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Review of the Treatment of Stored Carbon and the Non-Energy Uses of Fuel in the UK Greenhouse Gas Inventory

Report to Department for Environment, Food and Rural Affairs

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Review of the Treatment of Stored Carbon and the Non-Energy Uses of Fuel in the UK Greenhouse Gas Inventory

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This work forms part of the Climate Energy; Science and Analysis Programme of the Department for Environment, Food and Rural Affairs.

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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.

Executive Summary

This report set out the results of a work programme to review and update the treatment of stored carbon and the non-energy uses of fuels in the UK greenhouse gas inventory. This review involved discussions with UK inventory experts and with international experts also. This work was part of a wider programme of inventory review and improvement to prepare the UK's greenhouse gas inventory to deliver the UK's Assigned Amount under the Kyoto Protocol.

The UK has conducted a series of calculations to estimate the fate of carbon contained in the petroleum products shown in the 'non-energy use' line of the UK fuel commodity balance tables. The analysis indicates that most of the carbon is 'stored', although a significant quantity does appear to be emitted. Some of the emitted carbon has been included in previous versions of the greenhouse gas inventory, for example, carbon from chemical waste incinerators; most has not. This technical report presents a summary of the estimates of emitted and stored carbon from sources identified. The study also provides subjective, qualitative commentary regarding the quality of the estimates and an estimate of the uncertainty associated with carbon emissions.

As a result of this work, a number of changes were made to the UK 2004 GHG inventory (2006 National Inventory Report).

The following sources of carbon have been introduced:

- Petroleum waxes
- Carbon emitted during energy recovery - chemical industry
- Carbon in products - soaps, shampoos, detergents etc.
- Carbon in products - pesticides

The following sources of carbon have been removed:

- Emissions from benzoles and coal tars

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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	**1.2.1**	• First issue
1.0	**1.3**	• Completion of text and tables that was left unfinished in v1.2.1
1.0	**1.3.1**	• AEA front cover added

Abbreviations for Greenhouse Gases and Chemical Compounds

Type of greenhouse gas	Formula or abbreviation	Name
Direct	CH_4	Methane
Direct	CO_2	Carbon dioxide
Direct	N_2O	Nitrous oxide
Direct	HFCs	Hydrofluorocarbons
Direct	PFCs	Perfluorocarbons
Direct	SF_6	Sulphur hexafluoride
Indirect	CO	Carbon monoxide
Indirect	NMVOC	Non-methane volatile organic compound
Indirect	NO_X	Nitrogen oxides (reported as nitrogen dioxide)
Indirect	SO_2	Sulphur oxides (reported as sulphur dioxide)

HFCs, PFCs and SF_6 are collectively known as the 'F-gases'

Abbreviations, acronyms and definitions

AEQ	Air and Environmental Quality Division
base year review	A programme of work to review the accuracy and completeness of the emissions in the 2004 UK greenhouse gas inventory
C	Carbon
CRF	Common Reporting Format tables of emissions for submission to the FCCC.
CORUS	The owner of the many of the integrated steel works in the UK
CEF	Carbon Emission Factor
DTI	UK Department of Trade and Industry
DERV	Diesel Engined Road Vehicle fuel used in internal combustion engines that are compression ignition engines
Defra	Department for Environment Food and Rural Affairs
DUKES	Digest of United Kingdom Energy Statistics. Produced by the UK DTI. www.dti.gov.uk/energy/statistics
EA	Environment Agency for England and Wales
EU	European Union
ESI	Electricity Supply Sector
ETS	Emissions Trading Scheme
UN	United Nations
FCCC	Framework Convention on Climate Change
GCV	Gross Calorific Value
GHG	Greenhouse gas
GHGI	Greenhouse gas inventory
IPCC	Intergovernmental Panel on Climate Change
ISR	Inventory of Sources and Releases
kt	kilotonne
Mt	Mega tonne
NAEI	National Atmospheric Emissions Inventory www.naei.org.uk
NIR	National Inventory Report
NEU	Non-energy use
PI	Pollution Inventory produced by the Environment Agency The Pollution Inventory collects information on releases of pollutants and transfers of waste off-site from businesses regulated by the Environment Agency in England and Wales.
SPRI	Scottish Pollutant Release Inventory
UK	United Kingdom

UN/ECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

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.*, 2005). 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 GHG inventory is subject to a range of regular 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 expert review teams of the FCCC have recommended that the UK review its treatment of stored carbon (see **Appendix 1**).

This report set out the results of a work programme to review and update the treatment of stored carbon and the non-energy use of fuels in the 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.

1.2 WHAT IS STORED CARBON?

Not all fuel supplied to an economy is burned for heat energy. Some is used as a raw material (or feedstock) for manufacture of products such as plastics or ammonia or in a non-energy use (e.g. bitumen for road construction), without oxidation (emissions) of the carbon. This is called stored carbon, and is deducted from the carbon emissions calculation, or not included within the calculation. Estimating quantities of stored carbon requires data for fuel use by activities using the fuel as raw material. **Appendix 1** provides further details of the IPCC guidance.

