1
Other Industry (combustion)	Other Industries	27.8	27.8	27.8	28.1	28.8	27.7	27.3	27	26.9	26.6	26.8	26.7	26.5
Public services	Other Consumers	27.5	27.5	27.5	28.7	28.8	28.9	30.4	29.3	29.2	29.1	29.2	29.2	30.1
Railways (stationary sources)	Other Consumers	27.5	27.5	27.5	28.7	28.8	28.9	30.4	29.3	29.2	29.1	29.2	29.2	30.1
Autogenerators	Other Industries	27.8	27.8	27.8	28.1	28.8	27.7	27.3	27	26.9	26.6	26.8	26.7	26.5
Cement (Fuel combustion)	Other Industries	27.8	27.8	27.8	28.1	28.8	27.7	27.3	27	26.9	26.6	26.8	26.7	26.5

Table 3.10: Ratios of GCVs relative to 1990

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Agriculture	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.01	0.99	1.00	1.01	1.03	0.99
Collieries	1.00	0.98	0.94	0.94	0.99	0.99	0.92	0.97	1.04	1.02	1.04	1.04	1.04
Domestic	1.00	1.00	1.00	1.00	0.99	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.03
I&S (blast furnace)	1.00	1.01	1.01	1.01	1.01	1.01	1.03	1.03	1.03	0.98	0.97	0.98	0.98
I&S (combustion)	1.00	1.00	1.00	0.99	1.02	1.09	1.08	1.08	1.08	1.06	1.06	1.02	1.05
Lime Production (combustion)	1.00	1.00	1.00	1.01	1.04	1.00	0.98	0.97	0.97	0.96	0.96	0.96	0.95
Miscellaneous	1.00	1.00	1.00	1.04	1.05	1.05	1.11	1.07	1.06	1.06	1.06	1.06	1.09
Other Industry (combustion)	1.00	1.00	1.00	1.01	1.04	1.00	0.98	0.97	0.97	0.96	0.96	0.96	0.96
Public services	1.00	1.00	1.00	1.04	1.05	1.05	1.11	1.07	1.06	1.06	1.06	1.06	1.09
Railways (stationary sources)	1.00	1.00	1.00	1.04	1.05	1.05	1.11	1.07	1.06	1.06	1.06	1.06	1.09
Autogenerators	1.00	1.00	1.00	1.01	1.04	1.00	0.98	0.97	0.97	0.96	0.96	0.96	0.95

Table 3.11: Revised carbon emission factors for coal

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Agriculture	659.60	659.60	659.60	655.04	657.32	661.88	659.60	664.16	650.47	659.60	666.45	680.14	650.47
Collieries	659.60	645.76	618.09	618.09	650.37	650.37	604.25	641.15	682.66	675.74	682.66	687.28	684.97
Domestic	676.80	676.80	676.80	676.80	667.84	681.28	685.76	685.76	692.49	692.49	692.49	692.49	696.97
I&S (blast furnace)	-	-	-	-	715.23	714.55	728.21	728.21	728.21	694.07	691.79	694.07	694.07
I&S (combustion)	659.60	659.60	659.60	655.04	671.01	718.94	714.38	714.38	714.38	700.38	700.38	671.01	693.84
Lime Production (combustion)	659.60	659.60	659.60	666.72	683.33	657.23	647.74	640.62	638.25	631.13	635.87	633.50	628.76
Miscellaneous	659.60	659.60	659.60	688.38	690.78	693.18	729.16	702.77	700.38	697.98	700.38	700.38	721.96
Other Industry (combustion)	659.60	659.60	659.60	666.72	683.33	657.23	647.74	640.62	638.25	631.13	635.87	633.50	633.50
Public services	659.60	659.60	659.60	688.38	690.78	693.18	729.16	702.77	700.38	697.98	700.38	700.38	721.96
Railways (stationary sources)	659.60	659.60	659.60	688.38	690.78	693.18	729.16	702.77	700.38	697.98	700.38	700.38	721.96
Autogenerators	659.60	659.60	659.60	666.72	683.33	657.23	647.74	640.62	638.25	631.13	635.87	633.50	628.76

3.3.3.2 Cement production

We contacted the trade association for the UK cement producers - the British Cement Association (BCA) – and the National Energy Manager for Lafarge cement to gather information about the current usage and combustion conditions of coal in the cement sector. Cement kilns operate at high temperatures (for example, temperatures in the sintering zone of rotary kilns are around 1,450°C) and so fuels will be almost completely oxidised, and effectively 100% oxidation is achieved. The BCA indicated that the UK cement industry tends to now source their coal from abroad, whereas the current GHG inventory assumed UK coal is consumed. Therefore, the approach of directly scaling the current carbon factors to GCVs was felt to be unsuitable for this industry.

The time series of carbon emission factors (see **Table 3.12**) for coal used in the cement sector was provided by Rushworth (2004) and was based on the empirical relationship between calorific values and carbon emissions established using actual data for the years 2000 to 2004. Calorific values for mineral products for the years 1990 to 1999 were taken from DUKES (DTI, 2004) Table A2. These calorific values are supplied to the DTI by the BCA and therefore are consistent with the empirical relationship derived.

Table 3.12: Carbon emission factors and GCV for coal used by the UK cement industry

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Emission factor kt/Mt	757.8	757.8	757.8	792.7	760.4	728.2	736.3	725.5	714.8	717.5	725.5	725.5	725.5	749.7	744.3
GCV GJ per tonne	28.2	28.2	28.2	29.5	28.3	27.1	27.4	27.0	26.6	26.7	27.0	27.0	27.0	27.9	27.7

3.3.4 Coke

Calorific values for coke remained constant throughout the time series and so the factors remained unaltered.

3.3.5 Anthracite

In the UK inventory, carbon emissions from anthracite occur from domestic sources only. Anthracite emission factors were scaled to GCVs as described for coal. **Table 4.13** presents the carbon emission factors found in the current inventory, corresponding GCVs, and revised of emission factors.

Table 3.13: Current and proposed emission factors for anthracite (kt/Mt)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Current EF	813.4	813.4	813.4	813.4	813.4	813.4	813.4	813.4	813.4	813.4	813.4	813.4	813.4
GCV (GJ/t)	33.6	33.6	33.5	33.5	33.6	34.0	33.9	33.9	34.1	33.5	33.6	33.9	33.9
Proposed EF	813.4	813.4	811.0	811.0	813.4	823.1	820.7	820.7	825.5	811.0	813.4	820.7	820.7

3.3.5 Petroleum coke

3.3.5.1 Non-cement industry consumers

The UK Petroleum Industry Association (UKPIA) provided an updated estimate for the carbon factor for UK petroleum coke (UKPIA, 2004). The estimate was based on

analytical results of the carbon contents of UK petroleum coke. UKPIA recommended that the new factor should be 930 ktC/Mt across the whole time series, but this factor was not used for petroleum coke used by the cement sector.

3.3.5.2 Cement industry

The cement industry use petroleum coke, and we consulted the BCA about the sources and carbon contents of the fuel consumed. The BCA reported that all the petroleum coke consumed is not sourced from UK refineries, but is imported, and so the carbon emission factor supplied by UKPIA would not be applicable to the petroleum coke used by the UK cement industry. The BCA provided measured carbon contents for petroleum coke for 2000 to 2004. These data were averaged, and applied across the time series, from 1990 to 2004. The industry normally tightly controls the energy content of its fuels and the industry's European database shows emission factors across samples to be very similar. Therefore, applying a constant CEF to the time series seems a reasonable assumption.

