Emission factors programme
Task 7 – Review of Residential
& Small-Scale Commercial
Combustion Sources

Report to the Department for Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland
AEAT/ENV/R/1407/Issue 1
August 2003
Executive Summary

This report has been prepared for the Department for the Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland by netcen (an operating division of AEA Technology) under the contract EPG 1/3/195 - Emission factors for air pollutants.

The Department for Environment, Food and Rural Affairs (Defra) Air and Environment Quality (AEQ) Division is responsible for maintaining the UK National Atmospheric Emissions Inventory (NAEI). The NAEI is maintained by netcen on behalf of Defra. As part of the ongoing quality control of the NAEI the quantitative uncertainty in the national emission total of each component pollutant in NAEI is reviewed annually. Based on the findings of this review project EPG 1/3/195 aims to characterise and minimise uncertainty in the emission factors used in the compilation of the NAEI and by association that of other UK inventories. The project has objectives (Tasks) that are set and reviewed annually; these comprise data collection and evaluation via literature review, personal contact with industrial representatives, direct source measurement and other means as appropriate.

Project EPG 1/3/195 aims to improve inventory quality by characterising and minimising the uncertainty in the emission factors used in the compilation of the NAEI. The factors that influence an inventory’s quality are the transparency, completeness, consistency, comparability and accuracy of the data within the inventory.

This report details the findings of a desk-based study into the quality of emission factors pertaining to small-scale combustion units, with the aim of improving the confidence that an inventory user may place in the estimate of the mean emission factors within the NAEI for this range of activity.

The improvement of the inventory data for this sector has been driven according to the five key aspects of inventory data quality:

**Transparency** – assessment of data suitability to the activity sector, investigating and summarising the assumptions and measurement methodologies upon which the source data are based.

**Completeness** – a review of the small-scale combustion sector and the relevant inventory data has identified where specific activities may have been overlooked or where the emission factors have not been focussed closely upon the activity type.

**Consistency** – Regarding the consistency of inventory data compared to data from previous years, the cross-checking of data from a range of information sources provides a simple insight into the likely accuracy of emission factors.
pertinent to the small-scale combustion sector. The technical review of information sources goes some way to ensuring that the assumptions and measurement methods used to generate emission factors are based on consistent criteria.

**Comparability** – The study has involved comparison of NAEI data with other international inventories such as the AP-42 factors used by the US EPA, EMEP-CORINAIR data, RAINS model and other European inventories. The NAEI is already designed to utilise consistent standardised formats and assessment methodologies, and this study has continued to maintain this approach.

**Accuracy** – The inherent uncertainties in any emission factor must be assessed to allow a reasoned judgement of the usefulness of the data. The small-scale combustion sector has been identified as an area that requires further investigation because of the perceived uncertainties in historic NAEI data. This study has sourced many new research reports that have been specifically tailored to developing a better understanding of the values and variability of emission factors for small-scale combustion. By assessing these reports, some improvements to specific emission factors have been recommended. In addition, key areas have been identified that may require further research to improve accuracy of emission factors.

From the data collected, changes are recommended for emission factors applied to the following sub-sectors of the NAEI small-scale combustion sector:

- about 70% of the NOx, VOC, CO, PM10, Benz(a)pyrene and dioxins emission factors currently applied for six solid fuels in domestic combustion
- the PM10 and CO emissions for domestic combustion of natural gas
- about 80% of the NOx, VOC, CO, PM10, Benz(a)pyrene and dioxins emission factors currently applied for burning oil in domestic combustion
- about 70% of the NOx, VOC, CO, PM10, Benz(a)pyrene and dioxins emission factors currently applied for fuel oil use across four consumption sectors.

The following sub-sectors of the small-scale combustion sector are recommended for further technical investigation to improve NAEI emission factor data:

- Burning Oil (kerosene) consumption in domestic boilers and industrial space heating appliances
- Natural gas consumption in the different generic designs of CHP plant
- Gas oil combustion in the agricultural, public and commercial sectors
- Domestic and public and commercial combustion of LPG
- Domestic combustion of wood

In addition, the following sources of uncertainty in NAEI data warrant further investigation:
• **Activity data** – Significant disparity in UK coal consumption is evident between DTI-sourced data and industry-sourced figures. There may be an end-user group as yet unrepresented, or at least mis-represented, within the current NAEI data.

• **Domestic split between open fires, closed stoves and boilers** – progress has been made in identifying the trends regarding solid fuel use in different types of domestic appliance. The different appliances exhibit significantly different combustion profiles, and hence the assessment of the relative uses of the range of household appliances (broadly divided into: fireplaces, stoves and boilers) could be a significant source of error in the use of NAEI data. Annual estimates for these sub-sectors of activity data are therefore recommended to provide a mechanism to calculate a more accurate emission factor that is more representative of the whole of the domestic sector for each fuel.

A potential source of emission data research on small-scale combustion (and other sources) is via the national programmes of other countries and co-operative international emission inventory work programmes at UN ECE or EU level. Emissions from residential and other small-scale combustion sources are a common area of concern; it is known that work is being undertaken in several EU member States and the EC's Joint Research Centre, Emissions and Health Unit, has in place a work programme to co-ordinate this activity and encourage the exchange of information.

However, emission data from sources outside the UK are of little use to development of the NAEI if the source measurements are for combustion technologies or fuels which are not employed in the UK. To improve inventory uncertainty emission data should, wherever possible, be obtained from accredited test houses using recognised test protocols (for example EN or ISO Standards).
Contents

1 Introduction .............................................................................................................. 1
  1.1 EMISSION FACTORS PROGRAMME ................................................................ 1
  1.2 EMISSIONS FROM SMALL COMBUSTION SOURCES ...................................... 1
  1.3 REPORT STRUCTURE .................................................................................... 2

2 Methodology .......................................................................................................... 4

3 Small-Scale Combustion Sector ............................................................................. 6
  3.1 DESCRIPTION OF SECTOR ............................................................................ 6
  3.2 CONTRIBUTION TO TOTAL UK EMISSIONS ..................................................... 6
  3.3 FUEL CONSUMPTION AND TRENDS ............................................................. 7
      3.3.1 Digest of UK energy statistics ................................................................ 7
      3.3.2 Solid Fuel Consumption ........................................................................ 8
      3.3.3 Petroleum-Based Oils and Gases ............................................................ 8
      3.3.4 Natural Gas Consumption ..................................................................... 9
      3.3.5 Renewable Energy Consumption .......................................................... 10
  3.4 SMALL-SCALE COMBUSTION SUB-SECTORS ................................................. 10
      3.4.1 Residential Sources ............................................................................ 10
      3.4.2 Small Commercial & Institutional Boilers ............................................... 11
      3.4.3 Agricultural Sources ........................................................................... 12
      3.4.4 CHP plants ........................................................................................ 12
  3.5 SUMMARY OF COMMON CONTROL MEASURES .............................................. 15
      3.5.1 Domestic Sector ................................................................................ 15
      3.5.2 Public/Commercial and Agricultural Sectors ......................................... 16
      3.5.3 Combined Heat and Power ................................................................ 16

4 Coal ....................................................................................................................... 17
  4.1 USE ........................................................................................................ 17
  4.2 OXIDES OF NITROGEN .............................................................................. 17
  4.3 CARBON MONOXIDE ................................................................................. 18
  4.4 PM_{10} EMISSION FACTORS ................................................................. 18
  4.5 DIOXINS AND FURANS, PCBS .............................................................. 19
  4.6 VOC EMISSION FACTORS ........................................................................ 20
      4.6.1 VOC Emission Factors: 1998 UK Study ................................................. 20
      4.6.2 VOC Emission Factors: Other Sources ................................................... 22
  4.7 PAHS & BENZENE EMISSION FACTORS ...................................................... 23
  4.8 OXIDES OF SULPHUR .............................................................................. 24

5 Coke & Manufactured Solid Fuels ......................................................................... 26
  5.1 USE AND FUEL TYPES .............................................................................. 26
  5.2 EMISSION FACTORS FOR COKE .......................................................... 26
  5.3 MANUFACTURED SOLID FUELS (MSF) EMISSIONS ........................................ 27

6 Wood & Biomass .................................................................................................... 29
  6.1 USE ........................................................................................................ 29
  6.2 PM_{10} EMISSION FACTORS ................................................................. 30
  6.3 VOC EMISSION FACTORS ........................................................................ 30
  6.4 PAH AND BENZENE EMISSION FACTORS ............................................... 32
  6.5 DIOXINS AND FURANS ............................................................................ 33
1 Introduction

1.1 EMISSION FACTORS PROGRAMME

This report has been prepared for the Department for the Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland by netcen (an operating division of AEA Technology plc) under the contract EPG 1/3/195 - Emission factors for air pollutants.

The Department for Environment, Food and Rural Affairs (Defra) Air and Environment Quality (AEQ) Division is responsible for maintaining the UK National Atmospheric Emissions Inventory (NAEI). The NAEI is maintained by netcen on behalf of Defra. As part of the ongoing quality control of the NAEI the quantitative uncertainty in the national emission total of each component pollutant in NAEI is reviewed annually. Based on the findings of this review project EPG 1/3/195 aims to characterise and minimise uncertainty in the emission factors used in the compilation of the NAEI and by association that of other UK inventories. The project has objectives (Tasks) that are set and reviewed annually; these comprise data collection and evaluation via literature review, personal contact with industrial representatives, direct source measurement and other means as appropriate.

Project EPG 1/3/195 aims to improve inventory quality by characterising and minimising the uncertainty in the emission factors used in the compilation of the NAEI. The factors that influence an inventory’s quality are the transparency, completeness, consistency, comparability and accuracy of the data within the inventory.

This report details the findings of a desk-based study into the quality of emission factors pertaining to small-scale combustion units, with the aim of improving the confidence that an inventory user may place in the estimate of the mean emission factors within the NAEI for this range of activity.

1.2 EMISSIONS FROM SMALL COMBUSTION SOURCES

Enquiry has shown that research into emissions from smaller combustion sources is few and far between, and those reports that have been generated commonly demonstrate significant variability in the emissions from a given source. There is a resultant lack of comparability of the procedures and it is unlikely that the accuracy of the current emission factors is high. As a result, the error margins for
emission factors applicable to smaller combustion sources are considered to be much greater than those for larger combustion sources.

In addition, the application of combustion control and emission abatement technologies is not prevalent across smaller combustion units, due to economic and practical considerations. Domestic fireplaces, stoves and poorly maintained central heating units are also prone to poor combustion of fuel. Across this sector, therefore, significant emissions of pollutants such as Particulate Matter less than nominally 10µm (PM$_{10}$), carbon monoxide (CO) and organic species such as dioxins and furans and Polycyclic Aromatic Hydrocarbons (PAHs) may be produced.

This report summarises the findings of research into the small-scale combustion sector in the UK, drawing upon relevant emission factor research across the world and identifying fuel consumption data, technological changes and market trends pertinent to the UK. To help to define the scope of this research project, the term “Small-scale combustion plant” pertains to a unit of less than 20 MW net thermal input, as this is the threshold for a UK combustion facility to fall under local authority regulation.

1.3 REPORT STRUCTURE

In addition to providing guidance on the development of emission factors and furthering knowledge of this sector as a whole, this report identifies the key aspects of this section of the NAEI that require further investigation. The report is structured as follows:-

**Section 2: Methodology**
Outlines the sources and methodology employed during this study.

**Section 3: Description of Small-Scale Combustion Sector**
Includes a breakdown of fuel combustion across sub-sectors, a summary of target pollutants relevant to each sub-sector and an outline of trends in fuel consumption.

**Section 4: Coal**
Summary of sources and emission factors for coal use across all small-scale combustion sub-sectors.

**Section 5: Coke and Manufactured Solid Fuels**
Summary of sources and emission factors for coke use and manufactured solid fuel use across all small-scale combustion sub-sectors.

**Section 6: Wood and Biomass**
Summary of sources and emission factors for wood and biomass use across all small-scale combustion sub-sectors.

**Section 7: Petroleum-Based Oils and Gases**
Summary of sources and emission factors for the use of LPG, burning oil and fuel oil across all small-scale combustion sub-sectors.
Section 8: Natural Gas
Summary of sources and emission factors for the use of natural gas across all small-scale combustion sub-sectors.

Section 9: Conclusions and Recommendations
Summary of key findings and recommended future work.

Section 10: References
Details of source documents. Within the main text, references are usually indicated thus: [Reference No.].

Appendix A provides a summary of the UK energy consumption statistics for 2001.

Appendix B lists the emission factors determined for each fuel and combustion source.

Appendix C summarises and compares the combustion emission factors by fuel and combustion sector.
2 Methodology

The annual review of NAEI data has identified the need to understand and control the uncertainty in the emission factors used for small-scale combustion sector across a range of pollutants. For several fuel and pollutant combinations only a single emission factor was evident for a pollutant across the whole range of small-scale combustion sources.

Hence a desk-based study was commissioned to collate and review data and background information across two broad areas:

1) Emissions of pollutants from a range of different types of small-scale combustion device, incorporating inputs for different fuels where possible, to include: coal, coke, smokeless solid fuels, wood, oil & gas.
2) The market share of individual types of small-scale combustion device and fuel type within the UK.

The combination of these two information types provided a cost-effective way of developing reasoned assumptions for the simplification of an otherwise prohibitively complex task.

Literature searches of relevant journals and web-based resources were conducted to find current estimates of emission factors for the following pollutants:

- Carbon monoxide (CO)
- Nitrogen Oxides (NO\textsubscript{x})
- Particulate matter less than nominally 10µm (PM\textsubscript{10})
- Dioxins
- Polycyclic aromatic hydrocarbons (PAH)

Several sources included figures for other species such as SO\textsubscript{2}, benzene, PCBs, PCNs, and these have been recorded where appropriate. Note that for SO\textsubscript{2} in particular, the emission factors from combustion sources are dependent primarily on the sulphur content of the fuel.

Key sources of information included:

- the EMEP / CORINAIR Emission Inventory Guidebook, 3\textsuperscript{rd} edition (2001)
- UK-based research reports conducted by energy-focused organisations such as CPL Laboratories & the Coal Research Establishment.
- Studies conducted to demonstrate the compliance of a given combustion unit with the requirements of the UK Clean Air Act
- Review of the UK Domestic Heating Market (2001)
Research into the trends and current numbers, capacities and range of fuels & technologies across the small-scale combustion sector in the UK was conducted via web-based resources, Government publications and consultation with industry bodies and individual companies.

The data collated was assessed for its relevance to the UK emissions inventory, and technical emissions reports were reviewed by experts in emission monitoring to enable a critical appraisal of the source monitoring techniques employed and therefore a measure of the reliability of the emission factors derived. This study has aimed to achieve the following steps towards improvement of the NAEI data for the small-scale combustion sector:

- Identify the range of commonly used combustion appliances across the different sub-sectors of the UK small-scale combustion market.
- Improvement of the estimation of fuel use allocation across the different combustion appliances identified, to enable more accurate distribution of DUKES annual UK fuel use data within the sector.
- Identify the fuel/appliance combinations, by pollutant, which most influence the uncertainty of the ‘aggregate’ emission factors used in the inventory and focus the study in these areas.
- Examine the adequacy of available data for each of the different sub-sectors of the UK small-scale combustion market.

The areas most in need of accurate data to enable a representative assessment of the UK situation have been identified and default factors derived to compare and contrast against those used at present within the NAEI.
3 Small-Scale Combustion Sector

3.1 DESCRIPTION OF SECTOR

Small combustion processes include those from residential, commercial, public and agricultural combustion sources. The sub-20 MW combustion sector in the UK can be broadly divided into the following sub-sectors [1]:-

- Domestic fireplaces & stoves
- Domestic central-heating systems
- Small commercial & institutional boilers
- Agricultural heating systems
- Industrial space heating systems
- Combined Heat & Power (CHP) installations

Each of these sub-sectors exhibits its own variation in fuel sources and combustion appliances, although many of the emission factors developed for combustion in one sub-sector will be applicable to others.

A common feature of smaller-scale combustion devices is the release of significant quantities of Products of Incomplete Combustion (PICs) such as CO, unburned hydrocarbons, particles, tar and PAHs. The incomplete combustion is mainly caused by a combination of the following:-

- Low combustion temperatures
- Short residence times
- Poor mixing due to insufficient turbulence
- Oxygen shortage

Historically, technology to reduce such emissions is infrequently used in residential fireplaces and stoves due to economic & practical constraints. Small commercial boilers and larger combustion units do exhibit some flue gas treatment technologies, with the improvement of combustion control being the primary mechanism.

3.2 CONTRIBUTION TO TOTAL UK EMISSIONS

Despite the relatively low fuel throughput of the small-scale combustion sector, (compared to larger industry & power generation, for example) the poor combustion efficiency of appliances within the sector and their use in centres of population ensures that it can make a significant contribution to total UK emissions of pollutants and, can often have a high local impact. The table below illustrates the scale of the contribution of the small-scale combustion sector to total EC emissions of target pollutants, as calculated by the International Institute for Applied Systems Analysis (IIASA) using the Regional Air pollution Information and Simulation (RAINS) emission inventory model [2].
### 3.3 FUEL CONSUMPTION AND TRENDS

#### 3.3.1 Digest of UK energy statistics

The information in this section has been sourced from the 2002 Digest of UK Energy Statistics (DUKES [3]) and consultations with trade organisations and individual companies, including the Solid Fuel Association and HETAS Ltd.

A summary of fuel consumption across the smaller combustion sectors is given below, taken from the DUKES 2002 statistics:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Domestic</th>
<th>Public</th>
<th>Commercial*</th>
<th>Agriculture</th>
<th>Misc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Coal, tonnes (GWh)</td>
<td>1,428,000 (12,100)</td>
<td>126,000 (1070)</td>
<td>6000 (51)</td>
<td>5000 (43)</td>
<td>10,000 (86)</td>
</tr>
<tr>
<td>Anthracite, tonnes (GWh)</td>
<td>1,110,000 (9,100)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Manufactured solid fuels, tonnes (GWh)</td>
<td>513,000 (4070)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wood, Tonnes oil equiv. (GWh)</td>
<td>204,000 (2370)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Renewables, Tonnes oil equiv. (GWh)</td>
<td>-</td>
<td>49,000 (570)</td>
<td>71,000 (826)</td>
<td>72,000 (837)</td>
<td>-</td>
</tr>
<tr>
<td>Propane, tonnes (GWh)</td>
<td>253,000 (3510)</td>
<td>-</td>
<td>575,000 (7990)</td>
<td>109,000 (1510)</td>
<td>-</td>
</tr>
<tr>
<td>Butane, tonnes (GWh)</td>
<td>64,000 (880)</td>
<td>-</td>
<td>124,000 (1700)</td>
<td>1000 (14)</td>
<td>-</td>
</tr>
<tr>
<td>Burning oil, tonnes (GWh)</td>
<td>2,648,000 (35,000)</td>
<td>12,000 (160)</td>
<td>1,561,000 (20,600)</td>
<td>12,000 (160)</td>
<td>-</td>
</tr>
<tr>
<td>Gas Oil, tonnes (GWh)</td>
<td>193,000 (2400)</td>
<td>674,000 (8300)</td>
<td>402,000 (5000)</td>
<td>448,000 (5500)</td>
<td>109,000 (1350)</td>
</tr>
<tr>
<td>Fuel Oil, tonnes (GWh)</td>
<td>6000 (70)</td>
<td>40,000 (480)</td>
<td>34,000 (400)</td>
<td>11,000 (130)</td>
<td>18,000 (210)</td>
</tr>
<tr>
<td>Natural Gas (GWh)</td>
<td>(379,200)</td>
<td>(45,500)</td>
<td>(36,500)</td>
<td>(1300)</td>
<td>(28,200)</td>
</tr>
</tbody>
</table>

*Commercial figures include some general industry space heating figures for propane, butane and burning oil.

[Source: IIASA, 2002]
Summary tables by sector and by total energy consumption are included in Appendix A, to illustrate the distribution of fuel use across the sub-sectors. Further details for each fuel type are outlined in the following sections.

3.3.2 Solid Fuel Consumption
The DUKES figures for solid fuel consumption in 2001 indicate that 2.5 million tonnes of coal were consumed in the domestic sector. Figures provided by the Solid Fuel Association (SFA), however, suggest that total domestic consumption of solid fuels in 2001 totalled only 1.6 million tonnes, with steam coal comprising just under 50% of this amount [4]. This discrepancy may indicate that there is a category of end-user that is not represented accurately (or at all) within the NAEI data, and this element of activity data uncertainty needs some further investigation.

The SFA predictions for 2003 consumption total 1.2 million tonnes of solid fuel, which represents a 25% reduction over only 2 years, reflecting the trend towards use of gas and oil and away from solid fuel.

Further to this data, the SFA also commented that sales of domestic combustion appliances have remained buoyant in recent years, with multifuel appliances dominating the market. These types of appliance are typically used for secondary heating and occasional use. Only a limited number of appliance are commercially available that can burn wood or coal smokelessly.

3.3.3 Petroleum-Based Oils and Gases
The DUKES data presents petroleum products including a number of different fuel oil and gas grades that are used across the small combustion sector.

Propane – used mainly for industrial purposes and some domestic heating. Normally stored and transported in pressurised liquid form. The proportions of total propane consumption are as follows:-

Domestic heating and cooking: 27 %
Small commercial & industrial boilers: 61 %
Agricultural heating: 12 %

Butane – used mainly for industrial purposes and some domestic heating. Normally stored and transported in pressurised liquid form. The proportions of total butane consumption are as follows:-

Domestic heating and cooking: 34 %
Small commercial & industrial boilers: 66 %
Agricultural heating: 1 %

Burning Oil (kerosene) – Refined petroleum fuel, intermediate in volatility between motor spirit and gas oil. Used almost entirely for heating and lighting in
the domestic and industrial sectors. The proportions of total burning oil consumption are as follows:-

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic heating and cooking</td>
<td>63%</td>
</tr>
<tr>
<td>Small commercial &amp; industrial boilers</td>
<td>37%</td>
</tr>
</tbody>
</table>

**Gas Oil** (Diesel Oil) – Petroleum fuel with a distillation range between kerosene and fuel oil. Used predominantly as a burner fuel in heating installations and for industrial gas turbines. The proportions of total gas oil consumption are as follows:-

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic heating and cooking</td>
<td>11%</td>
</tr>
<tr>
<td>Small commercial &amp; industrial boilers</td>
<td>59%</td>
</tr>
<tr>
<td>Agricultural power, drying &amp; heating</td>
<td>25%</td>
</tr>
<tr>
<td>(Miscellaneous central heating)</td>
<td>17%</td>
</tr>
</tbody>
</table>

**Fuel Oil** – heavy petroleum residue blend used in atomising burners and for heavy duty diesel engines. The proportions of total fuel oil blend consumption are as follows:-

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic heating and cooking</td>
<td>5%</td>
</tr>
<tr>
<td>Small commercial &amp; industrial boilers</td>
<td>68%</td>
</tr>
<tr>
<td>Agricultural power, drying &amp; heating</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Trends in Oil Consumption, 1999-2001**
In the **domestic** sector, the key petroleum-based fuel is Burning Oil, and consumption of this fuel increased by 11% during these two years. Of the other fuels that are commonly used in the domestic sector, there seems to have been a shift from use of butane (down by 60% in 2 years) towards the use of propane (up by 82% over 2 years).