1.3 ESTIMATES OF EMISSIONS OF STORED CARBON AND EMISSIONS FROM NEU IN THE 2005 NIR

The 2003 UK GHG inventory – 2005 National Inventory Report (NIR) - did not use the IPCC default methodology for stored carbon because it was not clear what processes it represented or if it was applicable to the UK (Baggott *et al*., 2005). The procedure adopted was to report emissions from the combustion of fuels. Emissions, from the non-energy use of fuels were assumed to be zero (i.e. the carbon is sequestrated as products) unless a process emission could be identified.

The following process emissions were identified in the UK and were included in the inventory:

- Catalytic crackers – regeneration of catalysts;
- Ammonia production;
- Aluminium production – consumption of anodes;
- Benzoles and tars – produced in coke ovens and emissions assigned to the waste sector (**note this source is now excluded from the UK inventory**);
- Combustion of waste lubricants and waste solvents;
- Incineration of fossil carbon in products disposed of as waste.

There are other much smaller scale reformers of natural gas in the UK, producing H_2 and CO_2. These are not currently included in the GHG inventory, but the assumption is that this gas is oxidised and so emissions of carbon the GHG inventory are slightly conservative.

1.3.1 Ammonia production in the UK

Ammonia production is a NEU of natural gas, and involves the catalytic reformation of natural gas:

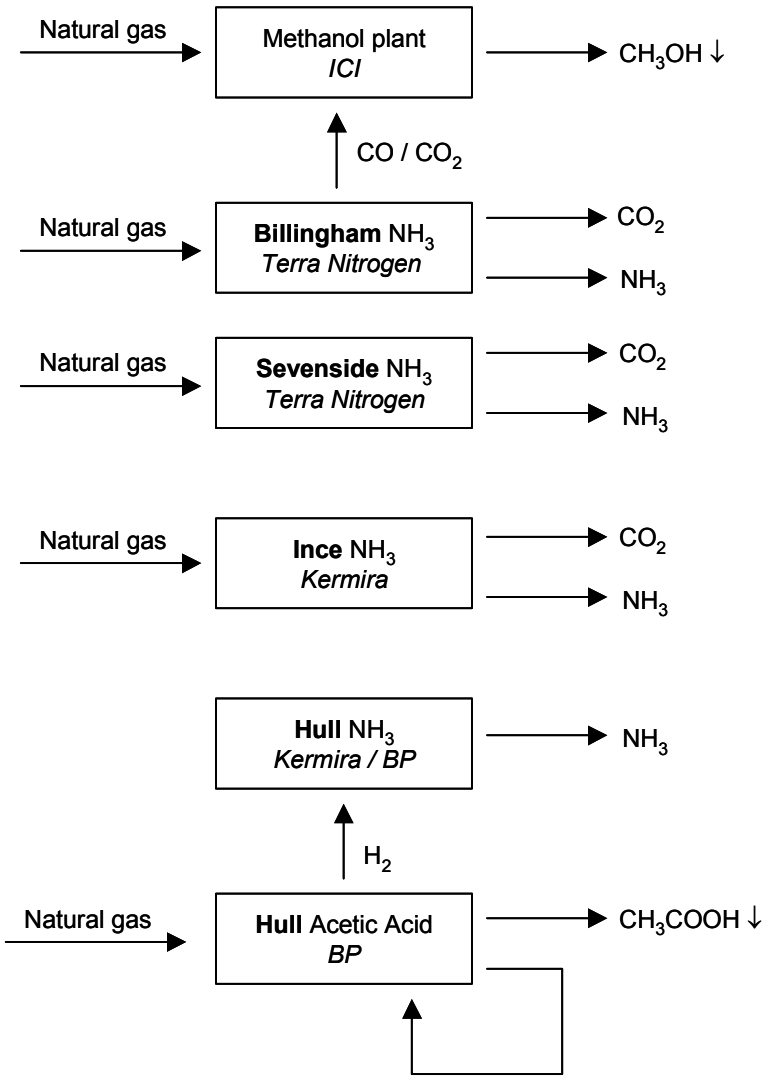
$$N_2 + H_2 \rightarrow NH_3 \text{ (ammonia)}$$
$$\uparrow$$
$$CH_4 \text{ (natural gas)} + H_2O \text{ (as steam)} \rightarrow H_2 + CO_2$$

UK ammonia plant in the UK are mainly integrated with methanol and acetic acid plant. The position is quite complex, and the flows of feedstocks and products are shown in **Figure 1**. This diagram shows the position before the methanol plant closed down in April 2001.

It is not possible to ratio CO_2 emissions on NH_3 production for the UK because of the interrelationships between the plants.

This work does not consider ammonia production further and this section is included for completeness.

Figure 1 Production of ammonia in the UK and associated flows of feedstocks and by-product chemicals.
Place names are in **bold**. Company names are in *italics*.