The BCA recommended a carbon emission factor of 829.6 ktC/Mt for the cement sector and this has been adopted.

3.4 EFFECT OF REVISING THE CEFs FOR SOLID FUELS ON CARON EMISSIONS

3.4.1 Coal – ESI sector

Tables 3.14 to **3.16** present the effects of introducing the revised coal CEFs for the ESI into the 2002 GHG inventory. **Table 3.14** displays the difference between overall UK carbon emissions from coal combustion before and after the CEF update for the ESI sector. **Table 3.15** shows the difference in the ESI sector only and finally **Table 3.16** displays the overall differences observed in carbon emissions (from the combustion of all fuels) in the UK.

Table 3.14: Changes in carbon emissions from coal (total for all sources consuming coal) after applying the revised coal CEF to the ESI (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using revised CEFs	% change to coal emissions
1990	57.25	58.64	2.43
1991	56.95	58.89	3.41
1992	53.60	55.21	3.01
1993	43.31	46.65	2.96
1994	42.20	43.38	2.79
1995	39.71	40.31	1.52
1996	36.49	37.68	3.27
1997	31.72	31.11	4.36
1998	31.97	33.68	5.35
1999	27.90	29.19	4.62
2000	29.34	30.72	4.69
2001	33.09	34.99	5.75
2002	30.68	32.66	6.48

Table 3.15: Changes in carbon emissions from the ESI sector after applying the revised coal CEF to the ESI (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using revised CEFs	% change to ESI coal emissions
1990	48.56	49.95	2.86
1991	48.25	50.19	4.02
1992	45.29	46.90	3.56
1993	37.70	39.04	3.56
1994	35.68	36.85	3.30
1995	34.08	34.69	1.77
1996	31.43	32.62	3.80
1997	26.66	28.04	5.19
1998	27.43	29.14	6.23
1999	23.28	24.57	5.54
2000	26.33	27.71	5.23
2001	28.99	30.90	6.56
2002	27.14	29.13	7.32

Table 3.16: Changes to overall UK carbon emissions after applying the revised coal CEF to the ESI (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using revised CEFs	% change to emissions
1990	164.63	166.02	0.84
1991	165.66	167.60	1.17
1992	161.62	163.23	1.00
1993	157.45	158.79	0.85
1994	156.26	157.44	0.75
1995	153.83	154.43	0.39
1996	159.35	160.54	0.75
1997	152.65	154.03	0.91
1998	153.46	155.17	1.11
1999	151.13	152.42	0.85
2000	152.17	153.54	0.90
2001	155.75	157.65	1.22
2002	150.26	152.25	1.32

Table 3.17 displays the overall percentage changes in carbon emissions between 1990 and 2002. It shows the decline in overall carbon emissions from the 2002 GHG inventory (from 1990 to 2002), and the decline in the carbon emissions after the revised CEF has been applied in the ESI sector. The effect of introducing the new CEF into the ESI sector is to reduce the decline in carbon emissions, although the effect is small.

Table 3.17: Percentage change in overall carbon emissions between 1990 and 2002

GHG inventory	% change
Original 2002 GHG inventory	-8.73
2002 GHG inventory and updated coal ESI factors	-8.29

3.4.2 Coal, anthracite, coke - other sectors

Tables 3.18 to **3.20** present the effects of introducing the revised coal (non-ESI sectors), anthracite and coke CEFs into the GHG inventory.

Table 3.18: Changes in carbon emissions from total coal consumption (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using scaled CEFs	% change to coal emissions
1990	57.25	57.76	0.88
1991	56.95	57.39	0.77
1992	53.60	53.94	0.64
1993	45.31	45.73	0.92
1994	42.20	42.66	1.08
1995	39.71	39.98	0.69
1996	36.49	36.86	1.02
1997	31.72	32.06	1.07
1998	31.97	32.30	1.03
1999	27.90	27.89	-0.04
2000	29.34	29.34	-0.02
2001	33.09	33.09	-0.02
2002	30.68	30.67	-0.03

Table 3.19: Changes in carbon emissions from total anthracite consumption (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using scaled CEFs	% change to anthracite emissions
1990	0.97	0.97	0.00
1991	1.32	1.32	0.00
1992	1.06	1.06	-0.30
1993	1.57	1.57	-0.30
1994	1.62	1.62	0.00
1995	1.18	1.19	1.19
1996	1.12	1.13	0.89
1997	1.04	1.05	0.89
1998	0.78	0.79	1.49
1999	0.73	0.73	-0.28
2000	0.75	0.75	0.00
2001	0.90	0.91	0.89
2002	0.65	0.66	0.89

Table 3.20: Changes in carbon emissions from total coke consumption (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using scaled factors	% change to coke emissions
1990	2.17	1.38	-36.10
1991	1.81	1.04	-42.51
1992	1.88	1.16	-38.47
1993	1.63	0.90	-44.54
1994	1.45	0.70	-51.70
1995	1.24	0.46	-62.82
1996	1.32	0.50	-62.17
1997	1.10	0.25	-77.11
1998	1.09	0.27	-74.72
1999	1.39	0.62	-55.60
2000	1.36	0.64	-53.04
2001	1.30	0.70	-46.24
2002	1.01	0.48	-52.72

Although the CEFs for coke remained unaltered from those given in the 2002 GHG inventory, emissions have changed due to the assumptions made about the carbon contents of other fuels. The change arises for coke used in blast furnaces and also for coal use in coke ovens. The important point about these source/fuel combinations is that they are artificial devices introduced into the UK GHG inventory many years ago to ensure that carbon balances for processes in steelworks balanced correctly. For example, coke ovens involve carbon input as coal and carbon output as coke, breeze and coke oven gas. The carbon content of these inputs/outputs was always fixed and the carbon would never balance. A correction was therefore applied in the form of the two source/fuel combinations, one for the coke oven carbon balance and one for the blast furnace carbon balance. These corrections are, effectively the difference between two large but similar numbers and so even a small percentage change in one of these large numbers leads to a large percentage change in the correction.

This methodology will be updated in future versions of the GHG inventory in order to eliminate the need for these corrections. Adopting this approach would not alter the overall UK carbon emission but would change the detailed allocation of emissions to individual sources, providing more accurate allocation.

3.4.3 Petroleum coke

Table 3.21 displays the changes in emissions caused by the update of the petroleum coke carbon emission factors.

Table 3.21: Changes in carbon emissions from total petroleum coke consumption (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA and cement industry (2004) CEFs	% change
1990	0.78	0.91	16.25
1991	0.83	0.97	16.25
1992	1.28	1.44	12.70
1993	1.38	1.55	12.23
1994	1.39	1.55	11.27
1995	1.62	1.81	11.41
1996	1.76	1.95	10.64
1997	1.72	1.91	11.35
1998	1.55	1.74	12.05
1999	1.35	1.53	13.44
2000	1.27	1.44	12.78
2001	0.93	1.04	11.38
2002	1.09	1.22	11.18

3.4.4 Overall change to carbon emissions resulting from revisions to the CEFs of the solid fuels

Table 3.22 displays the gross overall emission changes in carbon emissions caused by updates to the solid fuel factors in the 2002 GHG inventory. The effect of introducing the revised solid fuel CEFs is to increase emissions of carbon from the inventory, across the time series, by approximately 1% for each year.