In the **small commercial & public** sector, the main fuel for heating and boilers has historically been gas oil, with fuel oil the only other significant fuel source. However, both of these have been exhibiting declines in consumption in this sector, gas oil by 21% over 2 years. The shift in this sector has been towards the emerging markets of propane and butane use.

A similar story applies in the **agricultural** sector, where use of propane has grown significantly in recent years whilst the use of gas oil and fuel oil have slowly declined. Gas oil remains as the main fuel source for agricultural heating and power systems, but consumption between 1999 and 2001 fell by 24%.

3.3.4 **Natural Gas Consumption**
The use of natural gas for both direct heating and central heating boilers has grown over the years, as appliances for this clean-burning fuel have gradually replaced solid fuel units.
The key sector for natural gas use is domestic heating. The distribution of total gas consumption across smaller combustion sources in 2001 was as follows:

- Domestic heating and cooking: 77%
- Small commercial & industrial boilers: 17%
- Agricultural power, drying & heating: 0.3%
- (Miscellaneous central heating): 7%

In the domestic sector, gas use has been growing by 2-3% each year from 1997 to 2001, whilst each of the other sectors have remained fairly level, with fluctuations up and down of a few percent year-to-year.

The domestic heating sector is by far the most significant gas consumer of the small-scale combustion market, totalling an estimated 379,000 GWh of energy use in the UK in 2001.

### 3.3.5 Renewable Energy Consumption
The following DUKES figures for annual consumption of renewable resources in the UK in 2001, expressed in thousand tonnes of oil equivalent, are applicable to the small-scale combustion sector:

- Industrial wood waste combustion: 71,000 tonnes oil equiv.
- Domestic wood combustion: 204,000 tonnes oil equiv.
- Agricultural waste combustion: 72,000 tonnes oil equiv.
- Public sewage gas combustion: 49,000 tonnes oil equiv.

### 3.4 SMALL-SCALE COMBUSTION SUB-SECTORS

#### 3.4.1 Residential Sources
Domestic coal-burning in open fires was a significant source of particulate and other pollutants across the UK in the 1950s and 1960s, but with the development of legislation, the introduction of smoke control areas, and introduction of natural gas, domestic heating has changed significantly. The development of smokeless solid fuels and the widespread switch to gas and electricity for home heating has greatly reduced coal consumption in the domestic sector.

For example, a recent study on PM$_{10}$ emission sources [5] estimates that since 1970, national PM$_{10}$ emissions from the domestic sector have reduced by over 86% due primarily to the reduction in coal burning.

Emissions from domestic combustion may still be significant in small towns and villages where solid fuels are still widely used, and especially in Northern Ireland where natural gas is not widely available.

The lack of combustion controls and abatement technology on many domestic solid fuel combustion sources means that fuel often burns at relatively low temperatures, with insufficient turbulence and therefore poor mixing of volatiles.
with oxygen. In particular, poor combustion of volatiles within conventional fireplaces leads to the emission of many products of incomplete combustion (PICs).

However, the combustion efficiency of smaller stoves and fireplaces can be greatly improved through the introduction of newer techniques such as catalytic combustors, staged air combustion, better insulation of the combustion chamber or preheating inlet air. Such mechanisms can reduce the release of unburned components significantly [6].

As the most significant sub-sector of the small-scale combustion market as a whole, residential sources demonstrate a significant range of technologies that have a corresponding range of relative efficiency of fuel use and pollutant emissions. Hence further detail of this sector has been sought to enable closer inspection of the validity of emission factors for each fuel type.

From the overall consumption figures for the domestic heating sector, the order of the most commonly used fuels (that therefore require closest attention) is:-

gas > burning oil (kerosene) > steam coal > anthracite > other solid fuels

The UK domestic central heating sector is dominated by natural gas, which is estimated to be used in 76% of households [7], with oil-based systems growing their market share in recent years. The estimated numbers of new central heating installations (excluding electric) in recent years are outlined below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of new central heating installations</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gas</td>
<td>Solid Fuel</td>
<td>Oil</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>765,000</td>
<td>31,000</td>
<td>79,000</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>785,000</td>
<td>30,000</td>
<td>84,000</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>830,000</td>
<td>30,000</td>
<td>87,000</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>867,000</td>
<td>29,000</td>
<td>89,000</td>
<td></td>
</tr>
<tr>
<td>2004 forecast</td>
<td>975,000</td>
<td>27,000</td>
<td>95,000</td>
<td></td>
</tr>
</tbody>
</table>

[Source: AMA Research 2001]

Central heating systems include a range of technologies, but are dominated by combination boilers (> 50% of the market). There is a trend towards the installation of more fuel-efficient condensing boiler systems.

Solid fuel central heating systems have been in decline and now account for around 2% of domestic central heating systems. As regards domestic space heating, the use of secondary heat sources (fireplaces and stoves) for occasional use are the main use for fuels such as wood.

3.4.2 Small Commercial & Institutional Boilers
According to DUKES (from which the majority of the activity data in the NAEI is obtained) and the NAEI, the public service sector includes the following sub-sectors:-

➢ Public administration
➢ Education
Health and veterinary services

The miscellaneous sector includes:

- Sewage and other sanitary services
- Recreational, cultural and sporting activities
- Other service activities

This bracket of combustion sources is considered between the smaller domestic and larger CHP sources, although there is significant overlap between the technologies used in both the smaller and larger installations. There have been a series of UK-specific research projects to investigate small industrial and institutional boilers over recent years, including trials at boilers serving schools, industry and leisure facilities. Boiler sizes of 50-200 kW are typical for this sector, and hence research into furnaces and boilers around this range have been used to develop emission factors for the sector as a whole.

Note that figures for industrial space heating using LPG and burning oil have also been included within the small commercial & public sector data.

3.4.3 Agricultural Sources

The combustion of fuels in the agriculture sector is primarily for the provision of heat and power to greenhouses and other manufacturing buildings.

The key fuels pertinent to this sector are gas oil, propane (LPG) and natural gas.

This sector is one of the likely sources of significant expansion of micro-CHP units, with the on-site cogeneration of heat, power and carbon dioxide (for plant growth) being ideally suited to the demands of this sector.

Very little specific research into combustion appliances commonly used at agricultural sites has been identified within this study. However, the design and performance of these units is estimated to be similar to that applicable across other sectors (primarily the commercial and public sector). Hence the emission factors recommended for agricultural sources are frequently taken from research related to these other sub-sectors.

3.4.4 CHP plants

The growth of CHP across the UK during the 1990s has constituted a significant change in the national provision of energy and power. The environmental benefits of CHP have been identified by UK Government, and the expansion of this sector (predicted to double in volume over the next 5-7 years) plays a major role in the Government’s programme to achieve carbon dioxide emission reductions, in line with the Kyoto Protocol.

The key fuels within this sector and their respective CHP market share (Source: Digest of UK Energy Statistics, 2001) are indicated below:

- **Natural gas** (61 %; predominantly using combined cycle cogeneration technology)
Fuel Oil (7 %; also dominated by CC cogeneration technology)
Coal (6 %; predominantly Condensing Steam Turbine technology)
Other fuels (24 %; “other fuels” includes coke furnace, blast furnace and gas oils)

Combined Heat and Power systems provide increased fuel efficiency compared to traditional electricity generation systems, and the environmental benefits that stem from this are a significant contributor to the UK’s drive to reduce CO₂ emissions in line with the Kyoto Protocol. The UK has a target of 10 GWe (electrical output) CHP production by 2010, and the Government has implemented several incentive schemes and exempted CHP plants from the Climate Change Levy in order to promote development of CHP units [8,3].

The total capacity of CHP has grown steadily by about 7% per year throughout the 1990s, with installed capacity in 2001 of around 4.8 GWe which represents about 8% of the total electricity generation in the UK. Larger CHP plants serving industrial sites make up the majority of the total CHP capacity in the UK through 70-80 large sites of greater than 10 MWe capacity.

Hundreds of smaller schemes also exist, however, and the table below outlines the range of CHP scheme capacities during 2001:-

<table>
<thead>
<tr>
<th>Electrical Capacity Range</th>
<th>Number of Schemes</th>
<th>% of number of Schemes</th>
<th>Total Electrical Capacity (MWe)</th>
<th>% of total Electrical Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100 kW</td>
<td>679</td>
<td>43</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td>100 - 999 kW</td>
<td>631</td>
<td>40</td>
<td>154</td>
<td>3</td>
</tr>
<tr>
<td>1 - 9.9 MW</td>
<td>190</td>
<td>12</td>
<td>780</td>
<td>16</td>
</tr>
<tr>
<td>&gt; 10 MW</td>
<td>73</td>
<td>5</td>
<td>3826</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>1573</td>
<td>100</td>
<td>4801</td>
<td>100</td>
</tr>
</tbody>
</table>

The industrial capacity of CHP serves sectors such as chemical manufacture, oil refining, paper & pulp, food & drink and iron & steel. Smaller CHP schemes have flourished within institutions and buildings such as leisure centres, hotels, hospitals, universities and community heating schemes in some cities.

The principal fuel used by CHP installations is natural gas (61% of total installed capacity in 2001 according to DUKES 2002). Fuel oil and coal are also commonly used in CHP, together with various “waste” fuels such as refinery & blast furnace gases, landfill and biogases, and solid municipal waste. The current distribution of fuel use, given as a % of total energy production in 2001 is as follows:-

Natural Gas: 61 %
Fuel Oil: 7 %
Coal: 6 %
Refinery Gases: 6 %
Renewables: 2 %
Other fuels: 18 % (blast furnace gas, coke oven gas & gas oil)

There are four principal types of CHP installation: steam turbine, gas turbine, combined cycle and reciprocating engines.
Steam Turbine (ST): Steam at high pressure is generated in a boiler. This category includes: back-pressure ST systems where steam is wholly or partly used in a turbine before being exhausted at the required pressure for the site, and pass-out condensing ST systems where a proportion of the steam used by the turbine is extracted from the turbine at intermediate pressure with the remainder being fully condensed before being exhausted. ST boilers used in CHP schemes can burn a wide variety of fuels (including coal, gas and oil) and provide electrical efficiencies of 10-20%, with a further 30-70% available as useful heat. ST in CHP applications typically range from a few MW_e to over 100 MW_e.

Gas Turbine (GT): These systems are often aero-engine derivatives using gas or gas-oil combustion to drive the gas turbine, using exhaust gases either directly (in some process applications) or in a waste heat boiler to produce useable steam. Conventional GT systems range from about 1 MWe upwards (although smaller microturbines are now available), and typically achieve electrical efficiency of 23-30%, with a further 50% of fuel input available as useful heat. This technology has been common in CHP since the 1980s, and the waste heat boiler can be supported by supplementary firing using a range of auxiliary fuels.

Combined Cycle (CC): These systems usually comprise gas turbines where exhaust gases are used in a steam generator, the steam from which is passed (wholly or in part) to a steam turbine system. CC is suited to larger installations of about 7 MWe and above, and typically achieve higher electrical efficiency (up to 50%) than simple cycle schemes.

Reciprocating Engine (RE): These systems are commonly based on auto or marine engines converted to run on gas, using compression or spark ignition, and are mainly used where production of hot water, rather than steam, is the main requirement. These systems range from 100 kW_e to around 5 MW_e, and operate at around 28-33% electrical efficiency, with 33-50% of the fuel input available as useful heat.

In recent years, the trend has been towards the use of gas turbine and combined cycle technology, and away from steam turbine technology, resulting in an increased ratio of electrical to heat output.

CHP Trends
The UK Government aims to increase CHP capacity to 10 GWe by 2010, and a recent Royal Commission on Environmental Pollution report proposes an increase in the use of CHP and community heating to meet carbon dioxide emission reduction targets of 60% by 2050. The Commission suggests that the UK’s future energy infrastructure should contain the following:-

- approx. 20 medium scale (< 60 MW_e) CHP plants fuelled by Municipal Solid Waste
- approx. 4,000 small scale (<10 MW_e) CHP plants fuelled by biomass such as agricultural & forestry wastes and energy crops
- approx. 2.4 million gas-fired domestic CHP units
It is anticipated that the continued emergence of new technologies such as micro-turbines, fuel cells and domestic-scale CHP will continue to progress CHP technology into new markets.

**Small-scale CHP (< 1 MWe)** already plays a significant role in sectors such as hotels, leisure centres, hospitals and universities, with several hundred such installations UK-wide. These units are largely based on gas-driven reciprocating engine technology with engine jacket & exhaust heat recovery. The development of such units for small-scale community heating schemes is a potential area for significant CHP growth.

New low-emission **microturbines** are becoming commercially viable, especially within the horticultural sector; units of typically 30-500 kWe that provide heat, power and CO₂ to large glasshouses with significantly cleaner emissions (especially regarding NOₓ levels) have started to replace traditional diesel engines. These units are also popular as a standby power-source for building services and some designs are fuel-flexible.

The development of **fuel cell technology** provides great potential for small-scale cogeneration applications. Electricity is generated directly from chemical fuel conversion at up to 60% efficiency, and heat is recovered from the chemical process, producing up to 90% total energy efficiency. The technology to obtain such a significant power efficiency lends itself to modern office facilities where IT and air-conditioning requirements are high electricity consumers. Fuel cells currently remain at the early stages of commercial viability & development, but the advantages of such technology suggest that it will play a significant future role.

### 3.5 SUMMARY OF COMMON CONTROL MEASURES

#### 3.5.1 Domestic Sector

Frequently no combustion controls or flue gas treatment is evident for open fires or closed stove combustion where these units are primarily used for secondary space heating. Research into the improvement of combustion within such appliances suggests that the implementation of **Staged Air Combustion** may provide a cost-efficient approach to emissions reduction for smaller fireplaces and stoves, particularly for the reduction of NOₓ gases [6]. Any secondary measures for cleaning flue gases are usually restricted to larger combustions sources on economic grounds.

Central heating boilers and stoves used to provide the primary space heating and hot water provision in UK households will vary in their combustion efficiency according to their design, control and state of repair. However, these systems do provide some degree of combustion control, with significant progress in combustion efficiencies and emission reductions evident in modern appliances available on the UK market.
3.5.2 Public/Commercial and Agricultural Sectors
The most commonly used fuels in these sectors are natural gas and gas oil. These fuels typically burn much cleaner than the solid fuel options that are evident across the residential sector, and there is typically greater investment (and closer attention to cost-control and operating efficiency) for regular servicing and maintenance of larger boilers in these sectors.

In addition, the larger the boiler, the more cost-effective the application of emission abatement technology such as NO\textsubscript{x}-controls and particulate abatement kit, and these technologies are evident on several designs of small-scale commercial boilers.

3.5.3 Combined Heat and Power
Similar to the public, commercial and agricultural sectors, CHP is fuelled largely by cleaner-burning fuels (mainly natural gas) and the investment in combustion controls and pollution abatement technology becomes a more significant factor as boiler capacity increases.

The advent of more fuel-efficient cogeneration units, and the increase in uptake of micro-CHP across a range of industrial and public service sectors indicates that the development of this sector of the UK heat & power market plays a significant role in target pollutant emission reduction.
4 Coal

4.1 USE

Coal may be burnt domestically in either closed appliances or in open fires as a heating source. The main pollutants of concern from the combustion of bituminous and sub-bituminous coal include PM$_{10}$, CO and nitrogen oxides (NO$_x$).

At present, the following factors are used in the NAEI for the combustion of coal in the small-scale combustion sector (NO$_x$ is expressed as NO$_2$):

<table>
<thead>
<tr>
<th>Sector</th>
<th>NO$_x$</th>
<th>VOC</th>
<th>CO</th>
<th>PM$_{10}$</th>
<th>PCDD/Fs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>1.42$^a$</td>
<td>14</td>
<td>45$^b$</td>
<td>10.4$^c$</td>
<td>3.04$^d$</td>
</tr>
<tr>
<td>Public Service</td>
<td>3.96</td>
<td>0.05</td>
<td>4.1</td>
<td>2.5</td>
<td>50.54</td>
</tr>
<tr>
<td>Agriculture</td>
<td>4.31</td>
<td>0.05</td>
<td>4.1</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3.96</td>
<td>0.05</td>
<td>4.1</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
<td>Other Industry</td>
<td>4.65</td>
<td>0.05</td>
<td>4.1</td>
<td>2.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>


4.2 OXIDES OF NITROGEN

The following table summarises NO$_x$ emission factors (and sources) for small-scale coal combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>NO$_x$ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to domestic open fires)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>15</td>
<td>2.3</td>
<td>g/kg</td>
<td>UN ECE, 2002: dutch data, domestic coal use</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>8</td>
<td>g/kg</td>
<td>CRE, 1999: Uk data, 12.5kW stove, anthracite, medium burn rate</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>12</td>
<td>6.2</td>
<td>g/kg</td>
<td>ERA, 2000: UK research, bituminous coal in boilers</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to commercial boilers)</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>15</td>
<td>9.3</td>
<td>g/kg</td>
<td>UN ECE, 2002: dutch data, agricultural coal use</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>9.8</td>
<td>g/kg</td>
<td>Australian data: avge. from AUS power stations fired on black coal</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>8</td>
<td>g/kg</td>
<td>WSL, 1993: UK data, coal-fired 500MWe power station, low-NO$_x$</td>
</tr>
</tbody>
</table>

NO$_x$ emissions from coal combustion are primarily in the form of nitric oxide (NO), although some is emitted in the form of nitrogen dioxide (NO$_2$).
4.3 CARBON MONOXIDE

The following table summarises carbon monoxide emission factors (and sources) for small-scale coal combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>CO EF Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to domestic open fires)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>15</td>
<td>46.4 g/kg</td>
<td>UN ECE, 2002: dutch data, domestic coal use</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>709 g/kg</td>
<td>CRE, 1999: uk data, 12.5kW stove, anthracite, medium burn rate</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>12</td>
<td>1.8 g/kg</td>
<td>ERA, 2000: UK research, bituminous coal in boilers</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>10</td>
<td>10 g/kg</td>
<td>AEAT, 2001: bituminous coal, 500kW boiler</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>15</td>
<td>3.1 g/kg</td>
<td>UN ECE, 2002: dutch data, agricultural coal use</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>0.3 g/kg</td>
<td>Australian data: avge. from AUS power stations fired on black coal</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>0.25 g/kg</td>
<td>WSL, 1993: UK data, coal-fired 500MW power station, low-NOx</td>
</tr>
</tbody>
</table>

The above data illustrates the variability of CO emissions from domestic coal use, but the figures for larger plant are much more consistent.

4.4 PM$_{10}$ EMISSION FACTORS

The following table summarises the PM$_{10}$ emission factors (and sources) for small-scale coal combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>PM$_{10}$ EF Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>13</td>
<td>9 to 11 g/kg</td>
<td>CRE, 1997: household &amp; texan star (bituminous) coal, &lt; 10kW open fire</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>40.4 g/kg</td>
<td>CPL, 2002: yorkshire (bituminous) housecoal, &lt; 5kW open fire</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>15</td>
<td>4 g/kg</td>
<td>UN ECE, 2002: dutch data, “domestic coal use”</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.4 g/kg</td>
<td>IIASA, 2001: german data, “uncontrolled domestic coal furnace”</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>12</td>
<td>6 g/kg</td>
<td>ERA, 2000: UK research, bituminous coal</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.8 g/kg</td>
<td>IIASA, 2001: german data, “uncontrolled domestic coal boiler”</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>2</td>
<td>1.4 g/kg</td>
<td>IIASA, 2001: german data, “uncontrolled industrial coal boiler”</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>15</td>
<td>0.1 g/kg</td>
<td>UN ECE, 2002: dutch data, “agricultural coal use”</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>(None identified for PM$_{10}$)</td>
</tr>
</tbody>
</table>

CPL Study, 2002

The CPL study measured emissions and subsequently calculated emission factors from a range of pollutants released to air during the combustion of coal on an
open fire. The tests were carried out using bituminous coal and produced an estimated emission factor of 40.4 g PM$_{10}$ per kg of coal burnt.

**CRE Study, 1997**
The first is a report from the Coal Research Establishment (CRE) was prepared for Belfast City Council to support them as part of the first phase implementation of the air quality provisions of the Environment Act 1995. From the tests carried out by CRE an emission factor range for PM$_{10}$ from coal burnt in open appliances was determined to be 9 to 11 g PM$_{10}$ per kg of coal burnt.

This corresponds favourably to the PM$_{10}$ emission factors currently used in the NAEI, suggesting that coal burning on an open fire is represented well by the NAEI calculations.

**Summary**
PM$_{10}$ emission factors obtained from closed appliances tend to be substantially lower than those obtained from open fires. Whilst the PM$_{10}$ emission factors reported in the CRE study are similar to that currently used in the NAEI, the emission factor cited in the CPL study is significantly higher than anything else reported. Note that uncontrolled PM$_{10}$ emissions from coal-fired boilers include the ash from the combustion of the fuel as well as semi-volatile material resulting from incomplete combustion.

### 4.5 DIOXINS AND FURANS, PCBS

The following table summarises the dioxin and furan and PCB (polychlorinated biphenyl) emission factors (and sources) for small-scale coal combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Substance: EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>14</td>
<td>PCDD/Fs: 2.9</td>
<td>gTEQ/MT</td>
<td>CPL, 2002: yorkshire (bituminous) housecoal, &lt; 5kW open fire</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>PCBs: 6.1</td>
<td>gTEF/MT</td>
<td></td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to domestic stoves)</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>21</td>
<td>PCCD/Fs: 1-2.5</td>
<td>gTEQ/MT</td>
<td>EMEP/CORINAIR default factors for “small-scale coal combustion”</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>10</td>
<td>PCDD/Fs: 51</td>
<td>gTEQ/MT</td>
<td>AEAT, 2001: bituminous coal, 500kW boiler</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to agricultural sources)</td>
</tr>
<tr>
<td>CHP</td>
<td>17</td>
<td>PCDD/Fs: 0.51-0.85</td>
<td>gTEQ/MT</td>
<td>WSL, 1993: UK data, coal-fired 500MW$_{e}$ power station, low-NO$_x$</td>
</tr>
</tbody>
</table>
4.6 VOC EMISSION FACTORS

4.6.1 VOC Emission Factors: 1998 UK Study
A 1998 study for the European Commission [9] summarised UK research into the emissions of VOCs from coal-burning in appliances ranging from domestic open fires and closed stoves to 500 MW<sub>e</sub> pulverised fuel boilers. Specific findings for different sorts of UK appliances are outlined below, but in summarising total UK VOC emissions, the report stated the following:-

"This study has confirmed that the domestic sector is the major source of VOC emissions from coal combustion, accounting for about 95% of the total emissions, and this predominantly arises from the combustion of bituminous coal on open fires."