1.4 GENERAL APPROACH TO THIS WORK

This study:

- Reviewed the IPCC guidance (1996, Good Practice Guidance 2000, and the forthcoming 2006 Guidance) on the treatment of stored carbon, fate of carbon from the non-energy use (NEU) of products and the breakdown of those products;
- Reviewed the recent American, German and Dutch National Inventory Reports to determine what assumptions other countries made about stored carbon;
- Reviewed the potential sources of stored carbon in the UK;
- Produced a time series of emissions for these sources from 1990 onwards, or from 1970 onwards where the data allowed this extended time series;
- Assigned uncertainties to these emissions;
- Updated the treatment of stored carbon in the UK GHG inventory and documented the methods used.

The US 2005 NIR contained a clear and detailed methodology of the approach used in the US inventory to estimate emissions of stored carbon, and the US NIR presents 'storage factors' for a range of products. Some of these factors have been used in the new UK method. The lead author of the American GHG inventory was contacted during this study.

1.5 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 Review of the Methods used to Estimate Emissions From Coal Tars and Non-Energy Uses of Petroleum Products

2.1 SCOPE OF THE REVIEW

The review considered estimates of emissions from:

- the 'energy' uses of coal tars and benzoles, given in DUKES Tables 2.4-2.6
- the 'non-energy' uses of petroleum products, given in DUKES Tables 3.4-3.6

Since the UK GHG inventory estimates emissions of carbon, carbon which is not emitted (i.e. 'stored') can be calculated from DUKES consumption data by difference.

Estimates were made, according to fossil fuel category, in six categories:

1. coal tars & benzoles
2. lubricants (the use of lubricants in the UK GHG inventory has been subject to a recent review; Norris *et al.* (2006))
3. petroleum coke
4. petroleum waxes
5. bitumen
6. chemical feedstocks (ethane, propane, butane, other gases, naphtha, industrial spirit, white spirit, middle distillate feedstock)

Notes are provided in the sections below on the method used to estimate emissions for each category of fuel. Not all the sources identified were included in the revised GHG inventory; **Section 2.11.1** lists the new sources included.

2.2 COAL TARS & BENZOLES

Coal tars and benzoles are a by-product of the manufacture of coke. They are emitted from coal during the coking process and recovered from the coke oven gas. Subsequently, the coke oven gas is used as a fuel, and the recovered coal tars and benzoles are sold.

For versions of the GHGI up to 2002, it was assumed that the carbon contained in coal tars and benzoles was emitted from the coking process. In effect, it was assumed that they were used as fuels by coke ovens. For the 2003 GHGI, the methodology for fuel transformation processes was overhauled and improved, and this error was corrected. At that time, however, we had no information on the ultimate fate of the carbon in the coal

tars and benzoles so we assumed that it was emitted at the end of the useful life of products made from the coal tar/benzoles. This emission was reported under IPCC category 6A (managed waste disposal on land). Total UK emissions of carbon did not change as a result of these changes but carbon emission estimates for coke ovens, reported under IPCC category 1B1b (solid fuel transformation) became more accurate.

For the 2004 GHGI, we contacted Koppers Ltd, who buy coal tars and benzoles from Corus UK Ltd. The company distil the coal tars and benzoles into a range of products and a contact provided information on the uses for these products. Some of these uses result in emissions of carbon at some stage but, in each case, these emissions are already included elsewhere in the GHGI. Thus, to avoid double counting, the carbon in coal tars & benzoles is assumed all to be stored. The main emissive use is the use of coal tar pitch in anodes for aluminium smelting. Currently, all of the carbon emitted is treated as being from the petroleum coke which is also used to make the anodes. While this may not be technically correct, it does not matter in terms of emission totals.

2.3 LUBRICANTS

The fate of waste lubricants has been the subject of a separate study, carried out as part of the programme of work to review the base year emissions of the GHG inventory (the base year review), (Norris *et al*., 2006). Lubricants can be:

- burnt in the engines they lubricate;
- recovered from engines as wastes then used as fuels;
- recovered from engines as wastes then incinerated;
- lost from engines (e.g. as leaks) or recovered but not burnt.

The first three involve emission of the carbon in the lubricants, while the other one is assumed to result in long-term storage of the carbon.

The study carried out as part of the base year review only covered lubricating oils. Greases were not investigated and the carbon is assumed to be stored (note that the USEPA have made an estimate that 18% of carbon in greases is emitted).

We propose that the emission estimates for lubricants are considered within +/-50% of the true value.

2.4 PETROLEUM COKE

The DTI publication DUKES reports all consumption of petroleum coke as ‘non-energy use’ in the commodity balance tables. However, DUKES states elsewhere that some petroleum coke is used as a fuel. The GHGI includes estimates of petroleum coke burnt as a solid smokeless fuel and used by

power stations (both based on DUKES data), as well as petroleum coke used as a fuel by the cement industry (based on fuel use data compiled from member companies by the British Cement Association).

Only one true non-energy use of petroleum coke has been identified – the manufacture of carbon anodes for use by the aluminium industry. Carbon is emitted from the anodes during their use and these emissions are already included in the GHGI.