Table 3.22: Overall emission changes (gross) caused by revisions to the CEFs of the solid fuels (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using updated solid fuel factors	% change
1990	164.63	165.87	0.75
1991	165.66	167.40	1.05
1992	161.62	163.01	0.86
1993	157.45	158.64	0.76
1994	156.26	157.31	0.67
1995	153.83	154.12	0.19
1996	159.35	160.29	0.59
1997	152.65	153.73	0.71
1998	153.46	154.89	0.93
1999	151.13	151.82	0.45
2000	152.17	152.98	0.53
2001	155.75	157.16	0.91
2002	150.26	151.84	1.05

4 Gaseous fuels

4.1 INTRODUCTION

Within the UK the main gaseous fuel used is natural gas and this accounts for 38% of total UK carbon emissions. Smaller emissions arise from blast furnace gas (2% of total UK carbon emissions), Other Petroleum Gas (OPG) (1% of total UK carbon emissions) and Coke Oven Gas (less than 1% of total carbon emissions). **Table 4.1** shows the sources of natural gas within the inventory and their overall percentage contribution to natural gas emissions in 2002.

Table 4.1: Contribution of sources to natural gas emissions in 2002

Source	% contribution to overall natural gas emission
Domestic	34
Power stations	26
Other industry (combustion)	14
Miscellaneous	6
Public services	4
Autogenerators	3
Iron and steel (combustion)	2
Gas production	1
Ammonia and feedstock	1
Cement (fuel combustion) Refineries(combustion) Railways (stationary sources) Agriculture Lime production(combustion) Iron and steel (blast furnaces) SSF production Nuclear fuel production, Coke production Collieries	Minor emissions of less than 1% each arise from these sources

The main source of emissions for both blast furnace gas and coke oven gas is the iron and steel industry. This industry accounts for 96% of carbon emissions from blast furnace gas and 52% of emissions from coke oven gas. The majority of the remaining emissions from coke oven gas arise from coke production.

The main source of emissions from OPG is from combustion at refineries. This accounts for 88% of emissions from OPG.

4.2 CEFs OF GASEOUS FUELS USED IN THE 2002 GHG INVENTORY

4.2.1 Natural Gas

The current carbon emission factor for natural gas is 1.501 kt/Mth (52.16 t CO_2/TJ gross) and was supplied by British Gas in 1992. This emission factor

is applied across the time series from 1990 to 2002 for all the sources listed in **Table 4.1**.

4.2.2 Coke oven gas

The current coke oven gas carbon emission factor was supplied by British coal in 1989. The factor used is 1.599 kt/Mt and is applied across the whole time series of emissions.

4.2.3 Blast furnace gas

The current blast furnace gas carbon emission factor was supplied by British Coal in 1989. The factor used is 6.273 kt/Mt and is applied across the whole time series of emissions.

4.2.4 Other petroleum gas (OPG)

The current OPG carbon emission factor was supplied by the UK Petroleum Institute Association (UKPIA) in 1989. The factor used is 1.627 kt/Mtherm and is applied across the whole time series of emissions.

4.3 REVISED CEFs

4.3.1 Fraction of fuel unoxidised after combustion

The CEFs in this section account for the carbon left unoxidised after combustion. The assumption is that the oxidation is 100%.

4.3.2 Natural gas

A time series of carbon emission factors (CEF) for natural gas was obtained from Transco (2004). Data was provided for the years 1990, 1994, 1996, 1998, 1999, 2000, 2002, 2003 and is displayed in **Table 4.2**.

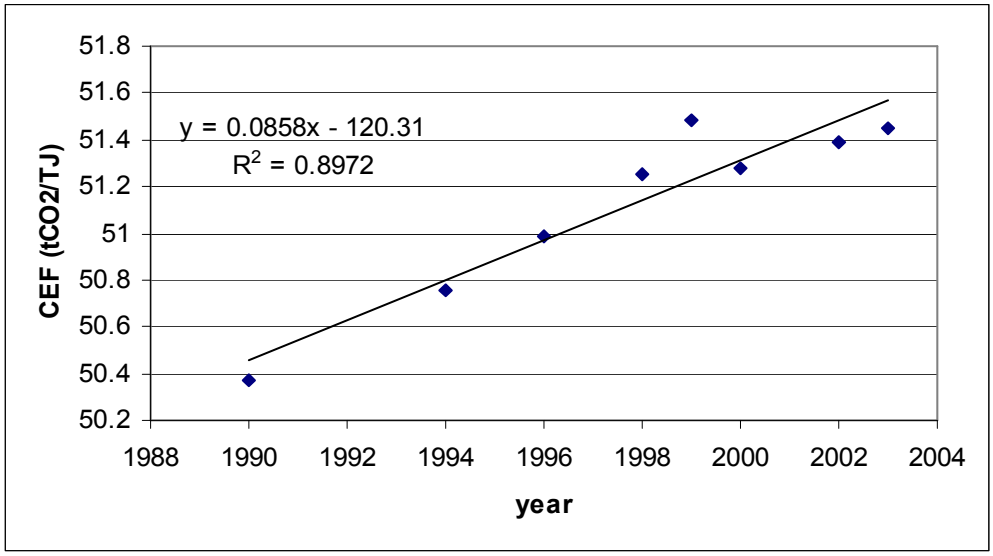
Table 4.2: Natural gas emission factors (Transco, 2004)

Year	Mean Carbon Emission Factor tCO_2/TJ(gross)
1990	50.37
1994	50.76
1996	50.99
1998	51.25
1999	51.48
2000	51.28
2002	51.39
2003	51.45

Details of the calculation procedures can be found in Transco (2004b-MPR039). Transco (2004a-MPR046) state that there are two main factors that contribute to the variability in annual mean CEFs. Firstly, the increasing influence over time from gas entering the supply network at the St Fergus entry point in Scotland, and secondly, the increasing CEF at this point. It is suggested that the gas quality changes observed at this point reflect changes in the economics of ethylene production and prevailing international factors (e.g. 1990 Gulf War).

The inventory requires emission factors for every year from 1990-2002. We concluded that the best method to derive CEFs for the years 1991, 92, 93, 95, 97 and 2001, was to linearly interpolate between the data for the years provided. This decision was made based on the observation that there was a statistically significant correlation between the year and the CEF measured in that year; see **Figure 4.1**.

Figure 4.1: Variation in the natural gas CEF with time (data supplied by Transco, 2004a)



Linearly interpolating between the data supplied by Transco provided the following CEFs for the intervening years:

Table 4.3: Linearly interpolated emission factors for natural gas

Year	CEF (tCO_2/TJ (gross))
1991	50.47
1992	50.57
1993	50.66
1995	50.88
1997	51.12
2001	51.34

Within the inventory, data is held in ktC/Mtherm for natural gas. The CEFs were converted from TJ to Therms using the following expression:

CEF ktC/Mth = ((A*(12/44))/0.009478)/1000

where

A = CEF tCO_2/TJ (gross)
0.009478 = Conversion factor for TJ to Mtherms (DTI, 2003)

The time series resulting from this calculation is shown in **Table 4.4**.

Table 4.4: CEFs for natural gas (ktC/Mtherm)

Year	CEF ktC/Mtherm
1990	1.4494
1991	1.4522
1992	1.4550
1993	1.4578
1994	1.4606
1995	1.4639
1996	1.4672
1997	1.4710
1998	1.4747
1999	1.4813
2000	1.4756
2001	1.4772
2002	1.4787
2003	1.4805

4.3.3 Coke oven gas

Updated emission factors for coke oven gas were obtained from Corus (2004). The factor recommended for use across the time series was 1.203 kt/Mt.

4.3.4 Blast furnace gas

Updated emission factors for blast furnace gas were obtained from Corus (2004). The factor recommended for use across the time series was 7.459 kt/Mt.