The figures shown below clearly demonstrate that the domestic sector is potentially a large source of VOC arisings from coal combustion, and hence the general trend away from domestic coal consumption and towards cleaner fuels such as oil and gas is likely to be beneficial in terms of VOC emission reductions.

<table>
<thead>
<tr>
<th>Plant Type &amp; Rating</th>
<th>Fuel</th>
<th>EF, Methane (g/kg)</th>
<th>EF, NMVOCs (g/kg)</th>
<th>No. of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open grate</td>
<td>bituminous</td>
<td>15.7</td>
<td>14.0</td>
<td>2</td>
</tr>
<tr>
<td>Domestic open grate</td>
<td>smokeless</td>
<td>5.8</td>
<td>4.9</td>
<td>2</td>
</tr>
<tr>
<td>17 kW underfeed</td>
<td>bituminous</td>
<td>0.43</td>
<td>0.61</td>
<td>8</td>
</tr>
<tr>
<td>13 kW gravity feed</td>
<td>anthracite</td>
<td>2.0</td>
<td>1.7</td>
<td>4</td>
</tr>
<tr>
<td>0.9 to 48 MW</td>
<td>bituminous</td>
<td>0.01</td>
<td>0.05</td>
<td>42</td>
</tr>
<tr>
<td>500 MWe</td>
<td>bituminous</td>
<td>0.01</td>
<td>0.03</td>
<td>5</td>
</tr>
</tbody>
</table>

[Source: "Emission of VOCs from Coal-Fired Appliances", EUR 17444 EN, 1998]

Further detail regarding the different appliances tested are summarised below.

**Domestic Open Fires**
VOC emissions vary markedly over a combustion cycle, with the highest VOC emissions evident at start-up and during re-fuelling (both periods where combustion efficiency is at its lowest). The low fuel-bed temperature results in the release of unburnt volatiles and smoke from the coal, and then VOC emissions reduce progressively during the combustion cycle until at the “red-fire” stage, emission factors are an order of magnitude lower than during refuel or start-up.

The following emission factors were derived:-

- Start-up / Refuel: 30 g/kg
- Red-fire stage: 2.3 g/kg
- Mean EF for complete cycle: 14 g/kg

Speciation of the VOC emissions indicated that methane was the highest emission, with low-RMM alkanes and alkenes (C<sub>2</sub>-C<sub>4</sub>) and benzene / toluene species predominating.

During the same research programme, smokeless fuels were burned in an open grate, and resultant VOC emission factors were found to be lower than for
bituminous coal but with very similar emission profile of VOC species. The mean EF for a complete combustion cycle of smokeless fuels was derived as 4.9 g/kg, but this figure was derived from tests from a single fuel brand, and hence may not be representative of smokeless fuels in general.

**Enclosed Domestic Stoves & Boilers**

The study also included monitoring of two enclosed appliances, each with heat exchangers for hot water supply: an underfeed stoker boiler fired on bituminous coal and a gravity-fed boiler fired on anthracite. Significant variation in VOC emission measurements was observed across 8 nominally similar tests conducted on the underfeed stoker, clearly demonstrating the inherent variability of coal combustion in small appliances and illustrating the degree of uncertainty in the results. The derived emission factors are shown below, with the range of results from individual tests in brackets:

- Underfeed stoker (8 tests) 0.6 g/kg (range: 0.1 - 1.7 g/kg)
- Gravity boiler (4 tests) 1.7 g/kg (range: 0.4 – 3.3 g/kg)

Note that the emission factors are significantly lower for enclosed appliances compared to open fires. This is due primarily to the higher combustion efficiency of the enclosed appliances from continuous feeding of fuel into a hot fuel bed rather than the inefficient cycling of batch-fed open fires.

From previous studies, anthracite is normally expected to generate lower volatiles under the same firing conditions, compared to bituminous coals. In this study, the bituminous coal-fed underfeed stoker has generated emission factors lower than the anthracite-fed gravity boiler. These data suggest that the VOC emission can be controlled more by appliance design than fuel type.

**Industrial and Power Station Plant**

The 1998 study included a comprehensive study of VOC emissions from a wide range of industrial coal-fired power units of the following capacities: 0.9 MW, 1 MW, 5 MW, 19 MW, 43 MW, 48 MW and 500 MWe (about 1400 MWth). The findings from this research are therefore applicable across a range of coal-fed commercial & institutional boilers as well as the full range of coal-fired CHP units in the UK.

The VOC emissions from all of these units were found to be very low (less than 0.1 g/kg) and around 2 orders of magnitude below the emission factors derived for domestic open fires. The emission factor for the coal consumption in the industrial and commercial sector may be derived from the mean figure from the 0.9 – 48 MW plants in this study, 0.05 g/kg.

The factor derived for the 500 MW unit was 0.03 g/kg, indicating a high degree of combustion control on larger facilities.

In order to determine whether the emission factor used for the UK NAEI should tend towards the open or closed fire results, the proportion of coal burnt in domestic open fires compared to that burnt in closed stoves must be estimated.
The assumption quoted in the report in 1998 was that 90% of domestic-sector bituminous coal consumption was burned on open fires. The derivation of a single emission factor for domestic coal combustion based on this assumption is shown below:-

\[(0.9 \times 14) + (0.1 \times 0.6) = 12.7 \text{ g/kg}\]

Coal consumption in the agricultural sector is likely to be in the form of units more akin to the commercial / institutional sector, and therefore the emission factors applicable to these sectors are considered most appropriate for agricultural coal consumption.

**4.6.2 VOC Emission Factors: Other Sources**

In addition to the above UK-focussed study, the following sources also provide research into VOC emission factor development. The table below summarises the findings for “VOC” emission factors and also “NMVOC” (Non-Methane Volatile Organic Compounds) emission factors.

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>VOC EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic closed stove</td>
<td>15</td>
<td>1.9</td>
<td>g/kg</td>
<td>UN ECE, 2002: dutch data, total VOCs “domestic coal use”</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>12</td>
<td>0.02</td>
<td>g/kg</td>
<td>ERA, 2000: UK research, total VOCs bituminous coal in boilers</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>1.2-6.0</td>
<td>g/kg</td>
<td>Rentz et al, 1998: hard coal, NMVOC, 35kW boiler, improved-uncontrolled</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>2.6-12.9</td>
<td>g/kg</td>
<td>Rentz et al, 1998: brown coal, NMVOC, 35kW boiler, improved-uncontrolled</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>16</td>
<td>0.2-0.9</td>
<td>g/kg</td>
<td>Rentz et al, 1998: hard coal, NMVOC, 200 kW boiler, improved-uncontrolled</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>15</td>
<td>1.1</td>
<td>g/kg</td>
<td>UN ECE, 2002: dutch data, total VOCs “domestic coal use”</td>
</tr>
<tr>
<td>CHP</td>
<td>17</td>
<td>0.06</td>
<td>g/kg</td>
<td>WSL: UK data, total VOCs, 500 MW_e power station, coal-fired, low-NO_x</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0.05</td>
<td>g/kg</td>
<td>Australian data: avge. NMVOC from AUS power stations fired on black coal</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.09</td>
<td>g/kg</td>
<td>Rentz et al, 1998: hard coal, NMVOC, 200 kW boiler improved &amp; abated</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.10</td>
<td>g/kg</td>
<td>Rentz et al, 1998: brown coal, NMVOC, 200 kW boiler improved &amp; abated</td>
</tr>
</tbody>
</table>

With the exception of the very low figure obtained from the ERA research in 2000, these figures demonstrate a consistent reduction in VOC releases as the scale of combustion unit increases, from 1.2-12.9 g/kg for domestic sources through to < 0.1 g/kg for power stations and larger boilers.

These results are consistent with the findings of the 1998 UK study.
4.7 **PAHS & BENZENE EMISSION FACTORS**

PAHs (polycyclic aromatic hydrocarbons) refer to a large group of chemical compounds with a similar structure comprising two or more joined aromatic carbon rings. The main environmental impact of PAHs relate to their health effects, focusing on their carcinogenic properties. The NAEI reports on the sixteen of most concern as indicated by the USEPA.

The following table summarises the PAH, PCN (Polychlorinates naphthalenes), benzene and benzo(a)pyrene emission factors (and sources) for small-scale coal combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Substance: EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>14</td>
<td>PCNs: 0.68</td>
<td>g/kT</td>
<td>CPL, 2002: yorkshire (bituminous) housecoal, &lt; 5kW open fire</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>33 PAHs: 254</td>
<td>T/MT</td>
<td>POPs Inventory, 2003: Russian data for residential coal use</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>19</td>
<td>B(a)P: 0.1</td>
<td>g/T</td>
<td>POPs Inventory: Polish data, domestic use of hard coal</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>10</td>
<td>B(a)P: 1.5</td>
<td>g/kT</td>
<td>POPS Inventory: Polish data, domestic use of brown coal</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>B(a)P: 0.9</td>
<td>g/kT</td>
<td>POPS Inventory: Polish data, domestic use of brown coal</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>B(a)P: 0.6-2.0</td>
<td>g/T</td>
<td>EMEP/CORINAIR default factors for “small-scale coal combustion”</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>22</td>
<td>B(a)P: 13-56</td>
<td>g/kT</td>
<td>MSC-E, 2001: Russian data, low-capacity heat-power boilers</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>B(a)P: 9.2</td>
<td>g/kT</td>
<td>MSC-E, 2001: Russian data, heat-power boilers</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>B(a)P: 2.3</td>
<td>g/kT</td>
<td>AEAT, 2001: bituminous coal, 500kW boiler</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Benzene: &lt; 0.01</td>
<td>Kt/MT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>33 PAHs: 1650</td>
<td>g/kT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>B(a)P: 14</td>
<td>g/kT</td>
<td>POPs Inventory, 2003: Russian data for industry / public utility use of coal</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>10</td>
<td>B(a)P: 1.5</td>
<td>g/kT</td>
<td>POPS Inventory: Polish data, agricultural use of hard coal</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>B(a)P: 0.9</td>
<td>g/kT</td>
<td>POPS Inventory: Polish data, agricultural use of brown coal</td>
</tr>
<tr>
<td>CHP</td>
<td>19</td>
<td>B(a)P: 9.2</td>
<td>g/kT</td>
<td>POPs Inventory, 2003: Russian data for power plant use of coal</td>
</tr>
</tbody>
</table>

Of specific relevance to the UK emission inventory, the 2001 study by Collings, AEA Technology [10] provides a detailed breakdown of specific PAHs from a small coal-fired boiler. The findings of this report are summarised below.

Collings et al [10] provides emission factors for PAHs, CO, benzene and dioxins from tests that were carried out on a small coal-fired school boiler. Comparison against existing NAEI Emission Factors is shown below.
<table>
<thead>
<tr>
<th>Pollutants</th>
<th>NAEI 2000 Emission Factors (kg/Mt)</th>
<th>Collings et al, 2001 Emission Factors (kg/Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acenaphthene</td>
<td>2622</td>
<td>9.5</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>3578</td>
<td>39.8</td>
</tr>
<tr>
<td>Anthracene</td>
<td>925</td>
<td>0.9</td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>894</td>
<td>7.7</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>775</td>
<td>2.3</td>
</tr>
<tr>
<td>Benzo[b]fluoranthene</td>
<td>35</td>
<td>35.4</td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td>408</td>
<td>8.9</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Chrysene</td>
<td>835</td>
<td>31.1</td>
</tr>
<tr>
<td>Dibenzo[ah]anthracene</td>
<td>896</td>
<td>3.7</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>1502</td>
<td>100.5</td>
</tr>
<tr>
<td>Fluorene</td>
<td>8105</td>
<td>1.7</td>
</tr>
<tr>
<td>Indeno[1,2,3 – cd]pyrene</td>
<td>596</td>
<td>17.5</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>61703</td>
<td>1055</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>3283</td>
<td>267</td>
</tr>
<tr>
<td>Pyrene</td>
<td>1491</td>
<td>9.3</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.0019</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Dioxins</td>
<td>2.4</td>
<td>51</td>
</tr>
</tbody>
</table>

The average benzene emission factor determined in this study are higher than those currently used in the NAEI. However, the benzene measurements are subject to a high degree of uncertainty as the measured concentrations were below the limit of detection.

The PAH emission factors are lower than those used in the current NAEI, sometimes by several orders of magnitude. On the other hand, the dioxin emission factor obtained in the Collings study is significantly higher than that currently used in the NAEI.

### 4.8 OXIDES OF SULPHUR

The following table summarises oxide of sulphur emission factors (and sources) for small-scale coal combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>NAEI 2000 Emission Factors (kt/Mt)</th>
<th>Collings et al, 2001 Emission Factors (kt/Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>61703</td>
<td>1055</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>3283</td>
<td>267</td>
</tr>
<tr>
<td>Pyrene</td>
<td>1491</td>
<td>9.3</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.0019</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Dioxins</td>
<td>2.4</td>
<td>51</td>
</tr>
<tr>
<td>Sub-sector</td>
<td>REF.</td>
<td>SO₂ EF</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>104</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>12</td>
<td>17.2</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>15</td>
<td>14.2</td>
</tr>
<tr>
<td>CHP</td>
<td>17</td>
<td>50</td>
</tr>
</tbody>
</table>
5 Coke & Manufactured Solid Fuels

5.1 USE AND FUEL TYPES

A wide range of solid smokeless fuels are used in the UK residential heating market. There are three main classes; natural smokeless fuels, manufactured smokeless fuels and washed high volatile bituminous coals.

Anthracite and dry steam coal are examples of natural smokeless fuels. Manufactured smokeless fuels (MSF) include cokes and briquetted fuels. Coke is the solid residue obtained from coal or lignite by heating it to a high temperature in the absence or near absence of air. It is high in carbon, low in moisture and organic matter. The major manufactured smokeless fuels in the UK include Phurnacite, Homefire, Sunbrite and Coalite. Like coal, these solid fuels can be burnt in the domestic sector either on open fires or in closed appliances.

5.2 EMISSION FACTORS FOR COKE

The NAEI uses the following emission factors for the combustion of coke in the small-scale combustion sector:

<table>
<thead>
<tr>
<th>Sector</th>
<th>NOx</th>
<th>VOC</th>
<th>CO</th>
<th>PM10</th>
<th>PCDD/Fs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/Mt</td>
</tr>
<tr>
<td>Domestic</td>
<td>1.33a</td>
<td>4.9</td>
<td>45</td>
<td>0.2875b</td>
<td>2.4c</td>
</tr>
<tr>
<td>Public Service</td>
<td>4</td>
<td>0.05</td>
<td>4.1</td>
<td>0.2875</td>
<td>2.4</td>
</tr>
<tr>
<td>Agriculture</td>
<td>4</td>
<td>0.05</td>
<td>4.1</td>
<td>0.2875</td>
<td>2.4</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>4</td>
<td>0.05</td>
<td>4.1</td>
<td>0.2875</td>
<td>-</td>
</tr>
<tr>
<td>Other Industry</td>
<td>4.8</td>
<td>0.05</td>
<td>4.1</td>
<td>0.2875</td>
<td>2.4</td>
</tr>
</tbody>
</table>

[a = Corinair 1992, b = S.Eggleston, 1997, c = EF from "other industry & power stations"]
The following table summarises VOC, CO, SO₂, NOₓ and PM₁₀ emission factors (and sources) for small-scale coke combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>13</td>
<td>PM₁₀</td>
<td>2.3-2.8</td>
<td>g/kg</td>
<td>CRE, 1997: pet coke blend, open fire</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>VOC</td>
<td>0.2-0.6</td>
<td>g/kg</td>
<td>BCC, 1998: domestic coke use</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>13</td>
<td>PM₁₀</td>
<td>2.6-3.2</td>
<td>g/kg</td>
<td>CRE, 1997: pet coke blend, closed stove</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>CO</td>
<td>1125</td>
<td>g/kg</td>
<td>CRE, 1999: 12.5kW stove, coke, medium burn rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>127</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOₓ</td>
<td>7</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>15</td>
<td>VOC</td>
<td>2.7</td>
<td>g/kg</td>
<td>UNECE, 2002: dutch data, Domestic coke use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>11.1</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOₓ</td>
<td>11.4</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>370</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>NM VOC</td>
<td>1.3-6.6</td>
<td>g/kg</td>
<td>Rentz et al, 1998: coke, 35kW boiler benchmark / improved</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>9</td>
<td>VOC</td>
<td>0.1-0.9</td>
<td>g/kg</td>
<td>BCC, 1998: industrial coke use</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>NM VOC</td>
<td>0.2-0.9</td>
<td>g/kg</td>
<td>Rentz et al, 1998: coke, 200kW boiler benchmark / improved</td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### 5.3 MANUFACTURED SOLID FUELS (MSF) EMISSIONS

At present the following emission factors are used in the NAEI for the burning of manufactured solid fuels in the small-scale combustion sector:-

<table>
<thead>
<tr>
<th>Sector</th>
<th>NOₓ</th>
<th>VOC</th>
<th>CO</th>
<th>PM₁₀</th>
<th>PCDD/Fs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/Mt</td>
</tr>
<tr>
<td>Domestic</td>
<td>1.32</td>
<td>4.9</td>
<td>45²</td>
<td>5.6³</td>
<td>3.0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3.96</td>
<td>0.05</td>
<td>4.1</td>
<td>0.23</td>
<td>-</td>
</tr>
<tr>
<td>Other Industry</td>
<td>4.75</td>
<td>0.05</td>
<td>4.1</td>
<td>0.23</td>
<td>2.4</td>
</tr>
</tbody>
</table>

[ a = CORINAIR 1992, b = USEPA 1977, c = S Eggleston, 1997.]
The following table summarises VOC, CO, SO₂, NOₓ and PM₁₀ emission factors (and sources) for small-scale MSF combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>13</td>
<td>PM₁₀</td>
<td>0.9-1.6</td>
<td>g/kg</td>
<td>CRE, 1997: smokeless coal brands, open fire &lt; 10kW</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>13</td>
<td>PM₁₀</td>
<td>1.0-1.2</td>
<td>g/kg</td>
<td>CRE, 1997: smokeless coal brands, closed stove &lt; 10kW</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>CO</td>
<td>275</td>
<td>g/kg</td>
<td>USEPA, 2000: developing world stove trials, charcoal</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>NM VOC</td>
<td>10.5</td>
<td>g/kg</td>
<td>USEPA, 2000: developing world stove trials, charcoal</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>CO</td>
<td>1190</td>
<td>g/kg</td>
<td>CRE, 1999: 12.5kW stove, manufactured briquettes, medium burn rate</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>VOC</td>
<td>0.3-7.7</td>
<td>g/kg</td>
<td>UNECE, 2002: swedish data, pellet boilers, 3-6 kW</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>NOₓ</td>
<td>2.0-2.2</td>
<td>g/kg</td>
<td>UNECE, 2002: swedish data, pellet boilers, 3-6 kW</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>NOₓ</td>
<td>0.5-1.1</td>
<td>g/kg</td>
<td>UNECE, 2002: swedish data, pellet boilers, 1.8-2 MW</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>CO</td>
<td>4-226</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>15</td>
<td>VOC</td>
<td>0.1</td>
<td>g/kg</td>
<td>UNECE, 2002: swedish data, briquette boilers, 1.8-2 MW</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>NOₓ</td>
<td>1.1</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>8.3</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
6 Wood & Biomass

6.1 USE

In the UK, wood is typically burnt domestically for heating on either open fireplaces or in various types of closed stoves. The main pollutants of concern from wood burning are particulates (PM\textsubscript{10}), VOCs, PAHs and nitrogen oxides (NO\textsubscript{x}).

During this study, several sources of data pertinent to biogas use in the small-scale combustion sector were identified. However, biogas is not used widely across the UK and detailed investigation into emission factors for biogas was not considered an efficient use of resources in this study.

The burning of wood and biomass has received more and more research effort in recent years, both from an environmental and a direct human health impact perspective, as the widespread use of biomass in developing countries has been identified as a potentially significant source of heavy metal and other toxin exposure.

The wide array of research results demonstrate that the combustion of wood and biomass fuels is subject to a much greater degree of variability than fossil fuel combustion. The emission range of a given component may vary considerably depending on factors such as:-

- Type of fuel
- Type of combustion unit
- Pre-treatment or seasoning of fuel source
- Combustion conditions

The NAEI currently uses the following emission factors for the burning of wood in the domestic sector:

<table>
<thead>
<tr>
<th>Sector</th>
<th>NO\textsubscript{x} (g/kg)</th>
<th>VOC (g/kg)</th>
<th>CO (g/kg)</th>
<th>Benzene (g/kg)</th>
<th>PCDD/Fs (g/Mt)</th>
<th>Benzo(a)pyrene (g/t)</th>
<th>PM\textsubscript{10} (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>0.72\textsuperscript{a}</td>
<td>5.4</td>
<td>99.3\textsuperscript{b}</td>
<td>1.6</td>
<td>0.24</td>
<td>1.3</td>
<td>7.9\textsuperscript{c}</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Corinair 1992, \textsuperscript{b} IPCC Guidelines, \textsuperscript{c} CPL Report, open fire study.

As yet, there are no emission factors within the NAEI that are pertinent to manufactured wax-logs or other wood-derived solid fuels used in the domestic sector. The energy content of manufactured wax logs can be as much as 75% higher (per unit mass) than seasoned wood, with moisture contents as low as 3%, compared to less than 20% for well-seasoned wood.

Emission studies in the USA have indicated that manufactured wax-logs and densified firelogs produce significantly lower emissions of target pollutants, compared to well seasoned “cordwood”. Particulate emissions were found to be
69% lower on average for manufactured wax logs, with CO emissions reduced by an average of 88%. [11]

6.2 PM$_{10}$ EMISSION FACTORS

The following table summarises the PM$_{10}$ emission factors (and sources) for small-scale wood combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>PM$_{10}$ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>14</td>
<td>7.9</td>
<td>g/kg</td>
<td>CPL, 2002: UK study, seasoned hardwood</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.5</td>
<td>g/kg</td>
<td>IIASA, 2001: german data, wood use in uncontrolled fireplaces</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>2</td>
<td>1.5</td>
<td>g/kg</td>
<td>IIASA, 2001: german data, uncontrolled wood stoves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0-2.0</td>
<td>g/kg</td>
<td>IIASA, 2001: dutch data, uncontrolled wood heating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5-2.9</td>
<td>g/kg</td>
<td>2001: RAINS data for domestic wood heating</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>2</td>
<td>0.5</td>
<td>g/kg</td>
<td>IIASA, 2001: german data, uncontrolled wood boilers</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>25</td>
<td>0.44</td>
<td>g/kg</td>
<td>AEAT, 2001: 1.5 MW wood boiler with cyclone abatement</td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Houck et al, 2001 [11] provides a TPM emission factor of 11.8 kt/mt for domestic wood combustion. The study was based on 388 tests on 112 different fireplaces, and constitutes a comprehensive study on the subject. This compares to a PM$_{10}$ emission factors of 7.9 kt/mt currently used in the NAEI.