The remaining petroleum coke is assumed to be used for non-energy applications and the carbon stored. Unfortunately, we have not identified uses for this petroleum coke and the proportion of petroleum coke that is classified as being for non-energy uses varies between 20% and 50% over the period 1990 and 2004. This suggests that one or more of the following are true:

- GHGI estimates for petroleum coke consumption for anodes, smokeless fuels or power station fuels are underestimated (the data for cement fuel is thought to be accurate);
- a significant quantity of petroleum coke is used as a fuel by another sector e.g. general industry, but is not included in the GHGI;
- a significant quantity of petroleum coke is used for a non-fuel application or applications which has/have not been identified.

Despite the areas of uncertainty, we consider that much of the data available on petroleum coke use is fairly reliable. We would therefore propose that the emission estimates are considered within +/-50% of the true value.

2.5 PETROLEUM WAXES

The USEPA have estimated that 42% of carbon in petroleum waxes are emitted. Uses of petroleum waxes that result in emissions in the US include packaging materials, candles, construction materials, firelogs, hot melt adhesives and many more. Almost all of the carbon in firelogs and candles is assumed by the USEPA to be emitted while most of the carbon in the other uses is assumed stored.

No attempt has been made to gather data on UK uses of petroleum waxes so the assumption that US data is appropriate for the UK remains untested. For the purposes of evaluating the uncertainty in emission estimates, we would propose that the figure for petroleum waxes be considered within a factor of 2 of the true figure.

2.6 BITUMEN

The dominant use of bitumen is in road dressings. Other uses, such as roofing materials, coatings etc. are relatively minor. Following the approach adopted in the US, all carbon in bitumen is assumed stored.

2.7 CHEMICAL FEEDSTOCKS

All remaining petroleum products are considered together. This is because, unlike the other products such as bitumen or petroleum coke, it is not possible to separately identify the uses of these products. Instead, all of these products are input into chemical manufacturing processes, producing a huge variety of products. The approach taken for chemical feedstocks has therefore been:

1. to calculate the carbon input into the chemical industry (in practice this is assumed to be the total carbon in non-energy uses of ethane, propane, butane, other petroleum gases, naphtha, industrial spirit, white spirit, and middle distillate feedstocks);
2. to estimate the carbon present in various emissions and environmental releases from chemical industry processes;
3. to estimate the carbon emitted during or after the use of certain products of the chemical industry;
4. to assume that the remaining carbon input to the chemical industry is stored.

2.7.1 Emissions and releases from chemical processes

Carbon can be released from chemical industry processes in various forms:

- process-related emissions of volatile organic compounds (VOC), carbon monoxide (CO), carbon dioxide and methane (CH_4);
- emissions of carbon dioxide resulting from the incineration of chemical wastes;
- emissions of carbon dioxide resulting from the flaring of chemical wastes or the use of chemical wastes as fuels, for example in steam-raising boilers;
- releases of carbon to landfill which are subsequently emitted to air;
- releases of carbon to sewer or surface waters which are subsequently emitted to air.

Process-related emissions of VOC, CO and CH_4 are already included in the UK inventory. The carbon content of these emissions can either be calculated from the molecular formula in the case of CO and CH_4, or estimated in the case of VOC. Emissions of VOC are speciated for AEQ Division of Defra, as part of the NAEI research programme and the speciated emission estimates can be used to derive estimates of the carbon content of VOC emissions. Process-related emissions of carbon dioxide have not been estimated due to the difficulty identifying such emissions amongst the emissions data reported in the Environment Agency's Pollution Inventory (PI). Most emissions of carbon reported in the PI will be from combustion processes and it is not easy to distinguish these emissions from any emissions resulting directly from chemical processes.

Emission estimates for VOC, CO and CH_4 from chemical processes are all considered fairly reliable and estimates of the carbon released will also be fairly reliable. As a working assumption, it is proposed that the estimates be considered to be within +/- 50% of the true value. The estimates for recent years are likely to be more reliable than those for, say, 1990, due to improvements in the quality and quantity of reporting of emissions by process operators.

Emissions of carbon dioxide from chemical waste incinerators are estimated based on limited data given in the Pollution Inventory (PI). Data are available for only a handful of sites, although these include most of the largest incinerators. All of the carbon reported is assumed to be from chemical waste, whereas some may be from support fuels. The data only relate to chemical waste incineration in England and Wales although we do not expect this shortcoming to be of major significance. As a working assumption, it is proposed that the estimates be considered to be within a factor of 2 of the true value. The estimates for recent years are likely to be more reliable than those for, say, 1990, due to improvements in the quality and quantity of reporting of emissions by process operators.

No estimates of the quantities of chemical wastes either flared or burnt as fuels have been found. However, the Environment Agency does collect some information on the quantities of wastes recovered for use as fuels. For this study, we had access to data recorded in the PI up to and including 2002 (subsequent reporting of the types and fate of waste has been more detailed and we will seek these data in order to improve estimates). The earlier PI data gives details of the tonnages of special and non-special wastes recovered as fuel. The exact nature of the waste is not specified so we assumed that the waste was chemical in nature if it was generated at a site operating in the chemical industry sector. Subjective judgements were required in order to select which data to include. The waste was assumed to have a carbon content of 865 kg/tonne, which is the figure used in the GHGI for waste solvents burnt by industry. This figure is probably too high because some wastes will presumably contain some water or inorganic chemical content. However, it is also uncertain how complete the PI data are – certainly they will not include data for processes in Scotland and Northern Ireland and they may not include data on wastes flared. The sensitivity of the estimate to the subjective judgements made has also not been checked. As a result, it is proposed that the estimate be considered to be no better than within an order of magnitude of the true value. We would recommend further development of these estimates using the more recent and detailed EA data and consulting with chemical industry contacts in order to derive more suitable carbon factors. It is not clear whether the PI data include waste chemicals sent to flare; if not, then this is a potentially significant missing source.