4.3.5 Other petroleum gas

An updated emission factor for other petroleum gas was obtained from UKPIA (2004). The factor recommended for use across the time series was 1.64398 kt/Mtherm.

4.4 EFFECT OF REVISING THE CEFs FOR GASEOUS FUELS ON CARBON EMISSIONS

4.4.1 Natural gas

Tables 4.5 to 4.7 display the results of introducing the new CEFs (Transco, 2004) for natural gas into the 2002 GHG inventory. **Table 4.5** shows the difference between natural gas emissions before and after the CEF update with **Table 4.7** showing the overall effect the update had on overall carbon emissions in the UK.

Table 4.5: Changes in carbon emissions after applying the revised natural gas CEF, from natural gas only (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using Transco (2004) factors	% change
1990	30.35	29.39	-3.17
1991	32.65	31.67	-3.01
1992	32.81	31.90	-2.77
1993	36.94	36.00	-2.55
1994	39.46	38.53	-2.36
1995	41.17	41.26	-2.16
1996	48.91	47.94	-1.98
1997	49.90	49.01	-1.78
1998	52.19	51.37	-1.57
1999	55.53	54.87	-1.19
2000	57.13	56.24	-1.54
2001	57.03	56.20	-1.45
2002	56.47	55.70	-1.35

Table 4.6: Changes to overall UK carbon emissions after applying the revised natural gas CEF (Mt)

Year	Emissions in the original 2002 GHG inventory	Emissions using Transco (2004) factors	% change
1990	161.75	160.79	-0.60
1991	162.75	161.77	-0.60
1992	158.66	157.76	-0.57
1993	154.43	153.49	-0.61
1994	153.19	152.25	-0.61
1995	150.68	149.77	-0.60
1996	156.18	155.21	-0.62
1997	149.49	148.60	-0.60
1998	150.32	149.50	-0.55
1999	147.99	147.33	-0.45
2000	148.99	148.10	-0.59
2001	152.58	151.76	-0.54
2002	147.08	146.31	-0.52

Table 4.7 displays the overall percentage changes in carbon emissions between 1990 and 2002, and the change in the carbon emissions after the revised natural gas CEF has been applied. The effect of introducing the new CEF is negligible.

Table 4.7: Percentage change in overall carbon emissions between 1990 and 2002 after introducing the revised natural gas CEF

4.4.1.1 Database	**% change**
Original 2002 GHG inventory	-9.07%
2002 GHG inventory and updated natural gas CEF factors	-9.00%

The tables in the following sections set out the effects of introducing the CEFs for selected gaseous fuels into the 2002 GHG inventory.

4.4.2 Blast furnace gas

Table 4.8: Changes to carbon emissions following revision of the blast furnace gas CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using Corus (2004) CEFs	% change
1990	4.14	4.92	18.91
1991	4.08	4.85	18.91
1992	3.82	4.54	18.91
1993	3.83	4.55	18.91
1994	3.97	4.72	18.91
1995	4.13	4.91	18.91
1996	4.34	5.16	18.91
1997	4.47	5.32	18.91
1998	4.29	5.11	18.91
1999	4.10	4.87	18.91
2000	3.82	4.54	18.91
2001	3.18	3.78	18.91
2002	2.83	3.36	18.91

4.4.3 Coke oven gas

Table 4.9: Changes to carbon emissions following revision of the coke oven gas CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using Corus (2004) CEFs	% change
1990	0.95	0.72	-24.18
1991	0.87	0.66	-24.20
1992	0.79	0.60	-24.19
1993	0.75	0.57	-24.15
1994	0.74	0.56	-24.18
1995	0.71	0.54	-24.03
1996	0.78	0.60	-23.13
1997	0.77	0.58	-23.78
1998	0.76	0.58	-23.12
1999	0.71	0.54	-24.33
2000	0.73	0.55	-24.63
2001	0.64	0.48	-24.28
2002	0.53	0.41	-24.24

4.4.4 Other petroleum gas (OPG)

Table 4.10: Changes to carbon emissions following revision of the OPG CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) CEFs	% change
1990	2.39	2.42	1.04
1991	2.37	2.40	1.04
1992	2.35	2.38	1.04
1993	2.52	2.54	1.04
1994	2.61	2.63	1.04
1995	2.73	2.75	1.04
1996	2.74	2.77	1.04
1997	2.53	2.56	1.04
1998	2.40	2.43	1.04
1999	2.36	2.38	1.04
2000	2.39	2.41	1.04
2001	2.27	2.29	1.04
2002	2.03	2.05	1.04

4.4.5 Overall change to carbon emissions resulting from revisions to the CEFs of the gaseous fuels

Table 4.11 shows the overall effect of updating all the CEFs for gaseous fuels on the carbon emissions from the 2002 GHG inventory. The effect of introducing the revised gaseous fuel CEFs is to slightly decrease emissions of carbon from the inventory, across the time series, by no more than 0.25% with the greatest effect in the early and later years of the inventory. The effect of revising the gaseous fuel CEFs is much smaller than revising the CEFs of the solid fuels.

Table 4.11: Overall effect on UK carbon emission totals using updated gaseous fuels CEFs (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using updated gaseous factors	% change
1990	161.75	161.36	-0.24
1991	162.75	162.35	-0.24
1992	178.66	158.31	-0.22
1993	154.43	154.05	-0.24
1994	153.19	152.85	-0.22
1995	150.68	150.41	-0.18
1996	156.18	155.88	-0.19
1997	149.49	149.29	-0.13
1998	150.32	150.15	-0.11
1999	147.99	147.95	-0.02
2000	148.99	148.67	-0.21
2001	152.58	152.23	-0.23
2002	147.08	146.74	-0.23

5 Liquid fuels

5.1 INTRODUCTION

There are a number of liquid fuels used within the UK. The major liquid fuels that are used are petrol, DERV, gas oil, burning oil and fuel oil. The percentage contribution to UK emissions listed in **Table 2.2**. Other fuels that are used include Aviation Turbine Fuel (ATF), premium burning oil, waste oils, aviation spirit, LPG and naphtha. **Table 5.1** displays the main sectors using each fuel and their percentage contribution to overall emissions from that fuel.

Table 5.1: Sources of carbon from liquid fuels in the UK

Fuel	Source	% contribution to overall fuel emission in UK reported in national totals to the IPCC
Petrol	Road transport	99
	Other industry (off road)	1
DERV	Road transport	99.9
	Domestic house and garden	0.1
Fuel oil	Power Stations	20
	Refineries (combustion)	53
	Public Services	4
	Miscellaneous	2
	Other industry (combustion)	14
	Iron and Steel (combustion)	5
	Coastal	1
Gas oil	Refineries	2
	Miscellaneous	6
	Public services	9
	Domestic	3
	Agriculture	2
	Other industry (combustion)	32
	Iron and Steel (combustion)	3
	Shipping, Naval	4
	Railways	4
	Coastal	8
	Fishing	1
	Agricultural power units	4
	Other industry off-road	19
Burning oil	Domestic	71
	Other Industry (Combustion)	28
	Railways	0.3
	Public Services	0.3
	Miscellaneous	0.3
Aviation turbine fuel	Domestic Aviation	55
	Military aviation	45
Aviation spirit	Domestic Aviation	100
Burning oil (premium)	Domestic	100
LPG	Refineries (combustion)	1
	Gas Separation Plant (combustion)	1
	Domestic	29
	Other Industry (combustion)	61
	Road Transport	8
Naphtha	Refineries (combustion)	100
Waste oils	Cement (fuel combustion)	100

5.2 CEFs OF LIQUID FUELS USED IN THE 2002 GHG INVENTORY

All the current factors for liquid fuels were supplied to AEA Technology by the United Kingdom Petroleum Industry Association (UKPIA) in 1989. **Table 5.2** shows each liquid fuel in the inventory and its corresponding emission factor. These emission factors apply across the time series of emissions from 1990 to 2002 inclusive.