The NAEI emission factor is obtained from a recent CPL Report (Perry, 2002). The PM$_{10}$ emission factor quoted in AP-42 is substantially higher than that quoted in the CPL Report.

6.3 VOC EMISSION FACTORS

The following table summarises the VOC emission factors (and sources) for small-scale wood combustion, identified during this study:-
<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>VOC EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>6</td>
<td>5.2</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: fireplaces</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.9-8.0</td>
<td>g/kg</td>
<td>BCC, 1998: UK data, wood in domestic fireplaces</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>6</td>
<td>17.5</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: traditional wood stoves, <strong>UHC as CH₄</strong></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.7</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: traditional wood stoves, <strong>VOCs</strong></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>2</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: modern wood stoves, <strong>UHC as CH₄</strong></td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>16</td>
<td>1.0-4.8</td>
<td>g/kg</td>
<td>Rentz et al, 1998: 35kW boiler, wood /charcoal, benchmark - improved</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>13.3</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: wood boilers, <strong>UHC as CH₄</strong></td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>15</td>
<td>0.5</td>
<td>g/kg</td>
<td>UNECE: Swedish data, 1.8-2 MW wood chip boilers</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.1</td>
<td>g/kg</td>
<td>ERA, 2000: wood boiler</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.04</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: stoker burners, <strong>UHC as CH₄</strong></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.67</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: grate burners, <strong>UHC as CH₄</strong></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.6-1.0</td>
<td>g/kg</td>
<td>BCC, 1998: UK wood use in industrial appliances</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.16-0.80</td>
<td>g/kg</td>
<td>Rentz et al, 1998: 200 kW boiler, wood /charcoal, benchmark - improved</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>&lt; 0.01</td>
<td>g/kg</td>
<td>UNECE: Swedish data, 1.8-2 MW logging residue boilers</td>
</tr>
<tr>
<td>CHP</td>
<td>6</td>
<td>0.01</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: Fluidized bed, <strong>UHC as CH₄</strong></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.02</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: Cyclone furnaces</td>
</tr>
</tbody>
</table>
### 6.4 PAH AND BENZENE EMISSION FACTORS

The following table summarises the PAH, benzene and other air toxin emission factors (and sources) for small-scale wood combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Substance: EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>14</td>
<td>PCBs: 1.2 gTEF/MT</td>
<td>CPL, 2002: seasoned hardwood, &lt; 5kW open fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCNs: 0.12 g/kT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 PAHs: 43 g/T</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>16-PAH: 220 g/T</td>
<td>OMNI, 2001: conventional stoves</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16-PAH: 130 g/T</td>
<td>OMNI, 2001: high-tech non-cat stoves</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16-PAH: 160 g/T</td>
<td>OMNI, 2001: catalytic stoves</td>
<td></td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>20</td>
<td>B(a)P: 2.5 g/kT</td>
<td>POPS Inventory: Polish data, domestic wood use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>B(a)P: 5 g/T</td>
<td>EMEP/CORINAIR default fig, fireplaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>PAH: 280-400 g/T</td>
<td>USEPA, 1998: conventional – improved wood stoves</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH: 160 g/T</td>
<td>USEPA, 1998: test stove A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH: 160 g/T</td>
<td>USEPA, 1998: test stove B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>PAH: 35 g/T</td>
<td>Norway Inst of Tech: traditional wood stoves</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH: 0.3 g/T</td>
<td>Norway Inst of Tech: modern wood stoves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>B(a)P: 2 g/T</td>
<td>POPS Inventory, 2003: Russian data for residential use of wood</td>
<td></td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>9</td>
<td>PAH: 0.3 g/T</td>
<td>Norway Inst of Tech: wood boilers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>B(a)P: 1.5-5 g/T</td>
<td>EMEP/CORINAIR default factors for “small-scale wood combustion”</td>
<td></td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>25</td>
<td>Benzene: &lt; 20 g/T</td>
<td>AEAT, 2001: 1.5 MW wood-burning furnace with cyclone</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33 PAH: 41 g/kT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCBs: 0.37 gTEF/MT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>PAH: 0.1 g/T</td>
<td>Norway Inst of Tech: stoker burners</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH: 40 g/T</td>
<td>Norway Inst of Tech: grate burners</td>
<td></td>
</tr>
<tr>
<td>Agricultural heater</td>
<td>20</td>
<td>B(a)P: 2.5 g/kT</td>
<td>POPS Inventory: Polish data, Agricultural wood use</td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td>6</td>
<td>PAH: 0.04 g/T</td>
<td>Norway Inst of Tech: fluidized bed</td>
<td></td>
</tr>
</tbody>
</table>
6.5 DIOXINS AND FURANS

The following table summarises the dioxin and furan emission factors (and sources) for small-scale wood combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>PCDD/F EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>14</td>
<td>0.23</td>
<td>gTEQ/MT</td>
<td>CPL, 2002: UK study, seasoned hardwood</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>21</td>
<td>5</td>
<td>gTEQ/MT</td>
<td>EMEP/CORINAIR default figure for small-scale wood furnaces</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>21</td>
<td>1.0-5</td>
<td>gTEQ/MT</td>
<td>EMEP/CORINAIR default figure for small-scale wood combustion</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>25</td>
<td>12.6</td>
<td>gTEQ/MT</td>
<td>AEAT, 2001: 1.5 MW wood boiler with cyclone abatement</td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

6.6 CARBON MONOXIDE

The following table summarises the CO emission factors (and sources) for small-scale wood combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>CO EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>6</td>
<td>67</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: fireplaces</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>64</td>
<td>g/kg</td>
<td>OMNI review, 2001: domestic wood use</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>6</td>
<td>70</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: traditional wood stoves</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>17</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: modern wood stoves</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>6</td>
<td>50</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: wood boilers</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>15</td>
<td>39</td>
<td>g/kg</td>
<td>UNECE: Swedish data, 1.8-2 MW wood chip boilers</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>6.2</td>
<td>g/kg</td>
<td>ERA, 2000: wood boiler</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4.6</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: stoker burners</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>19</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: grate burners</td>
</tr>
<tr>
<td>Agricultural</td>
<td>25</td>
<td>2.6</td>
<td>g/kg</td>
<td>AEAT, 2001: 1.5 MW wood furnace</td>
</tr>
<tr>
<td>CHP</td>
<td>15</td>
<td>0.42</td>
<td>g/kg</td>
<td>UNECE: Swedish data, 1.8-2 MW logging residue boilers</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: Fluidized bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.38</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: Cyclone furnaces</td>
</tr>
</tbody>
</table>

Houck et al [11] quotes a carbon monoxide emission factor of 64.1 kt/mt wood burnt for domestic fireplaces. This is around two thirds of the figure currently used in the UK NAEI. The Houck et al study has reviewed 24 studies and is therefore based on a substantial dataset compared to the IPCC guidelines (used in the NAEI). It is therefore suggested that consideration is given to amending
the NAEI emission factor for carbon monoxide emissions from domestic wood combustion.

### 6.7 OXIDES OF NITROGEN

NO\textsubscript{x} emissions from domestic wood-burning are determined primarily by combustion control and nitrogen content of the wood. For example, some wood sources such as plywood have a relatively high nitrogen content, leading to higher NO\textsubscript{x} emission levels. [6]

The following table summarises the NO\textsubscript{x} emission factors (and sources) for small-scale wood combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>NO\textsubscript{x} EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(No data identified specific to this sector)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>6</td>
<td>0.29</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: traditional wood stoves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.58</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: modern wood stoves</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>6</td>
<td>1.0</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: wood boilers</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.25</td>
<td>g/kg</td>
<td>UNECE: Swedish data, 1.8-2 MW wood chip boilers</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.7</td>
<td>g/kg</td>
<td>ERA, 2000: wood boiler</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>6</td>
<td>1.0</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: stoker burners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: grate burners</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.74</td>
<td>g/kg</td>
<td>UNECE: Swedish data, 1.8-2 MW logging residue boilers</td>
</tr>
<tr>
<td>CHP</td>
<td>6</td>
<td>1.7</td>
<td>g/kg</td>
<td>Norway Inst. Of Tech, 1995: Fluidized bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3</td>
<td>g/kg</td>
<td>Norway Inst of Tech, 1995: Cyclone furnaces</td>
</tr>
</tbody>
</table>

The emission factor provided for NO\textsubscript{x} from domestic wood combustion in US EPA AP-42 is 1.3 kt/Mt wood burnt, approximately twice that currently used in the NAEI.

### 6.8 OXIDES OF SULPHUR

Only a single source of new data was identified for SO\textsubscript{2} emissions from wood combustion; the ERA Consulting report from 2000 [12] identified an emission factor of 0.03 g/kg for wood combustion in a small commercial boiler.

The emissions of SO\textsubscript{x} from all fuels across the small-scale combustion sector are dependent entirely on the sulphur content of the fuel source, and wood combustion is no different in that regard.
7 Petroleum-Based Oils and Gases

7.1 USE AND FUEL TYPES

A range of different fractions of crude oil are commonly used for the provision of heat and power across the UK, with the key fuel sources applicable to the small-scale combustion sector falling into the following categories:

- Liquid Petroleum Gas (LPG: predominantly propane & butane)
- Burning Oil (light fuel oil, kerosene)
- Gas Oil (including diesel oil)
- Fuel Oil (heavier residual fuel oils)

Within the small-scale domestic sector the most commonly used fuel is Burning Oil and related light fuel oil fractions.

This study has investigated emission factor developments applicable to all of the above fractions, and the results are summarised here. Note that there was no new data found for gas oil use in any sub-sector of the small-scale combustion market. However, the differentiation between different petroleum oil fractions and the somewhat variable nomenclature employed around the world for these fractions is likely to be the main cause of this information gap.

In terms of volatility, gas oil sits between the lighter burning oil / kerosene fractions and the heavier fuel oil fractions. Where emission factor gaps exist for gas oil, comparison of the factors for burning oil and fuel oil is a reliable source of data for application to gas oil combustion.

The summary tables below outline the emission factor data identified for application to LPG, burning oil and fuel oil use in the small-scale combustion sector.

7.2 LIQUID PETROLEUM GAS

The following emission factors are currently used in the NAEI for combustion of LPG in small-scale combustion sectors:

<table>
<thead>
<tr>
<th>Sector</th>
<th>NO\textsubscript{X}</th>
<th>VOC</th>
<th>CO</th>
<th>PM\textsubscript{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/therm</td>
<td>g/therm</td>
<td>g/therm</td>
<td>g/therm</td>
</tr>
<tr>
<td>Domestic</td>
<td>4.9</td>
<td>0.194</td>
<td>0.86</td>
<td>0.39</td>
</tr>
<tr>
<td>Other Industry</td>
<td>9.4</td>
<td>0.194</td>
<td>0.25</td>
<td>0.29</td>
</tr>
</tbody>
</table>
The following table summarises CO, SO₂ and NOₓ emission factors (and sources) for small-scale burning oil (kerosene) combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF g/therm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to domestic open fires)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>24</td>
<td>CO</td>
<td>31.8</td>
<td>USEPA, 2000: developing world stove trials, LPG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NMVOC</td>
<td>40.2</td>
<td>USEPA, 2000: developing world stove trials, LPG</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>15</td>
<td>VOC</td>
<td>0.2</td>
<td>UNECE, 2002: dutch data, “domestic LPG use”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOₓ</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM₁₀</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>9</td>
<td>VOC</td>
<td>0.5</td>
<td>BCC, 1998: UK data, LPG use in commercial appliances</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>VOC</td>
<td>0.2</td>
<td>UNECE, 2002: dutch data, “agricultural LPG use”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOₓ</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM₁₀</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to CHP)</td>
</tr>
</tbody>
</table>

### 7.3 BURNING OIL

#### 7.3.1 NAEI emission factors

The NAEI uses the following emission factors for the combustion of burning oil in the small-scale combustion sector:

<table>
<thead>
<tr>
<th>Sector</th>
<th>NOₓ</th>
<th>VOC</th>
<th>CO</th>
<th>PM₁₀</th>
<th>PCDD/Fs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/Mt</td>
</tr>
<tr>
<td>Domestic</td>
<td>2.21</td>
<td>0.133</td>
<td>0.16</td>
<td>0.014</td>
<td>-</td>
</tr>
<tr>
<td>Public Service</td>
<td>2.84</td>
<td>0.086</td>
<td>0.16</td>
<td>0.014</td>
<td>-</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2.84</td>
<td>0.086</td>
<td>0.16</td>
<td>0.014</td>
<td>-</td>
</tr>
<tr>
<td>Other Industry</td>
<td>2.84</td>
<td>0.086</td>
<td>0.16</td>
<td>0.014</td>
<td>4.3</td>
</tr>
</tbody>
</table>

The key target pollutants for which significant data was obtained include PM₁₀ and VOCs, whilst some information was sourced regarding NOₓ, CO and SO₂. No new data was sourced for PAH or dioxin and furan emissions.
### 7.3.2 PM$_{10}$ Emission Factors

The following table summarises the PM$_{10}$ emission factors (and sources) for small-scale burning oil (kerosene) combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>PM$_{10}$ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific this sector)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>2</td>
<td>0.05 g/kg</td>
<td></td>
<td>IIASA, 2001: German data, Domestic light fuel oil use</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.21 g/kg</td>
<td></td>
<td>UNECE, 2002: dutch data, “domestic oil use”</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.4 g/kg</td>
<td></td>
<td>IIASA, 2001: EC figs, uncontrolled domestic boiler, light fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.01 g/kg</td>
<td></td>
<td>IIASA, 2001: German figs, uncontrolled domestic boiler, light fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.05 g/kg</td>
<td></td>
<td>RAINS, 2001: uncontrolled domestic boiler, light fuel oil</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>2</td>
<td>0.18 g/kg</td>
<td></td>
<td>IIASA, 2001: EC figs, uncontrolled industrial boiler, light fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.01 g/kg</td>
<td></td>
<td>IIASA, 2001: German figs, uncontrolled industrial boiler, light fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.05 g/kg</td>
<td></td>
<td>RAINS, 2001: uncontrolled industrial boiler, light fuel oil</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.21 g/kg</td>
<td></td>
<td>UNECE, 2002: dutch data, agricultural oil use</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to CHP)</td>
</tr>
</tbody>
</table>

### 7.3.3 VOC Emission Factors

The following table summarises the VOC emission factors (and sources) for small-scale burning oil (kerosene) combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>VOC EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to domestic open fires)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>24</td>
<td>14.9 g/kg</td>
<td></td>
<td>USEPA, 2000: developing world stove trials, kerosene wick, NMVOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19.2 g/kg</td>
<td></td>
<td>USEPA, 2000: developing world stove trials, kerosene pressure, NMVOC</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.7 g/kg</td>
<td></td>
<td>UNECE, 2002: dutch data, “domestic oil use”, total VOCs</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.7 g/kg</td>
<td></td>
<td>BCC, 1998: UK data, kerosene in domestic appliances, total VOCs</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.07-0.35 g/kg</td>
<td></td>
<td>Rentz et al, 1998: oil-fired 35 kW boiler, benchmark / improved, NMVOC</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>16</td>
<td>0.05-0.23 g/kg</td>
<td></td>
<td>Rentz et al, 1998: oil-fired 200 kW boiler, benchmark / improved, NMVOC</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.46 g/kg</td>
<td></td>
<td>UNECE, 2002: dutch data, agricultural oil use</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to CHP)</td>
</tr>
</tbody>
</table>
7.3.4 CO, NOx and SO2 Emission Factors
The following table summarises CO, SO2 and NOx emission factors (and sources) for small-scale burning oil (kerosene) combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to domestic open fires)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>24</td>
<td>CO</td>
<td>17.7</td>
<td>g/kg</td>
<td>USEPA, 2000: developing world stove trials, kerosene wick</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>62.1</td>
<td>g/kg</td>
<td>USEPA, 2000: developing world stove trials, kerosene pressure</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>15</td>
<td>SO2</td>
<td>4</td>
<td>g/kg</td>
<td>UNECE, 2002: dutch data, “domestic oil use”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOx</td>
<td>2.3</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>2.8</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to commercial boilers)</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>SO2</td>
<td>0.01</td>
<td>g/kg</td>
<td>UNECE, 2002: dutch data, “agricultural oil use”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOx</td>
<td>2.3</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>0.5</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to CHP)</td>
</tr>
</tbody>
</table>

7.4 FUEL OIL

7.4.1 Current NAEI emission factors
The NAEI uses the following emission factors for the combustion of fuel oil in the small-scale combustion sector:

<table>
<thead>
<tr>
<th>Sector</th>
<th>NOx</th>
<th>VOC</th>
<th>CO</th>
<th>PM10</th>
<th>PCDD/Fs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/Mt</td>
</tr>
<tr>
<td>Domestic</td>
<td>6.99</td>
<td>0.13</td>
<td>0.5</td>
<td>1.032</td>
<td>-</td>
</tr>
<tr>
<td>Agriculture</td>
<td>6.99</td>
<td>0.12</td>
<td>0.5</td>
<td>1.032</td>
<td>4.3</td>
</tr>
<tr>
<td>Public Service</td>
<td>6.99</td>
<td>0.12</td>
<td>0.5</td>
<td>1.032</td>
<td>-</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6.99</td>
<td>0.12</td>
<td>0.5</td>
<td>1.032</td>
<td>-</td>
</tr>
<tr>
<td>Other Industry</td>
<td>7.54</td>
<td>0.12</td>
<td>0.5</td>
<td>1.032</td>
<td>4.3</td>
</tr>
</tbody>
</table>

The key target pollutants for which significant data was obtained include PM10 and VOCs, whilst some information was sourced regarding PAHs, benzene, NOx, CO and SO2. No new data was sourced for dioxin and furan emissions.
### 7.4.2 PM$_{10}$ Emission Factors

The following table summarises the PM$_{10}$ emission factors (and sources) for small-scale fuel oil combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>PM$_{10}$ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>2</td>
<td>2.2 g/kg</td>
<td>g/kg</td>
<td>IIASA, 2001: EC figs, uncontrolled domestic boiler, heavy fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3-1.2 g/kg</td>
<td>g/kg</td>
<td>IIASA, 2001: German figs, uncontrolled domestic boiler, heavy fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9 g/kg</td>
<td>g/kg</td>
<td>RAINS, 2001: uncontrolled domestic boiler, heavy fuel oil</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>12</td>
<td>0.1 g/kg</td>
<td>g/kg</td>
<td>ERA, 2000: domestic boiler, fuel oil #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.8 g/kg</td>
<td>g/kg</td>
<td>ERA, 2000: domestic boiler, fuel oil #4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1 g/kg</td>
<td>g/kg</td>
<td>ERA, 2000: domestic boiler, fuel oil #5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 0.1-0.6 g/kg</td>
<td>g/kg</td>
<td>IIASA, 2001: German data, uncontrolled industrial heavy fuel oil use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 g/kg</td>
<td>g/kg</td>
<td>IIASA, 2001: German data, uncontrolled industrial heavy fuel oil use in boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9 g/kg</td>
<td>g/kg</td>
<td>IIASA, 2001: EC data, uncontrolled industrial heavy fuel oil use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.65 g/kg</td>
<td>g/kg</td>
<td>RAINS, 2001: uncontrolled industrial boiler, heavy fuel oil</td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### 7.4.3 VOC Emission Factors

The following table summarises the VOC emission factors (and sources) for small-scale fuel oil combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>VOC EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>9</td>
<td>0.4 g/kg</td>
<td>g/kg</td>
<td>BCC, 1998: UK data, residual fuel oil use in domestic appliances</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>12</td>
<td>0.03 g/kg</td>
<td>g/kg</td>
<td>ERA, 2000: domestic boiler, fuel oil #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.03 g/kg</td>
<td>g/kg</td>
<td>ERA, 2000: domestic boiler, fuel oil #4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.04 g/kg</td>
<td>g/kg</td>
<td>ERA, 2000: domestic boiler, fuel oil #5</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.35 g/kg</td>
<td>g/kg</td>
<td>BCC, 1998: UK data, residual fuel oil use in industry</td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>0.09 g/kg</td>
<td>g/kg</td>
<td>1998: Australian data, fuel-oil fired power station, <strong>NMVOC</strong></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.30 g/kg</td>
<td>g/kg</td>
<td>BCC, 1998; UK data, fuel oil use in power plant</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.04 g/kg</td>
<td>g/kg</td>
<td>Rentz et al, 1998: oil-fired 200kW boiler, improved and abated, <strong>NMVOC</strong></td>
</tr>
</tbody>
</table>
### 7.4.4 PAH, benzene and toluene Emission Factors

The following table summarises the PAH, benzo(a)pyrene, benzene and toluene emission factors (and sources) for small-scale fuel oil combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>20</td>
<td>B(a)P</td>
<td>3.4</td>
<td>g/T</td>
<td>Polish data: fuel oil use in residential sector</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>22</td>
<td>B(a)P</td>
<td>22</td>
<td>g/KT</td>
<td>MSC-E, 2001: Russian data, low-capacity heat-power boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B(a)P</td>
<td>13.2</td>
<td>g/KT</td>
<td>MSC-E, 2001: Russian data, water boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B(a)P</td>
<td>4.3</td>
<td>g/KT</td>
<td>MSC-E, 2001: Russian data, heat-power boilers</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>Benzene</td>
<td>0.57</td>
<td>g/T</td>
<td>VCAPCD, 2001: combustion of #1 &amp; #2 fuel oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Toluene</td>
<td>0.57</td>
<td>g/T</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAHs</td>
<td>6.5</td>
<td>g/T</td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td>20</td>
<td>B(a)P</td>
<td>3.4</td>
<td>g/T</td>
<td>Polish data: fuel oil use in agricultural sector</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to CHP)</td>
</tr>
</tbody>
</table>

### 7.4.5 CO, NO\textsubscript{X} and SO\textsubscript{2} Emission Factors

The following table summarises the CO, NO\textsubscript{X} and SO\textsubscript{2} emission factors (and sources) for small-scale fuel oil combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>12</td>
<td>CO</td>
<td>0.7</td>
<td>g/kg</td>
<td>ERA, 2000: commercial boiler, fuel oil #1, 5% Sulphur</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO\textsubscript{X}</td>
<td>2.7</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO\textsubscript{2}</td>
<td>20</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>CO</td>
<td>0.7</td>
<td>g/kg</td>
<td>ERA, 2000: commercial boiler, fuel oil #4, 5% Sulphur</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO\textsubscript{X}</td>
<td>2.7</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO\textsubscript{2}</td>
<td>20</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>CO</td>
<td>0.7</td>
<td>g/kg</td>
<td>ERA, 2000: commercial boiler, fuel oil #5, 5% Sulphur</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO\textsubscript{X}</td>
<td>7.4</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO\textsubscript{2}</td>
<td>21</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>NO\textsubscript{X}</td>
<td>8.1</td>
<td>g/kg</td>
<td>1998: Australian data, fuel-oil fired power station</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>0.6</td>
<td>g/kg</td>
<td></td>
</tr>
</tbody>
</table>
8 Natural Gas

8.1 FUEL USE

The fuel consumption figures for every sub-sector of the small-scale combustion market in the UK clearly indicate the importance that natural gas increasingly plays in this sector. Therefore, although natural gas is typically the cleanest fuel consumed in this sector, it is of key importance that the emission factors for gas combustion in the range of appliances across this sector are as accurate as possible.