Estimates of carbon released to sewers or surface waters are also based on information collected by the EA. As with the estimates for wastes used as fuels, the estimates we make rely on subjective judgements about which records relate to ‘chemical’ wastes, and the data is subject to similar concerns about completeness. A carbon factor of 714 kg/tonne is used for these

releases – this is the average carbon content of all VOC species in the NAEI. It is proposed that the estimate of carbon emissions be considered to be no better than within an order of magnitude of the true value.

It has not proved possible to generate an estimate of the quantity of carbon released to landfills from chemical processes. Some data are collected by the Environment Agency but the difficulty interpreting these data would have meant that any estimates would have had very little value. As with wastes used as a fuel, the Environment Agency has collected more detailed data since 2003 and an acceptable estimate might be generated from these data.

2.7.2 Emissions of carbon during use and disposal of products from the chemical industry

Some products of the chemical industry give rise to emissions to atmosphere during use – most significantly, solvents and aerosol propellants, but also fuel additives, certain industrial gases, explosives, and probably many more specialist products. Other products do not create emissions during their use but carbon can be released to the environment when they are disposed of. The most important classes of product in this category are detergents, soaps and other 'consumer products', where carbon is released as the products degrade subsequent to use. The US EPA have also identified some pesticides which will degrade and release carbon subsequent to use. Other products, such as plastics, rubbers, and synthetic fibres are assumed not to degrade and the carbon is stored. Emissions of carbon will, of course, occur if plastics and other chemical products are incinerated but these emissions are already included in the GHGI.

For solvents, emissions of carbon are based on NAEI emission estimates for VOC from solvent use. The VOC emission estimates are converted to carbon using speciation profiles which have been developed for each source as part of the NAEI research programme. An increasing proportion of solvent consumed is abated by some means such as oxidation so VOC emissions do not occur but emissions of carbon do. These emissions have been estimated using NAEI data on solvent consumed and abated by sector, again using species profiles to convert from solvent to carbon.

Some waste chemicals are used as fuels by the cement industry. The British Cement Association have provided data on consumption of these waste solvents and these data are used to calculate carbon emissions from this source.

The following carbon factors are used for consumer products and pesticides, based on USEPA data:

consumer products	219 kg/t consumer products
pesticides	400 kg/t active ingredient

AEA Energy & Environment make estimates of the consumption of both consumer products and pesticides as part of the annual compilation of VOC

emission estimates for Defra AEQ. These estimates have been used to calculate carbon emissions from these sources.

No attempt has been made to estimate carbon emissions from the use or disposal of other chemical products, partly because of a lack of consumption estimates, partly due to a lack of carbon emission factors from the USEPA, and partly due to the expectation that individual classes of chemical products will have a trivial impact on UK carbon emissions. However, should further research be considered, then priority might be given to emissions from the following types of chemical products:

- fuel additives;
- acetylene and other industrial gases;
- pharmaceuticals.

We would suggest that the estimate of carbon emissions from solvent use and use of waste solvents as fuel be considered to be within +/- 30% of the true value, while the estimates of carbon from pesticides and consumer products are expected to be within a factor of 3 of the true figure.

2.8 TIME SERIES OF EMISSIONS

Following on from the work described in the sections above, a time series of emission estimates have been made for the sources considered in this review.

Table 2.2a(i) presents the estimated emissions from these sources and **Table 2.2a(ii)** provides supplementary information. **Table 2.2b(i)** presents the estimates of quantities of stored carbon, and **Table 2.2b(ii)** provides supplementary information. The estimates of stored carbon are not currently reported in the NIR. Our estimate of uncertainties associated with the emission estimates is given in **Table 2.3.**