Table 5.2: Carbon emission factors for liquid fuels in the 2002 GHG inventory

Fuel	Current carbon emission factor (ktC/Mt)
Aviation spirit	859
Aviation turbine fuel	859
Burning oil	859
Burning oil premium	859
DERV	857
Fuel oil	850
Gas oil	857
LPG	1.712ktC/Mtherm
Naphtha	940
Petrol	855
Waste oils	859

These factors are applied across all sources for each fuel (as listed in **Table 5.1**).

5.3 REVISED CEFs

Updated emission factors for liquid fuels were obtained from UKPIA (2004) who carried out a survey of the carbon contents of selected fuels. **Table 5.3** shows the updated factors that were supplied. The CEFs of fuels not included in this list remain unchanged and were left equal to the values in the 2002 GHG inventory. A summary of the reasons for changes to the factors is given in the notes below the table and more detailed information is given in UKPIA (2004).

Table 5.2: Updated emission factors for liquid fuels (KteC/Mte), as supplied by UKPIA (2004)

Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Naphtha	854	854	854	854	854	854	854	854	854	854	854	854	854	854
Aviation spirit	853	853	853	853	853	853	853	853	853	853	853	853	853	853
Diesel	864	864	864	864	864	864	864	864	864	863	863	863	863	863
Gas oil	869	869	869	869	869	869	869	870	870	870	870	870	870	870
Fuel oil	867	868	865	865	865	865	865	868	871	874	875	875	877	879

Notes:

- Naphtha and aviation spirit assumed to be constant and based on UKPIA 2004 survey results
- Petrol is assumed to be constant and unchanged from current CEF assumed, and these assumptions are supported by UKPIA 2004 survey results
- Diesel is corrected for changes in sulphur content and density over time using smoothed sulphur contents from the annual UKPIA survey of sulphur contents and density from DTI DUKES
- Gas oil and fuel oil corrected for changes in sulphur content over time using smoothed sulphur contents from the annual UKPIA survey of sulphur contents

5.3.1 Fraction of fuel unoxidised after combustion

The CEFs in this section account for the carbon left unoxidised after combustion.

A short review was completed to determine what a suitable oxidation factor should be. During this review, we

- contacted the UK Petroleum Industries Association (UKPIA) to seek their view on the appropriate oxidation factors;
- considered the views of experts involved in the mobile combustion chapter of the 2006 IPPC guidelines;
- consulted with our transport sector, Tim Murrells, for his views on the mobile combustion.

The details of this review are given in **Appendix 2**. We concluded that the fraction oxidised for liquid fuels should remain at 100% across the time series, primarily because of the uncertainty in the estimates of the fractions of fuels unoxidised and the difficulties of generating an accurate and defensible time series of unoxidised fractions for each fuel used in the GHG inventory from 1990 to the most current year.

5.4 EFFECT OF REVISING THE CEFs FOR LIQUID FUELS ON CARBON EMISSIONS

The tables in the following sections set out the effects of introducing the CEFs for liquid fuels into the 2002 GHG inventory.

5.4.1 Naphtha

Table 5.4: Changes to carbon emissions following revisions to the naptha CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) naptha CEF	% change
1990	0.02	0.02	-9.14
1991	0.02	0.02	-9.14
1992	0.02	0.02	-9.14
1993	0.02	0.02	-9.14
1994	0.01	0.01	-9.14
1995	0.00	0.00	-9.14
1996	0.00	0.00	-9.14
1997	0.01	0.01	-9.14
1998	0.01	0.01	-9.14
1999	0.02	0.01	-9.14
2000	0.01	0.01	-9.14
2001	0.05	0.05	-9.14
2002	0.02	0.02	-9.14

5.4.2 Aviation spirit

Table 56.5: Changes to carbon emissions following revisions to the aviation spirit CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) aviation spirit CEF	% change
1990	0.02	0.02	-1.38
1991	0.02	0.02	-1.38
1992	0.02	0.02	-1.38
1993	0.02	0.02	-1.38
1994	0.02	0.02	-1.38
1995	0.02	0.02	-1.38
1996	0.02	0.02	-1.38
1997	0.03	0.03	-1.38
1998	0.03	0.03	-1.38
1999	0.03	0.03	-1.38
2000	0.04	0.04	-1.38
2001	0.05	0.05	-1.38
2002	0.04	0.04	-1.38

5.4.3 Fuel Oil

Table 5.6: Changes to carbon emissions following revisions to the fuel oil CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) fuel oil CEF	% change
1990	11.7	12.0	2.00
1991	11.6	11.9	2.12
1992	10.5	10.7	1.76
1993	9.95	10.1	1.76
1994	8.92	9.08	1.76
1995	7.66	7.80	1.76
1996	7.04	7.16	1.76
1997	5.31	5.43	2.12
1998	4.54	4.66	2.47
1999	3.78	3.89	2.82
2000	2.80	2.89	2.94
2001	3.45	3.55	2.94
2002	3.24	3.35	3.18

5.4.4 Gas oil

Table 5.7: Changes to carbon emissions following revisions to the gas oil CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) gas oil CEF	% change
1990	7.27	7.37	1.30
1991	7.27	7.38	1.40
1992	7.11	7.21	1.35
1993	6.99	7.09	1.36
1994	6.73	6.83	1.39
1995	6.51	6.60	1.40
1996	6.87	6.96	1.37
1997	6.64	6.75	1.48
1998	6.50	6.59	1.18
1999	6.02	6.11	1.48
2000	5.90	5.99	1.52
2001	5.88	5.97	1.52
2002	5.54	5.63	1.52

5.4.5 Diesel oil

Table 5.8: Changes to carbon emissions following revisions to the diesel oil CEF (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) diesel oil CEF	% change
1990	9.13	9.20	0.82
1991	9.16	9.24	0.82
1992	9.54	9.62	0.82
1993	10.1	10.2	0.82
1994	11.0	11.1	0.82
1995	11.5	11.6	0.82
1996	12.3	12.4	0.82
1997	12.8	12.9	0.82
1998	12.9	13.0	0.82
1999	13.2	13.3	0.70
2000	13.3	13.4	0.70
2001	14.0	14.1	0.70
2002	15.1	15.2	0.70

5.4.6 Overall change to carbon emissions resulting from revisions to the CEFs of the liquid fuels

Table 5.9 displays the overall effect that updating the liquid fuel CEFs has on overall inventory carbon emissions from the 2002 GHG inventory. Introducing the revised liquid fuel CEFs slightly increases the emissions of carbon from

the inventory across the time series, by no more than 0.25%, with the greatest effect in the early years of the inventory.

Table 5.9: Overall effect on UK carbon emissions using updated liquid fuel CEFs (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using UKPIA (2004) CEFs	% change
1990	164.6	165.0	0.24
1991	165.6	166.0	0.25
1992	161.6	161.9	0.22
1993	157.4	157.8	0.22
1994	156.2	156.6	0.22
1995	153.8	154.1	0.21
1996	159.3	159.6	0.20
1997	152.6	152.9	0.21
1998	153.4	153.7	0.20
1999	151.1	151.4	0.19
2000	152.1	152.4	0.17
2001	155.7	156.0	0.18
2002	150.2	150.5	0.19

6 Overall effect on carbon emissions of the revised CEFs

The following table displays the overall emissions as a result of revisions to all the solid, liquid and gaseous fuels documented in the report. Emissions are presented in MtC and are gross values. The overall effect is to increase the carbon emissions across the time series, by 1.3% in 1990 (the base year for the sources and fuels considered in this report), and by 1.5% in 2002.