8.2 NAEI EMISSION FACTORS

The NAEI uses the following emission factors for the combustion of natural gas in the small-scale combustion sector:

<table>
<thead>
<tr>
<th>Sector</th>
<th>NOX</th>
<th>CH₄</th>
<th>VOC</th>
<th>CO</th>
<th>PM₁₀</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/th</td>
<td>kg/th</td>
<td>kg/th</td>
<td>kg/th</td>
<td>kg/th</td>
</tr>
<tr>
<td>Domestic</td>
<td>0.00485</td>
<td>0.000285</td>
<td>0.000665</td>
<td>0.00086</td>
<td>0.000326</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.00488</td>
<td>0.00038</td>
<td>0.00038</td>
<td>0.00025</td>
<td>0.000326</td>
</tr>
<tr>
<td>Public Service</td>
<td>0.00488</td>
<td>0.00038</td>
<td>0.00038</td>
<td>0.00025</td>
<td>0.000326</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0.00488</td>
<td>0.00038</td>
<td>0.00038</td>
<td>0.00025</td>
<td>0.000326</td>
</tr>
<tr>
<td>Other Industry</td>
<td>0.0095</td>
<td>0.00038</td>
<td>0.00038</td>
<td>0.00025</td>
<td>0.000326</td>
</tr>
</tbody>
</table>

A considerable amount of data and information pertaining to natural gas combustion has been considered, and the findings are summarised below.

8.3 PM₁₀ EMISSION FACTORS

The following table summarises the PM₁₀ emission factors (and sources) for small-scale natural combustion, identified during this study:-

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>PM₁₀ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>2</td>
<td>0.00005</td>
<td>Kg/th</td>
<td>IIASA, 2001: German data, uncontrolled domestic gas furnaces</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.00003</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, domestic gas use</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.0005</td>
<td>Kg/th</td>
<td>ERA, 2000: gas boiler EFs</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.00002</td>
<td>Kg/th</td>
<td>IIASA, 2001: German data, uncontrolled domestic gas boilers</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>2</td>
<td>0.00001</td>
<td>Kg/th</td>
<td>IIASA, 2001: German data, uncontrolled industrial gas boilers</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.00002</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, agricultural gas use</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
</tbody>
</table>
## 8.4 VOC EMISSION FACTORS

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>VOC EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>28</td>
<td>0.0006</td>
<td>Kg/th</td>
<td>EMEP default figure for gas fireplaces,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>NMVOC</strong></td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>28</td>
<td>0.0003</td>
<td>Kg/th</td>
<td>EMEP default figure for gas stoves,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>NMVOC</strong></td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.0007</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>domestic gas use</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.0002</td>
<td>Kg/th</td>
<td>ERA, 2000: gas boiler EFs</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.0005-0.0032</td>
<td>Kg/th</td>
<td>BCC, 1998: UK data,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>domestic gas appliances</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.0003-0.0016</td>
<td>Kg/th</td>
<td>Rentz et al, 1998: 35kW boiler,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>improved-uncontrolled, <strong>NMVOC</strong></td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>9</td>
<td>0.0005</td>
<td>Kg/th</td>
<td>BCC, 1998: UK data,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>commercial gas appliances</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.0001-0.0005</td>
<td>Kg/th</td>
<td>Rentz et al, 1998: 200 kW boiler,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>improved-uncontrolled, <strong>NMVOC</strong></td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.0032</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>agricultural gas use</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>0.0002</td>
<td>Kg/th</td>
<td>1998: Australian data, gas turbines,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>NMVOC</strong></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.00006</td>
<td>Kg/th</td>
<td>1998: Australian data, gas boilers,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>NMVOC</strong></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.0005</td>
<td>Kg/th</td>
<td>BCC, 1998: UK data,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>gas power plant</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>0.0004</td>
<td>Kg/th</td>
<td>Rentz et al, 1998: 200 kW boiler,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>improved &amp; abated, <strong>NMVOC</strong></td>
</tr>
<tr>
<td></td>
<td>0.0017</td>
<td>Kg/th</td>
<td></td>
<td>AEAT, 1998: gas CHP &lt;20 MW,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no NOx control</td>
</tr>
<tr>
<td></td>
<td>0.0001</td>
<td>Kg/th</td>
<td></td>
<td>AEAT, 1998: gas CHP &lt;20 MW,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with NOx control</td>
</tr>
<tr>
<td></td>
<td>0.0003</td>
<td>Kg/th</td>
<td></td>
<td>AEAT, 1998: gas CHP 20 - 40 MW,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no NOx control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AEAT, 1998: gas CHP 20 - 40 MW,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with NOx control</td>
</tr>
</tbody>
</table>
### 8.5 PAH, PCDD/F EMISSION FACTORS

The following table summarises the PAH, benzo(a)pyrene, benzene and PCDD/F emission factors (and sources) for small-scale gas combustion, identified during this study:

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Commercial Boiler</td>
<td>22</td>
<td>B(a)P</td>
<td>7.5</td>
<td>ug/th</td>
<td>MSC-E, 2001: Russian data, low-capacity heat-power boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B(a)P</td>
<td>3.8</td>
<td>ug/th</td>
<td>MSC-E, 2001: Russian data, water boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B(a)P</td>
<td>3.2</td>
<td>ug/th</td>
<td>MSC-E, 2001: Russian data, heat-power boilers</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>Benzene</td>
<td>240</td>
<td>ug/th</td>
<td>VCAPCD, 2001: Gas-fired commercial boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAHs</td>
<td>20</td>
<td>ug/th</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>PAH</td>
<td>13</td>
<td>ug/th</td>
<td>USEPA, 1998: conventional gas furnace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH</td>
<td>3</td>
<td>ug/th</td>
<td>USEPA, 1998: high efficiency gas furnace</td>
</tr>
<tr>
<td>Agricultural</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to these sectors)</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
### 8.6 CARBON MONOXIDE

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>CO EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>28</td>
<td>0.0021</td>
<td>Kg/th</td>
<td>EMEP default figure for gas fireplaces</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>28</td>
<td>0.0011</td>
<td>Kg/th</td>
<td>EMEP default figure for gas stoves,</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.0017</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, domestic gas use</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.0009</td>
<td>Kg/th</td>
<td>ERA, 2000: gas boiler EFs</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.0011</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, agricultural gas use</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>0.0045</td>
<td>Kg/th</td>
<td>1998: Australian data, gas turbines,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0020</td>
<td>Kg/th</td>
<td>1998: Australian data, gas boilers,</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>0.0016- 0.0044</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP &lt;20 MW, no NOX control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0125</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP &lt;20 MW, with NOX control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.0002</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP 20 – 40 MW, no NOX control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0019</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP 20 - 40 MW, with NOX control</td>
</tr>
</tbody>
</table>

### 8.7 OXIDES OF NITROGEN

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>NOₓ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>28</td>
<td>0.0053</td>
<td>Kg/th</td>
<td>EMEP default figure for gas fireplaces</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>28</td>
<td>0.0053</td>
<td>Kg/th</td>
<td>EMEP default figure for gas stoves,</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.0061</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, domestic gas use</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.0042</td>
<td>Kg/th</td>
<td>ERA, 2000: gas boiler EFs</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.0069</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, agricultural gas use</td>
</tr>
<tr>
<td>CHP</td>
<td>18</td>
<td>0.019</td>
<td>Kg/th</td>
<td>1998: Australian data, gas turbines,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.016</td>
<td>Kg/th</td>
<td>1998: Australian data, gas boilers,</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>0.01- 0.016</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP &lt;20 MW, no NOX control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0037</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP &lt;20 MW, with NOX control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.017</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP 20 – 40 MW, no NOX control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.008</td>
<td>Kg/th</td>
<td>AEAT, 1998: gas CHP 20 - 40 MW, with NOX control</td>
</tr>
</tbody>
</table>
### 8.8 OXIDES OF SULPHUR

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>REF.</th>
<th>SO$_2$ EF</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic open-fire</td>
<td>28</td>
<td>0.00005</td>
<td>Kg/th</td>
<td>EMEP default figure for gas fireplaces</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>28</td>
<td>0.00005</td>
<td>Kg/th</td>
<td>EMEP default figure for gas stoves,</td>
</tr>
<tr>
<td>Domestic boiler</td>
<td>15</td>
<td>0.00002</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, domestic gas use</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.00002</td>
<td>Kg/th</td>
<td>ERA, 2000: gas boiler EFs</td>
</tr>
<tr>
<td>Commercial boiler</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
<tr>
<td>Agricultural</td>
<td>15</td>
<td>0.00002</td>
<td>Kg/th</td>
<td>UNECE. 2002: dutch data, agricultural gas use</td>
</tr>
<tr>
<td>CHP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(no data identified specific to this sector)</td>
</tr>
</tbody>
</table>
9 Conclusions & Recommendations

9.1 OVERVIEW

The review of data and literature sources identified that the small combustion sector is a complex co-existing mix of different fuels and technologies which are also varying with time. The existing NAEI default emission factors for the sector exhibit a very limited data set. Consequently, the NAEI estimates of emissions from small combustion sources are considered to have significant areas of uncertainty.

Appendix C comprises a summary table of emission factors from sources identified within this study, and includes (for direct comparison), the equivalent factors from the USEPA AP-42 5th Edition and the NAEI 2001. The country of origin for the source of alternative emission factors is included, to give an indication of the applicability to the UK NAEI.

9.2 NAEI STRUCTURE FOR SMALL COMBUSTION SOURCES

The NAEI uses the fuel use activity statistics provided by the Digest of UK Energy Statistics (DUKES). The classifications used by DUKES cover a wide range of combustion processes and technologies, particularly for domestic combustion. However, the NAEI uses the same pollutant emission factors for several source categories. This study indicates that there is scope for improving the default emission factors in several source categories.

The NAEI contains a limited subset of emission factors and process classifications for small-scale combustion. These classifications are considered to be too broad and the necessary aggregation of emission factors is not immediately transparent. Aggregate emission factors are also of limited use for inventory users outside the NAEI.

In many instances (and in particular for domestic heating systems) further work is required to determine the relative fuel consumption between various heating technologies. For the purposes of this report, aggregated emission factors have been developed assuming equal fuel use across these technologies, but this is unlikely to be representative of the UK market.

Some progress has been made in identifying the trends regarding solid fuel use in different types of domestic appliance. The different appliances exhibit significantly different combustion profiles, and hence the assessment of the relative uses of the range of household appliances (broadly divided into: fireplaces, stoves and boilers) could be a significant source of error in the use of
NAEI data. Annual estimations for these sub-sectors of activity data are therefore recommended to provide a mechanism to calculate a more accurate emission factor that represents the whole of the domestic sector for each fuel.

Two approaches are suggested to improve estimation of small combustion plant emissions in the NAEI:

1. Expand the set of NAEI emission factors allowing a more complete mix of technologies and fuels to be represented.

2. Adopt a ‘calculator’ based approach whereby aggregate emission factors are calculated on the basis of fuel use, knowledge of the equipment ‘pool’, and the most up-to-date emission factor information. This approach allows development of the current most representative emission factor for use in the existing NAEI source classifications.

The latter approach maintains consistency with existing source classifications and would also allow a more transparent estimation of the aggregate emission factors perhaps as a separate tier to the structure of the NAEI. The separate tier or sub-inventory may be more readily modified or extended, as new information becomes available.

Expansion of the NAEI would keep all the information in a single inventory but increase the level of detail in the inventory and may make it a more unwieldy tool.

A review of the NAEI is recommended to determine the most appropriate approach.

**9.3 INVENTORY COMBUSTION DATA PRIORITIES**

**9.3.1 Ranking by Fuel Consumption**

The most significant sub-sectors for focussing of emission factor development efforts were identified as the following:-

- **Domestic Natural Gas use** – this is the largest single sub-sector of fuel consumption.

- **Domestic Burning Oil use** – the second most significant sub-sector in terms of energy use.

- **Commercial & Agricultural Burning Oil and Gas Oil use** – the most significant fuels for these sub-sectors.

**9.3.2 Ranking by Pollutant Emissions**

The most significant fuels in terms of potential pollutant release are the solid fuels particularly in a domestic open fire.
**Domestic Solid Fuel use** – steam coal, anthracite, manufactured solid fuels and wood have wide variations in their combustion properties. In addition, the lack of combustion controls or abatement on domestic-scale solid fuel space-heating sources and the variability of combustion efficiency of domestic fireplaces and stoves provides a potentially significant source of Products of IncompleteCombustion. Therefore, whilst consumption of these fuels may be much lower than gas or oil, their contributions to total emissions of species such as CO, VOC, PM$_{10}$ and PAHs may nevertheless be significant.

**Burning, Fuel and Gas Oils** – Combustion of these fuels is inherently less polluting than a solid fuel but can give rise to significant emission of PM$_{10}$, CO, VOC and other emissions.

### 9.4 AVAILABILITY AND ACCURACY OF DATA

Across the small-scale combustion sector, the amount of available emissions data for different fuels and appliances is very limited. Improvement of the existing NAEI data has been hindered by the following:-

- This study has identified very little new emission data specific to UK combustion processes, although in many cases the emissions data sourced from overseas may be considered representative of the UK.
- No comprehensive profile of UK small-scale combustion sub-sectors exist that describe fuel consumption or pollutant emissions.
- In several cases, separate research into similar combustion processes have produced pollutant emission factors that are extremely variable (over two orders of magnitude difference in some instances).
- In addition to process variations, research studies employ different measurement methodologies (application of ISO, EN or National emission measurement standards is rare), reporting units are inconsistent and uncertainty data are not available. Consequently the uncertainty of the reported measurement data is often unknown.

### 9.5 DOMESTIC COMBUSTION OF NATURAL GAS

In general, the emission factors used in the NAEI show correspond reasonably well with the emission factors gathered for this study.

<table>
<thead>
<tr>
<th>Domestic Sector</th>
<th>NO$_x$ (kg/th)</th>
<th>CH$_4$ (kg/th)</th>
<th>VOC (kg/th)</th>
<th>CO (kg/th)</th>
<th>PM$_{10}$ (kg/th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAEI</td>
<td>0.00485</td>
<td>0.000285</td>
<td>0.000665</td>
<td>0.00086</td>
<td>0.00033</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0015</td>
<td>0.00002</td>
</tr>
<tr>
<td>Comment</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>Increase</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

- The PM$_{10}$ emission factor in the NAEI is currently 0.00033 kg/th for domestic gas combustion. This is consistent with the recent report from ERA Consulting [12], but is an order of magnitude higher than dutch and german emission
factors which range from 0.00002-0.00005 kg/th. A lower factor is proposed but this anomaly warrants further investigation.

- The CO emission factor in the NAEI is currently 0.00086 kg/th for domestic gas combustion. Recent UK and European research indicate that this figure is low. Although the NAEI figure is consistent with the ERA Consulting report from 2000 [12] which determined the CO factor to be 0.0009 kg/th, Dutch data from the UNECE and EMEP-sourced emission factors range from 0.0011 to 0.0021 kg/th.

### 9.6 DOMESTIC COMBUSTION OF SOLID FUELS

<table>
<thead>
<tr>
<th>Domestic Solid Fuel Sector</th>
<th>NO\textsubscript{2}</th>
<th>VOC</th>
<th>CO</th>
<th>PM\textsubscript{10}</th>
<th>BaP</th>
<th>PCDD/F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>kg/Mt</td>
<td>g/Mt</td>
</tr>
<tr>
<td>Coal :</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>1.42</td>
<td>14</td>
<td>45</td>
<td>10.4</td>
<td>1550</td>
<td>3.04</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>5</td>
<td>9</td>
<td>190</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Comment</td>
<td>Increase</td>
<td>Decrease</td>
<td>Increase</td>
<td>No change</td>
<td>Limited data</td>
<td>Increase</td>
</tr>
<tr>
<td>Coke :</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>1.33</td>
<td>4.9</td>
<td>45</td>
<td>0.29</td>
<td>30</td>
<td>2.4</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>9</td>
<td>3</td>
<td>750</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Comment</td>
<td>Increase</td>
<td>Decrease</td>
<td>Increase</td>
<td>Increase</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Anthracite :</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>1.6</td>
<td>1.7</td>
<td>45</td>
<td>3.6</td>
<td>30</td>
<td>2.1</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>9</td>
<td>3</td>
<td>750</td>
<td>2</td>
<td>-</td>
<td>2.4</td>
</tr>
<tr>
<td>Comment</td>
<td>No emission data for anthracite in domestic furnaces – treated as coke</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSF :</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>1.32</td>
<td>4.9</td>
<td>45</td>
<td>5.6</td>
<td>330</td>
<td>2.7</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>3</td>
<td>-</td>
<td>710</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Comment</td>
<td>Increase</td>
<td>No change</td>
<td>Increase</td>
<td>Decrease</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Wood :</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>0.72</td>
<td>5.42</td>
<td>99</td>
<td>7.9</td>
<td>1300</td>
<td>0.24</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>0.8</td>
<td>7</td>
<td>50</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Comment</td>
<td>Increase</td>
<td>Increase</td>
<td>Decrease</td>
<td>Decrease</td>
<td>Limited data</td>
<td>No data</td>
</tr>
</tbody>
</table>

### 9.6.1 Coal
- The range of studies on PM\textsubscript{10} emissions from domestic coal combustion appliances illustrate that results from open fire burning are extremely variable, but that the current NAEI figure of 10.4 g/kg is consistent with the average figure determined by recent trials.

In contrast, studies from across the UK and Europe indicate that the burning
of coal in closed stoves and domestic boilers is a more uniform process with significantly less variability on emission factors determined. On the whole, the emission factors for stoves and boilers are consistently found to be 3–6 g/kg. The current NAEI figure is therefore not representative of these types of appliance.

Further information on the types of fire in use is required to develop an improved aggregate PM$_{10}$ emission factor.

- The current NAEI NO$_x$ emission factor of 1.42 g/kg, is lower than data collated from UK and European sources which indicate that NO$_x$ values of 2–8 g/kg are characteristic for residential coal use. An increase in the default emission factor to 5 g NO$_2$ per kg is proposed. However, as for PM$_{10}$, a clearer picture of the use of coal across open fires, closed stoves and boilers would improve the estimate of the NO$_x$ figure.

- There is relatively little consistent data regarding CO emissions from domestic coal combustion sources however, the available suggest an increase in the aggregate factor to 190 g/kg.

- The emission of VOC from combustion sources often shows similar variation to CO and it is surprising to find that the VOC data are less variable than the CO data. Although there are limits to the VOC data (the definitions and expression are inconsistent) the data sources indicate a decrease in the aggregate emission factor.

- Emission factors for VOC and CO for domestic coal combustion are considered to have a particularly high uncertainty.

- The emission data suggest an increase in the aggregate dioxins emission factor is required.

### 9.6.2 Coke, Anthracite

- No data were obtained for anthracite combustion and netcen has assumed similar combustion properties to coke.

- A UK-focused study into domestic coal burning [13] reported PM$_{10}$ emission factors for the burning of coke in the domestic sector both on open fires and in closed appliances. This study shows PM$_{10}$ emissions from coke burning on domestic fires (both for open appliances and closed stoves) to be substantially higher than that currently used in the NAEI. It is therefore recommended that the PM$_{10}$ emission factors from domestic coke combustion in the NAEI be increased to 2 kg/tonne.

- An increase in the NO$_x$ emission factor is also proposed based on factors of 7 and 11 g NO$_2$ per kg reported by CRE and UNECE for coke stove and domestic boiler respectively. However, no information was found for open fires and the proposed factor may overestimate emissions from domestic open fires.
• The CRE and UNECE studies reported CO emission factors very much higher than the NAEI default factor and a higher aggregate emission factor of 750 g/kg is proposed. This is a similar order of magnitude as the aggregate factor for coal combustion, and is the mean factor derived from a very wide array of reported factors from sources identified (ranging from 120 to 1200 g/kg).

• No emission data were obtained for dioxins and Benz(a)pyrene for domestic coke or anthracite combustion.

• A decrease in the VOC emission factor for Coke is proposed but application of the same factor to Anthracite results in an increase in the aggregated factor.

9.6.3 Manufactured Solid Fuels

• A reduction of the PM$_{10}$ emission factor is proposed which is consistent with the application of these fuels as smokeless fuels. A number of sources report consistent factors of around 1 g/kg.

• An increase in the NO$_x$ emission factor is also suggested based on reported factors but the increase is not consistent with the increase in factors reported for Coke.

• The reported CO emission factors were extremely variable and did not include combustion on an open fire. Nonetheless the aggregate CO emission factor is still over an order of magnitude higher than the NAEI default factor. The aggregate factor is consistent with the other proposed aggregate emission factor for coal and coke.

• No emission data were obtained for dioxins and Benz(a)pyrene for domestic combustion of manufactured solid fuel.

• Regarding VOC emission factors for MSF use, only a single swedish source provided any additional data relevant to the UK market, quoting a range of figures from 0.3-7.7 g/kg. As this is consistent with the current NAEI figure of 4.9 g/kg, no alteration is recommended.

9.6.4 Wood

• Wood combustion emission data is generally based on US or Norwegian emission surveys and may not be applicable to UK domestic combustion practise and UK supply of wood fuel.

• From the data obtained, a reduction of the PM$_{10}$ emission factor to around 3 g/kg is recommended. Whilst the current NAEI figure is consistent with UK data for wood burning on open fires, all other UK and european-sourced data provides lower PM$_{10}$ figures, particularly for wood burning on closed stoves and in boilers.
• A very minor increase in the $\text{NO}_x$ emission factor is also suggested based on reported factors ranging from 0.3 to 1.0 g/kg.

• The reported $\text{CO}$ emission factors were surprisingly consistent across the various combustion appliances and indicate a reduction in the aggregate emission factor.