Table 2.2a(i) Time series of estimated emissions from sources of emitted carbon (kt carbon)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Coal tars & benzoles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lubricants	397.29	374.38	395.51	413.58	415.83	477.03	469.09	482.10	432.41	403.60	407.92	429.46	419.49	437.82	458.05
Petroleum coke	376.38	394.73	389.28	405.79	433.59	450.89	575.97	606.38	634.60	447.75	502.44	439.90	532.34	486.09	576.01
Petroleum waxes	19.87	17.70	16.98	17.34	16.98	15.89	15.89	15.89	6.50	13.36	11.56	11.92	18.42	20.59	18.06
Bitumen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chemical feedstocks (ethane/propane/butane/other gases/naphtha/industrial spirit/white spirit/MDF/fuel oil):															
Chemical process emissions - emitted as VOC	109.81	103.19	102.28	98.44	93.00	95.08	87.47	78.05	64.90	47.72	43.91	38.23	35.45	34.74	35.80
Chemical process emissions - emitted as CO	17.34	17.83	18.37	18.77	19.71	20.69	19.59	18.18	14.28	11.03	11.65	8.39	10.12	11.00	7.17
Chemical process emissions - emitted as CH_4	4.86	4.84	5.29	4.51	5.52	3.95	4.81	3.78	2.41	1.83	1.65	1.40	1.41	1.23	1.18
Carbon released to surface waters/sewer	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58	38.58
Carbon emitted from landfill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbon in solvent emissions	456.49	431.54	410.22	407.09	408.05	381.80	373.58	369.93	362.96	344.71	334.46	327.87	322.88	320.65	320.85
Carbon emitted by chemical waste incineration	83.08	83.08	83.08	83.08	82.89	82.70	82.51	82.31	82.12	67.93	68.02	75.62	71.84	66.08	63.92
Carbon emitted during energy recovery - chemical industry	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27	158.27
Carbon emitted during energy recovery - cement industry	-	-	-	11.46	36.49	64.87	65.32	65.77	66.22	66.66	67.11	77.06	102.57	80.17	99.11
Carbon in products - soaps, shampoos, detergents etc.	314.00	324.93	335.84	346.73	357.61	359.40	360.91	362.79	365.86	367.18	368.54	371.51	376.56	379.96	383.87
Carbon in products - pesticides	10.69	11.18	10.59	10.54	9.77	10.08	10.26	9.78	10.09	10.57	9.56	10.54	10.54	10.54	10.54
Total emitted carbon	1,986.65	1,960.25	1,964.27	2,014.17	2,076.27	2,159.23	2,262.24	2,291.81	2,239.21	1,979.20	2,023.66	1,988.75	2,098.47	2,045.71	2,171.42

Notes

- New sources included in the 2005 GHG inventory (2006 NIR) are in ***bold italic***

Table 2.2a(ii) Supplementary information for **Table 2.2a(i)**

Source	Time series of emissions available from 1970 onwards	Direct carbon emissions already included in GHGI	Indirect carbon emissions already included in NAEI/GHGI	Quality of estimates	Notes
Coal tars & benzoles	NA	NA	NA	NA	Assume no carbon emissions from coal tar & benzoles (some emissions do occur but are included in the petroleum coke line)
Lubricants	Yes	Yes	NA	High	Methodology revised following base year review of the GHG inventory
Petroleum coke	No	Yes	NA	High	Emissions are from use of pet coke as a fuel and use in anodes
Petroleum waxes	No	No	NA	Medium	Uses USEPA storage factor
Bitumen	No	NA	NA	NA	Assume no carbon emissions from bitumen
Chemical feedstocks (ethane/propane/butane/other gases/naphtha/industrial spirit/white spirit/MDF/fuel oil):	Yes				
	Yes				
Chemical process emissions - emitted as VOC	Yes	No	Yes	High	Carbon emission estimate based on NAEI emission estimates and VOC speciation profiles
Chemical process emissions - emitted as CO	Yes	No	Yes	High	Data from Pollution Inventory / SPRI / ISR
Chemical process emissions - emitted as CH_4	Yes	No	Yes	High	Data from Pollution Inventory / SPRI / ISR
Carbon released to surface waters/sewer	Yes	No	No	Low	Very crude estimate from PI data
Carbon emitted from landfill	NA	NA	NA	NA	No estimate can be made
Carbon in solvent emissions	Yes	No	Yes	High	Based on NAEI emission estimates and VOC speciation profiles
Carbon emitted by chemical waste incineration	Yes	Yes	NA	High	Based on Pollution Inventory data (so doesn't cover Scotland, N Ireland)
Carbon emitted during energy recovery - chemical industry	Yes	No	No	Low	Very simple estimate from EA PI data
Carbon emitted during energy recovery - cement industry	No	Yes	NA	High	British Cement Association has supplied fuel use data
Carbon in products - soaps, shampoos, detergents etc.	Yes	No	No	Medium	Uses USEPA storage factor
Carbon in products - pesticides	Yes	No	No	Medium	Uses USEPA storage factor

Notes

- New sources included in the 2005 GHG inventory (2006 NIR) are in ***bold italic***
- NA – Not Applicable

Table 2.2b(i) Time series of estimates of quantities of stored carbon (kt carbon)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Coal tars & benzoles	277.85	254.33	231.59	219.30	213.45	213.02	215.74	218.55	216.43	199.48	203.74	180.07	151.63	150.95	146.61
Lubricants	313.61	282.03	284.26	283.48	271.72	297.00	278.13	272.04	270.70	279.63	284.82	302.19	297.47	312.87	332.41
Petroleum coke	302.14	238.13	237.99	308.46	400.59	471.74	531.87	391.22	166.68	141.40	193.28	191.27	269.01	305.65	457.40
Petroleum waxes	27.43	24.44	23.44	23.94	23.44	21.95	21.95	21.95	8.98	18.46	15.96	16.46	25.44	28.43	24.94
Bitumen	2,356.49	2,378.24	2,417.03	2,386.76	2,454.87	2,289.32	2,030.12	1,906.19	1,860.78	1,823.89	1,868.35	1,829.56	1,893.89	1,853.21	1,883.49
Chemical feedstocks	3,583.70	4,261.69	4,340.23	4,322.85	4,491.69	4,585.89	4,665.50	4,584.69	4,679.68	4,999.95	4,295.10	3,333.19	3,732.08	4,409.77	4,249.03
Total stored carbon	6,861.22	7,438.87	7,534.54	7,544.80	7,855.76	7,878.92	7,743.31	7,394.65	7,203.25	7,462.81	6,861.25	5,852.75	6,369.52	7,060.89	7,093.89