Table 6.1: Overall effect on UK carbon emissions after applying all the revised CEFs (MtC)

Year	Emissions in the original 2002 GHG inventory	Emissions using updated factors	% change	Actual change
1990	164.6	165.8	0.76	1.25
1991	165.6	167.4	1.07	1.77
1992	161.6	163.0	0.86	1.40
1993	157.4	158.6	0.75	1.17
1994	156.2	157.3	0.67	1.05
1995	153.8	154.1	0.22	0.34
1996	159.3	160.3	0.60	0.96
1997	152.6	153.8	0.78	1.19
1998	153.4	155.0	1.02	1.57
1999	151.1	152.0	0.62	0.93
2000	152.1	152.9	0.50	0.76
2001	155.7	157.0	0.86	1.34
2002	150.2	151.7	1.02	1.52
% change 1990-2002	-8.73%	-8.50%		

Tables 6.2 and **6.3** display the emissions, according to fuel type, for the original 2002 GHG inventory, and for 2002 GHG inventory with the updated carbon emission factors. **Table 6.4** displays the percentage change overall, and by fuel type.

The overall effect of introducing the revised CEFs into the inventory was to slightly increase carbon emission across the time series. Emissions of carbon in 1990 increased by 0.8%, and by 1.0% in 2002.

Table 6.2: Carbon emissions in the original 2002 GHG inventory (MtC)

IPCC Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Anthracite	0.97	1.32	1.06	1.57	1.62	1.18	1.12	1.04	0.78	0.73	0.75	0.90	0.65
Aviation Gasoline	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04
Blast Furnace Gas	4.14	4.08	3.82	3.83	3.97	4.13	4.34	4.47	4.29	4.10	3.82	3.18	2.83
Coke Oven Coke	2.17	1.81	1.88	1.63	1.45	1.24	1.32	1.10	1.09	1.39	1.36	1.30	1.01
Coke Oven Gas	0.95	0.87	0.79	0.75	0.74	0.71	0.78	0.77	0.76	0.71	0.73	0.64	0.53
Coking Coal	0.45	0.38	0.28	0.29	0.29	0.35	0.32	0.40	0.39	0.49	0.37	0.46	0.38
Colliery Methane	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Gas/Diesel Oil	16.40	16.44	16.65	17.11	17.80	18.04	19.18	19.48	19.47	19.31	19.30	19.95	20.67
Gas Works Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jet Gasoline	1.63	1.33	1.33	1.40	1.37	1.38	1.38	1.33	1.34	1.31	1.26	1.31	1.37
Liquefied Petroleum Gas	0.88	1.02	0.91	0.93	0.99	0.97	1.09	1.00	1.00	0.96	0.92	1.01	0.88
Lubricants	0.28	0.26	0.27	0.28	0.28	0.31	0.30	0.30	0.28	0.27	0.28	0.28	0.29
Motor Gasoline	20.79	20.54	20.56	20.32	19.53	18.77	19.16	19.02	18.68	18.63	18.47	17.90	16.89
Municipal Solid Waste	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.14	0.20	0.19	0.20	0.22	0.24
Naphtha	0.02	0.03	0.03	0.02	0.02	0.00	0.00	0.02	0.02	0.02	0.02	0.05	0.03
Natural Gas	30.35	32.65	32.81	36.94	39.46	42.17	48.91	49.90	52.19	55.53	57.13	57.03	56.47
Non-Fuel Combustion	10.63	9.83	9.56	9.09	9.66	8.95	9.15	9.01	9.07	8.75	8.17	7.95	7.45
Non IPCC	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07
Orimulsion	0.09	0.25	0.77	0.85	0.73	0.76	0.52	0.11	0.00	0.00	0.00	0.00	0.00
Other Bituminous Coal	56.80	56.57	53.31	45.02	41.91	39.35	36.17	31.33	31.58	27.41	28.97	32.63	30.29
Other Kerosene	1.77	2.05	2.12	2.25	2.28	2.38	2.87	2.87	3.07	3.12	3.30	3.65	3.31
Other Oil	0.02	0.03	0.04	0.05	0.09	0.09	0.11	0.07	0.06	0.07	0.09	0.11	0.11
Patent Fuel	0.94	0.93	0.84	0.90	0.75	0.60	0.67	0.50	0.50	0.45	0.41	0.38	0.33
Petroleum Coke	0.78	0.83	1.28	1.38	1.39	1.62	1.76	1.72	1.55	1.35	1.27	0.93	1.09
Refinery Gas	2.39	2.37	2.35	2.52	2.61	2.73	2.74	2.53	2.40	2.36	2.39	2.27	2.03
Residual Fuel Oil	11.78	11.68	10.59	9.95	8.92	7.66	7.04	5.31	4.54	3.78	2.80	3.45	3.24
Scrap Tyres	0.00	0.00	0.00	0.00	0.05	0.06	0.09	0.09	0.06	0.05	0.02	0.02	0.02
Total emissions (ktC)	**164.6**	**165.7**	**161.6**	**157.4**	**156.3**	**153.8**	**159.3**	**152.6**	**153.5**	**151.1**	**152.2**	**155.8**	**150.3**

Table 6.3: Carbon emissions after introducing CEFs for solid, liquid and gaseous fuels (MtC) into the 2002 GHG inventory

IPCC Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Anthracite	0.97	1.32	1.06	1.57	1.62	1.19	1.13	1.05	0.79	0.73	0.75	0.91	0.66
Aviation Gasoline	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.04
Blast Furnace Gas	4.92	4.85	4.54	4.55	4.72	4.91	5.16	5.32	5.11	4.87	4.54	3.78	3.36
Coke Oven Coke	1.38	1.04	1.16	0.9	0.7	0.46	0.5	0.25	0.27	0.62	0.64	0.7	0.48
Coke Oven Gas	0.72	0.66	0.6	0.57	0.56	0.54	0.6	0.58	0.58	0.54	0.55	0.48	0.41
Coking Coal	0.74	0.65	0.52	0.52	0.52	0.56	0.65	0.73	0.73	0.52	0.39	0.49	0.41
Colliery Methane	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Gas/Diesel Oil	16.57	16.62	16.82	17.29	17.98	18.23	19.37	19.69	19.68	19.49	19.48	20.14	20.86
Gas Works Gas	0	0	0	0	0	0	0	0	0	0	0	0	0
Jet Gasoline	1.63	1.33	1.33	1.4	1.37	1.38	1.38	1.33	1.34	1.31	1.26	1.31	1.37
Liquefied Petroleum Gas	0.88	1.02	0.91	0.93	0.99	0.97	1.09	1	1	0.96	0.92	1.01	0.88
Lubricants	0.28	0.26	0.27	0.28	0.28	0.31	0.3	0.3	0.28	0.27	0.28	0.28	0.29
Motor Gasoline	20.79	20.54	20.56	20.32	19.53	18.77	19.16	19.02	18.68	18.63	18.47	17.9	16.89
Municipal Solid Waste	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.14	0.2	0.19	0.2	0.22	0.24
Naphtha	0.02	0.03	0.02	0.02	0.01	0	0	0.0.1	0.01	0.02	0.02	0.05	0.02
Natural Gas	29.39	31.67	31.9	36	38.53	41.26	47.94	49.01	51.37	54.87	56.24	56.2	55.7
Non-Fuel Combustion	10.63	9.83	9.56	9.09	9.66	8.95	9.15	9.01	9.07	8.75	8.17	7.95	7.45
Non IPCC	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07
Orimulsion	0.09	0.25	0.77	0.85	0.73	0.76	0.52	0.11	0	0	0	0	0
Other Bituminous Coal	58.41	58.69	55.03	46.55	43.32	40.02	37.4	32.72	33.28	28.66	30.32	34.5	32.25
Other Kerosene	1.77	2.05	2.12	2.25	2.28	2.38	2.87	2.87	3.07	3.12	3.3	3.65	3.31
Other Oil	0.02	0.03	0.04	0.05	0.09	0.09	0.11	0.07	0.06	0.07	0.09	0.11	0.11
Patent Fuel	0.94	0.93	0.84	0.9	0.75	0.6	0.67	0.5	0.5	0.45	0.41	0.38	0.33
Petroleum Coke	0.91	0.97	1.44	1.55	1.55	1.81	1.95	1.91	1.74	1.53	1.44	1.04	1.22
Refinery Gas	2.42	2.4	2.38	2.54	2.63	2.75	2.77	2.56	2.43	2.38	2.41	2.29	2.05
Residual Fuel Oil	12.02	11.93	10.78	10.13	9.08	7.8	7.16	5.43	4.66	3.89	2.89	3.55	3.35
Scrap Tyres	0	0	0	0	0.05	0.06	0.09	0.09	0.06	0.05	0.02	0.02	0.02
Total emissions (ktC)	**165.9**	**167.4**	**163.0**	**158.6**	**157.3**	**154.2**	**160.3**	**153.8**	**155.0**	**152.1**	**152.9**	**157.1**	**151.8**