• The reported $\text{VOC}$ emission factors were also quite consistent across the various combustion appliances, ranging from 1 to 17.5 g/kg. An aggregate emission factor of 7 g/kg is recommended from the UK, Norwegian and German data sourced in this study.

• No emission data were obtained for dioxins. PAH and Benz(a)pyrene data are published but are limited and are not expressed consistently. Consequently no change is proposed to the current default factors however, a more detailed review of the source data could provide data.

9.7 COMBUSTION OF OILS

9.7.1 Burning oil

<table>
<thead>
<tr>
<th>Activity</th>
<th>$\text{NO}_x$</th>
<th>$\text{VOC}$</th>
<th>$\text{CO}$</th>
<th>$\text{PM}_{10}$</th>
<th>$\text{BaP}$</th>
<th>$\text{PCDD/F}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>kg/Mt</td>
<td>g TEQ/Mt</td>
</tr>
<tr>
<td>Domestic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>2.21</td>
<td>0.133</td>
<td>0.16</td>
<td>0.014</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>2.31</td>
<td>0.5</td>
<td>1.8</td>
<td>0.34</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
<td>Corinair small-scale combustion default</td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>2.84</td>
<td>0.086</td>
<td>0.16</td>
<td>0.014</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>-</td>
<td>0.14</td>
<td>-</td>
<td>0.08</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>No data</td>
<td>Increase</td>
<td>No data</td>
<td>Increase</td>
<td>Corinair small-scale combustion default</td>
<td></td>
</tr>
<tr>
<td>Commercial/Industrial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>2.84</td>
<td>0.086</td>
<td>0.16</td>
<td>0.014</td>
<td>-</td>
<td>4.3</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>-</td>
<td>0.14</td>
<td>-</td>
<td>0.08</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>Proposed factors for Public, Institutional boilers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>2.31</td>
<td>0.46</td>
<td>0.46</td>
<td>0.21</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>Dutch data</td>
<td></td>
<td></td>
<td></td>
<td>Corinair small-scale combustion default</td>
<td></td>
</tr>
</tbody>
</table>

For the domestic sector:-

• A single dutch figure of 2.31 g/kg was sourced for $\text{NO}_x$ emissions.
Sources of UK, Dutch and German data were found to be very consistent for \textbf{VOC} emissions, and an aggregate factor of 0.5 g/kg is recommended.

Limited data was identified regarding \textbf{CO} emissions. The aggregate from Dutch and American sources provides the figure of 1.8 g/kg.

An aggregate figure of 0.34 g/kg derived from Dutch, German and American sources is recommended for \textbf{PM}_{10} emissions for domestic combustion of burning oil.

For the public & commercial / industrial sectors, only limited data from German sources was obtained pertaining to \textbf{VOC} and \textbf{PM}_{10} emission factors, and in both cases these data suggest that the current NAEI figure ought to be increased slightly.

No factors currently exist in the NAEI for agricultural burning oil combustion. A single source of Dutch data was identified, and emission factors from this source are proposed for each pollutant.

\textbf{9.7.2 Other oils :}

Note that almost all of the source data summarised in the following table are actually for heavier fuel oils. The applicability to gas oil is not known. Combustion conditions are broadly comparable but the fuel characteristics are very different.

Very little information has been sourced pertaining precisely to gas oil use, but many factors from fuel oil are estimated to be representative of gas oil use.

- Emission factor data for fuel oil use across all sectors would suggest that a figure of 1 g/kg may be a reliable estimate for a \textbf{PM}_{10} emission factor gas oil use.

- UK & AP-42 \textbf{VOC} emission factor data for fuel oil use across all sectors would suggest that figures of around 0.2 g/kg (Public, commercial and industrial sectors) and 0.1 g/kg (agricultural and CHP) may be reliable estimates for gas oil use.

- UK & AP-42 \textbf{CO} data for fuel oil use across all sectors would suggest that figures of around 0.7 g/kg may be a more reliable estimate for gas oil use than the current NAEI estimate.
### Table

<table>
<thead>
<tr>
<th>Activity</th>
<th>NO\textsubscript{X}</th>
<th>VOC</th>
<th>CO</th>
<th>PM\textsubscript{10}</th>
<th>BaP</th>
<th>PCDD/F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>g/kg</td>
<td>kg/Mt</td>
<td>g TEQ/Mt</td>
</tr>
<tr>
<td>Domestic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI (gas oil)</td>
<td>2.16</td>
<td>0.13</td>
<td>0.24</td>
<td>0.25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NAEI (fuel oil)</td>
<td>7.0</td>
<td>0.13</td>
<td>0.5</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>-</td>
<td>0.4</td>
<td>-</td>
<td>1.4</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>No data</td>
<td>Increase</td>
<td>No data</td>
<td>Increase</td>
<td>Corinair small-scale combustion default</td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI (gas oil)</td>
<td>2.84</td>
<td>0.086</td>
<td>0.24</td>
<td>0.25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NAEI (fuel oil)</td>
<td>7.0</td>
<td>0.12</td>
<td>0.5</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>6</td>
<td>0.2</td>
<td>0.7</td>
<td>1</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>Decrease</td>
<td>Increase</td>
<td>Increase</td>
<td>No change</td>
<td>Corinair small-scale combustion default</td>
<td></td>
</tr>
<tr>
<td>Commercial/Industrial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI (gas oil)</td>
<td>3.46</td>
<td>0.086</td>
<td>0.24</td>
<td>0.25</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>NAEI (fuel oil)</td>
<td>7.5</td>
<td>0.12</td>
<td>0.5</td>
<td>1.0</td>
<td>4.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>4.3</td>
<td>0.12</td>
<td>0.7</td>
<td>0.7</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>Decrease</td>
<td>No change</td>
<td>Increase</td>
<td>Decrease</td>
<td>Corinair small-scale combustion default</td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAEI (gas oil)</td>
<td>2.84</td>
<td>0.13</td>
<td>0.71</td>
<td>0.25</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>NAEI (Fuel oil)</td>
<td>7.0</td>
<td>0.12</td>
<td>0.5</td>
<td>1.0</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Proposed factor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Comment</td>
<td>No data</td>
<td>Polish data</td>
<td>Corinair default</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 9.7.3 Domestic and Public & Commercial Combustion of LPG

Apart from VOC emissions, no UK-focussed research has been identified pertaining to LPG combustion. This fuel only accounts for 1.7% of total GWh production across the small-scale combustion sector, however, and with the exception of VOC, is likely to demonstrate emissions similar to those of natural gas.

In the absence of source data, the emission factors proposed for natural gas provide a sound estimate.

### 9.8 OTHER AREAS RECOMMENDED FOR FURTHER STUDY

Areas of uncertainty that warrant more investigation including:

- **Activity data** – Significant disparity in UK coal consumption is evident between the DUKES data and industry-sourced figures. There may be an end-
user group as yet unrepresented, or mis-represented, within the current NAEI data.

- **CHP technology** – This study has identified that there are four or five main technological options for small-scale CHP installations. Although technology based on gas-fired gas turbines has the greatest share of the market; other fuels and technologies also make a significant contribution to CHP generation and may exhibit very different emission profiles. A greater understanding of the variability of emissions from these CHP technologies would be a significant step in improving the quality of NAEI data for this growing sector.

A potential source of emission data research on small-scale combustion (and other sources) is via the national programmes of other countries and co-operative international emission inventory work programmes at UN ECE or EU level. Emissions from residential and other small-scale combustion sources are a common area of concern; it is known that work is being undertaken in several EU member States and the EC’s Joint Research Centre, Emissions and Health Unit, has in place a work programme to co-ordinate this activity and encourage the exchange of information.

However, emission data from sources outside the UK are of little use to development of the NAEI if the source measurements are for combustion technologies or fuels which are not employed in the UK. To improve inventory uncertainty emission data should, wherever possible, be obtained from accredited test houses using recognised test protocols (for example EN or ISO Standards).

### 9.9 IMPACT OF RESEARCH ON INVENTORY QUALITY

The research detailed in this report is the first stage of a process of improvement of a major source of air pollution - small combustion plant. At this stage it is not possible to quantify exactly how much emission estimates will change as a result of this work since much remains to be done, either extending the level of detail in the NAEI or producing an ‘emissions calculator’. The approaches recommended in this report could also be extended to medium sized combustion plant i.e. plant upto 50MWth in size leading to further, as yet, unquantified improvements in inventory quality. This would also help to improve estimates for large combustion plant since, if these plant were treated separately in the NAEI, then emissions data for these plant, reported by the Environment Agency, Scottish Environment Protection Agency and DOE (Northern Ireland) could be used as the basis of estimates for these sites. The work started with this report could have far-reaching and significant impacts on the quality of the NAEI.

For the moment, some indication of the scale of change in the NAEI that might occur as a result of this process, can be derived by examining the change in emission totals that would occur if emissions from small combustion were estimated using emission factors recommended in this report rather than current NAEI emission factors.
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Change</th>
<th>National total</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>+ 1303 ktonnes</td>
<td>3758 ktonnes</td>
<td>+35%</td>
</tr>
<tr>
<td>Oxides of nitrogen</td>
<td>+17 ktonnes</td>
<td>1681 ktonnes</td>
<td>+1%</td>
</tr>
<tr>
<td>VOC</td>
<td>- 3 ktonnes</td>
<td>1514 ktonnes</td>
<td>0%</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>- 12 ktonnes</td>
<td>191 ktonnes</td>
<td>-6%</td>
</tr>
<tr>
<td>B[a]P</td>
<td>+ 0.02 tonnes</td>
<td>10.47 tonnes</td>
<td>0%</td>
</tr>
<tr>
<td>Dioxins</td>
<td>- 9 grammes</td>
<td>357 grammes</td>
<td>-2%</td>
</tr>
</tbody>
</table>

The changes shown in this table are based on a simple substitution of one set of emission factors for another, rather than the radical overhaul of the estimation methodology used in the NAEI for combustion sources that has been recommended here. The figures given can therefore only be a guide but suggest that, for certain pollutants such as carbon monoxide and PM$_{10}$ and, to a lesser extent NOx and dioxins, this research could lead to major changes in national emission totals.
10 References

1 UK NAEI 2001
2 "Fuel Combustion in stationary sources" IIASA,
3 "Digest of UK Energy Statistics", DTI, 2002
4 "UK Emissions Inventory, Solid Fuel", personal communication from the UK Solid Fuel Association, March 2003
5 "Source Apportionment of Airborne Particulate in the UK", APEG, 1999
7 UK Domestic heating market report 2001, AMA Research
8 "Market Review & Prospects" CHPA 2001
10 "Determination of Atmos. Pollutant Efs at a small coal-fired heating boiler", for Defra, by AEAT (Collings et al), 2001
11 "Review of wood heater & Fireplace Efs", OMNI, (Houck et al) 2001?
13 "PM10 Efs for domestic solid fuels", CRE for Belfast CC (Briggs et al), 1997
14 "Report on...Efs...for a range of pollutants...during combustion of solid fues on an open fire", CPL (Perry et al), 2002
15 "Emissions from Small & Medium Combustion Plants" UNECE TFEIP Workshop (Dilara et al), 2002
16 "Residential Combustion Plants", Karlsruhe University (Rentz et al), 1998
17 "Prelim report: Emission factor measurements at Cottam Power Station", WSL (Coleman et al), 1993
18 "Air Toxic Efs for Combustion Sources using petroleum-based fuels" WSPA & API (Hansell et al), 1998
20 "Polish Efs: BaP" POPS Inventory
21 "Additions & refinements to the EMEP/CORINAIR Emission Inventory...", NAS Belarus (Kakareka et al), 2003
22 "PAH Emission Inventories & Emission expert Estimates" MSC-E (Tsibulsky et al), 2001
24 "Greenhouse Gases from small-scale combustion in developing countries" USEPA National Risk Mgmt, 2000
25 "Determination of Atmos. Pollutant Efs at a small industrial wood-burning furnace", for Defra, by AEAT (Collings et al), 2001
27 "AB 2588 Combustion Emission Factors" VCAPCD 2001
28 "Emission Inventory Guidebook - Small Combustion Sources: Update" (Kakareka et al) 2003
29 "A survey of Gaseous emissions to atmosphere from UK Gas Turbines", AEAT (Stewart), 1998

Further information sources:
USEPA AP-42, 5th Edition,
"L&LE Air Emissions fromSources of Benzene" USEPA, 1998
European Dioxin Inventory, 2002
"Residential Wood Combustion - PM2.5 Emissions" WESTAR EI Workshop (Houck et al), 1998
"ARB Emission Inventory, 7.1: Residential Wood Combustion" www.arb.ca.gov, 1997
"Residential Wood Combustion in Europe" TPS&RIT (Nykoping et al) 1998
Appendices

CONTENTS

Appendix A  Fuel Consumption by Sector
Appendix B  Summary of Emission Factors and Information Sources, sorted by Fuel
Appendix C  Summary of Recommended Emission Factors, sorted by Fuel and Sub-Sector
Appendix A

Fuel Consumption by Sector
Table A1: Total GWh consumption of fuels by sector (2001: DUKES figures)

<table>
<thead>
<tr>
<th></th>
<th>Domestic</th>
<th>Public</th>
<th>Commercial</th>
<th>Industry</th>
<th>PC&amp;I</th>
<th>Agriculture</th>
<th>Miscellaneous</th>
<th>Total (fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam coal</td>
<td>12138</td>
<td>1071</td>
<td>51</td>
<td></td>
<td>1122</td>
<td>43</td>
<td>86</td>
<td>13389</td>
</tr>
<tr>
<td>Anthracite</td>
<td>9142</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9142</td>
</tr>
<tr>
<td>Manufacture Solid fuel</td>
<td>4069</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4069</td>
</tr>
<tr>
<td>Wood</td>
<td>2373</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2373</td>
</tr>
<tr>
<td>Renewables</td>
<td>0</td>
<td>0</td>
<td>1396</td>
<td></td>
<td>1396</td>
<td>837</td>
<td>0</td>
<td>2233</td>
</tr>
<tr>
<td>Propane</td>
<td>3514</td>
<td>0</td>
<td>5250</td>
<td>2736</td>
<td>7986</td>
<td>1514</td>
<td>0</td>
<td>13014</td>
</tr>
<tr>
<td>Butane</td>
<td>876</td>
<td>0</td>
<td>849</td>
<td>849</td>
<td>1698</td>
<td>14</td>
<td>0</td>
<td>2588</td>
</tr>
<tr>
<td>Kerosene</td>
<td>34974</td>
<td>158</td>
<td>0</td>
<td>20617</td>
<td>20775</td>
<td>158</td>
<td>0</td>
<td>55907</td>
</tr>
<tr>
<td>Gas oil</td>
<td>2387</td>
<td>8338</td>
<td>4973</td>
<td>24202</td>
<td>129166</td>
<td>5542</td>
<td>1348</td>
<td>22588</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>71</td>
<td>475</td>
<td>403</td>
<td></td>
<td>878</td>
<td>131</td>
<td>214</td>
<td>1294</td>
</tr>
<tr>
<td>Natural gas</td>
<td>379200</td>
<td>45500</td>
<td>36500</td>
<td></td>
<td>82000</td>
<td>1300</td>
<td>28200</td>
<td>490700</td>
</tr>
<tr>
<td>Total (sector)</td>
<td>448744</td>
<td>55542</td>
<td>49422</td>
<td>24202</td>
<td>129166</td>
<td>9539</td>
<td>29848</td>
<td>617297</td>
</tr>
</tbody>
</table>

Table A2: Sector distribution of fuel consumption as percentage of total consumption in small combustion sector

<table>
<thead>
<tr>
<th></th>
<th>Domestic</th>
<th>PCI</th>
<th>Agriculture</th>
<th>Miscellaneous</th>
<th>Total (fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam coal</td>
<td>2.0</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Anthracite</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Manufacture Solid fuel</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Wood</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Renewables</td>
<td>0.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Propane</td>
<td>0.6</td>
<td>1.3</td>
<td>0.2</td>
<td>0.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Butane</td>
<td>0.1</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Kerosene</td>
<td>5.7</td>
<td>3.4</td>
<td>0.0</td>
<td>0.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Gas oil</td>
<td>0.4</td>
<td>2.2</td>
<td>0.9</td>
<td>0.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Natural gas</td>
<td>61.4</td>
<td>13.3</td>
<td>0.2</td>
<td>4.6</td>
<td>79.5</td>
</tr>
<tr>
<td>Total (sector)</td>
<td>72.7</td>
<td>20.9</td>
<td>1.5</td>
<td>4.8</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table A3: Sectoral Summaries of fuel consumption, as % of total sector consumption in GWh

<table>
<thead>
<tr>
<th></th>
<th>Domestic %</th>
<th>Public, Commercial, Industrial %</th>
<th>Agriculture %</th>
<th>Misc %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam coal</td>
<td>12138</td>
<td>1122</td>
<td>43</td>
<td>85</td>
</tr>
<tr>
<td>Anthracite</td>
<td>9142</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Manufacture Solid fuel</td>
<td>4069</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wood</td>
<td>2373</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Renewables</td>
<td>3514</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Propane</td>
<td>876</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Butane</td>
<td>34974</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kerosene</td>
<td>2387</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gas oil</td>
<td>71</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Natural gas</td>
<td>379200</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total (sector)</td>
<td>448744</td>
<td>129166</td>
<td>9539</td>
<td>28848</td>
</tr>
</tbody>
</table>
Appendix B

Summary of Emission Factors and Information Sources, sorted by Fuel
### Table B1: Summary of Source Reference Documents for EF Information

<table>
<thead>
<tr>
<th>FUEL =&gt;</th>
<th>Coal</th>
<th>Gas</th>
<th>Burning Oil &amp; Gas Oil</th>
<th>Fuel Oils</th>
<th>Wood</th>
<th>SSF</th>
<th>Renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMBUSTION UNIT TYPE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Open Fire</td>
<td>5, 6, 7, 18 (11, )</td>
<td>7, 11, 14</td>
<td>14</td>
<td>29</td>
<td>5, 7, 9, 11 (12, 26 )</td>
<td>6, 7, 11 29</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>21, 28, 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>6, 7, 11, 18 (4, 5 )</td>
<td>7, 11, 14 27</td>
<td>11</td>
<td>14, 18, 27 (11,29 )</td>
<td>7, 9, 11</td>
<td>5, 12, 26</td>
<td>6, 7, 11 28</td>
</tr>
<tr>
<td></td>
<td>21, 28, 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>4, 7, 11 (5, 6 )</td>
<td>7, 11, 14 16, 18, 27</td>
<td>11</td>
<td>14, 16, 18 (11, 29 )</td>
<td>7, 9, 11, 12 (5, 17 )</td>
<td>6, 7, 11</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>16, 18 21, 28, 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small commercial or institutional boiler</td>
<td>4, 7, 11 (5, 6 )</td>
<td>7, 11, 14 16, 18, 27</td>
<td>11</td>
<td>14, 16, 18 (11, 29 )</td>
<td>7, 9, 11, 12 (5, 17 )</td>
<td>6, 7, 11</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>16, 18 21, 28, 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural Heater</td>
<td>4, 7, 11 (5, 6 )</td>
<td>7, 11, 14 16, 18</td>
<td>11</td>
<td>14, 16, 18 (11, 29 )</td>
<td>7, 9, 12 ,5, 17+Q41</td>
<td>6, 7, 18</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>16, 18, 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td>11, 13, 16 (10, )</td>
<td>11, 13, 14 16, 18</td>
<td>11</td>
<td>13, 14, 16</td>
<td>16, 18</td>
<td>6, 7</td>
<td></td>
</tr>
</tbody>
</table>