Notes

- New sources included in the 2005 GHG inventory (2006 NIR) are in ***bold italic***

Table 2.2b(ii) Supplementary information for **Table 2.2b(i)**

Source	Time series of emissions available from 1970 onwards	Quality of estimates	Notes
Coal tars & benzoles	Yes	Medium	Assume no carbon emissions from coal tar & benzoles (some emissions do occur but are included in the petroleum coke line)
Lubricants	Yes	High	Methodology revised following base year review of the GHG inventory
Petroleum coke	Yes	High	
Petroleum waxes	Yes	Medium	
Bitumen	Yes	High	
Chemical feedstocks	Yes	Low	

Notes

- New sources included in the 2005 GHG inventory (2006 NIR) are in ***bold italic***
- NA – Not Applicable

2.9 UNCERTAINTIES

Table 2.3 below summarises our estimates of the uncertainty associated with each emission estimate. There were little quantitative data to base these estimates on, so they represent expert judgements.

Table 2.3 Uncertainty associated with the sources considered

Fuel type	Uncertainty
Coal tars & benzoles	(no emissions)
Lubricants	+/- 50%
Petroleum coke	+/- 50%
Petroleum waxes	factor of 2
Bitumens	(no emissions)
Chemical feedstocks:	
chemical process emissions	+/- 50%
chemical waste incineration	factor of 2
chemical wastes used as fuels	order of magnitude
releases of carbon to sewer/surface	order of magnitude
Waters	
solvent use	+/- 30%
waste solvents used as fuel	+/- 30%
consumer product use	factor of 3
pesticide use	factor of 3

2.10 INITIAL RECOMMENDATIONS FOR REVISIONS TO THE UK GHG INVENTORY

Estimates for some sources (lubricants, petroleum coke, chemical waste incineration, waste solvents used as fuel) were already included in the 2003 version of the GHGI, although the methodology may have been less advanced than the approach described here. Our initial view was that the following emissions should be added to the 2004 GHG inventory:

- chemical process emissions (VOC emissions);
- solvent use (VOC emissions, some of which are incinerated);
- petroleum waxes;
- consumer product use (carbon in products);
- pesticide use.

Further research would be useful so that improvements could be made to the methodology and more reliable estimates included in the next version of the inventory.

We considered that estimates for the following sources are not sufficiently accurate to include in the GHGI at present:

- chemical wastes used as fuels

- chemical wastes released to sewer/surface waters

Emissions from these sources are likely to be small, but further research might be warranted so that improvements could be made to the methodology and more reliable estimates could be made available to the inventory.

2.11 FINAL REVISIONS MADE TO THE UK GHG INVENTORY

The findings of this work were discussed with UK Defra. After considering the magnitude of the sources covered in this review in relation to the national totals, the uncertainty associated with emissions, and the likely forthcoming IPCC reporting requirements in the 2006 Guidelines, the changes listed below were included in the 2004 UK GHG inventory.

2.11.1 New sources of carbon included

The following sources of carbon have been introduced:

- Petroleum waxes
- Carbon emitted during energy recovery - chemical industry
- Carbon in products - soaps, shampoos, detergents etc.
- Carbon in products - pesticides

2.11.2 Sources of carbon removed

The following sources of carbon have been removed:

- Emissions from benzoles and coal tars

2.12 REPORTING OF EMISSIONS

A full time series of emissions from the new sources of carbon listed in **Section 2.11.1** has been included in the 2004 GHG inventory.

In the UK's initial submission to the FCCC (15th April), emissions from the new sources in **Section 2.11.1** were reported in under IPCC sector 7 to increase the transparency of the reporting – custom reporting categories were defined by the UK under this sector. However, discussions with the European Commission indicated that emissions in sector 7 may not count towards the UK's Assigned Amount, and so these emissions were re-allocated to sector 2 (category 2B). There are limitations to reporting emissions in this sector of the CRF as the current structure of the CRF does not allow emissions from the NEU of fuels to be reported in a fully transparent way. The traditional non-energy use of fossil fuels table presented in the CRF in Table 1.A(d) only allows countries to report the fuels being used, but not the products from fuels.

3 Potential Sources of Emissions Not Considered

The estimates presented in **Chapter 2** do not cover a number of potentially significant sources of carbon and also exclude a number of known carbon sources.

3.1 VOC EMISSIONS

Carbon is emitted in the form of VOC emissions from various processes involved in the production, handling and processing of crude petroleum e.g. oil production platforms, terminals and refineries. These emissions have not been included in the stored carbon calculations since they are not related to the consumption of products covered by DUKES Tables 2.4-2.6 and Tables 3.4-3.6. Carbon emissions could, however, easily be calculated from the VOC emission estimates in the UK inventory, using NAEI species profiles.