Table 6.3: Percentage change in carbon emissions, according to fuel, after introducing the revised CEFs into the 2002 GHG inventory

IPCC Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Anthracite	0.00	0.00	-0.29	-0.29	0.00	1.19	0.89	0.89	1.49	-0.30	0.00	0.89	0.89
Aviation Gasoline	-1.38	-1.38	-1.38	-1.38	-1.38	-1.38	-1.38	-1.38	-1.39	-1.39	-1.39	-1.39	-1.39
Blast Furnace Gas	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.91	18.91	18.91	18.91	18.91
Coke Oven Coke	-36.09	-42.51	-38.47	-44.53	-51.70	-62.81	-62.17	-77.11	-74.72	-55.60	-53.04	-46.24	-52.72
Coke Oven Gas	-24.18	-24.20	-24.19	-24.14	-24.17	-24.03	-23.12	-23.77	-24.12	-24.33	-24.62	-24.28	-24.24
Coking Coal	63.22	68.63	84.31	78.27	75.87	59.96	104.92	84.47	85.50	6.59	4.45	6.03	6.31
Colliery Methane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas/Diesel Oil	1.03	1.07	1.04	1.04	4.03	1.02	1.01	1.04	1.04	0.94	0.95	0.94	0.92
Gas Works Gas	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-
Jet Gasoline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquefied Petroleum Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lubricants	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motor Gasoline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Municipal Solid Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naphtha	-9.14	-9.14	-9.14	-9.14	-9.14	-	-	-9.14	-9.15	-9.15	-9.15	-9.15	-9.15
Natural Gas	-3.16	-3.00	-2.76	-2.55	-2.36	-2.15	-1.98	-1.78	-1.57	-1.19	-1.54	-1.45	-1.35
Non-Fuel Combustion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non IPCC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orimulsion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-
Other Bituminous Coal	2.82	3.74	3.21	3.40	3.36	1.69	3.40	4.43	5.40	4.55	4.68	5.73	6.45
Other Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Patent Fuel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum Coke	16.25	16.25	12.70	12.23	11.27	11.41	10.64	11.34	12.05	13.44	12.78	11.38	11.18
Refinery Gas	1.044	1.044	1.044	1.044	1.044	1.044	1.044	1.044	1.04	1.04	1.04	1.04	1.04
Residual Fuel Oil	2.00	2.11	1.76	1.76	1.76	1.76	1.76	2.11	2.47	2.82	2.94	2.94	3.18
Scrap Tyres	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall % change	**0.76%**	**1.06%**	**0.86%**	**0.74%**	**0.67%**	**0.22%**	**0.60%**	**0.78%**	**1.02%**	**0.62%**	**0.50%**	**0.86%**	**1.02%**

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- **Wilson, Dave** (UK DTI)
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Appendix 1

A1.1 BUNKER EMISSIONS

International shipping and aviation emissions are not included in national total emissions, but are submitted to the IPCC annually. Modifications to the CEFs will affect the emissions from fuels consumed by international shipping and aviation, and for completeness, the revised bunker emissions are presented in this Appendix.

Table A1.1.1: International bunker emissions (MtC)

IPCC	IPCC Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Emissions in 2002 Greenhouse Gas Inventory												
International Marine	Gas/Diesel Oil	0.59	0.63	0.70	0.66	0.75	0.64	0.72	0.66	0.96	0.73	0.72
International Marine	Residual Fuel Oil	1.18	1.09	1.11	1.12	0.94	1.15	1.24	1.53	1.43	1.00	0.79
Aviation Bunkers	Jet Gasoline	4.03	3.97	4.39	4.70	4.88	5.20	5.53	5.89	6.59	7.22	8.02
Emissions in Carbon Emissions Factor modified Greenhouse Gas Inventory												
International Marine	Gas/Diesel Oil	0.60	0.64	0.70	0.67	0.73	0.65	0.73	0.67	0.97	0.74	0.74
International Marine	Residual Fuel Oil	1.21	1.12	1.13	1.14	0.96	1.17	1.26	1.56	1.46	1.03	0.82
Aviation Bunkers	Jet Gasoline	4.03	3.97	4.39	4.70	4.88	5.20	5.53	5.89	6.59	7.22	8.02

Table A1.2.2: Coal GCV for the cement industry (GJ per tonne)

SOURCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cement (combustion)	28.2	28.2	28.2	29.5	28.3	27.1	27.4	27	26.6	26.7	27	27	27	27.9	27.7

- 1990-93 and 1994-99 - DUKES GCV - Mineral products
- 1994 - average of 93 and 95 DUKES data
- 2000-2004 - Data supplied by Cement industry

Table A1.2.3: Coke GCV (GJ per tonne)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8

Table A1.2.4: Petroleum Coke GCV (GJ per tonne)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5

Table A1.2.5: Liquid fuel GCVs (GJ per tonne)

Fuel	Dukes class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Gas oil	Gas/Diesel Oil (incl DERV)	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.5	45.6	45.6	45.6	45.6
Fuel oil	Fuel Oil	43.2	43.2	43.2	43.2	43.2	43.2	43.2	43.3	43.2	43.2	43.1	43.5	43.4
Petrol	Motor Spirit	47	47	47	47	47	47	47	47	47	47.1	47	47.1	47.1
DERV	Gas/Diesel Oil (incl DERV)	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.5	45.6	45.6	45.6	45.6
Aviation Spirit	Aviation Spirit & Wide Cut Gasoline	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3	47.3
Aviation Turbine fuel	Aviation Turbine Fuel	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2	46.2

Table A1.2.6: Natural Gas GCVs from DUKES and TRANSCO (2004) (MJ/m^3)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DUKES	37.97	37.80	38.52	38.80	39.09	39.6	39.1	39.1	39.1	39.5	39.4	39.8	39.8	39.6
Transco	38.61	-	-	-	38.89	-	39.27	-	39.52	39.76	39.41	-	39.51	39.5

A1.3 CONVERSION FACTORS FOR GROSS TO NET ENERGY CONSUMPTION

Table A1.3.1 displays the conversion factors used for Gross to Net Energy consumption as listed in the UK Greenhouse Gas Inventory 1990-2002, (Baggott et al, 2004).