- a) steam turbine (ST)
- b) gas turbine (GT)
- c) comb. Cycle (CC)
- d) recipr. Engine (RE)
- e) condensing ST (CST)
<table>
<thead>
<tr>
<th>COMBUSTION UNIT TYPE</th>
<th>FUEL</th>
<th>Coal</th>
<th>Gas</th>
<th>Propane</th>
<th>Butane</th>
<th>Burning Oil</th>
<th>Gas Oil</th>
<th>Fuel Oils</th>
<th>Wood</th>
<th>SSF</th>
<th>Renewable</th>
<th>Other CHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total domestic</td>
<td></td>
<td>250000 tonnes</td>
<td>2157.3 GWh</td>
<td>1514 GWh</td>
<td>3614 GWh</td>
<td>3697.4 GWh</td>
<td>2396.8 GWh</td>
<td>60000 tonnes</td>
<td>1075000 tonnes</td>
<td>2090000 tonnes</td>
<td>513000 tonnes</td>
<td>1200000 tonnes</td>
</tr>
<tr>
<td>Small commercial or institutional boiler</td>
<td>130000 tonnes</td>
<td>5 % coal</td>
<td>379000 tonnes</td>
<td>62000 tonnes</td>
<td>12000 tonnes</td>
<td>190000 tonnes</td>
<td>204000 tonnes</td>
<td>60000 tonnes</td>
<td>253 GWh</td>
<td>1366 GWh</td>
<td>1200000 tonnes</td>
<td>1600000 tonnes</td>
</tr>
<tr>
<td>Industry Space Heating</td>
<td>0 tonnes</td>
<td>0.3 % gas</td>
<td>157000 tonnes</td>
<td>2796 GWh</td>
<td>949 GWh</td>
<td>3184000 tonnes</td>
<td>41841 GWh</td>
<td>740000 tonnes</td>
<td>8816 GWh</td>
<td>720000 tonnes</td>
<td>1200000 tonnes</td>
<td>1596 GWh</td>
</tr>
<tr>
<td>Agricultural Heater</td>
<td>0 %</td>
<td>3 % gas</td>
<td>150000 tonnes</td>
<td>1514 GWh</td>
<td>25 GWh</td>
<td>4480000 tonnes</td>
<td>5542 GWh</td>
<td>110000 tonnes</td>
<td>131 GWh</td>
<td>2224 GWh</td>
<td>36705 GWh</td>
<td>637 GWh</td>
</tr>
<tr>
<td>CHP</td>
<td>7256 GWh</td>
<td>66894 GWh</td>
<td>1300 GWh</td>
<td>1300 GWh</td>
<td>1514 GWh</td>
<td>2224 GWh</td>
<td>456 GWh</td>
<td>247 GWh</td>
<td>9866 GWh</td>
<td>7 %</td>
<td>2 %</td>
<td>0 %</td>
</tr>
<tr>
<td>SECTOR</td>
<td>REF</td>
<td>Comments</td>
<td>Substance</td>
<td>EF</td>
<td>Units</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----</td>
<td>---------------------------------------------------------------------------</td>
<td>-----------</td>
<td>----</td>
<td>---------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Open Fire</td>
<td>6</td>
<td>CRE PM10 research: open fire, &lt; 10 kW, household coal (bit)</td>
<td>PM10</td>
<td>9</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>CRE PM10 research: open fire, &lt; 10 kW, texan star coal (bit)</td>
<td>PM10</td>
<td>11</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5 kW, yorkshire housecoal (bit)</td>
<td>PCDDs</td>
<td>0.72</td>
<td>gTEQ/MT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5 kW, yorkshire housecoal (bit)</td>
<td>PCDFs</td>
<td>2.2</td>
<td>gTEQ/MT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5 kW, yorkshire housecoal (bit)</td>
<td>PCBs</td>
<td>6.1</td>
<td>gTEQ/MT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5 kW, yorkshire housecoal (bit)</td>
<td>PCNs</td>
<td>0.68</td>
<td>kg/MT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5 kW, yorkshire housecoal (bit)</td>
<td>PM10</td>
<td>0.254</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5 kW, yorkshire housecoal (bit)</td>
<td>PM10</td>
<td>40.4</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: domestic open grate, bituminous coal</td>
<td>NMVOC</td>
<td>14</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: domestic open grate, bituminous coal</td>
<td>CH4</td>
<td>15.7</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>11</td>
<td>UNECE TFEIP: Dutch data for domestic coal use</td>
<td>VOC</td>
<td>60</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Dutch data for domestic coal use</td>
<td>SO2</td>
<td>420</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Dutch data for domestic coal use</td>
<td>NOx</td>
<td>75</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Dutch data for domestic coal use</td>
<td>CO</td>
<td>1500</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Dutch data for domestic coal use</td>
<td>PM10</td>
<td>120</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, anthracite, medium burn rate</td>
<td>CO</td>
<td>709</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, anthracite, medium burn rate</td>
<td>SO2</td>
<td>104</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, anthracite, medium burn rate</td>
<td>NOX</td>
<td>8</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic coal furnace</td>
<td>PM10</td>
<td>110</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>11</td>
<td>UNECE TFEIP: Polish figs for various coals in 50kW and 150kW stoves, CO, SO2, NO2, VOC, PAHs, PCDD/Fs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler EfTs, bituminous coal</td>
<td>CO</td>
<td>1.8</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler EfTs, bituminous coal</td>
<td>NOx</td>
<td>6.2</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler EfTs, bituminous coal</td>
<td>PM10</td>
<td>6</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>16</td>
<td>ERA research: Boiler EfTs, bituminous coal</td>
<td>SOx</td>
<td>17.2</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler EfTs, bituminous coal</td>
<td>VOC</td>
<td>0.02</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: 17 kW underfeed, bituminous coal</td>
<td>NMVOC</td>
<td>0.61</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: 17 kW underfeed, bituminous coal</td>
<td>CH4</td>
<td>0.43</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: 13 kW gravity feed, anthracite</td>
<td>NMVOC</td>
<td>1.7</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: 13 kW gravity feed, anthracite</td>
<td>CH4</td>
<td>2</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: hard coal, 35 (0-120) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>195</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: hard coal, 35 (0-120) kW boiler, improved</td>
<td>NMVOC</td>
<td>40</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: brown coal, 35 (0-120) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>380</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: brown coal, 35 (0-120) kW boiler, improved</td>
<td>NMVOC</td>
<td>76</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small commercial or institutional boiler</td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic coal boilers</td>
<td>PM10</td>
<td>90</td>
<td>g/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>Poland: residential use of hard coal</td>
<td>BaP</td>
<td>1.5</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>Poland: residential use of brown coal</td>
<td>BaP</td>
<td>0.9</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale coal combustion</td>
<td>PCDD/Fs</td>
<td>1.25</td>
<td>gTEQ/MT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale coal combustion</td>
<td>BaP</td>
<td>0.6-2.0</td>
<td>g/1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Russian POPs data: residential</td>
<td>BaP</td>
<td>0.1</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>MSC-E research: russian low capacity heat-power boilers</td>
<td>BaP</td>
<td>13.56</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>MSC-E research: russian heat-power boilers</td>
<td>BaP</td>
<td>9.2</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>AEAT research: bituminous coal-fired boiler, rated 500kW</td>
<td>BaP</td>
<td>2.3</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>AEAT research: bituminous coal-fired boiler, rated 500kW</td>
<td>benzene</td>
<td>&lt;0.01</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>AEAT research: bituminous coal-fired boiler, rated 500kW</td>
<td>CO</td>
<td>10</td>
<td>kg/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>AEAT research: bituminous coal-fired boiler, rated 500kW</td>
<td>PCDD/Fs</td>
<td>51</td>
<td>gTEQ/MT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>AEAT research: bituminous coal-fired boiler, rated 500kW</td>
<td>PAHs</td>
<td>1650</td>
<td>ug/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: 0.9 - 48 MW boilers, bituminous coal</td>
<td>NMVOC</td>
<td>0.05</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: 0.9 - 48 MW boilers, bituminous coal</td>
<td>CH4</td>
<td>0.01</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

34 Rentz et al: hard coal, 200 (120-300) kW boiler, benchmark
34 Rentz et al: hard coal, 200 (120-300) kW boiler, improved
34 Rentz et al: brown coal, 200 (120-300) kW boiler, benchmark
<table>
<thead>
<tr>
<th>SECTOR</th>
<th>REF</th>
<th>Comments</th>
<th>Substance</th>
<th>EF</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Open Fire</td>
<td>6</td>
<td>CRE research: open fire, &lt; 10 kW, smokeless coal brands</td>
<td>PM10</td>
<td>0.9 - 1.6</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>CRE PM10 research: open fire, &lt; 10 kW, pet coke blends</td>
<td>PM10</td>
<td>2.3 - 2.8</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: domestic coke use</td>
<td>VOC</td>
<td>5.0 - 20</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.15-0.60</td>
</tr>
<tr>
<td>Domestic Closed Stove</td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, charcoal</td>
<td>CO</td>
<td>275</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, charcoal</td>
<td>TNMOC</td>
<td>10.5</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, charcoal</td>
<td>TSP</td>
<td>2.4</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, charcoal</td>
<td>CO</td>
<td>121</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, charcoal</td>
<td>TNMOC</td>
<td>16.1</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, charcoal</td>
<td>TSP</td>
<td>2.9</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>CRE research: closed stove, &lt; 10 kW, smokeless coal brands</td>
<td>PM10</td>
<td>1.0 - 1.2</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>CRE PM10 research: closed stove, &lt; 10 kW, pet coke blends</td>
<td>PM10</td>
<td>2.6 - 3.2</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, coke, medium burn rate</td>
<td>CO</td>
<td>1125</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, coke, medium burn rate</td>
<td>SO2</td>
<td>127</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, coke, medium burn rate</td>
<td>NOX</td>
<td>7</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, manuf briq, medium burn rate</td>
<td>CO</td>
<td>1193</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, manuf briq, medium burn rate</td>
<td>SO2</td>
<td>75</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>CRE: Uk 12.5 kW roomheater, manuf briq, medium burn rate</td>
<td>NOX</td>
<td>4</td>
<td>g/kg</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>11</td>
<td>UNECE TFEIP: dutch figures for coke use</td>
<td>VOC</td>
<td>91</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch figures for coke use</td>
<td>SO2</td>
<td>371</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch figures for coke use</td>
<td>NOX</td>
<td>382</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch figures for coke use</td>
<td>CO</td>
<td>12400</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch figures for coke use</td>
<td>PM10</td>
<td>6</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 3-6 kW</td>
<td>TSP</td>
<td>15-65</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 3-6 kW</td>
<td>THC</td>
<td>10-250</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5-2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.3-7.7</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 1.8-2 MW</td>
<td>NOX</td>
<td>64-73</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 1.8-2 MW</td>
<td>TSP</td>
<td>32-43</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 1.8-2 MW</td>
<td>THC</td>
<td>0.050</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 1.8-2 MW</td>
<td>NOX</td>
<td>17-37</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, pellet boilers 1.8-2 MW</td>
<td>CO</td>
<td>140-7400</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: coke, 35 (0-120) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>220</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: coke, 35 (0-120) kW boiler, improved</td>
<td>NMVOC</td>
<td>44</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.3</td>
</tr>
<tr>
<td>Small Commercial or Institutional Boiler</td>
<td>11</td>
<td>UNECE TFEIP: sweden, briquette boilers 1.8-2 MW</td>
<td>TSP</td>
<td>36</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, briquette boilers 1.8-2 MW</td>
<td>THC</td>
<td>2</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, briquette boilers 1.8-2 MW</td>
<td>NOX</td>
<td>35</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: sweden, briquette boilers 1.8-2 MW</td>
<td>CO</td>
<td>270</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: industrial coke use</td>
<td>VOC</td>
<td>1.0 - 30</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.03-0.9</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: coke, 200 (120-300) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>30</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: coke, 200 (120-300) kW boiler, improved</td>
<td>NMVOC</td>
<td>6</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.2</td>
</tr>
</tbody>
</table>

- **Agricultural Heater**
  - (none)

- **CHP**
  - a) steam turbine (ST)
  - b) gas turbine (GT)
  - c) comb. Cycle (CC)
  - d) recipr. Engine (RE)
  - e) condensing ST (CST)
Table B5: GAS EF Info Summary

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>REF</th>
<th>Comments</th>
<th>Substance</th>
<th>EF</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Domestic Open Fire</strong></td>
<td>30</td>
<td>EMEP default factors for gas use in fireplaces</td>
<td>SO2</td>
<td>0.5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in fireplaces</td>
<td>NOX</td>
<td>50</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in fireplaces</td>
<td>PCDD/Fs</td>
<td>0.025</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in fireplaces</td>
<td>CO</td>
<td>20</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in fireplaces</td>
<td>NM VOC</td>
<td>6</td>
<td>g/GJ</td>
</tr>
<tr>
<td><strong>Domestic closed stove</strong></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic gas “furnaces”</td>
<td>PM10</td>
<td>0.5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in stoves</td>
<td>SO2</td>
<td>0.5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in stoves</td>
<td>NOX</td>
<td>50</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in stoves</td>
<td>PCDD/Fs</td>
<td>2</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in stoves</td>
<td>CO</td>
<td>10</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in stoves</td>
<td>NM VOC</td>
<td>3</td>
<td>g/GJ</td>
</tr>
<tr>
<td><strong>Domestic Boiler</strong></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for domestic gas use</td>
<td>VOC</td>
<td>6.3</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for domestic gas use</td>
<td>SO2</td>
<td>0.22</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for domestic gas use</td>
<td>NOX</td>
<td>57.5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for domestic gas use</td>
<td>CO</td>
<td>15.8</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for domestic gas use</td>
<td>PM10</td>
<td>0.3</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, natural gas</td>
<td>CO</td>
<td>8.5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, natural gas</td>
<td>NOX</td>
<td>40.2</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, natural gas</td>
<td>SOX</td>
<td>0.2</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, natural gas</td>
<td>VOC</td>
<td>2.1</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in domestic boilers</td>
<td>SO2</td>
<td>0.5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in domestic boilers</td>
<td>NOX</td>
<td>70</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in domestic boilers</td>
<td>CO</td>
<td>units are a mess</td>
<td>30 ng/kj?</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>EMEP default factors for gas use in domestic boilers</td>
<td>NM VOC</td>
<td>units are a mess</td>
<td>3 ng/kj??</td>
</tr>
<tr>
<td><strong>Domestic Boiler</strong></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic gas boilers</td>
<td>PM10</td>
<td>0.2</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: UK use of gas in domestic appliances</td>
<td>VOC</td>
<td>5.0 - 30</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: gas, 35 (0-120) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>15</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: gas, 35 (0-120) kW boiler, improved</td>
<td>NMVOC</td>
<td>3</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Russian POPs data: residential</td>
<td>BaP</td>
<td>1.5</td>
<td>mg/1000m3</td>
</tr>
<tr>
<td><strong>Small commercial or institutional boiler</strong></td>
<td>7</td>
<td>Belarus: gas use in small &amp; medium boilers</td>
<td>BaP</td>
<td>0.38</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>VCAPC: gas fired combustion kit, 1-100 MMBTUh</td>
<td>benzene</td>
<td>0.0023</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>VCAPC: gas fired combustion kit, 1-100 MMBTUh</td>
<td>PAHs</td>
<td>0.0002</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>MSC-E research: russian low capacity heat power boilers</td>
<td>BaP</td>
<td>3.5</td>
<td>mg/tonne</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>MSC-E research: russian water boilers</td>
<td>BaP</td>
<td>1.8</td>
<td>mg/tonne</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled industrial gas boilers</td>
<td>PM10</td>
<td>0.1</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>USEPA RWC research paper: conventional gas furnace</td>
<td>PAHs</td>
<td>0.00012</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>USEPA RWC research paper: high efficiency gas furnace</td>
<td>PAHs</td>
<td>0.000003</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: UK use of gas in commercial appliances</td>
<td>VOC</td>
<td>5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: gas, 200 (120-300) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>5</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: gas, 200 (120-300) kW boiler, improved</td>
<td>NMVOC</td>
<td>1</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Russian POPs data: industry / public utility</td>
<td>BaP</td>
<td>1.5</td>
<td>mg/1000m3</td>
</tr>
<tr>
<td><strong>Agricultural Heater</strong></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for agricultural gas use</td>
<td>VOC</td>
<td>30</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for agricultural gas use</td>
<td>SO2</td>
<td>0.22</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for agricultural gas use</td>
<td>NOX</td>
<td>65</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for agricultural gas use</td>
<td>CO</td>
<td>10</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data for agricultural gas use</td>
<td>PM10</td>
<td>0.15</td>
<td>g/GJ</td>
</tr>
<tr>
<td><strong>CHP</strong></td>
<td>13</td>
<td>Aus power stations - ave for gas turbines</td>
<td>NOX</td>
<td>179</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Aus power stations - ave for gas turbines</td>
<td>CO</td>
<td>43</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Aus power stations - ave for gas turbines</td>
<td>NMVOC</td>
<td>2.1</td>
<td>g/GJ</td>
</tr>
</tbody>
</table>
# Table B6: LPG, Propane & Butane EF Info Summary

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>REF</th>
<th>Comments</th>
<th>Substance</th>
<th>EF</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Open Fire</td>
<td>(none)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Closed Stove</td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, LPG</td>
<td>CO 14.9</td>
<td>g/kg</td>
<td>0.0318 kg/th</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, LPG</td>
<td>TNMOC 18.8</td>
<td>g/kg</td>
<td>0.0402 kg/th</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, LPG</td>
<td>TSP 0.51</td>
<td>g/kg</td>
<td>0.0011 kg/th</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic LPG use</td>
<td>VOC 2</td>
<td>g/GJ</td>
<td>0.0002 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic LPG use</td>
<td>SO2 0.22</td>
<td>g/GJ</td>
<td>0.00002 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic LPG use</td>
<td>NOx 40</td>
<td>g/GJ</td>
<td>0.0042 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic LPG use</td>
<td>CO 10</td>
<td>g/GJ</td>
<td>0.0011 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic LPG use</td>
<td>PM10 2</td>
<td>g/GJ</td>
<td>0.0002 kg/th</td>
</tr>
<tr>
<td>Small Commercial or Institutional Boiler</td>
<td>29</td>
<td>BCC Research: UK use of LPG in commercial appliances</td>
<td>VOC 5</td>
<td>g/GJ</td>
<td>0.0005 kg/th</td>
</tr>
<tr>
<td>Agricultural Heater</td>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural LPG use</td>
<td>VOC 2</td>
<td>g/GJ</td>
<td>0.0002 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural LPG use</td>
<td>SO2 0.22</td>
<td>g/GJ</td>
<td>0.00002 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural LPG use</td>
<td>NOx 40</td>
<td>g/GJ</td>
<td>0.0042 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural LPG use</td>
<td>CO 10</td>
<td>g/GJ</td>
<td>0.0011 kg/th</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural LPG use</td>
<td>PM10 2</td>
<td>g/GJ</td>
<td>0.0002 kg/th</td>
</tr>
<tr>
<td>CHP</td>
<td>(none)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) steam turbine (ST)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) gas turbine (GT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) comb. Cycle (CC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) recipr. Engine (RE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) condensing ST (CST)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Table B7: FUEL OIL EF Info Summary

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>REF</th>
<th>Comments</th>
<th>Substance</th>
<th>EF Units</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Open Fire</td>
<td>(none)</td>
<td>(none)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>29</td>
<td>BCC Research: UK use of residual oil in domestic appliances</td>
<td>VOC</td>
<td>10</td>
<td>g/GJ 0.4 g/kg</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>Polish Efs for fuel oil use in residential sector</td>
<td>BaP</td>
<td>3.4</td>
<td>g/Mt</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic heavy fuel oil use</td>
<td>PM10</td>
<td>8.0-27</td>
<td>g/GJ 0.0-1.2 g/kg</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: EC figs for uncontrolled domestic heavy fuel oil use</td>
<td>PM10</td>
<td>53</td>
<td>g/GJ 2.2 g/kg</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>RAINS figs for uncontrolled domestic heavy fuel oil use</td>
<td>PM10</td>
<td>20</td>
<td>g/GJ 0.9 g/kg</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Russian POPs data: residential</td>
<td>BaP</td>
<td>4.3</td>
<td>mg/t</td>
</tr>
<tr>
<td>Small commercial or institutional boiler</td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #1, 5% sulfur</td>
<td>CO</td>
<td>15.6</td>
<td>g/GJ 0.7 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #1, 5% sulfur</td>
<td>NOX</td>
<td>62.4</td>
<td>g/GJ 2.7 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #1, 5% sulfur</td>
<td>PM10</td>
<td>3.1</td>
<td>g/GJ 0.1 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #1, 5% sulfur</td>
<td>SOX</td>
<td>449</td>
<td>g/GJ 19.5 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #1, 5% sulfur</td>
<td>VOC</td>
<td>0.6</td>
<td>g/GJ 0.03 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #4, 5% sulfur</td>
<td>CO</td>
<td>15.4</td>
<td>g/GJ 0.7 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #4, 5% sulfur</td>
<td>NOX</td>
<td>61.4</td>
<td>g/GJ 2.7 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #4, 5% sulfur</td>
<td>PM10</td>
<td>18.5</td>
<td>g/GJ 0.8 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #4, 5% sulfur</td>
<td>SOX</td>
<td>467</td>
<td>g/GJ 20.3 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #4, 5% sulfur</td>
<td>VOC</td>
<td>0.6</td>
<td>g/GJ 0.03 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #5, 5% sulfur</td>
<td>CO</td>
<td>15.4</td>
<td>g/GJ 0.7 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #5, 5% sulfur</td>
<td>NOX</td>
<td>169</td>
<td>g/GJ 7.4 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #5, 5% sulfur</td>
<td>PM10</td>
<td>26.4</td>
<td>g/GJ 1.1 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #5, 5% sulfur</td>
<td>SOX</td>
<td>488</td>
<td>g/GJ 21.2 g/kg</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>ERA research: Boiler Efs, fuel oil #5, 5% sulfur</td>
<td>VOC</td>
<td>0.9</td>
<td>g/GJ 0.04 g/kg</td>
</tr>
<tr>
<td>Small commercial or institutional boiler</td>
<td>18</td>
<td>MSC-E research: russian low capacity heat-power boilers</td>
<td>BaP</td>
<td>22</td>
<td>mg/tonne</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>MSC-E research: russian water boilers</td>
<td>BaP</td>
<td>13.2</td>
<td>mg/tonne</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>MSC-E research: russian heat-power boilers</td>
<td>BaP</td>
<td>4.3</td>
<td>mg/tonne</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>VCAPCD research: external combustion of #1-#2 fuel oil</td>
<td>benzene</td>
<td>0.014</td>
<td>g/GJ 0.0006 g/kg</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>VCAPCD research: external combustion of #1-#2 fuel oil</td>
<td>toluene</td>
<td>0.014</td>
<td>g/GJ 0.0006 g/kg</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>VCAPCD research: external combustion of #1-#2 fuel oil</td>
<td>PAHs</td>
<td>0.16</td>
<td>g/GJ 0.007 g/kg</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BCC Research: UK use of residual fuel oil in industry</td>
<td>VOC</td>
<td>8</td>
<td>g/GJ 0.35 g/kg</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled industrial heavy fuel oil use</td>
<td>PM10</td>
<td>3.0-14</td>
<td>g/GJ 0.1-0.6 g/kg</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled industrial boilers: heavy fuel oil</td>
<td>PM10</td>
<td>33</td>
<td>g/GJ 1.0 g/kg</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: EC figs for uncontrolled industrial boilers: heavy fuel oil</td>
<td>PM10</td>
<td>20</td>
<td>g/GJ 0.87 g/kg</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>RAINS figs for uncontrolled industrial boilers: heavy fuel oil</td>
<td>PM10</td>
<td>15</td>
<td>g/GJ 0.65 g/kg</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Russian POPs data: industry / public utility</td>
<td>BaP</td>
<td>4.3</td>
<td>mg/t</td>
</tr>
<tr>
<td>Agricultural Heater</td>
<td>33</td>
<td>Polish Efs for fuel oil use in agric sector</td>
<td>BaP</td>
<td>3.4</td>
<td>g/Mt</td>
</tr>
<tr>
<td>CHP</td>
<td>13</td>
<td>Australian power station using fuel oil</td>
<td>NOX</td>
<td>186</td>
<td>g/GJ 8.09 g/kg</td>
</tr>
<tr>
<td>a) steam turbine (ST)</td>
<td>13</td>
<td>Australian power station using fuel oil</td>
<td>CO</td>
<td>14</td>
<td>g/GJ 0.61 g/kg</td>
</tr>
<tr>
<td>b) gas turbine (GT)</td>
<td>13</td>
<td>Australian power station using fuel oil</td>
<td>NMVOC</td>
<td>2.1</td>
<td>g/GJ 0.09 g/kg</td>
</tr>
<tr>
<td>c) comb. Cycle (CC)</td>
<td>29</td>
<td>BCC Research: UK use of fuel oil in power plant</td>
<td>VOC</td>
<td>6.8</td>
<td>g/GJ 0.30 g/kg</td>
</tr>
<tr>
<td>d) recipr. Engine (RE)</td>
<td>34</td>
<td>Rents et al. &quot;oil&quot;, 200 (120-300) kW boiler, improv &amp; abate</td>
<td>NMVOC</td>
<td>1</td>
<td>g/GJ 0.04 g/kg</td>
</tr>
<tr>
<td>e) condensing ST (CST)</td>
<td>36</td>
<td>Russian POPs data: power plant</td>
<td>BaP</td>
<td>4.3</td>
<td>mg/t</td>
</tr>
<tr>
<td>SECTOR</td>
<td>REF</td>
<td>Comments</td>
<td>Substance</td>
<td>EF</td>
<td>Units</td>
</tr>
<tr>
<td>--------</td>
<td>-----</td>
<td>----------</td>
<td>-----------</td>
<td>----</td>
<td>-------</td>
</tr>
<tr>
<td>Domestic Open Fire</td>
<td>(none)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, kerosene wick</td>
<td>CO</td>
<td>17.7</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, kerosene wick</td>
<td>TNMOC</td>
<td>14.9</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, kerosene wick</td>
<td>TSP</td>
<td>0.5</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, kerosene pressure</td>
<td>CO</td>
<td>62.1</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, kerosene pressure</td>
<td>TNMOC</td>
<td>19.2</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>USEPA: fuel use in developing world home stoves, kerosene pressure</td>
<td>TSP</td>
<td>0.7</td>
<td>g/kg</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic light fuel oil use</td>
<td>PM10</td>
<td>1</td>
<td>g/GJ</td>
<td>0.05</td>
</tr>
<tr>
<td>19</td>
<td>IIASA: EC figs for uncontrolled domestic boiler light fuel oil</td>
<td>PM10</td>
<td>30</td>
<td>g/GJ</td>
<td>1.39</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic &quot;oil&quot; use</td>
<td>VOC</td>
<td>15</td>
<td>g/GJ</td>
<td>0.69</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic &quot;oil&quot; use</td>
<td>SO2</td>
<td>87</td>
<td>g/GJ</td>
<td>4.02</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic &quot;oil&quot; use</td>
<td>NOX</td>
<td>50</td>
<td>g/GJ</td>
<td>2.31</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic &quot;oil&quot; use</td>
<td>CO</td>
<td>60</td>
<td>g/GJ</td>
<td>2.77</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on domestic &quot;oil&quot; use</td>
<td>PM10</td>
<td>4.5</td>
<td>g/GJ</td>
<td>0.21</td>
</tr>
<tr>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic boiler light fuel oil</td>
<td>PM10</td>
<td>0.2</td>
<td>g/GJ</td>
<td>0.01</td>
</tr>
<tr>
<td>19</td>
<td>RAINS figs for uncontrolled domestic boiler light fuel oil</td>
<td>PM10</td>
<td>1</td>
<td>g/GJ</td>
<td>0.05</td>
</tr>
<tr>
<td>29</td>
<td>BCC Research: UK use of kerosene in domestic appliances</td>
<td>VOC</td>
<td>15</td>
<td>g/GJ</td>
<td>0.69</td>
</tr>
<tr>
<td>34</td>
<td>Rentz et al.: &quot;oil&quot;, 35 (0-120) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>7.5</td>
<td>g/GJ</td>
<td>0.35</td>
</tr>
<tr>
<td>34</td>
<td>Rentz et al.: &quot;oil&quot;, 35 (0-120) kW boiler, improved</td>
<td>NMVOC</td>
<td>1.5</td>
<td>g/GJ</td>
<td>0.07</td>
</tr>
<tr>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale oil combustion</td>
<td>PCDD/Fs</td>
<td>0.2</td>
<td>ugTEQ/t</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale oil combustion</td>
<td>BaP</td>
<td>0.0043</td>
<td>g/t</td>
<td></td>
</tr>
<tr>
<td>Small commercial or institutional boiler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Rentz et al.: &quot;oil&quot;, 200 (120-300) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>5</td>
<td>g/GJ</td>
<td>0.23</td>
</tr>
<tr>
<td>34</td>
<td>Rentz et al.: &quot;oil&quot;, 200 (120-300) kW boiler, improved</td>
<td>NMVOC</td>
<td>1</td>
<td>g/GJ</td>
<td>0.05</td>
</tr>
<tr>
<td>19</td>
<td>IIASA: German figs for uncontrolled industrial boiler light fuel oil</td>
<td>PM10</td>
<td>0.3</td>
<td>g/GJ</td>
<td>0.01</td>
</tr>
<tr>
<td>19</td>
<td>RAINS figs for uncontrolled industrial boiler light fuel oil</td>
<td>PM10</td>
<td>1</td>
<td>g/GJ</td>
<td>0.05</td>
</tr>
<tr>
<td>Agricultural Heater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural &quot;oil&quot; use</td>
<td>VOC</td>
<td>10</td>
<td>g/GJ</td>
<td>0.46</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural &quot;oil&quot; use</td>
<td>SO2</td>
<td>0.22</td>
<td>g/GJ</td>
<td>0.01</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural &quot;oil&quot; use</td>
<td>NOX</td>
<td>50</td>
<td>g/GJ</td>
<td>2.31</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural &quot;oil&quot; use</td>
<td>CO</td>
<td>10</td>
<td>g/GJ</td>
<td>0.46</td>
</tr>
<tr>
<td>11</td>
<td>UNECE TFEIP: dutch data on agricultural &quot;oil&quot; use</td>
<td>PM10</td>
<td>4.5</td>
<td>g/GJ</td>
<td>0.21</td>
</tr>
</tbody>
</table>