Similarly, carbon emitted in the form of VOC emissions from the distribution of liquid fuels is not covered by the estimates. VOC emissions from petrol distribution could be converted into carbon emissions using species profiles from the NAEI but these have not been included in the estimates.

The guidance about whether to include emissions of carbon in the form of VOCs in national totals is not prescriptive. Neither the UNFCCC reporting guidelines, nor the 1996 IPCC Guidelines clearly state that indirect CO_2 from NMVOC should be included in the totals. Emissions of CO_2 from Paint Application, Degreasing and Dry Cleaning, and Other country specified categories can be entered in CRF Table 3, but emissions of CO_2 from Chemical Products, Manufacture and Processing cannot.

In the UK GHG inventory, the CO_2 equivalent of the total NMVOC emission from solvent use and other product use are reported as a footnote in the CRF. Guidance was sought from an experienced inventory reviewer (Anke Herold, Oeko-Institute) about the reporting requirements, and the reporting arrangements of other countries for NMVOCs.

An analysis of the 2005 NIRs submitted to the FCCC showed that the following countries report NMVOC emissions, but do not calculate the resulting CO_2 emissions (and therefore do not report CO_2):

- Australia, Belgium, Finland, Germany, Japan, New Zealand, Switzerland, UK, USA;

and that the following countries report both NMVOC and CO_2 from NMVOC and include CO_2 in national totals:

- Austria, Denmark, France, Greece, Hungary, Ireland, Italy, Latvia, Netherlands, Norway, Portugal, Romania, Slovenia, Spain, Sweden.

Considering all the guidance and expert views, we took the decision to continue to exclude the contribution of CO_2 from NMVOC in the UK national totals. Also, the 2006 IPCC Guidelines[1] do not state that countries should report indirect CO_2 with direct CO_2 emissions.

3.2 SOURCES FOR WHICH ESTIMATES ARE NOT CURRENTLY AVAILABLE

Potential sources of carbon emissions for which no estimates are currently available include:

- waste chemicals disposed of to landfills;
- chemicals other than solvents/propellants where carbon is emitted during use (e.g. fuel additives, industrial gases);
- chemicals other than consumer products and pesticides where carbon can be emitted subsequent to use (e.g. pharmaceuticals).

It is possible that the estimates do not include emissions of carbon from chemical wastes sent to flare. Clarification of the scope of data in the Pollution Inventory will be sought but this is potentially a missing source.

[1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm

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Appendix 1

A1.1 EXTRACT FROM THE FCCC FOURTH CENTRALISED REVIEW OF THE UK 2005 NIR

The following text is an extract from the FCCC Fourth Centralised Review and presents the comments made by the FCCC on the UK's approach to the estimation of stored carbon and emissions from the non-energy uses of fuels.

"**Feedstocks and non-energy use of fuels**

The United Kingdom only reports emissions from feedstocks and the non-energy uses of fuels in those instances where an emissive use of the fuels concerned can be identified. These include emissions from: catalytic crackers – regeneration of catalysts; ammonia production; aluminium production – consumption of anodes; benzoles and tars produced in coke ovens (emissions allocated to the Waste sector); combustion of waste lubricants and waste solvents; and incineration of fossil carbon in products disposed of as waste. For the remaining instances of non-energy uses of fuels, the United Kingdom does not use the IPCC default storage factors for the fuels, but instead assumes a 100 per cent storage of the carbon in those fuels. When questioned by the ERT on this method, the United Kingdom replied that the subject of stored carbon is under review. The ERT encourages the United Kingdom in this review and recommends that, rather than assume total storage, it apply the default storage factors, or use more suitable assumptions, consistent with the Revised 1996 IPCC Guidelines. The United Kingdom has indicated, in response to these comments, that it has initiated country-specific research to update the current method and determine appropriate end-use emission factors from feedstocks and non-energy use of fuels."

Reference: Report of the individual review of the greenhouse gas inventory of the United Kingdom of Great Britain and Northern Ireland submitted in 2005. FCCC/ARR/2005/GBR. March 2006.

A1.2 IPCC GUIDANCE ON ESTIMATING STORED CARBON

The following text is the introduction to the method for estimating stored carbon set out in the IPPC 1996 Reference Manual.

"Stored Carbon: Some of the fuel supplied to an economy is used as a raw material (or feedstock) for manufacture of products such as plastics, fertiliser, or in a non-energy use (e.g. bitumen for road construction, lubricants). In some cases, the carbon from the fuels is oxidised quickly to CO_2. In other cases the carbon is stored (or sequestered) in the product, sometimes for as long as centuries. The amounts stored for long periods are called *stored carbon* and should be deducted from the carbon emissions calculation. Estimation of stored carbon requires data on fuel used as feedstock and/or quantities of non-energy fuel products produced. The calculations are discussed within each of the alternative approaches presented in this section."

Reference: IPCC (1996). IPPC Reference Manual Chapter 1/Ref1. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3.