Table A1.3.1: Conversion factors for Gross to Net energy consumption

Fuel	Conversion factor
Other Gaseous Fuels	0.9
Solid and Liquid Fuels	0.95
LPG and OPG	0.92
Blast Furnace Gas	1.0

Appendix 2

A2.1 REVIEW OF FRACTIONS OF CARBON LEFT UNOXIDISED AFTER COMBUSTION IN LIQUID FUELS

Background
Emissions of carbon can be estimated from the quantities of fuel burnt, their carbon contents, and the fraction of carbon that is not oxidised during the combustion.

The current assumption in the UK Greenhouse Gas inventory is that 100% of the liquid fuels and gaseous fuels are oxidised. The EU ETS default is 99.5%.

Review
To review the assumptions currently used, we have

- contacted the UK Petroleum Industries Association (UKPIA) to seek their view on the appropriate oxidation factors
- considered the views of experts involved in the mobile combustion chapter of the 2006 IPPC guidelines
- consulted with our transport sector, Tim Murrells, for his views on the mobile combustion

Response from UKPIA
From an analysis of data provided by Ian McPherson of UKPIA, Malcolm Watson, UKPIA, has suggested that for large combustion plant in refineries the carbon oxidation is 99.9%. This analysis ignores any soot deposited in and around the combustion chamber (JW - but this is likely to negligible).

Views of authors involved in the 2006 IPCC GLs
A table of oxidation factors were produced for the IPCC 2006 GLs by Kainou Kazanuri from a range of sources, including the IPCC EF database, and data from the IEA. This covered all the IPCC fuels.

Jos Olivier (RIVM, Netherlands) makes the point that in general the non-oxidised fraction (i.e. that remains as particles following combustion) is very small, and is much smaller than the uncertainty in the emission factors and certainly much smaller than the accuracy of the activity data. He considers this correction term more of an 'academic' character (i.e. in principle OK), than of an topic of any significance for accurately estimating CO2 emissions. Jos recommended to apply values other than 1 in cases where there is a significant fraction carbon non-oxidised.

Greg Marland (Oak Ridge National Laboratory) notes that there is an analysis within the US EPA that suggests 100% oxidation of fuel for modern automobiles. Greg notes that he does not know if this assumption can be extended to the full mobile sector.

View of Tim Murrells (NAEI transport sector expert)
This is an issue we regularly have to consider when calculating fuel consumption and CO_2 factors for road transport by specific vehicle types.

When data sources provide fuel consumption factors in g fuel/km for different fuels and types of vehicles, they actually derive these from measurements of CO_2 tailpipe emissions and work back to calculate fuel consumption from measured tailpipe CO_2 emissions and the measured tailpipe emissions of other carbon containing species CO, hydrocarbons and PM. There are text-book equations to do this using the carbon contents of these other species. These are

based on the assumption that all PM emitted from vehicle exhausts is in the form of elemental carbon and they assume an average carbon content of the emitted hydrocarbons.

The terminology that is used is 'tailpipe CO_2' (the amount of CO_2 actually emitted) and 'ultimate CO_2', (the amount that has the potential of forming CO_2 based on the total amount of carbon emitted). It is ultimate CO_2 that is related to fuel consumption rates.

The actual amount of carbon emitted in forms other than CO_2 is time-variable, depending on the make-up of the fleet. Old petrol cars without three-way catalysts emitted a significant amount of carbon as CO and hydrocarbons. But with improvements in engines and abatement technology, this has reduced significantly. Recent test data we have just been analysing for DfT shows that for modern cars, about 99.4 - 99.7% of carbon is emitted as CO2 from the tailpipe of petrol cars and 99.6 - 99.9% of carbon is emitted as CO2 from diesel cars.

This doesn't make any difference to us if it is assumed (as we do) that regardless of what the carbon is emitted as it has the potential (and will) form CO_2 in the atmosphere. For CO and hydrocarbons that is a fair assumption, but I have never been comfortable with the idea that emitted PM can potentially form CO2 and to this end I think we ought to subtract the amount of exhaust PM emitted as carbon (from our calculation of PM emissions) from DUKES fuel consumption stats.

The 0.3-0.6% of carbon that is not emitted as CO_2 from petrol vehicles is virtually all emitted as CO and HC, so there are no worries here in using the DUKES figures and carbon content factors as this means all the carbon in the fuel is emitted in a form that will go on to form CO_2. For diesel vehicles, though, a significant amount of the 0.1-0.4% of carbon that is not emitted as CO_2 is emitted as PM, so that ought to be taken into account in the calculations from DUKES figures on diesel consumption.

Some calculations I've done show that for modern vehicles, <0.01% of carbon in petrol is emitted as PM and 0.05-0.1% of carbon in diesel is emitted as PM. I should stress though the figures for diesel are time-varying, as cleaner engines and technologies penetrate the fleet, the amount of PM emitted is decreasing. In 1990, the allowance for diesel emitted PM in the carbon calculations will be higher. Also, don't take this figure for diesel as generic - for gas-oil consumption in diesel trains, machinery, shipping etc, these are less well-designed engines with no PM abatement, and a more significant fraction of carbon in the diesel consumed by these engines will be emitted as PM, so a bigger correction in the DUKES figures ought in theory to be made.

I could develop a "fleet-weighted" correction factor based on diesel PM emissions that can be applied to the road transport CO_2 calculations from DUKES diesel consumption, but it depends what you intend to do with the information. There could be a tricky issue in that the PM emissions for road transport are calculated from traffic data and the carbon emissions being calculated from DUKES figures exclude the contribution of 'fuel tourism' vehicles that contribute to the UK traffic and therefore contribute to our PM inventory, but not our carbon inventory.

Recommendation

Our view is that the fraction oxidised for liquid fuels should remain at 100% across the time series, primarily because of the uncertainty in the estimates of the fractions of fuels unoxidised and the difficulties of generating an accurate and defensible time series of unoxidised fractions for each fuel used in the GHG inventory from 1990 to 2004.

Adopting this approach will mean that the base year emissions will be unaffected. This will result in a slightly conservative estimate of carbon emissions – possibly more so in 1990 where combustion technology was not so advanced and the fraction of carbon unoxidised would have been slightly greater.

Appendix 3

A3.1 PROJECT MEETINGS

Date	Meeting	Attendees
01.07.2004	***Gas emission factors and calorific values for use in ETS and NAEI*** Defra, Ashdown House, London	Jim Penman Defra Sayeeda Tauhid Defra Caroline Doble Defra Sarah Baggott Defra/AEAT-netcen John Watterson AEAT-netcen Howard Rudd AEAT-FES David Wilson DTI Rob Gemmill EA Dave Lander Transco Chris Allen Transco Phil Pryor NG Transco Mike Cunningham SEPA
10.08.2004	***Natural Gas Calorific Values and Emission Factors for Use in the NAEI and the EU ETS*** Defra, Ashdown House, London	DEFRA – Chris Dodwell, Caroline Austwick, Sayeeda Tauhid NETCEN – John Watterson, Sarah Baggott FES – Philip Wright Transco – Dave Lander, Phil Prior DTI – Margaret Maier, Roger Lampert EA – Haydn Jones SEPA – Mike Cunningham, Stephen Boyle