CHP:
- a) steam turbine (ST)
- b) gas turbine (GT)
- c) comb. Cycle (CC)
- d) recipr. Engine (RE)
- e) condensing ST (CST)
Table B9: BIOFUELS EF Info Summary

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>REF</th>
<th>Comments</th>
<th>Substance</th>
<th>EF</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Open Fire</td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5kW, seasoned hardwood</td>
<td>PCDDs</td>
<td>0.068</td>
<td>gTEQ/MT</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5kW, seasoned hardwood</td>
<td>PCDFs</td>
<td>0.16</td>
<td>gTEQ/MT</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5kW, seasoned hardwood</td>
<td>PCBs</td>
<td>1.2</td>
<td>gTEQ/MT</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5kW, seasoned hardwood</td>
<td>PCNs</td>
<td>0.12</td>
<td>kg/MT</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5kW, seasoned hardwood</td>
<td>PAHs</td>
<td>0.43</td>
<td>T/MT</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>CPL Research: open fire, &lt; 5kW, seasoned hardwood</td>
<td>PM10</td>
<td>7.9</td>
<td>t/MT</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>OMNI review: conventional stoves</td>
<td>16-PAH</td>
<td>0.223</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>OMNI review: high-tech non-catalytic stoves</td>
<td>16-PAH</td>
<td>0.127</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>OMNI review: catalytic stoves</td>
<td>16-PAH</td>
<td>0.161</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>OMNI review: hundreds of source studies,</td>
<td>CO</td>
<td>64.1</td>
<td>g/dry kg</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>OMNI review: hundreds of source studies,</td>
<td>TPM</td>
<td>11.8</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: open fire, seasoned hardwood</td>
<td>CO</td>
<td>6700</td>
<td>g/GJ</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: open fire, seasoned hardwood</td>
<td>VOC</td>
<td>520</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: open fire, seasoned hardwood</td>
<td>PAH</td>
<td>105</td>
<td>g/T</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>BCC Research: UK use of wood in domestic appliances</td>
<td>VOC</td>
<td>90-800</td>
<td>g/GJ 0.98</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic wood fires</td>
<td>PM10</td>
<td>150</td>
<td>g/GJ 1.5</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>26</td>
<td>USEPA: biogas use in developing world homes</td>
<td>CO</td>
<td>1.95</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: biogas use in developing world homes</td>
<td>PAHs</td>
<td>15.6</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>USEPA: biogas use in developing world homes</td>
<td>TPM</td>
<td>0.53</td>
<td>g/kg</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>Polish EISs for wood use in residential sector</td>
<td>BaP</td>
<td>2.5</td>
<td>g/kT</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic wood stoves</td>
<td>PM10</td>
<td>150</td>
<td>g/GJ 1.5</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: Dutch figs for uncontrolled domestic wood &quot;heating&quot;</td>
<td>PM10</td>
<td>150-200</td>
<td>g/GJ 1.0-2.0</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>RAINS figs for domestic wood &quot;heating&quot;</td>
<td>PM10</td>
<td>150-250</td>
<td>g/GJ 1.5-2.9</td>
</tr>
<tr>
<td>Domestic closed stove</td>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale wood &quot;furnaces&quot;</td>
<td>PCDD/Fs</td>
<td>5</td>
<td>ugTEQ/t</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale wood &quot;furnaces&quot;</td>
<td>BaP</td>
<td>5</td>
<td>g/t</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>USEPA: wood stove research, 1998, conventional stove</td>
<td>PAHs</td>
<td>40</td>
<td>g/GJ 0.4</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>USEPA: wood stove research, 1998, improved stove</td>
<td>PAHs</td>
<td>28</td>
<td>g/GJ 0.28</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>USEPA: wood stove research, 1998, test furnace A</td>
<td>PAHs</td>
<td>15.6</td>
<td>g/GJ 0.5</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>USEPA: wood stove research, 1998, test furnace B</td>
<td>PAHs</td>
<td>16.1</td>
<td>g/GJ 0.61</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: traditional wood stoves</td>
<td>NOx</td>
<td>29</td>
<td>g/GJ 0.29</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: traditional wood stoves</td>
<td>CO</td>
<td>4000</td>
<td>g/GJ 70</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: traditional wood stoves</td>
<td>UHC as CH4</td>
<td>1750</td>
<td>g/GJ 17.5</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: traditional wood stoves</td>
<td>VOC</td>
<td>670</td>
<td>g/GJ 17</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: traditional wood stoves</td>
<td>PM10</td>
<td>350</td>
<td>g/UJ 35</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: modern wood stoves</td>
<td>NOx</td>
<td>58</td>
<td>g/GJ 0.58</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: modern wood stoves</td>
<td>CO</td>
<td>1700</td>
<td>g/GJ 17</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: modern wood stoves</td>
<td>UHC as CH4</td>
<td>200</td>
<td>g/GJ 2</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: modern wood stoves</td>
<td>PAH</td>
<td>26</td>
<td>g/UJ 0.26</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Russian POPs data: residential</td>
<td>BaP</td>
<td>2</td>
<td>g/t</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>11</td>
<td>UNECE TFEIP: Sweden, wood chip boilers 1.8-2 MW</td>
<td>TSP</td>
<td>51</td>
<td>g/GJ 0.51</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Sweden, wood chip boilers 1.8-2 MW</td>
<td>THC</td>
<td>48</td>
<td>g/GJ 0.48</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Sweden, wood chip boilers 1.8-2 MW</td>
<td>NOx</td>
<td>25</td>
<td>g/GJ 0.25</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>UNECE TFEIP: Sweden, wood chip boilers 1.8-2 MW</td>
<td>CO</td>
<td>3500</td>
<td>g/GJ 35</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: wood, charcoal, 35 (0-120) kW boiler, benchmark</td>
<td>NMVOC</td>
<td>480</td>
<td>g/GJ 4.8</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Rentz et al: wood, charcoal, 35 (0-120) kW boiler, improved</td>
<td>NMVOC</td>
<td>96</td>
<td>g/GJ 0.96</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>IIASA: German figs for uncontrolled domestic wood boilers</td>
<td>PM10</td>
<td>50</td>
<td>g/GJ 0.5</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale wood combustion</td>
<td>PCDD/Fs</td>
<td>1.0-5</td>
<td>ugTEQ/t</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>EMEP/CORINAIR default figs: small-scale wood combustion</td>
<td>BaP</td>
<td>1.5-5</td>
<td>g/t</td>
</tr>
<tr>
<td>Domestic Boiler</td>
<td>9</td>
<td>Norway Inst of Tech: wood boilers</td>
<td>NOx</td>
<td>101</td>
<td>g/GJ 1.01</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: wood boilers</td>
<td>CO</td>
<td>5000</td>
<td>g/GJ 50</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Norway Inst of Tech: wood boilers</td>
<td>UHC as CH4</td>
<td>1330</td>
<td>g/GJ 13.3</td>
</tr>
<tr>
<td>Reference Log</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 USEPA AP-42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 UK NAEI 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 UK Domestic heating market report 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Determination of Atmos. Pollutant Efs at a small coal-fired heating boiler&quot;, for DEFRA, by AEAT (Collings et al), 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 &quot;Report on...Efs...for a range of pollutants...during combustion of solid fuels on an open fire&quot;, CPL (Perry et al), 2002</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 &quot;PM10 Efs for domestic solid fuels&quot;, CRE for Belfast CC (Briggs et al), 1997</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 &quot;Additions &amp; refinements to the EMEP/CORINAIR Emission Inventory...&quot;, NAS Belarus (Kakareka et al), 2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 &quot;Source Apportionment of Airborne Particulate in the UK&quot;, APEG, 1999</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 &quot;Emissions from Biomass Combustion&quot;, Norwegian Inst. Of Technology (Saanum et al), 1995</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 &quot;Prelim report: Emission factor measurements at Cottam Power Station&quot;, WSL (Coleman et al), 1993</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 &quot;Emissions from Small &amp; Medium Combustion Plants&quot; UNECE TFEIP Workshop (Dilira et al), 2002</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 &quot;Determination of Atmos. Pollutant Efs at a small industrial wood-burning furnace&quot;, for DEFRA, by AEAT (Collings et al), 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 &quot;Air Toxic Efs for Combustion Sources using petroleum-based fuels&quot; WSPA &amp; API (Hansell et al), 1998</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 &quot;AB 2008 Combustion Emission Factors&quot; VCAPCD 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 &quot;L&amp;E Air Emissions from Sources of Benzene&quot; USEPA, 1998</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 &quot;Boiler / Oven Fuel Emission Factors&quot; REGMET 6.2, ERA Consulting, 2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 &quot;Review of wood heater &amp; Fireplace Efs&quot;, OMNI, (Houck et al) 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 &quot;PAH Emission Inventories &amp; Emission expert Estimates&quot; MSC-E (Tsibulsky et al), 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 &quot;Fuel Combustion in stationary sources&quot; IASA, 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 European Dioxin Inventory, 2002</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 &quot;Residential Wood Combustion - PM2.5 Emissions&quot; WESTAR El Workshop (Houck et al), 1998</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 &quot;Market Review &amp; Prospects&quot; CHPA 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 &quot;Greenhouse Gases from small-scale combustion in developing countries&quot; USEPA National Risk Mgmt, 2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 &quot;Emission Inventory Guidebook - Small Combustion Sources: Update&quot; (Kakareka et al) 2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 UK Emissions Inventory, Solid Fuel&quot;, personal communication from the Uk Solid Fule Association, March 2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 &quot;Digest of UK Energy Statistics&quot;, DTI, 2002</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C

Summary of Emission Factors, sorted by Fuel and Sub-Sector
### Table C1 – Summary of emission factors

<table>
<thead>
<tr>
<th>FUEL Sector</th>
<th>Species</th>
<th>EF</th>
<th>Units</th>
<th>Comment (country)</th>
<th>AP-42</th>
<th>Comment</th>
<th>NAEI 2001</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>PM10</td>
<td>10 (9-11)</td>
<td>g/kg</td>
<td>open fire (UK)</td>
<td>10.4</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>PM10</td>
<td>4 (3.4-6)</td>
<td>g/kg</td>
<td>stove (D, ND)</td>
<td>10.4</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>PM10</td>
<td>4 (2.8-6)</td>
<td>g/kg</td>
<td>boiler (D, UK)</td>
<td>10.4</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>VOC</td>
<td>14</td>
<td>g/kg</td>
<td>open fire (UK)</td>
<td>45</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>VOC</td>
<td>0.6</td>
<td>g/kg</td>
<td>boiler (UK)</td>
<td>45</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>46-709</td>
<td>g/kg</td>
<td>stove (UK)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>1.8</td>
<td>g/kg</td>
<td>boiler (UK)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>NOX</td>
<td>2.3</td>
<td>g/kg</td>
<td>stove (ND)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>13-104</td>
<td>g/kg</td>
<td>fuel-dependent (ND, UK)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>V. C.</td>
<td>1.7</td>
<td>g/kg</td>
<td>boiler (UK)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>NOX</td>
<td>8</td>
<td>g/kg</td>
<td>stove (UK)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>8.5-10</td>
<td>g/kg</td>
<td>fuel-dependent (UK)</td>
<td>1.42</td>
<td>g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>BaP</td>
<td>0.03-0.1</td>
<td>g/kg</td>
<td>(UK, D)</td>
<td>1.1</td>
<td>g/kg</td>
<td>mean of several firing configs</td>
<td>1.1</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>0.3</td>
<td>g/kg</td>
<td>(UK and AUS)</td>
<td>6.6</td>
<td>g/kg</td>
<td>uncontrolled, spreader stoker</td>
<td>6.6</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>NOX</td>
<td>8.6-10</td>
<td>g/kg</td>
<td>boiler (UK)</td>
<td>3.0</td>
<td>g/kg</td>
<td>uncontrolled overfeed stoker</td>
<td>3.0</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>PM10</td>
<td>1</td>
<td>g/kg</td>
<td>estimated from D data</td>
<td>2.5</td>
<td>g/kg</td>
<td>spreader stoker, bit</td>
<td>2.5</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>0.0002</td>
<td>kg/th</td>
<td>(ND)</td>
<td>0.02</td>
<td>g/kg</td>
<td>power station, pulv coal</td>
<td>0.02</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>BaP</td>
<td>0.042</td>
<td>kg/th</td>
<td>boiler (ND)</td>
<td>5.0</td>
<td>g/kg</td>
<td>mean of several firing configs</td>
<td>5.0</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>0.0011</td>
<td>kg/th</td>
<td>boiler (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.0011</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>0.0042</td>
<td>kg/th</td>
<td>fuel-dependent (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.0042</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>NOX</td>
<td>0.0011</td>
<td>kg/th</td>
<td>fuel-dependent (UK)</td>
<td></td>
<td></td>
<td></td>
<td>0.0011</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>VOC</td>
<td>0.0002</td>
<td>kg/th</td>
<td>boiler (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.0002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>0.0002</td>
<td>kg/th</td>
<td>fuel-dependent (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.0002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>NOX</td>
<td>0.0042</td>
<td>kg/th</td>
<td>boiler (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.0042</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>0.0011</td>
<td>kg/th</td>
<td>boiler (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.0011</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>0.00002</td>
<td>kg/th</td>
<td>fuel-dependent (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>BaP</td>
<td>0.00002</td>
<td>kg/th</td>
<td>fuel-dependent (ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>0.00011</td>
<td>kg/th</td>
<td>(ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00011</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>0.00002</td>
<td>kg/th</td>
<td>(ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>BaP</td>
<td>0.00002</td>
<td>kg/th</td>
<td>(ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>CO</td>
<td>0.00011</td>
<td>kg/th</td>
<td>(ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00011</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>SO2</td>
<td>0.00002</td>
<td>kg/th</td>
<td>(ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00002</td>
<td>g/kg</td>
</tr>
<tr>
<td><strong>Coal Domestic</strong></td>
<td>BaP</td>
<td>0.00002</td>
<td>kg/th</td>
<td>(ND)</td>
<td></td>
<td></td>
<td></td>
<td>0.00002</td>
<td>g/kg</td>
</tr>
<tr>
<td>FUEL</td>
<td>Species</td>
<td>EF</td>
<td>Units Comment</td>
<td>AP-42</td>
<td>NAEI 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>----</td>
<td>---------------</td>
<td>-------</td>
<td>-----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(country)</td>
<td>Units</td>
<td>Units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>Domestic</td>
<td>PM10</td>
<td>0.00005 kg/th</td>
<td>stove (D)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM10</td>
<td>0.00005-0.0005 kg/th</td>
<td>boiler (D, ND, UK)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.00006 kg/th</td>
<td>fire (EC)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.00003 kg/th</td>
<td>stove (EC)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.00002-0.0003 kg/th</td>
<td>boiler (UK, ND, D)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>0.00021 kg/th</td>
<td>fire (EC)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>0.0011 kg/th</td>
<td>stove (EC)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>0.0009-0.0017 kg/th</td>
<td>boiler (UK, ND)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOX</td>
<td>0.00053 kg/th</td>
<td>fire &amp; stove (EC)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOX</td>
<td>0.0040-0.0061 kg/th</td>
<td>boiler (UK, ND)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO2</td>
<td>0.00005 kg/th</td>
<td>fire &amp; stove (EC)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>P&amp;C</td>
<td>PM10</td>
<td>0.000011 kg/th</td>
<td>stove (D)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.00001-0.0006 kg/th</td>
<td>boiler (D, UK)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BaP</td>
<td>0.003-0.008 kg/th</td>
<td>4E-06 kg/th (RUS)</td>
<td>0.00046 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH</td>
<td>3.0-20 kg/th</td>
<td>uncontrolled (USA)</td>
<td>0.00025 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>Agric</td>
<td>PM10</td>
<td>0.000002 kg/th</td>
<td>stove (ND)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.00002 kg/th</td>
<td>(ND)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BaP</td>
<td>0.0011 kg/th</td>
<td>(ND)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOX</td>
<td>0.00069 kg/th</td>
<td>(ND)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO2</td>
<td>0.000002 kg/th</td>
<td>(ND)</td>
<td>0.000326 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td>CHP</td>
<td>PM10</td>
<td>&lt;0.00001 kg/th</td>
<td>estimated (D, D)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.000005-0.0006 kg/th</td>
<td>boiler (UK, AUS, D)</td>
<td>0.021 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BaP</td>
<td>0.002-0.013 kg/th</td>
<td>(UK, AUS)</td>
<td>0.00025 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOX</td>
<td>0.004-0.02 kg/th</td>
<td>(UK, AUS)</td>
<td>0.00025 kg/th</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>Domestic</td>
<td>PM10</td>
<td>1.5-7.9 g/kg</td>
<td>open fire (D, UK)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM10</td>
<td>1.0-2.9 g/kg</td>
<td>closed stove (D, ND, EC)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM10</td>
<td>0.5 g/kg</td>
<td>boiler (D)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>0.9-8.0 g/kg</td>
<td>open fire (UK, NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>2.175 g/kg</td>
<td>closed stove (NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VOC</td>
<td>1.0-13.5 g/kg</td>
<td>boiler (D, NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BaP</td>
<td>2.0-5 g/T</td>
<td>closed stove (RUS, EC)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BaP</td>
<td>1.5-5 g/T</td>
<td>boiler (EC)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH</td>
<td>0.1-1.1 g/kg</td>
<td>open fire (USA, NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH</td>
<td>0.16-0.4 g/kg</td>
<td>closed stove (USA, NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAH</td>
<td>0.3 g/kg</td>
<td>closed stove (USA, NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>64-67 g/kg</td>
<td>open fire (USA, NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>17-70 g/kg</td>
<td>closed stove (NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO</td>
<td>50 g/kg</td>
<td>boiler (NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOX</td>
<td>0.3-0.6 g/kg</td>
<td>closed stove (NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOX</td>
<td>1 g/kg</td>
<td>boiler (NOR)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO2</td>
<td>0.03 g/kg</td>
<td>boiler, fuel dependent (UK)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCDD/F</td>
<td>0.23 gTEG/MT</td>
<td>open fire (UK)</td>
<td>17.3 g/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>